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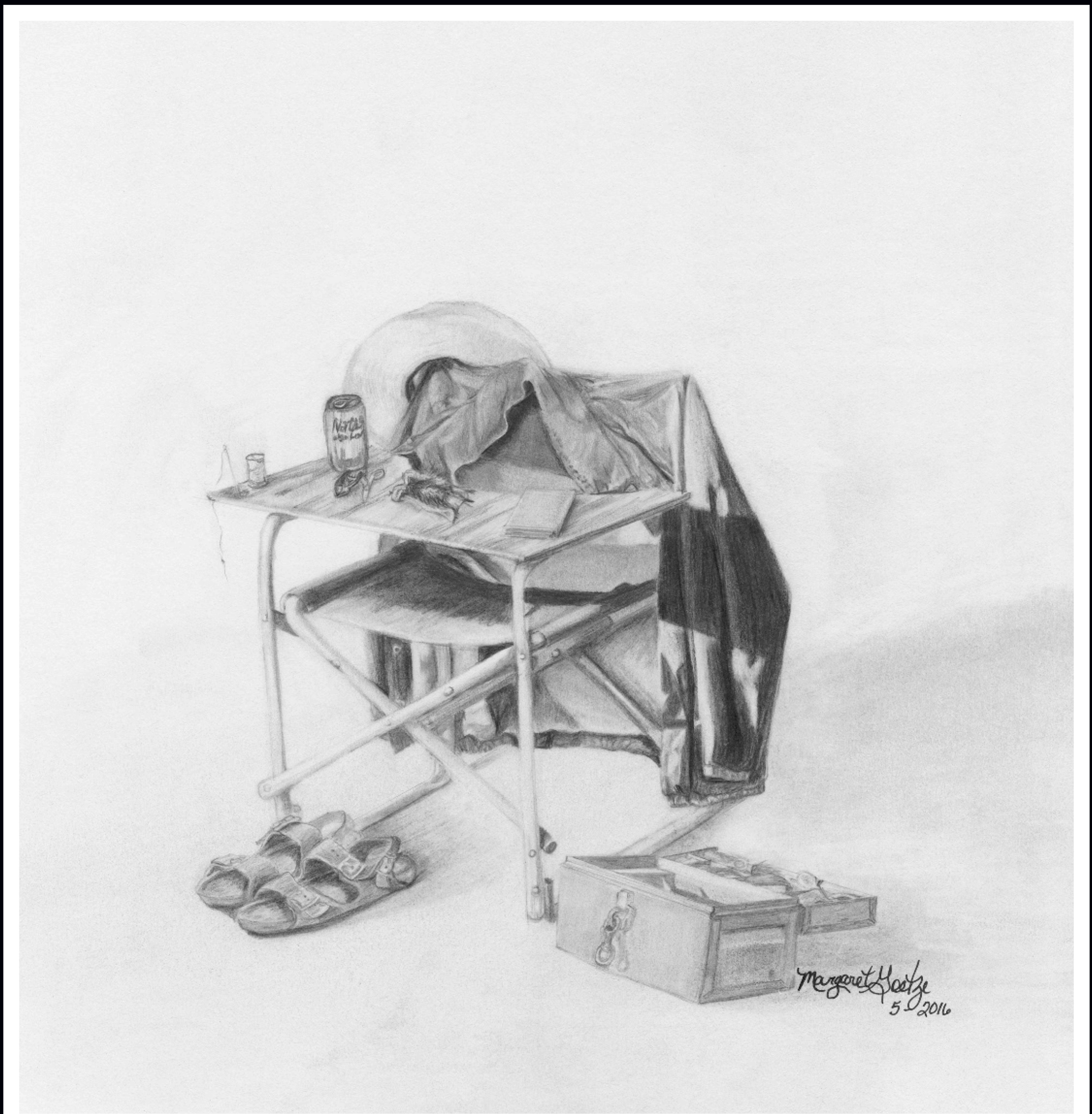
CONTRIBUTIONS IN NATURAL HISTORY: A MEMORIAL VOLUME IN HONOR OF CLYDE JONES



EDITED BY

RICHARD W. MANNING, JIM R. GOETZE, AND FRANKLIN D. YANCEY, II

Artist's Statement and Memory

My name is Margaret Goetze. I have a BFA in studio art from Texas A&M Corpus Christi. It was my privilege to know Dr. Clyde Jones for almost 20 years, and, from our first associations, I always felt welcomed and accepted into his 'circle of scientists.' Clyde always expressed an interest in my art and it seemed to me that he often was my biggest fan. Therefore, I was excited and honored to be commissioned to design the covers for this book, and it took me some time and a great deal of thought to complete the commission.

Front cover.—Anyone who knew or worked with Clyde knows this chair and what it represents. My hardest decision was to leave the background blank. This was intentional. Clyde was cosmopolitan in his travels and his research interests and, even in the time that I knew him, Clyde and his chair had been many places. Therefore, as you look at the cover, the chair and Clyde are wherever you want them to be.

Back cover.—"Clyde, here is the Spotted Bat, *Euderma maculatum*, that I always wanted to draw for you. I hope that you would be pleased."

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Richard W. Manning, Jim R. Goetze, and Franklin D. Yancey, II

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Editors' Preface and Acknowledgments

It is with great pleasure that we present this volume containing research works, encomia, photographs, and art work in honor of Clyde Jones. Clyde was a teacher, mentor, colleague, and dear friend, as well as doctoral committee chair or co-chair for the three of us. Discussion of a volume in honor of Clyde Jones first was entertained in June 2013, in a group setting between the three of us and Mark Lockwood, Mike Bogan, Cindy Ramotnik, and Mary Ann Jones. This occurred during a field trip at Big Bend Ranch State Park in the Trans-Pecos region of Texas. Clyde participated in the trip, but was unaware of our conversations regarding the planning of this volume. We originally discussed possible publication of a festschrift honoring Clyde, but unfortunately he passed away on 6 April 2015 after a lengthy period of illness.

In July 2015, we decided to proceed with work on a memorial volume to honor him. We began inquiries regarding the possibility of publication of such a book through the Museum of Texas Tech University. We then solicited potential contributors—a group that included former colleagues and graduate students of Clyde's, and other individuals who had been associated with or worked with Clyde throughout his long and distinguished career.

Although not everyone contacted was able to respond and contribute to this volume, nonetheless this work contains 11 research articles ranging in scope from Pleistocene/Holocene faunal analyses, ecological and ethological studies on terrestrial and volant mammals, the description of a new species of *Myotis*, and resurrection and redefinition of an 'older' species of *Peromyscus*, to a first record of an avian species in Texas, and even a rather botanically-related research study. If you consider the wide-ranging and eclectic research interests of Clyde Jones, as evidenced in the included Abbreviated Résumé and Bibliography, we think that "El Jefe" (as we often referred to CJ) would be pleased with the contributions.

We also decided to include encomia or "songs of praise" in honor of Dr. Jones, memory statements, a transcript of an interview with Clyde, and photographs. We believe that all of the aforementioned works and contributions will allow readers a glimpse of the complex character, breadth of knowledge, and outstanding accomplishments of Clyde Jones. Some of the materials may, hopefully, even make readers smile, and we are quite sure that Clyde would enjoy that!

This project required tremendous contributions of time and effort from Robert D. Bradley, Series Editor, and Lisa Bradley, Production Editor, of the Natural Science Research Laboratory (NSRL) of the Museum of Texas Tech University. In addition, many external reviewers generously gave their time and provided valuable suggestions for the papers. We thank Fred Stangl and Terry Maxwell for providing final reviews of the entire volume.

In addition to publishing this volume, much of the cost of production was subsidized by the NSRL of the Museum of Texas Tech University. We wish to thank the NSRL, as well as the Texas Tech University Libraries and several individuals, for their generous contributions toward the production of this volume.

Clyde could exhibit a 'stormy' personality at times (at least when necessary in order to accomplish a task or properly 'motivate' an individual) but, more often, he displayed an open, generous, friendly temperament and a warm smile for those that he met. Dr. Jones often portrayed himself as a simple country boy from the Nebraska Sandhills (see Résumé and Prologue) and indeed he was that person. However, as those who knew him can attest and those who read this volume will learn, Clyde Jones was much, much more…

Richard W. Manning
Jim R. Goetze
Franklin D. Yancey, II

Clyde Jones
1935–2015

Abbreviated Résumé

General Information.—Born in Scottsbluff, Nebraska, 3 March 1935; married; two married children.

Education.—Burwell High School, Burwell, Nebraska, graduated 1952; Hastings College, Hastings, Nebraska, graduated 1957 with BA in History, Biology, and Education; University of New Mexico, Albuquerque, New Mexico, graduated 1960 with MS in Zoology and Botany; University of New Mexico, Albuquerque, New Mexico, graduated in 1964 with PhD in Biology.

Professional Employment History.—University of New Mexico, Department of Biology: Field Research Assistant, 1958–1959; Graduate Assistant, 1957–1961; Teaching Assistant, 1961–1962; Assistant Curator, Museum of Southwestern Biology, 1962–1964. Tulane University, Department of Biology: Assistant Professor of Biology, 1965–1969. Delta Regional Primate Research Center, Covington, Louisiana: Research Associate, 1967–1969. United States Fish and Wildlife Service: National Museum of Natural History, Chief of Mammal Section, Bird and Mammal Laboratories, 1970–1973; Director of National Fish and Wildlife Laboratory, 1973–1979; Denver Wildlife Research Center, Director, 1979–1982. Texas Tech University: Director of the Museum, Texas Tech University, 1982–1985; Department of Museum Science, Chairman, 1982–1987; Department of Biological Sciences, Professor, 1987–1999, Paul Whitfield Horn Professor, 1999–2003, Paul Whitfield Horn Professor Emeritus, 2004–2015.

Professional Organizations.—American Society of Mammalogists (life member); Asociación Mexicana De Mastozoologia, A.C.; Asociación Mexicana Para El Estudio De Los Mamiferos Marinos, A.C.; Big Bend Natural History Association; Biological Society of Washington; Chihuahuan Desert Research Institute; Society for Big Bend Studies; Society of Systematic Biologists; Southwestern Association of Naturalists; Texas Academy of Science; Texas Society of Mammalogists; Washington Biologist's Field Club.

Professional Organization Activities.—American Society of Mammalogists (various committee membership, Board of Directors, Editor for Reviews, Managing Editor); Asociación Mexicana Para El Estudio De Los Mamiferos Marinos, A.C. Vocale (served on committees, as an elected officer, as an editor, managing editor, and board member); Biological Society of Washington (council member, Vice President, President); Chihuahuan Desert Research Institute (Board of Scientists member); Texas Society of Mammalogists (served on various committees, established scholarship fund, President Elect, President, Executive Committee).

Task Forces and Additional Committee Service.—Antarctic Observer; Antarctic Inspection Team; Whale Policy Committee; International Conference on the Biology of Whales; Marine Mammal Task Force; Antarctic Task Force; Research Management System Development Task Force; Delegation to the Plenipotentiary Conference (CITES); Lacey Act Proposed Interpretation Task Force; Antarctic Resources Study Panel and Sub-Panel; U.S. and Mexico Joint Commission on Wildlife Conservation; Permits Study Committee; Kangaroo Management Evaluation Committee; Joint NOAA-FWS International Marine Mammal Task Force; U.S. and Mexico Joint Committee on Marine Mammals; Wildlife Biology Advisory Committee; Wild Boar Management Advisory Committee; CSRS Review Team; Rosenthal Seminar Series; Interagency Grizzly Bear Technical Review Panel; Joint Council on Food and Agricultural Sciences; Interagency Grizzly Bear Steering Committee; Old Growth as Wildlife Habitat Program; Museum Assessment Program; Museum Studies Committee; Zuni Museum Advisory Board. Also served on numerous committees within the Texas Tech University System.

Teaching Experience.—Hastings High School (Biology), 1956; Hasting College (Invertebrate Zoology laboratory), 1956; University of New Mexico (laboratories in General Biology, General Zoology, Plant Anatomy, Cytology, and Histology), 1957–1962; Tulane University (lectures and laboratories in Terrestrial Ecology, General Biology, Environmental Biology, Mammalogy, Comparative Anatomy, Biology of Primates), 1965–1966, 1969; University of Maryland (lectures and labs in Mammalogy, team taught), 1975; Colorado State University (lectures and labs in Vertebrate Pest Management, team taught), 1981; Texas Tech University (lectures in Professional Ethics in Museums, Collection Management, Zoological Nomenclature, Field Methods, Biology of Animals, Vertebrate Structure and Development, Introduction to Mammalogy, Advanced Mammalogy, Special Topics in Mammalogy, Vertebrate Natural History, Bat Communities, History of Mammalogy, Scholarly Writing in Zoology, and graduate labs in Field Methods), 1984–2002.

Awards.—Phi Sigma Outstanding Graduate Student Award; USFWS Outstanding Performance Award; Antarctic Service Medal; USFWS Special Achievement Award; Commendation from the Secretary, U.S. Department of the Interior; USFWS Letter of Commendation; USFWS Quality Performance Award; Texas Tech University Press Award of Excellence; Outstanding Researcher Award Texas Tech University; American Society of Mammalogists Hartley H. T. Jackson Award; Paul Whitfield Horn Professor Award, Texas Tech University; Paul Whitfield Horn Professor Emeritus Award, Texas Tech University.

Honors.—Phi Sigma; Sigma Xi; Phi Kappa Phi; American Men and Women of Science; Research Associate Department of Vertebrate Zoology National Museum of Natural History; Research Associate Museum of Southwestern Biology; Senior Executive Service (Charter Member) U.S. Civil Service Commission; Associate of International Center for Arid and Semi-arid Land Studies; Athletic Hall of Fame, Hastings College; Fellow of Texas Academy of Science; Honorary Member Texas Society of Mammalogists; Honorary Member American Society of Mammalogists.

Graduate Students.—Served on the following graduate student's committees either as chairperson or co-chair for Masters or PhD degree. Tulane University: Merilyn Warkentin Hasler (MS), Fernando Alvarez (PhD), John Pagels (PhD), Frances Miller Cashner (PhD). Texas Tech University: Stephen MacDonald (MA), Mary Candee (MA), Pat Brown (MA), Tommy Eaton (MA), Lorelei Mount (MA), Brenda Cooke (MA), Nancy Hildreth (MA), Patsy Jackson (MA), Mark Murphy (MA), David Zuflacht (MA), Dawn Kaufman (MS), Deidre Parish (MS), Maryann Lynch (MS), Kristie Jo Roberts (MS), Robert Hollander (PhD), Paisley Cato (PhD), Richard Manning (PhD), Larry Choate (PhD), Jim Goetze (PhD), Franklin Yancey, II (PhD).

Research Interests.—Taxonomy, systematics, distribution, ecology, and biogeography of Recent mammals, especially bats and rodents of America, as well as bats, primates, and rodents of West Africa. Distribution, ecology and status of amphibians and reptiles in North America. Biodiversity, conservation, and management of mammals and wildlife habitats. Management and conservation of specimens in museums.

Editors' note: For an excellent, abbreviated autobiography, refer to Dr. Jones' article entitled "You Have to Catch Them First" that is found within the book *Going Afield* (2005), published by the Museum of Texas Tech University, Lubbock (Carleton J. Phillips and Clyde Jones, editors). A PDF copy may be obtained at the following URL address: http://www.nsrl.ttu.edu/publications/otherpubs/Going%20Afield.pdf.

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Prologue

"We learned about field work, and for some reason we loved it": Oral History Excerpts from the Reminiscences of Clyde Jones

David Marshall

Part I: Recollections of Formative Years and Early Career

Interview of 6 November 2003 at Texas Tech University, Lubbock, Texas

Clyde Jones (CJ): I was born in Scottsbluff, Nebraska, March 3, 1935, a typical Depression baby… One of the remarkable things about my family—I was raised by older people. My mother was forty-two when I was born, and at that time that was unusual. And I had an older brother who was nine years older than me, so I was obviously sort of a tag-along…

Shortly thereafter my mother and father were divorced. My father remarried, and my mother never did. She had been a career school teacher in Nebraska, and she decided for some reason not to re-enter that profession. So she went into the cattle business with my unmarried uncle and my unmarried aunt and they raised purebred Hereford cattle. And we lived on a small ranch ten miles north of Burwell, Nebraska. We lived in the Sand Hills, and I had a great childhood. I thought and thought and thought and I can't remember anything bad about my childhood, and I think part of it was that I was raised by older people. There were no other children in the family. I had two additional aunts who were school teachers and they married very late… they never had children. My uncle Bob, who became my surrogate father, he never married and my aunt never married. And so I was protected and babied by those people…

I started school in a country school which was about three miles from the ranch headquarters. My brother and I went to school there, starting in the first grade, and I was sort of bored by all of that because I knew how to read and write and everything because of my school teacher aunts. On those long winter evenings they would read to me, and I would read to them…

My brother dropped out of school and joined the Marine Corps, and he was killed in the battle of Iwo Jima. That had an impact [*spoken emotionally*]…

Between the second and the eighth grade I skipped a year—I skipped a half a year and then another half a year. And so I was pretty young when I entered high school. I graduated when I was sixteen, and then my mother insisted that I lay out a year before entering college so I would again be with people my own age. And so I worked for the Navy at a defense plant building hundred-and-five-millimeter shells…

Because I lived on the ranch, I was interested in prairie dogs, and gopher snakes, and things like that. I had a big gopher snake and I put him in a cage in my bedroom upstairs in the old ranch house and one day went upstairs and he was gone. And I sort of looked around, and my mother had some ladies down stairs in the living room and then my mother called. This plaintive voice, said, "Clyde, could you come down here please?" And what happened was my mother would have some ladies come visit her and then toward the end of the visit my mother would play the old pump organ that we had and they would sing, or she would just play. Or my Uncle Bob, Aunt Mary, and I would be summoned to come and sing and that was a real trip, you know. But there was this gopher snake lying on the keyboard of the pump organ, and so all of them were aghast at all of this, but I got him and put him back in his cage. That was the beginning of the banning of pets in the house. No more! Okay?

David Marshall (DM): Did you hunt in the Sand Hills?

CJ: Yeah, there was quite a bit of stuff, you know, a lot of water fowl, a lot of mammals on the ranch. And I had another—the uncle who married one of my school teacher aunts was an amateur taxidermist. And he knew most of the animals, and he collected. We picked up things, and he prepared them in his amateur way. They were mostly awful but we didn't know that at the time…

We had pocket gophers, they were common in the Sand Hills, and we grew grass. We grew purebred Hereford cattle and grass, and we had those old bar mowing machines, single-bar mowing machines. And the gopher mounds, the sand would wear out the plates on them, and so I was hired to go trap pocket gophers. My uncle bought me a couple of sets of Victor Gopher Traps and on the weekends I would ride around and trap gophers. And I didn't know it but I was a mammologist.

DM: Did you ever skin them or cut them open to see how they ticked?

CJ: No, no, no, we just trapped them and poked them back down the hole and covered the hole, and buried and flattened out the mound, you know.

DM: You did mention… that you butchered cattle on the ranch.

CJ: Yeah, we butchered cattle and we butchered one pig. Let me tell you the pig story. My brother and I were out on our horses and we encountered this strange thing, and the horses were jumping around because they had never seen such a thing, and it was a pig. It was a red pig… and it had a paint bucket stuck on its face, and it was roaming around on our property. And we finally got a rope on it and we dragged it home and my uncle Bob came out of the barn and he kicked the paint bucket off of this pig. And I guess I was the first thing the pig saw—the pig imprinted on me and it just followed me everywhere and tried to follow me into the house and it just followed me everywhere. Finally, my mother let it come on to the porch but, you know, no pets in the house. That was a firm rule. Well anyway, I babied the damn pig. The pig grew up and my mother got on the phone and tried to find the owner of the pig and no one ever claimed the pig. So it grew up and we butchered it and we ate it. (laughs) But yeah, we butchered our own cattle, we had a big garden. Times were tough. We didn't have much cash. We had the land, we had the livestock, we had the equipment, which we were constantly working with, but cash was a little—we had to sell something to get money, that's simply how it worked. We had to sell something to get cash, and I guess that was typical of that era following the Great Depression. I'd like to say here that my parents—they never got over the Great Depression, they were sure it would come again, and maybe it has. They were sure that the Dust Bowl would come again. They were sure that World War I and World War II would happen again. These things always came up in sort of idle conversation around the dinner table, or on some Sunday gathering or something. Those things were never forgotten.

DM: Was that area pretty well devastated during the Dust Bowl days?

CJ: Yeah, I remember going out with my uncle and he would burn Russian Thistles [Tumbleweeds] that piled up in great masses against the fences. And we went to great expense to go to metal fence posts so we could burn the Russian Thistles that piled up against them. There were a lot of them. I remember that as a vivid experience, that in the Sand Hills, Russian Thistles sprouted and grew quite well.

DM: Do you recall any wildlife observations?

CJ: Deer were very scarce. Deer and wild turkeys were very scarce when I was a young boy. Now they're very common in that area. Jackrabbits were common, bunnies were common, pheasants were common, grouse were still present. The best place to hunt grouse was, they would get on top of the haystack in the winter time, and so you just go out and shoot them, shoot all of them. And we would hunt a lot of waterfowl. The plan there was to put a gunny sack over you and crawl up on a playa lake and shoot, and you quit when you filled the gunny sack. We were supposed to be conservationists but we weren't. But one of my uncles became appointed as a game warden. Well, that changed all the rules. (laughs) That changed all the rules immediately. He came and lectured to us and we learned about limits and things like that, and that changed everything.

Bill Tydeman (BT): Well you mentioned… some favorite books that you had in your early years that you still have in your family library?

CJ: Yeah I still have those.

BT: And one is [James Gilchrist] Lawson's *Wild Animals: Photographs and Descriptions of 100 Important Wild Animals*.

CJ: Oh, it's a wonderful book from that era. I still have all these at home. Yeah, it's just a book with portfolio photographs of animals, important animals…

I don't know why I kept those things either, except those were the things I learned. I learned about mammals from those books, and those were all very non-technical kinds of productions. But it was great, for a kid like me it was great, okay? This was an inroad into knowledge about mammals that I couldn't get, that didn't exist anywhere else. There wasn't a *Mammals of Nebraska*, or there wasn't *Mammals of the Sand Hills*. There weren't any of those things. Those things didn't come along, my God, until the late Knox Jones wrote *The Mammals of Nebraska* in the 1950s.

BT: The other thing that interests me, Clyde, in talking about your days at home and the influence of your mother, you mentioned that you had in a sense a family story hour, or a time in which each week you would tell stories, or talk about your readings?

CJ: Yeah, she was very strict about that. She included herself—she and my two school teacher aunts who lived with us or they stayed with us on weekends. They lived with a family near their school, a country school where they taught during the week, but they lived with us on weekends. And we had reading assignments, to read some book and then after dinner we would report on it. And she was very strict about that, and I got into these mammal books and so that's what I would read with a couple of exceptions: the *Trail of the Loop,* I think I mentioned there, and then along came a book titled *Old Jules*, which was a real classic about an early settler who came alone to the Sand Hills and it's the story of his life. He had what, three or four wives?

BT: Yes, and a daughter that becomes pretty significant—

CJ: Yeah, his daughter Mari Sandoz became a very important writer in Nebraska history. Yeah, we had to report on these. I mean, and you didn't miss a report, okay? That was another thing that didn't—you didn't say, "Well I don't have anything to report." You didn't. This was one of those, as my uncle Bob called them, this was a non-negotiable.

DM: I have the feeling that this reading was more inspiring than high school biology, from some of the comments you've made. Could you tell me a little bit about high school biology? Or what was the real impact on your life that would cause you to become a mammologist?

CJ: Well, let's touch on high school very briefly. I learned one important thing in high school: I learned to type because my mother made me take typing. And as one of two guys in the class of about thirty females, you can imagine the names we were called. But here we are, two football players taking typing, and those old unmarked keys, a-s-d-f-j-k-l-semicolon. Jesus! How could you ever forget that? And that's why I think, yeah, I think I've been fairly effective because I learned to type like a typist, rather than hunt and peck…

I was sort of an undisciplined brat in high school. High school biology didn't thrill me very much because I knew something about all of that stuff. I knew about reproduction, I knew about reproduction systems by watching the cows and the dogs. We had a bunch of dogs—you know. I knew all that stuff. I enrolled in college, and I had saved enough money to pay for the first full year of my tuition and my lodging. I lived in the dorm.

DM: This was at Hastings?

CJ: At Hastings College which is a Presbyterian college. And I went to talk to the football coach and he checked me over. He weighed me. I weighed one-hundred and eighty pounds, and he said, "What are you?" And I said, "Well, I'm a center or a guard." He kind of laughed and said, "Yeah, he's a center or a guard." He said, "Here's the line coach why don't you talk to him." And the line coach said, "Yeah, you're a center to guard, you know." He said, "Why don't you snap the ball to me a few times." And I did, and he said, "Yeah, you're a center." But he said, "You're kind of small." And I said, "Well, you know, I was an honorary mention all-conference in high school." And he said, "I don't care about that shit. I want to know what you can do in college." And so we practiced and the B-Team, which I was on, we had a game with an outfit at Norfolk, which was a junior college at the time. And we went there and he said, "Now, you guys are going to learn the difference between high school and college. This is your first game." And the Korean vets [veterans] were returning. H e said, "There're going to be some older guys and they're going to be tough on you." And we got in this game and the guy across from me, he just flattened me two or three times, and bloodied my face—oh, at that time we didn't have face masks, okay? We just had interesting pots and no face guards, and I got my face bloodied, and the coach said, "Well, we know who's looking around in there, you're looking around in there, you're getting your face bloodied." And that guy was just flattening me, and I said, "Well, if you put me back in, I think I can take him." And he just flattened me again. And they called a timeout and we were running to the sideline and this guy was just standing there, and I just gave him one as I went by, I hit him right in the neck and he just dropped, and it was a totally illegal and unconscionable thing but nobody saw it except my coach and he said, "You know, Jones," he said, "You have possibility." (laughs)…

I played three years at Hastings. I lettered three years. I didn't play my senior year because I discovered science. I used to go down to… a little museum in Hastings called "The House of Yesterday," and it's a typical mid-western city museum. It has farm equipment and all kinds of things. But I used to go down there, and I went down there so often they let me go behind the little exhibits and things. And there was a guy down there skinning birds, and I was fascinated by that. And I found out that you could make a living doing that. You could get paid to skin birds and skin mammals and things. And I went back to the college and talked to my advisor, who was a guy named Dr. Moulton—"Moldy" Moulton we called him. And he said, "Yeah, there is a field there." But he said, "You have to take the following courses." I had been going to be a history major, and I thought my future was in teaching history and coaching in high school some place, because that's what you did in that generation. Women were either secretaries or school teachers; men were either ranchers or taught school and coached. I mean, those were the opportunities in that time, in that place. And so, in my senior year, he enrolled me for about twenty hours of biological sciences—comparative anatomy, all that good stuff. And God that was great stuff. I thought it was great. And Gene [Eugene] Fleharty and I had become friends in 1953, and Gene was a year ahead of me, and he went off to graduate school. He went to [University of] New Mexico. And he and Jim Findley found each other. And Gene influenced me to apply at New Mexico and my advisor John Moulten said, "Yeah, you should go to New Mexico." He said, "They never do anything practical down there." And I thought, well, that was an interesting thing for him to say. And I didn't know about wildlife biology even though my uncle had become a game warden. I didn't know what you did—I mean he was just a rancher and he was appointed a game warden. I thought, that's the luck of the draw, I thought, that's how that happens. But, Fleharty started filling me in on what he did and I talked it over with my mother and she thought I should go. She thought I should go to New Mexico because I could learn about different cultures. I could get out of the Sand Hills, and besides that she wanted to come visit me, and so, okay.

DM: What about Fleharty, was he from right around Hastings?

CJ: He's from Hastings. He comes from a family of six boys in that family.

BT: Was he on a clear biology track as an undergraduate?

CJ: No, I don't think he knew what he wanted to do either. But John Moulton encouraged us to apply to graduate schools, and so he was accepted at New Mexico and he went there. And I was accepted at, let's see, some place in Illinois but I didn't really want to go there so—

DM: Didn't you teach high school for a little brief period too?

CJ: As a practice and a substitute teacher.

DM: While you were attending Hastings?

CJ: Yes. And I quickly decided that high school teaching was not for me. I quickly decided that's not my bag…

So we went to New Mexico, and Jim Findley loves to tell this story: I walked into his office wearing a shirt with the sleeves cut out and an old cowboy hat on and a pair of boots. And Findley tells the story that I still had horse shit on my boots. I don't think that's true. And he said, "What do you want?" And I said, "I came to get my PhD." And Fleharty was with me, and Findley looked at my transcript from Hastings College…

Findley took a look at my college transcript and he said, "You know if you were here you would hardly be a senior." I didn't take chemistry in college… I never had botany, either, as an undergraduate because botany wasn't taught at Hastings. They didn't have one. They had a one-man biology department, one-man biology and geography department, and so, we were a little weak in background information.

DM: But, you know, they produced two biologists. Is that just coincidence? Are there others that went into biology at Hastings?

CJ: They produced others—there's a guy visiting us from Lincoln, Nebraska, named Hugh Genoways. He's a graduate of Hastings. They have produced half-a-dozen mammologists.

DM: Why is that?

CJ: We don't know. We don't know. And I guess the track that Fleharty and I led sort of attracted a couple of other people. It attracted Hugh Genoways, who [thought] "I'll follow in the footsteps of those guys." And he did. But as Findley put it, "I had to make something out of two jocks." (laughs) And I don't know if he did or not but we survived. I think my first semester as a graduate student I think I got four hours of graduate credit, all the rest were leveling courses—botany, chemistry, stuff like that. Jesus! I got a C in one of my chemistry courses, and the rules were: if you got six hours of C you were out. And Findley said, "Well, you got that out of the way; now you don't have to get another C." That was his positive approach to it, you know. (laughs) For God's sake! Actually, I was very happy with my C at the time. And we learned about trapping and skinning mice. And we learned about field work, and for some reason we loved it…

We did a lot of field work. NSF [National Science Foundation] came out with a program of grants for terminal [degree] people to finish their research and we both applied for that, and for Christ's sakes, we got them. And they paid a bunch of summer money to us, so we gave the money to our wives and we went and lived in the field. Gene lived at a place called Wall Lake. He was studying garter snakes for his PhD. I lived at a place called Willow Creek because I was studying bats. Bat nets had just become available. And we didn't really know what we were doing, okay?

DM: Before bat nets became available was there anyone doing that kind of work? Were they finding a way to—

CJ: The only way to get bats was to shoot them. And out of a case of shells you might get two or three, because they're pretty quick, you know. The other way to get them was to stretch a wire about that far above the surface of the water and they would come in drinking and fly into it, and if you were quick enough, you could get them.

DM: Did the use of bat nets really promote the study of bats? Did it have a real significant impact?

CJ: Yeah. The study of bats exploded; it exploded with the availability of bat nets.

DM: And you were right there?

CJ: Yeah, we were on top of it. And science was funny then too. Remember, this was—statistics hadn't been invented yet, computers hadn't been invented yet, things were primitive, and the whole concept of hypotheses hadn't been invented yet. The approach was, we go into the field with a sack and a stick and collect everything we can collect, and then bring it back and try to decide what to do with it. It was that approach, and it worked. We were working with Jim Findley on the *Mammals of New Mexico*. And so we were collecting, and we were collecting everything in sight, literally. We were shooting it or trapping it or netting it. We were collecting everything. And I became interested in bats because I stopped in at the University of Arizona, and E. Lendell Cockrum—who's still alive, incidentally—he was a bat person there, and he said, "You ought to study bats." He says, "There's a real need for it." And I thought, yeah, I ought to study bats. And I convinced Findley that I should, and he was a little nervous about that at first. And it turned out that I lucked into something. I caught a whole bunch of bats and it worked out that different species forage at different times and, therefore, they feed on different things. And that was sort of the beginning of resource partitioning as we now know it. And we didn't even call it that then. We just said, "Yeah, these bats feed at this time, these bats feed at this time, and these bats drink at this time, and these bats drink at that time." You know the phrase "resource partitioning" hadn't been invented yet either. (laughs)

DM: Where were you doing most of your bat netting at this time?

CJ: At various places in the mountains of west-central New Mexico. I lived in a tent at Willow Creek and traveled around to several places and netted bats... It's in the Mogollons. And Fleharty lived at Wall Lake. And about every two weeks I would go see him or he would come see me. And the road from Willow Creek to Wall Lake was a real bitch, and if it rained, it was worse than that, it was just solid mud.

DM: Can you describe your camp life?

CJ: I don't think we were ever lonely, maybe a little bit sometimes, but we were busy. First of all, subsistence was important. We were busy feeding ourselves and keeping ourselves dry. And in the mountains it would rain frequently. In the summertime, the summer monsoons came through, and August was rainy. It would rain. And he was working on garter snakes and he was in the lake a lot. I was netting bats a lot. We didn't have waders at the beginning. Later on, I got a pair of chest waders and they were wonderful. But yeah, we were just busy. We would—I would net bats all night and then skin bats all day.

DM: What about food and shelter?

CJ: Well I lived in a tent. I lived in a ten-by-ten umbrella tent, and I'd cook a good meal maybe once a day; lunch the rest of the time. Peanut butter sandwiches are really good, you know, they'll carry you a long way. (laughs) Yeah, you can live a long time on peanut butter sandwiches. Peanut butter is also rat bait.

DM: When you launched into this field work, early on, did you feel that you had found your niche, or did you question whether this was really what you wanted to do?

CJ: This is what I wanted to do the rest of my life, was trap and bag mice, and net and bag bats. This was it. And I discussed this with my mother. And as I comment in there, I'm not sure she ever really understood what and why I did what I did, but she supported it…

But yeah, this is what I wanted to do, and I wanted to teach other people how to do the same thing. I wanted to teach and do this. And then I finished—well, let me tell you another story. Fleharty and I were roaming around the mountains, and I was driving. Jim Findley loaned us his old Chevrolet pick-up, and he had a camper on the back made out of plywood, you know how those are... It was an awful beast. We took a trip and went into the Black Range of New Mexico and we patched the tire with hand tools, and patched the tire with a sleeping bag patching kit—and the damn thing held! (laughs) And so we went on with our trip and I was driving… and he says, "Stop, stop, I just saw a white chipmunk." Yeah, yeah, yeah, white chipmunk? White elephant yes, white chipmunk, no way. He says, "Back up, back up, I saw, I'm telling you, I saw a white chipmunk." And I thought "This guy, he's nuts." He says, "Back up goddamn it, I saw a white chipmunk." So I backed up, and sure enough, there was a white chipmunk sitting on a rock and he shot it. And we skinned it and stuffed it. You know, whoever heard of a white chipmunk? So we got back to Albuquerque and—oh, we got to Silver City and a guy at a Standard filling station there sold us a tire on the promise that we'd pay him the next time we came by. How about that? We had like five dollars and he said, "No, I'll just sell you a tire and next time you come through, I recognize the truck, the next time you come through you pay me for the tire." It was like thirty dollars or something. And we thought, "Hey, this is great, we should have bought all four of them." (laughs) And we called Findley, called him on the phone from this service station, and he said, "Now what have you done?" And we said, "Well, we bought a tire, and we will have to pay for it the next time we come through Silver City." "Yeah, yeah, yeah, give me another bullshit story." "Well, we shot a white chipmunk." "Great guys [*Findley said in disbelief*], when are you coming home?" "Well, we're starting home right now, we will get there tomorrow." And so we wrote a paper on this white chipmunk and submitted it to the *Journal of Mammalogy*, and it was accepted. And we thought, "Hey, Jesus, this is really neat, you know, you can publish on what you do." And so we went to Findley and we said, "Well, there's this thing about buying reprints, and we don't have any money." And he said, "You go to the chairman and you ask him to buy your reprints." And he set us up. So we walked in—we made an appointment, we walked into the chairman's office and we said, "We wrote this paper on this white chipmunk, and we have to buy some reprints, and we wondered if the department would buy reprints." And the chairman just looked up at us and he said, "Graduate students don't publish." And we thought, "What the hell was this?" And Findley was waiting right outside the door laughing his ass off. He said, "I'll buy the reprints; I just wanted you guys to get the departmental philosophy." That was the philosophy: graduate students don't publish. (laughs) And that was the beginning of it all—hey you can publish this stuff, and you can publish it in the *Journal of Mammalogy*, shit, we'll be famous. (laughs) That's what we said to each other, "We'll be famous." And Findley said, "Yeah, yeah, you guys are already—'infamous'—is the word." Geez, but that was the philosophy. Graduate students don't publish. So—

BT: But at the time that you're at New Mexico doing your graduate work, and you're talking about the methods and practices that existed then, I mean Watson and Crick are just coming out, the double helix, and the—

CJ: Oh God, did I luck out on that one. Yeah, I was taking my final exams for my PhD…. The night before my oral exam, I went to the drug store to buy a relaxant. And there while waiting to checkout, there was a *Life* magazine with the double helix on it, and a big article about Watson and Crick. And I bought the magazine. I thought, "I better buy that." And I read that damn thing that evening and the next day at my oral exam, the first question out of the box, Jim Findley said, "Have you ever heard of DNA?" And I thought, "I'll just get the bastard." I jumped up and I drew the double helix on the blackboard. I talked about it for about three minutes, and Findley said, "You son of a bitch, you found the magazine." (laughs) That was in the early sixties, Jesus. It was luck, just luck. Just blind luck all of my life…

DM: Was it Findley that got you the museum curator position at UNM? Didn't you work there in the museum for a while?

CJ: Yeah, Findley got that job for me. That was great… I finished my PhD and I was hired as the assistant curator. I was the assistant curator for mammals, birds, fossils, plants, reptiles, and amphibians. I was busy.

DM: What kind of work did you prefer: the teaching, or the museum work, or the field work?

CJ: Well, field work of course number one; it still is. Museum work is very important. Teaching is a way to achieve those things…

My mother was very, very supportive of me going to graduate school and becoming a college teacher. She was very supportive of that, in every way. I can't think of a single incident that she was not supportive of. She was extremely—almost pushy—supportive that I would find myself, I would be a college teacher, and I would have a better life than she had. I heard that many times. So, I had the assistant curatorship at Albuquerque and I realized that I would just always be Clyde the graduate student, that I had to get away from there, I had to leave, I had to go someplace. And I applied around and interviewed at two or three places…

Fleharty had left. He went to Nebraska Wesleyan in Lincoln, Nebraska, for one year. He was paid five thousand dollars and we thought, "Hey, hey, we're on the right road here." I got a temporary job at Tulane University to replace Norman Negus, who was on sabbatical for a year, and I was paid eight thousand dollars. And, Jesus, everybody was hanging around me, you know. And so we moved to New Orleans, moved to New Orleans in my Dodge with a small U-Haul trailer with everything we owned, and lived in a little apartment on campus; finally found an apartment of our own out by Lake Pontchartrain, and lived out there. [I] taught eighteen contact hours and [would] come dragging into my office at nine o' clock in the evening. And I picked up a couple of graduate students, picked up three graduate students in fact, and they would say, "Why do you come to your office at nine o' clock?" And I said, "Stupid, that's when my last class ends." I taught my ass off at Tulane.

DM: What kind of an adjustment was that, having grown up in Nebraska, lived in Albuquerque, and then moving to New Orleans, of all places?

CJ: That was an experience. Albuquerque was a very cosmopolitan city and the University of New Mexico was a very interesting place. All the news media focused on Berkeley [University of California]. Berkeley didn't have it, man—we had it, but we were a small place, okay? I mean, we had everything, mixed marriages, mixed couples, this was the hippie era. We all grew hair. We were going to strike once for—oh, because of the dress code. And we pushed this all the way to meet with the President of the University of New Mexico. And we had a spokesperson and everything, and he met with us, he was a guy named Tom Popejoy. And he met with us, and he was very patient. He listened to us and he said, "You know, I'm going to take this under advisement; I'm going to think about it for a month. I'll meet with you a month from today." And he said, "Oh by the way, I'm going to freeze salaries until a month from today." And he left, and we looked at each other and we said, "This isn't working out." (laughs) "This is not what we had in mind." And we met with him a month later, everybody had clothes, everybody had a shirt with a collar, and everybody had socks and shoes on. Sometimes one blue sock and one grey sock but everybody had clothes. And he said, "You guys are a good looking bunch of guys, you are going to be paid, here are your checks." (laughs) Jesus! That was our learning experience about organizations and striking and unions. And that lasted with us, we have never belonged. Fleharty and I have never belonged to a union or an organization like that since. We learned—he was great, he was a great President…

When I arrived at Tulane, Tulane had integrated itself racially and sexually, and that was interesting. And living in New Orleans was very interesting also for a guy from the Sand Hills…

I became acquainted with the director of the Primate Center who was a guy named Art Riopelle. And I don't know, for some reason he liked me too, and he said, "You ought to come to some of our seminars." And so, okay, I'll go to some of his seminars, you know, I don't have enough to do already. So, I went to one and it was a girl [speaker] named Jane Goodall. And he introduced me to her and her husband who then was Baron [Hugo] van Lawick. And we talked about her work in Africa, she gave a seminar on her chimp work, and I was just totally enthralled with this. And she said that the late Mr. [Louis] Leakey was looking for somebody to study primates in West Africa—lowland gorillas. And I didn't think anything about it. We talked about Dian Fossey and her work with highland gorillas, and I didn't think anything about it. And she went away, and I went back across the river, across Lake Pontchartrain… I was beavering around Tulane and Art Riopelle called me and said, "Why don't you come over and see me? Why don't you come over and visit with me?" Okay, so I went over and he said, "I think we ought to apply for a grant; I think we ought to apply for a grant to send you to West Africa." And any young mammologist that doesn't want to go to Africa is not worth anything, okay? I wanted to go to Africa, but I thought, "This is unreal, this can't be happening." And he said, "Yeah, I'll draft the grant, you fill in the information about yourself, and we'll get some money from the National Institute of Health, and we will get some money from [the] National Geographic [Society], and we'll send you to Africa for a year." And I thought "Okay, I'll take a shot." So we put the grant together, and we submitted it, and, quite frankly, I sort of forgot about it. And that summer [Royal] Suttkus taught—it was the summer of 1965. Suttkus had an environmental training grant, and he took a group of students from Florida to San Diego, and I went with him on that trip. God, it was great. We collected the shit out of everything. We collected a thousand mammals; a thousand specimens…

And I got home, and my wife said, "You're to call Art Riopelle immediately." "Okay." So I called him and he said, "Hey I have good news for you, we got the grant!"…

So, in the summer of 1966, I went to Africa. I went to Spain and met the Spanish coordinator who was the director of the Barcelona Zoo, and his biologist who was Jordi Sabater Pi, and I slogged around Spain. It was a wonderful place, wonderful beer in Spain, wonderful. San Miguel [beer] is just for your taste. You can get it here…

And I went to Africa by myself. Jesus! Went to Rio Muni [present Equatorial Africa] and met the people and the army and everybody. It was a Spanish colony, and so I met everybody. Jesus Christ! What an operation and what a place to get into and to get out of.

BT: You mean all kinds of bureaucratic regulations and things that just—?

CJ: Oh God—yeah, and there were essentially two governments in Rio Muni: the Spanish government, and they had what they called an "autonomous government." They were training a government to run the place, because it was going to become independent. You know, you deal with the *Guardia Civil*, which was the army government that ran the place, and then you had to deal with the civil government, and that was a nightmare. Bureaucracy rampant, and double paperwork, and "Oh, that doesn't work, you have to fill this out," and so on and so on. Anyway, I slogged around Rio Muni and selected a couple of places I wanted to study. And I had to arrange to rent a house and ordered a car, ordered a Land Rover, which would be delivered sometime in the future, and incidental things like that. Checked out the medical facilities, caught malaria, had a great time. I went to get my—I'll tell you a small story—I went to get my paperwork to leave and you had to have a blood test, a test for malaria, before you could leave the country. So I was standing in line, and I got up front and the guy taking the blood had a lancet, and he would take somebody's blood and then he would wipe it off with an old rag. And I said, "I don't want you to do that, I want you to use another lancet." And he said, "This is the only one I have." And I went to my Land Rover and got in my skinning kit and punctured my finger. I didn't want hepatitis on top of everything. And I came back and taught in the fall semester at Tulane… And so I went, took my family to Africa in January of 1967…

I had been there in the summer of '66 and this was in January of '67. Went to Spain, went to Africa from Madrid to Fernando Po, it's now called Macias Nguema, the island on the west coast. That was a ten-hour prop plane flight, and everybody was sick, everybody barfed at least once on that flight. Flying over the West African desert was like that in a prop plane. Landed at Fernando Po, and I had convinced my son [Craig] that the reason to go to Africa was that he wouldn't have so many Joneses around him. In New Orleans there were thousands of Joneses, okay, thousands of them. And so we walked into the terminal at Fernando Po, and there's this tall black guy standing there and my son walks up to him and says, "My name's Jones, how are you?" And the guy says [*in a British accent*], "I say, my name's Jones also." (laughs) Craig says, "I want to go home." (laughs) It was a British-educated Nigerian. [It was] really strange to hear that accent, incidentally, really strange.

DM: How many total months did you spend in West Africa?

CJ: Well, we spent a total of nineteen months… We were supposed to spend a year and a fortunate thing happened. The Spanish devaluated the peseta. So, suddenly, I had more money than I thought I had, and I wired Riopelle and he contacted National Geographic, and they said, "Stay, take the money and stay." On the way there I stopped in Washington and went to National Geographic where I met Dian Fossey for the first time, and they had a wonderful director of research [Leonard Carmichael]. He was the former secretary of the Smithsonian, and he said, "I'm not interested in glossy-paged articles, I'm interested in science." And I thought, "This guy knows what he's talking about." And so, we were in Africa, the house I had rented, the furniture I had arranged for was still there, the brand new Land Rover was there—diesel Land Rover. If you have never driven a diesel Land Rover you haven't experienced anything. It's a diesel jeep, oh God, bump, bump, bump, bump. But Rio Muni is a small country about seventy-five miles wide and a hundred and twenty-five miles long and about five-hundred thousand people; about twenty white people when we were there. They thought at first we were French, or German, and when they found out we were American, we were very popular, because we were the only ones there. And they thought we were something special, I guess, I don't know. They had all kinds of questions about life in America. And when I worked, I would go out and arrange to stay in a village, and hire a woman, stay in a nice house or some place, and hire a woman to boil water and to cook for me, and hire a boy to keep the goddamn goats off of me. (laughs) They had thousands of goats and they were everywhere. In my bed, in my car, on top of the Land Rover, they were everywhere. I had to hire some young man to keep the damn goats away from me. Jesus!

DM: What were you trapping?

CJ: Well, I was studying primates.

DM: Just primates?

CJ: And I wrote *The Bats of Rio Muni* and I wrote numerous—I wrote nineteen papers from the nineteen months I stayed there. That was my goal, and I achieved it…

BT: You mean you went in with the idea of a paper a month?

CJ: Yeah, I went there and said "I'll write a paper a month." And I achieved that goal, nineteen papers in nineteen months.

BT: Did you begin to think about, well maybe primates is what I want to do, to do primate research, or did you see it just as a separate path?

CJ: I looked at primates from a zoologist point of view. And they're really interesting, and there are some really interesting problems. But I came to the realization that those problems will never be solved, because primates remind you of little people and there's a lot of emotion tied to getting permits to study primates. What really ought to be done is, somebody ought to go shoot about a hundred of them of every species, but you could never get a permit to do that. And the specimens that are in museums, the British Museum, the National Museum [of Natural History], the American Museum [of Natural History], Chicago [Field Museum], they are all caliper-worn from being measured for a hundred years, and they need new material to study the problems, and you would never get a permit to get it.

DM: On a broader scale, do you have that problem with mammals where you wouldn't have it with herps?

CJ: Yeah, it's a problem with mammals, it's a problem…

The African experience was a wonderful experience scientifically; it was a wonderful experience personally. The political problems were incredible. There was little to do in Bata for entertainment. Well, going to the market was entertaining and problematic, of course. They had a movie theater. The movies were all in Spanish. We went to the movies a lot. They had soccer games there; they played teams from Cameroon and Gabon and Nigeria. We used to go to soccer games—we were sort of special there because we were the only white people and my wife was the only woman there. It was a men's thing, but we went. One time one of my trackers came by and he said, "Don't go to the soccer game Sunday." I thought, "Well, he wants my tickets or something." He said, "No, please, don't go to the soccer game Sunday." Well, as it turned out, during intermission they brought out some political prisoners and shot them, and he knew that was going to happen. Everybody knew everything. I thought—I used to joke and say it must be drums, because something simple would happen—the license tag fell off my Land Rover, and I didn't know it, and I heard about it for about a hundred miles. And I thought, "If I don't recover that license plate, everybody is going to go crazy, they all know about it." It's a fantastic society. You get inland just a little bit and there are people there that have never seen the ocean, and the whole country is one hundred and twenty-five miles. And they're very clan-oriented. They are called the Fang, it's a sub-group of African culture. It's very interesting. I liked them. I learned to like them and respect them, and yet I feel sorry for what they are subjected to and they are still subjected to incredible human rights problems. But it's a small place, they don't have anything. They discovered oil in 1995, I believe, and oil companies pour some money into the country. Most of it goes to the dictator—it's a mess.

DM: Did you happen to write anything about the society while you were writing about—

CJ: I wrote a little bit about it, just a little bit. Yeah, my daughter says she thinks I should write a book about that, and I don't know if I will or not. It's a wonderful—the people are wonderful once you get to know them. They're wonderful and they are clever and they can do wondrous things with their hands. I went down a river once with a dugout canoe with an outboard motor on it, and the motor quit, and we beached the boat. And this guy, with a Swiss Army knife, took the motor all apart, laid all the pieces out, and I thought, "Oh Christ, we'll never get out of here, we're in the mangrove swamps." He laid all the pieces out on a rag and wiped every piece off with a rag, and put it back together and cranked it up, and I was amazed at this. I couldn't do that; I couldn't do that. They're amazing.

DM: Did you happen to keep journals during your field work?

CJ: Yeah, I have field journals of all that stuff… That was a wonderful period of time for us and the children were very young, but they still speak Spanish; that's all they had. We returned to the Primate Center and bought a house in Mandeville, Louisiana, and enrolled my son and daughter in the public school there. And one day I got a call at the Primate Center that the principal of the school wanted to talk to me. And I wandered in there and he said, "I have to talk to you about a problem. Your son and daughter are lining up with the black kids at the black drinking fountain." He said, "Are you a blockbuster, or what are you trying to do here?" And I was absolutely flabbergasted by this—this was in 1968. And I did not realize that they still had a white and black drinking fountain, and I tried to explain to this guy that we spent nineteen months in Africa; the only children my kids knew were black children or Spanish children; they don't know any better, they don't get the segregation part, they don't know any better, it's purely an act of innocence. And I don't think he ever really believed me. And I talked to Sherry and Craig about this and they said, "Well, I mean, we were talking to so and so, and she went to get a drink, and I went with her." And I said, "That's perfectly fine, I want you to do that. I just want you to know that things are a little different here than they were in Rio Muni." And my son had sort of a wise comment. He said, "Yeah, things were better in Rio Muni, weren't they Dad?" And I said, "Well, in some ways, yes, they were, yeah." I couldn't believe that. That was in 1968…

I came back from Africa and was housed at the Primate Center and I had from National Geographic funds to write for a year. And I was looking for a job and I saw this ad with the Fish and Wildlife Service, and I applied for the job, and went for the interview and lucked out and I got the job.

DM: This was Chief of Mammals—

CJ: Chief of the mammal section of the old Burton Mammal Laboratories, which is a remnant of the Biological Survey that C. Hart Merriam operated. And, my God, I lucked out, I got this job. And it paid $13,300 for a year.

DM: And that started in 1970?

CJ: Yes.

DM: How long were you in that position?

CJ: Oh, I spent ten years there, but I became the director of the lab and I don't remember exactly when that happened. And then, after ten years, the Fish and Wildlife Service moved me to Denver and combined the old Denver lab with the lab in Washington. And I lasted there until 1982. President Reagan appointed a gentleman named James Watt to be the Secretary of the Interior, and he came to visit me and I decided I should search elsewhere. (laughs)…

I was very happy. I had a wonderful time in D.C., a wonderful ten years there. I had enough. And I'm a western person. I had enough of the government structure. Don't misunderstand me; those were wonderful years for me. I made real lasting associations with a lot of people. I got to hire a lot of people. Our outfit grew and bloomed, especially under the Carter administration. He understood in part what we were trying to do, and yeah, I got to hire and see some wonderful people grow and develop, some of whom are still there. It was a wonderful ten years. I just wanted to move back to the Midwest…

I loved it at Denver, okay? I loved that job. I had about two hundred people working for me. My management style is sort of different. I had an executive secretary, an assistant director, and a business manager; they reported to me. The assistant director took care of everybody else. It was a wonderful job. We opened and developed field stations in Haiti, the Sudan, Philippines, all over the world. In Alaska, we had field stations in Anchorage and one at Fairbanks; had the California situation. The Marine Mammal Act was passed. The Fish and Wildlife Service portion was given to me. Suddenly I had four million dollars and not a marine mammologist on the staff, and so I hired one. And he hired others and it was great fun, it was just great fun. When I left, we had two hundred people and about twenty-million dollars plus a whole bunch of money from AID [Agency for International Development] for the foreign field stations. I hated to leave Denver. The option was to move back to Washington. I and my then-wife were not terribly enthralled with that idea. I mean, we had spent ten years there; it was enough. We wanted to be in the west somewhere…

And the late Knox Jones called me and he said, "I don't know if you're interested, but," he said, "There's a position coming open at Tech." He said, "I have it that the museum director is going to resign." And I thought, "Huh, I could do that." So I applied and I lucked out…

I was interested in returning to work in the Chihuahuan Desert. And I came here as director of the museum. The so-called museum support groups were very strong because of weaknesses on the part of former directors. I put up with that for a while, and then I decided, "Bullshit, I'll just go back to biology and be a professor and work on mammals of the Chihuahuan Desert," which I did, with a fair level of success…

Within my lifetime we've gone from no techniques, we've gone from where data overshadowed the technology, to now where the technology overshadows the data. This is a tired old phrase: "We need more data." We went from having to hand-make distribution maps to making them with the touch of a key now, and there are a lot of holes, there are a lot of gaps, there are a lot of things we don't know. There's a collection of Chihuahuan Desert mammals here, we have, and other things. We have a hundred-thousand specimens. What do we know about the Chihuahuan Desert? Not much, not much—and it's a very crucial area now, with the issue of water.

Part II: Further Thoughts on Living and Working in Rio Muni

Interview of 27 February 2012 at the home of Clyde Jones, Lubbock, Texas

David Marshall (DM): Can you tell me the circumstances that took you to research in West Africa?

Clyde Jones (CJ): Yeah, I was a young professor at Tulane, and I had finished my graduate work from New Mexico working on mammals of the southwestern desert, and I became acquainted with Arthur Riopelle. He was the director of the former Delta Primate Research Center, and he was a young man who was a psychologist, of all things. And he said, "Let's do an African study." And he had made a contact with a person at the Barcelona

Zoo and he said, "Yeah, we could get a Spanish contact and work in the Spanish colony in West Africa…" And, well, I knew a lot about Africa. I knew where it was, geographically, and I had read "Tarzan," and that's about it. And a great surprise to me, we obtained funding. We applied to the National Geographic Society and to the National Institutes of Health, and both of them were approved… So, I went to Rio Muni, in the summer of 1966…

He had also made a contact with Louis Leakey, who was a mentor of Jane Goodall and Dian Fossey, and he brought Jane Goodall to the Primate Center to give a talk…

The primate center had a colony of captive chimps which Arthur Riopelle had studied, but he was interested in Lowland gorillas and chimps, and the ecological separation between the two. And so, I went to Rio Muni with the understanding that I could study other mammals as they came available to me. You know, I'd never seen a gorilla before. So I went to Rio Muni. Jordi Sabater Pi was there and he was familiar with the language. He spoke some Fang… One of the first things I learned was that most of the Fang that lived out in the villages were frightened of the rainforest. Their lives were centered around the village, and the slash-and-burn agriculture. And most of the men, women, and children never ventured into the rainforest. They had all kinds of mythical tales about what would happen to them if they went into the rainforest. Like they would be chased by a gorilla or chimp-like monsters, or be killed, raped, or pillaged. You know, all kinds of weird stories…

But in most villages there was a hunter who went into the rainforest, and he captured bush meat. And he captured monkeys and small dik-diks, and all kinds of animals and birds. They ate everything. They ate fruit bats; they ate birds; they ate mammals; they ate everything. And it was usually a hunter, so I eventually learned to find one. It was usually someone who stood around the outside, and he would come around later and say, "I'm your man."

DM: So he wasn't *in* society; he was kind of on the periphery.

CJ: He was kind of on the outside.

DM: Why was that?

CJ: Well, because he went into the rainforest. And he was considered a brave, very brave man. And for some reason, they were armed with crossbows and blowguns and the ever present machete. And then all the hunters smoked a pipe. And I soon realized what it was, it was marijuana, which there was a patch at every village, and that was called an anti-fear device by me. These guys smoked the pipe and then went in to the forest, and I went with them on a hunt a couple of times. And they used the blowgun, and a poison dart, and they shot a monkey up high in the tree, and the monkey came crashing down. And he cut a slot in the arms and legs and put them together, and put them on his back, and put one of them on my back, and back we went to the village. And I was worried about the poison dart that might be somewhere. But what he did was, he felt all over, and found the poison dart, and extracted it.

DM: Now what about the poison in the system, and then eating that monkey?

CJ: Now that didn't seem to bother them. But they had a way that they went at it, especially the pygmoids. When they got a monkey, they went at it by opening it up and eating the stomach contents. That was the first thing they did.

DM: Raw?

CJ: Yes, just cut it open and eat it, ghastly stuff.

DM: You tasted this?

CJ: Yes, it was terrible stuff.

DM: This is what you said looked like split pea soup?

CJ: Oh yeah, they ate it. They kind of danced around, and you know, scooped it up with their hands and ate it. They didn't have—the people that lived in the woods— the pygmoids, or they were called the *Bajeles*—they didn't have any utensils; they ate everything with their hands—everything.

DM: Did they eat everything raw or did they cook some?

CJ: They cooked sometimes; they cooked some meat or some things, but they just ate it with their hands.

DM: And they ate it with gusto, the contents of the stomach?

CJ: Yeah, oh yeah, it was a ceremonial kind of thing.

DM: Now what was the ceremonial part of it? You said they got excited.

CJ: Yeah they were excited, they danced around you know, and the guy would hand some to somebody, and he'd take it and eat it, and yeah, it was some kind of ceremony. I never did figure out their language, but for some reason that one little woman just sort of adopted me, and she took care of me, and she was quite observant. She observed me sitting on a stump or something, writing my field notes, and I went out with the guys and they came back, and there was a little table and a little stool, and she indicated that that was for me…

DM: Were the pygmoids hospitable generally, or was this an individual characteristic?

CJ: At first they were very standoffish, and, well, they'd never seen anything like me and they were quite standoffish—but in time, they came around. She quickly adopted me. Well anyway, I sat on this stool, and of course I smashed it flat and my feet came up and broke the table all to pieces… because it was made out of little sticks, made for them, not for me. And they threw themselves on the ground laughing. They rolled on the ground laughing, all of them laughed, and that was the funniest thing they'd ever seen. And I laughed too. When I laughed they laughed.

DM: Now, they lived in the forest. They weren't afraid of the forest?

CJ: They were not afraid of anything. They were mostly—the men were armed with spears, but I never saw a machete in their hands either. They were armed with spears and they broke the plants apart to build their little huts and stuff; and they were totally forest people, they lived in the forest, they were like the forest animals. They just lived there. They were part of it.

DM: Did they also use poison in the hunt?

CJ: Yes. And they knew which it was; they knew what was poisonous and what was not. That's evolutionary. That's species selection right there. But they knew, and those several women and the two men were the only ones I ever saw, and I never saw any others. They went from camp to camp, but always within the big rainforest. They never left it, and they never migrated, and they never saw the sea. They never saw anything other than—they were part of a forest—they were amazing people.

DM: Even though the sea was how far from where they lived?

CJ: Thirty miles, maybe. Yeah, maybe thirty miles… They never saw the sea or anything. And all of those women seemed to have a little age on them. I never saw young girls. I saw that one young boy. But I never saw any other young people.

DM: I wonder why.

CJ: I don't know.

DM: A high mortality rate, I imagine, but still—

CJ: Child mortality was very high. But yeah, I never saw any in all the time I spent there.

DM: Maybe they were afraid of you. Do you think they saw you, but kept their distance where you couldn't see them?

CJ: Sabater Pi talked about this, and he said they had them hidden somewhere. But I never saw any of them, other than that one young boy.

DM: Which shows up in one of your photographs—

CJ: Which is kind of tucked in behind me, hiding there—

DM: He has kind of a western shirt on…

CJ: I got that shirt for him; he didn't have any clothes when I first saw him. He didn't have any. I got those shorts and that shirt for him. I bought them and took them up there and helped him put them on, and I never saw him without them. He never took them off. And I never saw…they were very conscious about below their waist. They were totally opened above their waist but they were totally very conscious—the women were very conscious about the below the waist cover.

DM: Were they carnivores, or did they eat the plants of the forest also? And did they seem to really know their botany?

CJ: They knew the plants, especially those that were soft and those that they used for thatch and those that they used to build their huts. They ate very few fruits, they mostly were carnivores.

DM: Okay, did you notice any medicinal use?

CJ: They had some things. They would get some cuts and scratches. They had some plants they would rub on themselves, ostensibly for healing purposes. But, yeah, they ate—they had little nets that they spread in the forest and they caught dik-diks—the little antelopes—and they caught the giant flying squirrels that would come to the ground. Pangolins were a real treat for some reason. Pangolins were some kind of special treat for them.

And then with their spears they took an occasional monkey. And they talked about killing an elephant for me, and I wouldn't—they translated it back and forth, which took about half an hour to do anything. I wouldn't let them and they acted put out about that. Most of these feelings were acts. They would act terribly put out about something. They were very fascinated with me writing my field notes. Every evening I would sit down and recap the day and write in my book. I had an audience every evening.

DM: Did they seem to know what you were doing? Did they think this was some form of communication?

CJ: Yeah. They were really attentive, but just ringed around me watching this every evening. It was an event.

DM: Were they concerned about any predators in the forest?

CJ: They didn't seem to be. They didn't seem to be concerned about the gorillas or the chimps which were almost right with them—

DM: In size?

CJ: Yeah.

DM: Or larger, maybe?

CJ: Larger. The adult gorilla and the adult chimp, they were larger, but I never saw them attack or try to kill one of those. They always took monkeys, and smaller ones. I never saw them mess with gorillas or chimps. They always—when a group of gorillas or chimps got near their little group of huts, they would yell and wave their hands and shoo them away. But I was very fascinated with that relationship.

DM: Were there any predators in that area, like large cats of any kind that they should be concerned with, or would be concerned with?

CJ: Yeah, there were West African lions, bush lions. And the main concerns were the elephants. They were concerned that the elephants would come through the camp and trash everything. We were out looking for gorillas and chimps once, and there were elephants nearby, and they indicated for me to climb into a small tree, so I did. But then I saw the elephants pushing trees over and I thought, "This is not a good idea." And I got the heck out of there. That was their first response, climb a tree. No, no, that is not a good idea. They're fascinating people. I think they were on the decline. Well, among the Fang, infant mortality initially was very high, and towards the end of my stay there, groups of missionaries came in and introduced baby formula. Infant mortality went way down. But everything started going to heck because, before, the women would nurse children until they were three and four years old. I mean I was sort of taken aback when a woman would be sitting in a chair or a stool and a youngster would walk up and stand there and start nursing, just everyday life. But infant mortality was increased and everything just sort of broke down at the end. The *Guardia Civil* thought they were very much in charge. But, you know, when they came to a village then everybody pretty much stood up, and they spoke to them and then they left and then they all kind of chatted, "Well, they're gone now, no problem, we'll go back to our old ways."

DM: It was a momentary disruption.

CJ: Yeah. It was a strictly—a multicultural situation. Most of the country was occupied by the Fang, who were oriented toward the village and the slash-and-burn fields, with the hunter, who supplied bush meat. And there was a group that lived along the coast called the Bubis. They were fishermen. They never went inland and there's no intermixing between the two groups. And then the pygmoids. There was a *Guardia Civil* Spanish army, and then they had a local army that they were training. These were the young men that were supposed to be in training to be in control….

They had a small navy. All they had were dugout canoes.

DM: Did [the Bubis] use boats, did they use dugouts?

CJ: Yeah. They went out and put out nets, and then they dried fish, and sold them to people. The Fang would come into Bata for the market. And then a few of the young men came in and had jobs, like, we had to hire a houseboy. When I stopped in Spain… they said I had to do several things. I had to hire a house person for the house, and I had to hire somebody to help maintain the yard. I didn't need anybody, but I had to not disrupt the local economy. And I was advised that a good tracker—I might pay one U.S. dollar or the equivalent of one U.S. dollar a day, no more. And that seemed to be an amazing fee, to pay that. But I would hire somebody in one village, and in another village twenty miles away. When I got ready to hire the guy, he would say, "Well, you paid that guy the equivalent of a dollar, so many pesetas, and that's what I charge." And how they knew—I mean—they knew. I thought it was drums or something. Drums were active at night and I thought it had to be drums. That's how they must have known.

DM: Were there really drums active at night?

CJ: Yes, there were really drums active at night.

DM: You were probably the subject of some conversation in the province.

CJ: They just knew everything; they just seemed to know everything. That happened to me, and everywhere I was, they seemed to know. How they knew, I have no idea. But they knew. And they would give me guidance: "Okay, now you paid that guy." And also, I would rent a house in the Fang village. I'd rent a house, and the first thing I would do was negotiate the price, which was always equivalent to less than a dollar a day; it was like so many pesetas, like it was twelve to fifteen pesetas per dollar, and twelve pesetas was the order. And I would have to hire a young boy in the village to keep the goats off of me. The damn goats were everywhere. To keep the goats from getting on my bed, in the car, they were everywhere. And I would have to hire—they had a main house, a decent house, and then they had a house out back where the women lived and did the cooking—and that is where you went to eat, the women would heat food, or wash clothes, all for a price, of course. But it seemed to be twelve to fifteen pesetas, that seemed to be the going rate for everything.

DM: Well, was there not much stratification of society? Were there not the rich and the poor among the Fang, for example?

CJ: The goats were animals of wealth.

DM: Oh yeah.

CJ: Yeah, the guy who had fifty goats was better off than the guy that had twenty… And when it came time to butcher a goat, or eat a goat, usually the guy that only had twenty had to furnish the goat. But the damn goats were just, they were everywhere—

DM: They did real well in that rainforest.

CJ: They certainly did. And they milked them. They milked the female goats and had goat milk, which is good for you.

DM: Was goat meat a frequent dish or was it more of a ceremonial dish?

CJ: Not frequent.

DM: Did they have sacrifices?

CJ: They had—

DM: Religious sacrifices?

CJ: Yes, I think they did. And they had the chiefs—the head of the village had multiple wives, of course. The other thing I had to do was meet the chief, and meet all the wives. He would have them lined up. I met all of them you know: "*Umbulo, Umbulo, Umbulo, Umbulo*." And that was the group that would wash my clothes for me. For some reason, one of them would volunteer, one of them somewhere in the rank. They had some kind of rank in the way they were lined up, and one of them would volunteer to wash my clothes for me…

The women always lived in the house behind the house. The head house is where the men lived and they had a house out back where the women lived.

DM: That was standard throughout, then?

CJ: Yes, everywhere… And the women had their mats and their beds in this cook house, and they had a constant fire going there, and they cooked there and they ate there. They did everything there and that's where the women and kids lived. The men lived in the men's house—interesting cultural thing…

DM: You said there was not much interaction between the Bubi and the Fang. But what about the pygmoids? How did they all interrelate? Was there interrelation?

CJ: I never saw any of the Fang interact with the pygmoids…. I never saw any of the Fang—there was no interbreeding or any interaction with the Bubis other than the sale of fish. That's all I ever saw. And the market was a wonderful experience. I was interested in the bush meat and it was everywhere: chimp arms and legs, gorilla arms and legs, and young gorillas and monkeys, and stuff like that.

DM: When you say arms and legs, was it the arm with the hair and everything?

CJ: Yeah. They just cut it off and there was an arm. When I was first there, before I got my Land Rover, I was riding the bus, and that was a *trip*. And that was an interesting thing. First of all, early on they wouldn't let me on. Well, most of them had never seen anything like me. And this bus went on into the interior. And I'd ride the bus and it occurred to me what was happening—a bus would pull up to a bus stop, and there would be a structure there with an arm, and monkeys with the tail looped up around their necks. [They] made a slit around the tail and [they'd] bring it up and put it around the neck like a suitcase. And the monkeys would be on this structure, and the women would lean out of the bus and pull the hair on the bellies to see if it was fresh or not, because there was a difference in price.

DM: If it came right out, then it had been there too long.

CJ: Yeah. But there was a definite difference in price between the old ones and the new ones. Well, then they would bring these stinking damn monkeys into the bus. And sometimes they'd just put the tail of the monkey over their head, or they'd put the monkey on their back and get off the bus. That's also where I learned about the relationships of distance with people. I would be sitting on a log, waiting for the bus, and a hunter would come over the hill and the bus would stop everywhere, but he would come up and sit right next to me… That was an interesting kind of thing. It was as if we'd known each other all of our lives, you know. He would come up and put down and stick his cross bow in the ground and lay his machete down, and lay his blow gun across his lap and he'd sit right *there*… I always had an audience; everywhere I went, I had an audience right *there*…

DM: They didn't touch?

CJ: No, they were close. They never touched.

DM: Did they shake hands?

CJ: After some work and, oh, when they got paid they would shake hands. And they had this other damnable habit—when you give them something and they have to give you something. And so I would—well, the money transaction was a very interesting thing. The grant money was sent to Tulane. Arthur Riopelle was there to handle communications and handle fiscal operations, which was very important. Money went from Tulane to the Chase Manhattan Bank, was transferred from the Chase Manhattan Bank to the Bank of Spain in Madrid, and it was transferred from the bank in Madrid to the branch bank in Bata. And they had the attitude in Bata that these people could never handle anything bigger than a hundred peseta note. So I would get my money in kind of a loaf of bread-type structure. And I [would] just put it in the seat of the Land Rover and drive out. And then I would pay these guys who had worked for me for four or five or seven days. Well, I'd pay them and they'd have to give me something. Early on, they'd give me a big stalk of bananas, and I would drive home and the kids would go "Oh boy, oh boy, bananas!" Well, several months later it was, "Oh God, bananas." But that was a damnable custom they had. You couldn't give anybody anything, but they'd have to give you something, whether you wanted it or not.

DM: Was it always food?

CJ: No, sometimes I would get a little wood carving, or a cane, or wooden spear, or a little figurine or something. That's how I got most of the stuff that I got.

DM: When you had your loaf of money, or anytime, really, did children beg? Did they come to you for little handouts?

CJ: No, they didn't beg.

DM: That was not part of the culture.

CJ: No, I never had a—in Bata I had a couple of beggars it seems but out in the villages I never felt begged upon, never. They used *everything*. They stockpiled *everything* in the woman's house. And over in the corner there was a little fence-like thing. And it was stuffed with rags, cans, bottles, a piece of paper, everything. I mean, if I threw something out, it hardly hit the ground. It was gone. It was put in this. They would use it, eventually.

DM: You pointed out in the photographs that there was no litter along the roads because of this.

CJ: It was terribly clean. The whole country was terribly clean. And you noticed there were very few cars and fuel. The Land Rover was a diesel. And the guy that imported it and sold it to me explained that the diesel was the thing. That was the thing.

DM: That's what buses ran on also?

CJ: The buses ran on diesel. This is 1967 and '68. I was paying the equivalent of five dollars a gallon for diesel and I was very happy to get it. The first priority went to the buses, and what was left over was what I got. All the cars were diesel. What cars there were, they were diesels.

DM: How far into the bush could you drive the Land Rover? It seems like your limitations would be pretty great.

CJ: Well, it was a four wheel drive, which I hardly ever used because other than the main road, there was no side road that went anywhere. You walked.

DM: You had to chop a trail if you walked?

CJ: Yeah. To go someplace away from the main road you had to hire a man to lead you, and you had to hire a woman to carry your stuff. And I learned that this was usually a woman who was infertile—couldn't bear children. And she was a—I have one of their carry baskets in that room. I don't know if you've seen it or not. It's a big tall one with—they'd load that thing up, and they'd put a band around it and put it on her forehead and put it on her back.

DM: A tumpline.

CJ: And sometimes it would weigh a hundred pounds. And we'd have to help her to her feet, and she would just go, and never stop.

DM: She was infertile, so they found a niche for her.

CJ: She had a place in the system, but she never left the trail and the trails were—sometimes you'd cross logs and stuff like that—sometimes they were primitive. And that village I showed you and I said "Those were the tracks from my Land Rover," I think that was probably the first vehicle that village had ever seen. And they came out and they just touched the Land Rover. They just petted it, you know. But early on I was advised; I mean, it just had a canvas top, and you couldn't lock it, and I had my camera and binoculars, a loaf of bread of money, everything in there. And they told me to find a woman who would put a little spirit on the Land Rover. And she gave me a little leaf-ball about the size of a golf ball, and it was on a little cord, a little vine cord, and I hung that on the rear view mirror. I never, ever lost a thing out of the Land Rover. And I would leave the Land Rover, and we'd be out in the woods for a week.

DM: This was protection by the spirits.

CJ: Yes. This was a voodoo-type thing.

DM: Do you know what kind of leaf it was by any chance?

CJ: I have no idea what was in the—I was told don't ever open it. You hang it there and leave it there and it will protect the Land Rover. And it did. I never lost—I would leave a loaf of bread of money. I would leave everything and be out in the woods for a week, and I never lost anything. It was total protection.

DM: That's amazing.

CJ: Very strange.

DM: Did children wear amulets around their necks and things like that?

CJ: Sometimes, yes.

DM: Similar kind of thing, leaves and—?

CJ: Yeah. Very interesting people, good people, I learned high regard for them.

DM: You mentioned that coming into this village… that they told you to drive your Land Rover across a couple of logs to get it over a creek or a river.

CJ: Get it over a small ravine. And I wasn't going to do it. And the logs had moss and stuff on them, and they took a machete and roughed up the top and said, "Okay, now drive across." And I did. If it had fallen down, I never would have gotten it out. But yeah, they did, they went "buk, buk, buk, buk," and roughed up the top so I could drive it and have traction. Clever!

DM: There wouldn't be much need for bridges out in the remote areas. Did people ford, or did they use logs for foot paths usually?

CJ: Oh yes, every trail I was on had a log crossing a small ravine or something, or small creek or something, every one… I learned to just cross them.

DM: Without thinking about it, just go on across?

CJ: Yeah just go. And I always had my pack, and my camera, and my binoculars, and my stuff, you know.

DM: You were talking about the market earlier, and you were talking about that level of interaction between the Bubi and the Fang—just the trade. Was it mostly barter, or was it money exchange?

CJ: No, it was barter, they had very little money.

DM: When the Fang made an exchange with the the bush meat hunters—

CJ: Bush meat for fish.

DM: That's what it was, bush meat for fish. How did they [the Fang villagers] acquire the bush meat from the [Fang] hunters? What would they have exchanged?

CJ: I never really figured that out. The hunter seemed to have some special role in the society of the village. It was always kind of aside, kind of different, because he went into the forest. That was one difference. He was a brave man, who went into the forest, and he always had his crossbow and his blow gun and his machete within reach, always within reach, and that's how I would locate him. He'd be standing over there, kind of on the fringe. The whole village would come and listen to me, or be around to watch me, and he'd be over on the side, a little bit. But I never saw them give him any exchange, or any gifts or anything. That was just his role—was to go out and capture something; a dik-dik, or monkey, or something.

DM: Did the villages have their own little exchanges? There was a market in the main towns, but was there any kind of little exchange going on in the small villages that you saw?

CJ: A very special event would be butchering a goat. And they would hang the damn goat up by its hind legs, and cut its throat, and they'd scoop out a little dish in the sand, and the blood would flow into this place in the sand, and it would congeal, and then they would slice it, and eat it.

And that was really tough for me. I think it was the texture of the sand that was really tough, which—I had to do it. That was the ceremony of butchering a goat—well, you see this in Mexico sometimes too, the congealed blood. They call it blood pudding, or whatever they call it.

DM: Which makes you wonder about the universality of something like that, when you hear about it in the Americas and Africa. Did you get the indication that this sacrifice of a goat was in any way connected to a spirit or deity, or was it just an event in itself as far as you could tell?

CJ: As far as I could tell it was just, yeah, they just selected a goat and butchered it. It was sort of a ceremonial thing, collecting of the blood, eating of the blood, and then they would divide up the meat, you know. They would take the damn machete and divvy up the goat in some sort of hierarchical structure in the village.

DM: It was a community thing at least.

CJ: It was. Everybody watched.

DM: Did everybody regardless of age and gender eat?

CJ: When they divvied up the meat it was a free for all—women, kids, men, everybody feasted and they also would trade bush meat for the little clothing they had. The Fang were the same way [as the pygmoids]; they were conscious about below the waist coverage, but very unconscious about the top.

DM: Did you see any indication of prostitution?

CJ: There were, no, but I saw a couple of cases—usually one of the wives would have sex with somebody else, and they would cut off her breasts. I saw several cases of that. I had a tracker once that was missing these two fingers. They were just gone.

DM: The index and the middle finger.

CJ: And I just thought it was a machete accident or something. And one time I asked him about it, and he got real embarrassed, and he walked away. And he came back and said "Okay," he said, "I'm an ex-thief." That is what he explained and that was the deal, and the drill in the village. If a woman committed adultery they'd cut off one or more of her breasts. How they all kept from bleeding to death, well they—they cauterized them. They'd take a stick out of the fire and the guy would just be there and not show any emotion or anything. I never saw them cut off the breast of a woman, but it looked like it'd been cauterized. Again, they were totally unconscious about the top. Here's a woman with one breast and just a big scar and advertising who she was.

DM: Did you ever see any indication of a judicial procedure where they had a council within the village that sat for a judgment?

CJ: The chief—the village chief, they went to him, and he made these decisions.

DM: So they would just go to his home?

CJ: Yeah, he had a place where he would sit and his wives would be there, and they would make the pitch, and he made the decision.

DM: Was he chief for life or was this a—?

CJ: I think it was once a chief, always a chief, all the time I was there. I got one of the little wands he had. He wanted to loan me one of his wives, and finally it hit on me—the explanation I could use was that it was against my religion. And when we were getting ready to leave, one of the guys was rather insistent on giving us a damn pig. And I wouldn't eat, if I knew about it I wouldn't eat their pork, because of infestations. But finally I had to explain that it was against my religion. Finally, I hit on that explanation, and they accepted that…

I can tell you a very interesting experience. We used to go to the soccer games and… my former wife would not only be the only white woman, she'd be the only woman in the stands… Me and my wife and two kids—a little girl, and a little boy—had a place where they would put us. And we would go to the soccer games because there wasn't anything else. And one time, one of my trackers came to my house and said, "You don't want to go to the soccer game tomorrow." And I thought, "Oh, he wants my tickets or something." And he was very insistent: "No, you don't want to go tomorrow. Or, if *you* go, don't take the woman or the children." So I took him. And so at intermission they brought out some bad guys, and killed them. And he knew that was going to happen, but he wouldn't tell me what it was. He just said, "If you insist on going, don't take the woman and children." But that's what they did.

DM: How did they kill them?

CJ: The *Guardia Civil* lined them up and just shot them. And I never knew what their crimes were. But, they just brought them out, and lined them up, and mowed them down, and dragged them off. It was just the thing to do.

DM: As long as they had everybody together, there was a public execution.

CJ: There was a lesson there, some kind of lesson.

DM: These teams that would compete in soccer games, were they all within one village and divided into a team?

CJ: Some teams came in from Cameroon and some teams came in from Gabon. Cameroon to the north, and Gabon to the south, they had some come in from across the borders.

DM: So they had little provincial or national teams that moved about.

CJ: Oh yeah, they were very strong, they had a very strong fan following.

DM: Were they professional you think, or were they semiprofessional?

CJ: I think they were semiprofessional; they were pretty good.

DM: Another thing I wanted to ask you about the marketplace—we were talking about the Fang and the Bubi. Did the pygmoids ever come to the market?

CJ: No.

DM: Did they have any transactions at all outside of their group?

CJ: Not that I ever saw.

DM: Did they have any transactions within their group that you ever saw?

CJ: Not that I ever saw; and they seemed to be—well, I described them as territorial; they seemed to just have a home range in which they worked, and that was theirs, and other groups were over there. I never saw any interactions with anybody.

DM: They were completely self-sufficient, seems like.

CJ: Totally. And where they got their clothes—I know they got them somewhere and that's all they had, and they obviously never took them off.

DM: They had cloth, didn't they? Some of these [in the photographs] were made from bolts of cloth, it looks like.

CJ: Well, the woman that adopted me just had one. She tied it around her waist, and that was all she had. And obviously they never took them off.

DM: So they had a limited range and they lived completely off the land. Do you think they practiced infanticide, or did they even have to practice infanticide [with the high mortality rate]?

CJ: That could have been one of the explanations of why I never saw young people other than this one. Maybe it was infanticide, maybe it was a limitation on what they could provide, because they knew within their area, they knew where all the animals were, they just *knew.* I mean, how they knew, I don't know. It's like they would have this conversation, and the two guys would have this conversation with the women. They'd have this group blab—a group conversation—and then a guy would explain, finally explain to me, that they were going to go get a monkey and they did. They knew where it was and they would go get it. Uncanny little animals, but really nice, after the initial standoffish bit with me, yeah, we became friends, and it was like they sort of took care of me.

DM: Did they have *any* agriculture on any level?

CJ: No.

DM: Not even incipient?

CJ: None. The pygmoids had no agriculture at all.

DM: Did they have any animal domestication?

CJ: No. None. I never saw any.

DM: Wow, the opportunity to see a culture like that!

CJ: I would really like to know today, what's happened to them. But I can't go there; no white man can go to Equatorial Guinea. You chance your life if you go. First of all, you couldn't get passage there; you'd have to walk in from Cameroon or Gabon, and you'd probably be killed. The word is out from the dictator. I know there was one Spanish guy that went in. When I was still teaching at Tech, Robert Owen was still there and there was a Spanish guy that worked on bats, and he came to spend some time with Owen. And he and I immediately became friends, because he had been back to Rio Muni, and that's when he told me that there was no municipal power in Bata or any of the headquarter villages, there was no municipal power. The dictator had all this control, and it all went up to him. And being in the rainforest they had discovered oil, of course, and the oil companies were pouring—the figure is four million a year into it. And it all went to the dictator. The cultural salary and everything was still the same, according to him. They would say, "Yeah there was this guy here years ago, and he paid us twelve pesetas a day, and that's what you pay us." They knew and they remembered me, these various hunters remembered me.

DM: So Robert Owen conveyed that information—that they still remembered your time there.

CJ: And he introduced me to this guy and we became good friends, and he sat right here and explained modern day Rio Muni to me. I would like to go back, but on the other hand, I wouldn't want to go back. My experience and my career are to go in and have your time, and you don't go back. And that's even becoming one of my thoughts about working in Big Bend and areas like that. For example, I wouldn't go stay in Lajitas anymore. And that used to be a place where we *always* went and stayed, but I wouldn't go there anymore.

DM: You had your time.

CJ: It's different.

DM: Right, a little bit heartbreaking sometimes?

CJ: Yes. It's very expensive, very different, and they closed the border, you know, the border patrol closed the border.

DM: You can't just wander across the border to Mexico.

CJ: We used to just either walk across the border or drive over. I had a really wonderful experience, [when] we were walking across. I mean, the water hardly went above our ankles in the river, the Rio Grande, and we walked across. And we were walking up the sandy road and I found a marble just lying in the dirt. I found a marble. And there were a couple little kids playing marbles, and I got down and took a couple of shots and of course gave it to them. In a subsequent visit they came running up to me saying *"Tengo canicas. Quiero jugar?"* "I have marbles, do you want to play?" They remembered; they knew.

DM: Did you ever see anything in Mexico—you did a lot of work in Mexico—did you ever see anything there that reminded you of Rio Muni?

CJ: That behavior did. They knew, and in Mexico too it was the same thing, from one village to another, they knew we were coming, they knew what we were after. They knew we were after the rats and the bats, but they *knew*. And how in the hell they knew, I don't know—yeah, they *knew*. That was the most interesting thing to me, was the communication that somehow preceded us. Didn't you find that in the Tarahumara too? That they knew you were coming and they knew what you wanted to do? How the hell did they know?

DM: It's big news, I guess.

CJ: Yeah, I don't know how.

DM: How it spreads, I'm not sure.

CJ: Well, the one other thing about Mexico was they were always very sensitive. They would always say, "You can't drink the water." That was the first piece of advice we always—"You can't drink the water; here you have to drink beer." And their women and kids, little kids, they were drinking beer for breakfast, you know. But yeah, "You guys can't drink the water; don't drink the water." Mike Bogan and I were working in Baja California Sur, and we stopped at a little truck stop. There were a couple of trucks parked there, so we stopped and the lady had a pot, and she was serving coffee to the truck drivers and we said, "Well, we'll have a cup of coffee." And she went to take the cup and dip it and the truck driver said "No," and he explained to her, "*They* can't drink it like that." So she took her apron and wiped out the cup, and gave it to us—cleaned it.

DM: What were the water conditions in Rio Muni? You had a picture of drinking from a vine—

CJ: Yeah, they would cut a piece of vine. They never carried water. They would always just cut a vine and drink it and discard the vine, or lay it by the trail, because it might be used later. The vine might be made into a blow gun even though it was crooked. It might be made into a blow gun and they would compensate for that, you know.

DM: By aiming a little to one side or the other. (laughter)

CJ: Yes, they would aim over here and they would shoot over there. They were uncanny in doing that. But yeah, the waters in the streams that were fast-moving cataract-type streams, that was—for them—that was safe water. They caught on very quickly that I wasn't supposed to drink the water. I had to carry my own, which was bottled water from Bata. They had a remarkable little plant about the size of this room [about 144 square feet] in Bata, and it was a Coca-Cola plant and they had bottled water, which I had.

DM: So you could drink that and you could drink from the vines. Do the vines affect you?

CJ: No, but you know—

DM: It was filtered enough?

CJ: It was clean for some reason.

DM: But they couldn't just dip into a river. They had to get it also from a running water source, I mean a cascade?

CJ: Yeah. But they knew what was safe water, and what wasn't safe water. They knew.

DM: Another interesting thing in those photographs was the huts that the pygmoids lived in. Can you describe them, and how they were constructed; what they used to cover them? It looked like maybe palm fronds or something.

CJ: All the roofs were thatched with palm fronds… In some cases, the walls were made of a series of small sticks and then packed with mud.

DM: And were these the Fang or the pygmoids?

CJ: The Fang. The pygmoids, they just had sticks. They had fronds and sticks and poles, small poles, and they would cut it up the center and off to the side, and they could make one of those huts while you watched. They could just make one. But they knew which plants to get, and they knew what poles to get. They knew everything.

DM: Did you go inside these huts? Did they have any kind of baskets inside or storage of any kind?

CJ: They'd have maybe a basket or two, or maybe, yeah, no pots…

DM: Did they have any kind of matting for a bed?

CJ: They would have a mat for a bed. They were really taken with my cot. I had a cot where you put the legs in and you would set it up about that high. They were really fascinated with that, and toward the end of my stay there, I gave my cot to one of my hunter friends Pancrasio Sima. I gave him my cot. Well, and the next place I went, they wanted to know why I didn't give them my cot.

DM: You disrupted the economy. (laughter)

CJ: Yeah. There I went.

DM: Hard not to do. So, okay—

CJ: Long pants and long sleeve shirts… were a necessity because of the insects. And I would have a ring, just a raw ring around where the biting flies were on my wrist. When I was taking pictures or doing something, they would just have a ring around the end of my cuff.

DM: You've given a good description about this before: It's one hundred percent humidity, and I don't know what the temperature is—

CJ: Two hundred inches of rain a year—very high humidity. The temperatures were—when it got in the mid-seventies I was cold. And I think—because of the humidity—I was cold and I needed a blanket.

DM: How warm was it when you went into the jungle?

CJ: The high [was] 79, 80.

DM: And you were buttoned up at the neck and the wrist, long sleeved—

CJ: Long pants, long sleeves—

DM: Because of the flies mostly—

CJ: Insects, biting flies, and sometimes ants, soldier ants. I'd get into a pile of ants—well, then you'd just take your clothes off and get them off of you, [then] put your clothes back on, you know, no problem.

DM: But you mentioned the ring of bites around your wrist, where the sweat was coming out.

CJ: Yeah, the biting flies were going for moisture. And when it rained—well, my son wanted a rain gauge, so I had a rain gauge. Well, there came a shower, and the rain gauge overflowed. Well it would come up a shower and it would rain maybe seven inches, you know. It would just *pour.* And they [the locals] would just cut a leaf, and hold it over their head, and go on about their business. Y ou know, that was just the way it was. It rained—so it rained. No problem.

DM: You said you got a touch of malaria.

CJ: Yes, we all had malaria. My former wife and the kids had malaria. They remember being sick. They just—yesterday I was talking with my daughter and I mentioned what I was doing, and what you and I were doing, and she said she remembered having malaria. And then I had dengue fever. And I was out in the village and I got, I started to get "not myself." I got sick. And my tracker insisted on riding back to Bata with me. But, well, he couldn't drive. And we hit a road stop by the *Guardia Civil*. And they were mostly interested that I would let him in the Land Rover with me. That was the big issue, it was an issue—why was he in the Land Rover with me? Because, "No, no; they walk. They don't ride, they walk." And then I finally got it across that I was very sick and we got to Bata and I was really, really sick. And we went to see a Spanish doctor and he said "Well, I don't know, come by tomorrow, maybe we can make a diagnosis." I got up the next morning and I just had a red rash all over me. And he said "Oh we have a diagnosis. You have Dengue fever. Now, you probably won't die of it." Because I was a white man, yeah, probably won't die of it. The Spanish doctors, I don't know how they selected them, or how they chose to go to the colony, but if you ever needed a supply of gin you would find a Spanish doctor. He always had a supply.

DM: For medicinal purposes?

CJ: Of course, it scares off malaria.

DM: Can you talk a little bit about your work there, tracking the lowland gorilla groups, for example? And especially relate the incident where you had a close call with a silverback.

CJ: Well we would find a—my hunter-tracker and I—I had to pay him, because it took him from his job of collecting bush meat. I didn't have to pay him for doing a service to me. I had to pay him for that distraction. So we would find a troupe of gorillas and we would follow them. And I would make observations and do whatever I did. And late in the study when the gorillas bedded down at night, I would bed down also. The tracker would make a little bed of vegetation for me, and I would stay awake and observe all night long. And that's when I discovered that they did that [*pats stomach rhythmically*] all night long, lying on their back—

DM: Patted their stomachs?

CJ: Yes

DM: And you could hear this?

CJ: Yeah. And then finally, I figured it out, it was a form of communication. It was like "I'm okay, I'm over here and I'm okay. Are you okay?" That's what it was, yeah. Jane Goodall agreed with me, that's what it was…

They had little fat bellies and they're lying on their back [*pats stomach*]. A little drum thing like that would go on all night long; and I could hear that. "What the hell is that?" And that's what it was. Well, then the next morning the tracker would—well he would leave at night. He wouldn't stay in the woods. He would leave, and the next morning his job was to come and find me; and he always did. He never ever left me alone [otherwise]. He never left me, or I wouldn't be here. But he always came. And we were following a group of gorillas one time, and one of the showers had started, pouring down rain, and there was a big log that was down. And so we got under the log and we were sitting under the log, and I was writing notes. So we were under this log and we were whispering of course, which is what we always did. We whispered or communicated with hand signals. It stopped raining and I stood up and put my hands on this log. And there was like, from you to me, there was a silverback gorilla—

DM: This is three feet away?

CJ: And just like that, the other side of the log, like the distance from you to me. And he went, "Rawr!" [*shouted loudly*]. And he spit seeds and stuff all over me, and he defecated all over my boots. And I'm not sure he was the only one [that defecated on the boots]. But that's the closest I've ever been. And then he left; he didn't attack; he left; he went. He screamed at me and then he left; he thundered off. And his females were following him. That was the closest I ever came and it was like a distance from you to me.

DM: He was as startled as you?

CJ: I guess he knew I was there… He screamed and spewed seeds—*Aframomum* seeds—all over me.

DM: How long did it take you to recover from that?

CJ: I sat back down and the tracker was lying on the ground going, "*Pobre nosotros, pobre nosotros*"—"poor us, poor us, poor us."

DM: You said that sometimes—as I recall—sometimes they would get a little frustrated with your presence and break branches or trunks—small trunks.

CJ: They would break branches, chest-beat, defecate, urinate, and go around and break stuff and throw branches, and throw defecate. And the gorillas would do that. And the real behaviorists were the chimps. And there's a—Arthur Riopelle studied chimp distance. There's a distance that you can get to a chimp and if you invade that distance, look out. And we did that once. We were following a group of chimps, and again it was raining, and we got too close and this big adult male chimp, about twice as big as me, came just thundering toward us. Just thundering, you know, breaking branches; just thundering toward us and grabbed a hold of a sapling about that big and just spun around it.

DM: About four inches [in diameter]?

CJ: Yeah, just spun around it just like a kid, spun around a pole. And we dove into the buttress of a tree. We were in there and my tracker was fooling around over there with something, cutting a pole, whacking something and it turned out to be a Gabon viper. And it just didn't—it could have bitten both of us but it just didn't. It's one of those deals—it just didn't. And I was watching this chimp. The chimp was just really creating a ruckus and the tracker was killing that viper. Yeah, it was one of those remarkable events; it just didn't bite us. Because that's the way they hunt. They just lay and they wait until something comes by. And that's why they are colored the way they are. But that was a close call.

DM: From two sides.

CJ: I was more frightened of the chimp. I didn't even see the damn snake but it was lying there in the leaves.

DM: That's as close as the chimp came, though—around the tree and then took off?

CJ: Well, that was about from here to that wall.

DM: That's about ten feet.

CJ: Yeah, and it looked—it spun around that tree, smashing everything, and hooting and hollering to beat hell, and throwing everything, throwing defecate, throwing everything.

DM: So the beating of the chest was a warning. The beating of the tummy softly at night was, maybe, a sign of contentment.

CJ: I'm convinced that was some kind of communication. And I've discussed that with Jane Goodall, and she agrees with me. She doesn't know much about gorillas, but she knows a hell of a lot about chimps and she thinks it was a kind of communication. These little soft things like that.

DM: What can you tell me about Jane Goodall's personality? What is she like? What is her real contribution? Can you talk about her for a little bit? What was, maybe, your first impression?

CJ: This was a young schoolgirl that Louis Leakey chose for some reason to go to Africa to study chimps. And she went to the Gombe Forest, and she took her mother with her the first trip so she wouldn't die out there alone in the forest. But she learned how to work within the system and work with the native people in her area. And she spent twenty-five years studying chimps in the Gombe Stream area and the Gombe Stream Reserve—now it's called. She's written numerous papers on chimp behavior. She wrote a book summarizing her twenty-five years of studying chimps. And she's a delightful person—quiet schoolgirl-type person. She was married once and had a child, reared the child in the Gombe Stream Reserve along with the chimps. And she and that husband divorced, and she has another husband that she lives with. He has a home in Mombasa. And she travels the world three hundred days a year giving talks in various places. She's one of my favorite people. She's a delightful person, very thoughtful, gave me a lot of good advice on how to deal with the local culture. Louis Leakey is now, of course, dead. But he had Jane Goodall, he had Dian Fossey, and there was another one that was studying highland gorillas. And she [Dian Fossey] was also a schoolgirl that he chose and supported her until she was murdered. And she was a delightful person also. She came to the National Geographic and came to the Smithsonian to visit with me several times, and we had lunch together several times. Louis Leakey had Jane Goodall, Dian Fossey, and I met him on my way to Rio Muni the first time. I stopped in Washington, D.C. and was at National Geographic. And Louis Leakey was there and we talked and had a really intense conversation for a couple of days. And then finally he said that "I like young people who don't know anything." And he liked me and he liked Jane Goodall, and he liked Dian Fossey. He liked young people who don't know anything.

DM: Was that distinction made at that point—with you working on lowland gorillas, Dian Fossey working on highland gorillas, and Jane Goodall working with chimps—*Pan troglodytes*, right?

CJ: Yes, and I was the only one that was working with both gorillas and chimps. Dian Fossey was working with highland gorillas singularly, and Jane was working with chimps. I was the only one that had both of them in close sympatry and wrote a report on them, and wrote that report on the ecology of gorillas and chimps. Both Jane Goodall and Dian Fossey congratulated me on that piece of work. And you have Jane Goodall's book on twenty-five years of chimp study and it has—inside the front cover is a small note from Jane. I reviewed that book and she wrote a thank you note to me. And yeah, we were a far apart team—young people who don't know anything. Jordi Sabater Pi came out of the research lab at the Barcelona Zoo, and for some reason Art Riopelle made contact with the director of the Barcelona Zoo, which was Señor Jonch, and he recommended that Sabater Pi would be our—we had to have a Spanish collaborator to go into a Spanish colony. Sabater Pi packed up his wife and two boys and moved to Bata, and he went out in the field with me on numerous occasions. He spoke some Fang and he was helpful. And later in time, he stayed in Bata, and he sort of did administrative stuff. He talked to the *Guardia Civil*.

He was a Catalan. He was from Barcelona. He was a Catalan and he talked to people about me and what I was doing, and for them to leave me alone and he was very helpful in renewing—each of us had to have a passport. Two kids, and my wife, and me, each had to have a passport; and we could only have it for sixty days. And he was very helpful in renewing the passports in Rio Muni which was a problem every time. I got a guy, a Spanish guy yelling at me and complaining about me, and so I decided I'd just yell back. And so I said, "I'll just take our passports and I'll just leave." And the guy just says, "Well," and he just snatched one of the passports and he said, "We'll just deport this one." And it was my son's passport and so I sat back down and we negotiated. And bribes were the order of the day. But late the next day—they had an immigration office manned by the *Guardia Civil*, and a couple of them standing around armed, and then they had an autonomous government immigration desk. And I would go there and say, "Well, I've dealt with the *Guardia Civil*," and they would say, "Well, we don't care about that." So bribes were the order of the day. I would have a loaf of bread and give them some money, both of them, the Spaniards and the Fang. But the civil governor of Rio Muni, for some reason he befriended—he liked me for some reason and he and his wife, and me and my family, we would meet. They had a restaurant and a bar down on the beach, the beach bar, and we would meet there and have some drinks and some snacks. And that made us sort of standoffish too, because he was obviously befriending me. And the other thing that happened was, my God, the ambassador, the U.S. ambassador to Spain, came to the colony and came to see me, and, oh man, that did it. That set off the gossip that obviously I was a CIA officer, or some kind of spy, or something. They were really taken, that that guy would come to see me. And I was really taken by that too. I mean, here came his car with the flags on the fender and up my driveway and parked in front of my house, and I didn't know he was coming. And he introduced himself as Angier Biddle Duke, the U.S. ambassador to Spain. And he had his wife with him and his daughter, and they were interested in what I was doing. They came in the house, after we recovered, and we told them what we were doing.

DM: This was unannounced?

CJ: Yes, just like that. I had some cages with some animals in them, and he wanted to see them. And they were really taken with the hairy frog and with the giant frog. And he was a very nice man, and she was, his wife was very nice. They were very common-type people. They came to see us. They came in our house. And, you know, we had, not lavish livings, just bare necessities. But those events really touched off both the Spaniards and the Fang. They were all both really taken by that and the Spaniards became very watchful of me after that.

DM: And what about the Fang?

CJ: Oh, they were just—they were kind of laughing about it. This high-powered person came to see me.

DM: Now, Sabater Pi was there on behalf of the Barcelona Zoo?

CJ: He was my coworker from Barcelona, Spain—from the Barcelona Zoo. And as it turned out later he—when he was stationed in Bata to do administrative things while I was out tromping around, he became an animal collector, to collect animals and ship to the Barcelona Zoo, including the white gorilla. He got the famous white gorilla.

DM: Named "Snowflake."

CJ: Yes.

DM: The white gorilla.

CJ: *Copito de Nieve*, Snowflake.

DM: You visited years later in the Barcelona Zoo right?

CJ: Yeah, it was a magnificent animal, huge, huge, male gorilla that sired numerous offspring. All of those were normal; all of those were black.

DM: I've heard it said that this is the—not only a rare thing, an albino gorilla, but that Snowflake is the only known albino gorilla. Have you heard—?

CJ: He's the only one ever known, yeah, only one ever known.

DM: I mention here for the recording: in the collection of photographs from Sabater Pi, there are some of Snowflake when he was a young gorilla, when he was first obtained. So that's interesting as well. Well, what was his, Sabater Pi's personality like? What kind of person was he?

CJ: Well he was a Catalan, and one of our friends. One of the few other Spanish couples was a Basque, and he was the only other Spaniard there. And he was a fisherman, but he was the only other Spaniard, so naturally he and Sabater got together frequently. And there were always these political discussions about the Basques separating from Spain and the Catalans separating from Spain; and there was always this, every time, this political discussion. But Sabater Pi, he was a nice man, very set in his ways, and very stubborn. The typical Catalan, I think. He and his wife, and two sons, were friends of ours. They were good to us. He coauthored numerous papers with me including the gorilla-chimp one that you have ["Comparative Ecology of *Gorilla gorilla* and *Pan troglodytes* in Rio Muni"] but he was a little stubborn.

DM: He was not an academically trained scientist, was he?

CJ: No, he was just a person that rose up, like some in the U.S. that I got to know when I was at the Smithsonian who just, you know, started out as a squeegee person and later rose up to be a curator. He floated up due to his enthusiasm. He worked hard—he was a hard worker.

DM: It wasn't family connections or anything like that?

CJ: No.

DM: Did he coauthor with you the article on chimpanzee use of tools ["Sticks Used by Chimpanzees in Rio Muni"]?

CJ: Yes, which you have, I believe.

DM: Can you tell me how that research came about, and that discovery?

CJ: Well, we just discovered chimps hovered around a termite mound, and lots of hooting and hollering, lots of, you know, jumping around. And then we saw these sticks lying there. We just looked at the termite mound and there were these sticks, and holy cow!

DM: Were they lying there or were they stuck into the mound?

CJ: They were both stuck in and others just thrown down, and so I just collected a bunch of these sticks and we got to observing this. This is obviously a learned behavior trait, using these sticks to stick in the termite mound and pull out— there would be a termite attached to it, a *Macrotermes muelleri*, and they're about that long, big ones—

DM: About a quarter-inch or half-inch long?

CJ: About a half-inch long, and about half of that was jaws. And the hooting and hollering was—they would bite the chimps on the lips. But they were eating them, because they were a good source of protein, but, yeah—

DM: And, by the way, there are photographs of these termite mounds and sticks, also in your collection.

CJ: I had a couple, you saw a couple that I had.

DM: And there's a sketch, also on the front, I believe, of the article, and I don't know if that was a Sabater Pi sketch—

CJ: No, that was a sketch made by Wilma Martin of the Delta Primate Center… Leonard Carmichael paid for me to be at the Primate Center for a year to write, to write the results of my work, and look for a job.

DM: At about the same time, Jane Goodall was doing similar work. I don't know if she was specifying the use of sticks in termite mounds—

CJ: She got on to it.

DM: Okay, was this independent of each other?

CJ: No, we communicated that, and she got on to it. She found it and it was an interesting find, I thought.

DM: Did your [discovery] precede hers, do you think? Or… did she hear about your research?

CJ: Yes, we talked about it, and I recall talking to her about it. But she got on to it too about the same time. And I collected—those sticks are at Tulane.

DM: That was my next question. And they are, hopefully, tagged and described.

CJ: They are labeled as if they were specimens in the mammal collection at Tulane. The interesting thing is that [my] longtime friend and curator at Tulane is dead and they don't have a mammalogist. Al Gardner, who is at the National Museum at the Smithsonian, he was hired to replace me at Tulane and then I hired him, I hired him to come to D.C. And Tulane has never replaced him and they've never had a mammalogist since then. But my friend [Royal] Suttkus [a professor at Tulane]—who was a collector of everything—he took care of the mammals.

DM: I know one of his big things was fish.

CJ: Yeah, oh, yes, like several million fish. And that is the biggest collection of freshwater fishes in the world. Well anyway, so Al Gardner goes down to Tulane—his daughter is a student at Tulane—Al Gardner goes to New Orleans and he packs up the mammals that I got from Rio Muni and took them to the National Museum. He just packed them up, and took them to D.C.

DM: Yet, the sticks are still there—?

CJ: Yeah.

DM: At Tulane?

CJ: I was impressed, he just packed them up.

DM: So to see this work, a lot of the work you did, you go to the National Museum [of Natural History].

CJ: So all the flying squirrels, the pangolins, that stuff, that's all now at the National Museum, where it should be, because they have an African initiative.

[At present, the Clyde Jones specimen collection from Rio Muni is housed at the National Museum of Natural History, Washington, D.C.; the bulk of his Chihuahuan Desert specimen collection is at the Natural Science Research Laboratory, Museum of Texas Tech University; and his interviews, manuscripts, and photographs, including those appearing in this article, are at the Southwest Collection/Special Collections Library, Texas Tech University, Lubbock, Texas.]

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A New Species of *Myotis* (Chiroptera: Vespertilionidae) from Suriname

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Abstract

We describe a new species of bat in the genus *Myotis* (Vespertilionidae: Myotinae) from the district of Sipaliwini, Suriname. The new species (*Myotis clydejonesi* sp. nov.), known from a single specimen, is sister to a clade of *M. nigricans* (Schinz) from southern South America, but differs from all Neotropical species of *Myotis* in qualitative and quantitative morphological characters and in its cytochrome-*b* gene sequence. Our findings also indicate that *M. nigricans* remains composite and provide support for restricting *M. nigricans* (sensu stricto) to southern South America.

Key words: Guiana Shield, Myotinae, Neotropics, South America

Introduction

The Guiana Shield comprises part of eastern Colombia, southern Venezuela, northern Brazil, Guyana, Suriname, and French Guiana (Gibbs and Barron 1993; Huber 1994). Some authors (e.g., Hollowell et al. 2001; Lim et al. 2005) exclude eastern Colombia and northern Brazil from their definition of the Guiana Shield. For this more restricted area, Lim et al. (2005) reported 148 species of bats, including five species of *Myotis* Kaup, 1829—*Myotis albescens* (Geoffroy, 1806), *M. nigricans* (Schinz, 1821), *M. oxyotus* (Peters, 1866), *M. keaysi* Allen, 1914, and *M. riparius* Handley, 1960. Three of these (*albescens, nigricans,* and *riparius*) occur in Suriname (Husson 1962; Lim et al. 2005).

The three species that occur in Suriname are widespread in the Neotropics, their distributions extending from Central America southward into southern South America (Wilson 2008). Among them, *M. albescens* has been retrieved as a monophyletic, morphologically cohesive group (Moratelli and Oliveira 2011; Larsen et al. 2012). On the other hand, *M. nigricans,* as currently recognized, appears to be a composite of several species (Moratelli et al. 2011, 2013; Larsen et al. 2012).

In the course of a critical review of collections of Neotropical *Myotis*, we found one specimen from Sipaliwini, Suriname, that has a peculiar cranial morphology. Based on pelage color and texture, and cranial features, this specimen is unquestionably allied with species in the *albescens* group (sensu Moratelli et al. 2013), but qualitative and quantitative morphological features, along with its cytochrome-*b* (*Cytb*) profile, distinguish the Suriname specimen from these and all other Neotropical *Myotis*.

Methods

Specimens examined.—The source of the material for the description of this new species is one adult lactating female deposited in the Museum of Texas Tech University (TTU 109227). It was collected by H. H. Genoways on 23 January 2008 at Raleigh Falls (04°43' N, 56°12' W), district of Sipaliwini, Suriname.

This research is part of a critical review of collections of Neotropical *Myotis* for which more than 3,800 specimens have been examined, including all species currently recognized (see Moratelli and Wilson 2014). Recognizing TTU 109227 as unusual, we compared it directly with 368 vouchers (Appendix) representing all species currently recognized from northern South America (see Moratelli et al. 2013), giving special attention to those species from the Guiana Shield (see Moratelli et al. 2015). These vouchers are preserved in the American Museum of Natural History (AMNH, New York, USA); Carnegie Museum of Natural History (CM, Pittsburgh, USA); Centre for the Study of Biological Diversity, University of Guyana (M, Georgetown, Guyana); Muséum d'histoire naturelle (MHNG, Geneva, Switzerland); Museum of Texas Tech University (TTU, Lubbock, USA); Museu de Zoologia da Universidade de São Paulo (MZUSP, São Paulo, Brazil); Natural History Museum, University of Kansas (KU, Lawrence, USA); National Museum of Natural History, Smithsonian Institution (USNM, Washington, DC, USA); and Royal Ontario Museum (ROM, Toronto, Canada). These specimens were identified according to criteria described by Moratelli et al. (2013, 2015).

Morphology and morphometrics.—Descriptive terminology for craniodental morphology follows Moratelli et al. (2013). Measurements were taken of adults only, and are reported in millimeters (mm), and the body mass is in grams (g). We recorded the total length (TL), tail, hind foot, ear, and body mass from skin labels, reported to the nearest millimeter or gram. Other measurements were taken using digital calipers accurate to 0.02 mm. Craniodental measurements were taken with the aid of binocular microscopes under low magnification (usually 6×). These dimensions were recorded and analyzed to the nearest 0.01 mm, but values were rounded off to 0.1 mm throughout the text because this is the smallest unit that allows accurate repeatability with calipers (Voss et al. 2013). Measurements, as defined in Moratelli et al. (2013:3), include forearm length (FA), third metacarpal length (3MC), length of dorsal hair (LDH), length of ventral hair (LVH), greatest length of skull (GLS), condylocanine length (CCL), condylobasal length (CBL), condyloincisive length (CIL), basal length (BAL), zygomatic breadth (ZB), mastoid breadth (MAB), braincase breadth (BCB), interorbital breadth (IOB), postorbital breadth (POB), breadth across canines (BAC), breadth across molars (BAM), maxillary toothrow length (MTL), length of the upper molars (M1–3), mandibular length (MAL), and mandibular toothrow length (MAN). Descriptive statistics (mean and range) were calculated for all dimensions with sample size (n) ≥ 3. A discriminant function analysis (DFA) was applied to a subset of the craniodental dimensions (MAB, CIL, MAL, BAL, GLS, POB, M1–3, BAC) to compare TTU 109227 with representatives of the most similar species. Statistics was performed in SPSS (IBM Corp. 2012). The list of specimens used in the DFA is in the Appendix.

Phylogenetic analyses.—Phylogenetic analyses of *Cytb* sequences were conducted for Neotropical species of *Myotis*, which Ruedi et al. (2013) found to represent a monophyletic group. A total of 118 *Cytb* sequences for species in this clade, and four and seven sequences for *Myotis brandtii* and *M. gracilis*, respectively, were retrieved from GenBank (Table 1). We used *Myotis brandtii* and *M. gracilis* as an outgroup because Ruedi et al. (2013) found they were sister to the Neotropical clade. Sequences were aligned using default options of MAFFT v.7.017 (Katoh and Standley 2013) as implemented in Geneious v.7.1.5 (Biomatters, http://www.geneious.com/). Subsequently, the Bayesian Information Criterion (BIC), as implemented in PartitionFinder ver. 1.0.1 (Lanfear et al. 2012), was used to determine both the most suitable partition scheme and the best-fit models of nucleotide substitution. This analysis only considered models that can be applied in MrBayes (see below).

Maximum likelihood (ML) and Bayesian inference (BI) were used as optimality criteria. The ML analysis consisted of 20 independent searches in the Genetic Algorithm for Rapid Likelihood Inference (GARLI 2.0; Zwickl 2006) applying the best fit-model and the best partitioning scheme (see Results) and default settings. The Bayesian analysis was conducted in MrBayes v. 3.2 (Ronquist et al. 2012). The search started with a random tree. The Markov chains were run for 100 million generations, and trees were sampled every 1,000 generations. Default values were kept for the "relburnin" and "burninfrac" options in MrBayes; therefore, the first 25,000,000 generations (25,000 trees) were discarded as burn-in, and posterior probability estimates of all model parameters were based on the remaining (75,000) trees. Convergence and stationarity were assessed in the Bayesian analyses by plotting likelihood values in Tracer 1.5 (Rambaut and Drummond 2007).

Table 1. Terminals (focal species and putative species of the genus *Myotis*; see Methods) and corresponding GenBank accession numbers. Note that the information presented herein for terminal taxonomic identifications results from re-identification of voucher specimens (see Methods), and do not necessarily match those identifications assigned by researchers that generated the corresponding sequence(s) available at GenBank.

Terminal	GenBank accession number
M. albescens	AF376839, JX130444, JX130445, JX130463–JX130465, JX130472, JX130500–JX130504, JX130522
M. atacamensis	AM261882
M. austroriparius	AM261885
M. brandtii	AF376844, AM261886, AY665139, AY665168
M. cf. *lavali*	AF376864
M. cf. *nigricans* (Suriname)	JN020570–JN020572
M. cf. *nigricans* (Tobago)	JN020573, JN020574
M. cf. *nigricans* (western Ecuador)	JX130523, JX130541, JX130546–JX130550
M. cf. *nigricans* (eastern Peru)	JX130452, JX130537, JX130538
M. cf. *pilosatibialis*	AF376852, JX130449, JX130489, JX130514, JX130519, JX130525
M. chiloensis	AM261888
M. clydejonesi	JX130520
M. dinellii	JX130475
M. dominicensis	AF376848, JN020554–JN020556
M. gracilis	AB106609, AB243025–AB243030
M. handleyi	JN020569, JX130529–JX130533, JX130535, JX130543, JX130544
M. levis	AF376853
M. martiniquensis	AM262332, JN020557–JN020561
Myotis sp.	JX130493
M. nesopolus	JN020575–JN020577
M. nigricans	JX130450, JX130455, JX130496, JX130498, JX130499, JX130528, JX130539, JX130540
M. nyctor	JN020562–JN020567
M. oxyotus	AF376865
M. pilosatibialis	JX130526
M. riparius	AF376866, AF376867, AM261891, AM262336, JX130436, JX130469, JX130473, JX130474, JX130479–JX130481, JX130485, JX130486, JX130488, JX130491, JX130492, JX130506, JX130513, JX130515, JX130516, JX130572
M. velifer	AF376870, AY460343, EF222340, EU680298, EU680299, JX130438, JX130462, JX130468, JX130477, JX130478, JX130589, JX130592
M. vivesi	AJ504406, AJ504407
M. yumanensis	AF376875

Nonparametric bootstrapping (Felsenstein 1985) for the ML analysis, and posterior probabilities for the BI analysis, were used to assess nodal support (Ronquist et al. 2012). The ML bootstrap analysis was performed in GARLI 2.0 using 100 pseudoreplicated data matrices, with 10 searches performed on each. Bayesian posterior probabilities were calculated simultaneously with the search for the best Bayesian topology, conducted as described earlier. Throughout the text, we refer to different degrees of nodal support for the ML bootstrap analysis using the following categories: strong support, for bootstrap values ≥ 75%; moderate support, for bootstrap values > 50% and < 75%; negligible support, for values ≤ 50%. For the BI analysis, we refer to degrees of nodal support with two categories, significant or strong in cases in which a node's posterior probability was ≥ 0.95, and insignificant or negligible for posterior probability values < 0.95.

High values of sequence divergences are neither necessary nor sufficient for recognition of linages at the species level (Ferguson 2002; Dávalos and Russell 2014). However, genetic distances provide a heuristically useful basis for comparisons of genetic variation within and among lineages (Gutiérrez et al. 2010). Therefore, we report average uncorrected (p) distance and average Kimura 2-parameter-corrected (K2P) distance within and among haplogroups of interest for our taxonomic objective. Genetic distances were calculated using MEGA version 5.2.1 (Tamura et al. 2011).

Results

Molecular analyses.—The *Cytb* matrix contained ca. 8% of missing data. PartitionFinder found that the most suitable partitioning scheme was not to use subsets, and that the best-fit model of nucleotide substitution was the Hasegawa, Kishino, and Yano model, with gamma-distributed rate heterogeneity and a proportion of invariant sites (HKY + Γ+ I).

Our results show that *M. nigricans*, as currently understood, is polyphyletic, with representatives in five distinct, strongly supported haplogroups (Fig. 1). One comprises samples from Bolivia and Paraguay, and whose sister terminal was found to be specimen TTU 109227. Another comprises samples from eastern Peru, and was recovered sister to *M. nesopolus* Miller, 1900, albeit with negligible nodal support. The third group comprises samples from western Ecuador, but its relationship to other closely related haplogroups remains equivocal. The fourth includes two samples from Tobago and was recovered, with strong support, as sister to the clade including the *M.* cf. *nigricans* haplogroup from western Ecuador; *M.* cf. *handleyi, Myotis* sp., *M.* cf. *nigricans* from eastern Peru; and *M. nesopolus*. The last *M.* cf. *nigricans* haplogroup includes samples from Suriname (except TTU 109227), and was recovered, with strong support, as sister to *M. nyctor* LaVal and Schwartz, 1974 from the Lesser Antilles. Our primary motivation for this research was to determine the identity and taxonomic status of TTU 109227; hence, our results and discussion are focused on the phylogenetic positioning and morphological distinctiveness of this specimen. From here on we refer to Bolivian and Paraguayan samples as *M. nigricans* due to geographical proximity to its type locality (southeastern Brazil [LaVal 1973; Moratelli et al. 2011]). We refer to the other population samples in the remaining haplogroups tentatively assigned to *M. nigricans* as *M.* cf. *nigricans*.

We found the specimen of interest—TTU 109227—to be sister to *M. nigricans* (Fig. 1). Sequence divergences between TTU 109227 and *M. nigricans* are 5.4% and 5.7% for p- and K2P-distances, respectively. Note that to accomplish the calculation of these between-groups distances, the DNA sequence of specimen TTU 109227 was duplicated. The within-group sequence divergence for the *M. nigricans* haplogroup is 1.5% for both metrics. Within-group sequence divergence could not be calculated for the clade containing TTU 109227 because only a single sequence is available for it.

Morphological analysis.—Considering the assemblages of *Myotis* known from northern South America (Moratelli et al. 2013) and the Guiana Shield (Moratelli et al. 2015), the Surinamese voucher TTU 109227 can be distinguished morphologically from species in the *ruber* group (i.e., *keaysi*, *pilosatibialis*,

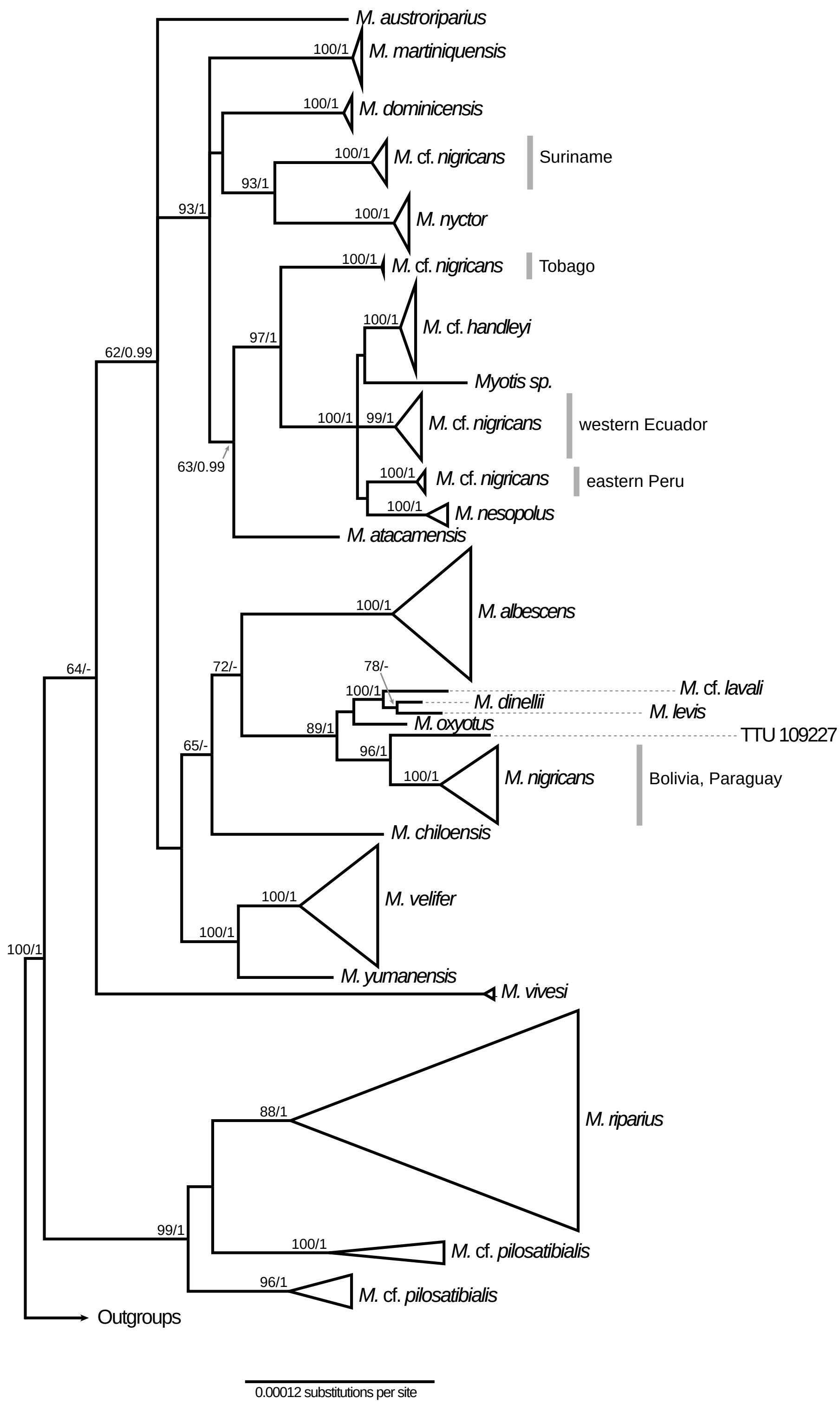

Figure 1. Phylogenetic tree resulting from the Bayesian inference analysis of the cytochrome-*b* sequence data. Nodal support from both the Bayesian inference and the maximum-likelihood analyses are shown right and left of slashes ("/"), respectively. See Methods for more information.

riparius, and *simus*) by its silky pelage, low sagittal and lambdoidal crests, and rounded, relatively uninflated occipital region. TTU 109227 is morphologically close to species in the *albescens* group (i.e., *albescens, caucensis, handleyi, nigricans, oxyotus,* and *nesopolus larensis*) in the traits described above. However, it can be distinguished from all species in this group by the depressed braincase (Fig. 2), and the unique combination of dorsal fur blackish and ventral fur with blackish bases and yellowish-red tips. From *M. nigricans*—the most closely related species—TTU 109227 can be distinguished by its anteriorly shallower rostrum, more robust occipital condyles, supraoccipital not as inflated and not projecting as far behind occipital condyles (Fig. 2), and more laterally expanded mastoid region. We provide additional information on its description and distinction from other species under the subheading "Morphological description and comparisons."

Morphometric analyses.—In a discriminant analysis, the cranial morphology of TTU 109227 was compared with the morphology of *M. nigricans* from Bolivia and Paraguay and of *M.* cf. *nigricans* from Suriname (Fig. 3, Table 2). In this analysis, the first two discriminant functions (DF1 and DF2) summarized 100% of the among-group variation, with DF1 comprising 82% and DF2 18%. Along the first axis (DF1), TTU 109227 and *M. nigricans* had low negative values, and *M.* cf. *nigricans* had high positive values. Along the second axis (DF2), TTU 109227 had high negative

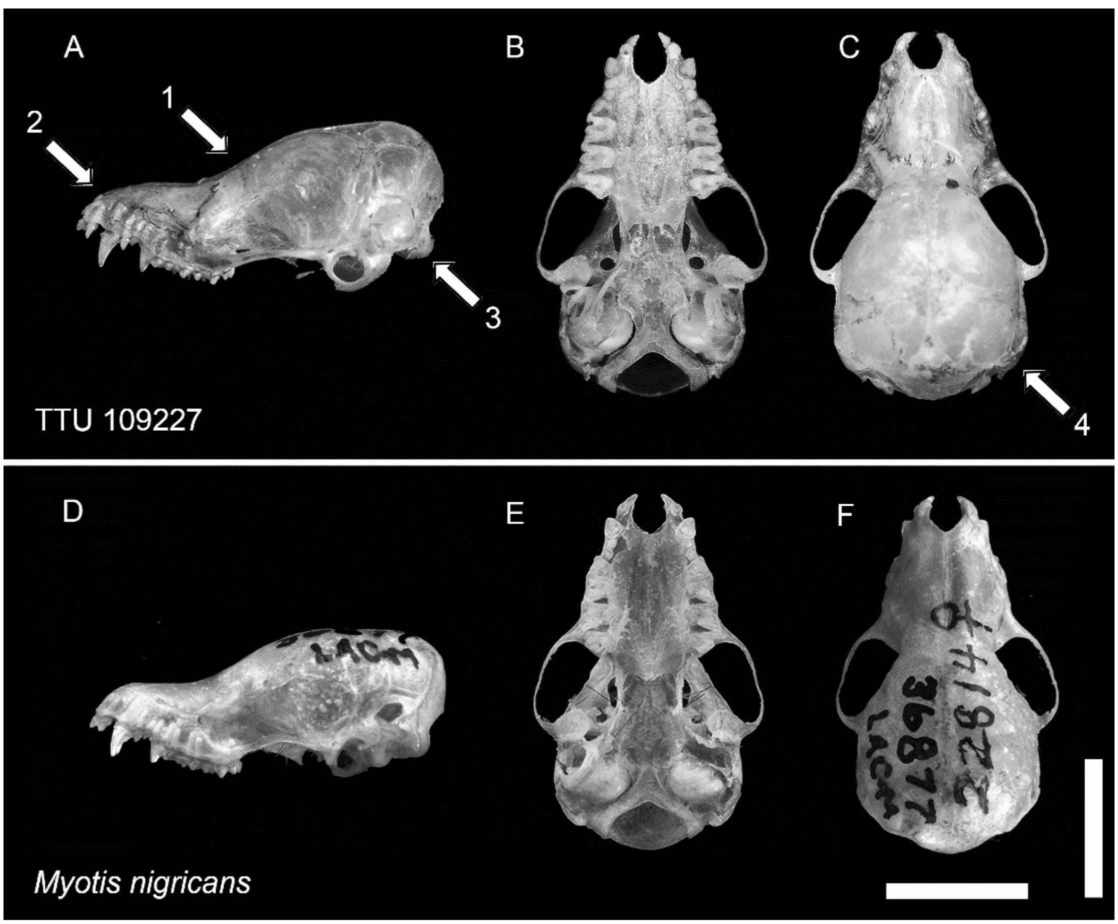

Figure 2. Lateral (A), ventral (B), and dorsal (C) views of the skull of the holotype of *Myotis clydejonesi* (TTU 109227), and lateral (D), ventral (E), and dorsal (F) views of the neotype of *M. nigricans* (LACM 36877). Scale bar = 5 mm. See Table 1 for measurements. Arrows indicate the comparatively depressed braincase (1), anteriorly shallower rostrum (2), more robust occipital condyles (3), and more laterally expanded mastoid region (4).

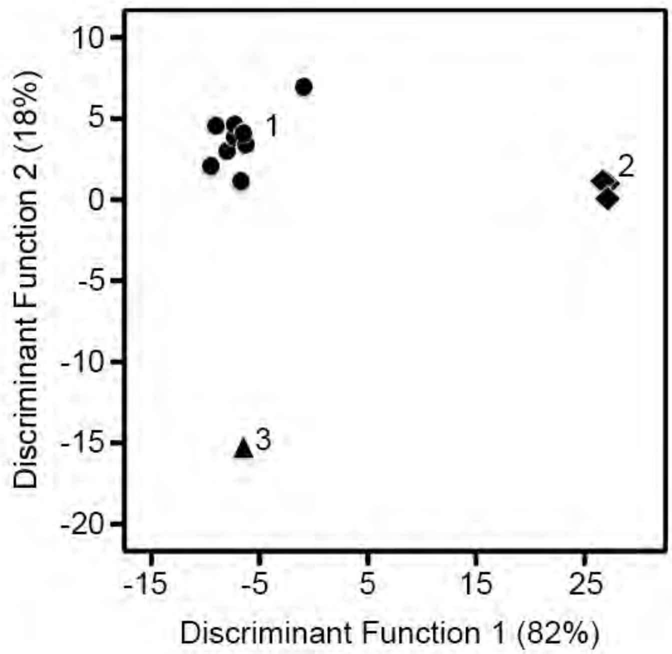

Figure 3. Plots of multivariate individual scores in the first two discriminant functions (DF1, DF2). Samples: *M. nigricans* from Paraguay (*n* = 10 [circles; group 1]), *M.* cf. *nigricans* from Suriname (*n* = 3 [diamonds; group 2]), and the holotype of *Myotis clydejonesi* (triangle; group 3).

Table 2. Coefficients of discriminant functions (DF1, DF2) for samples of *Myotis clydejonesi*, *M.* cf. *nigricans*, and *M. nigricans*. See Methods for variable abbreviations.

	DF1	DF2
Characters	82.4%	17.6%
GLS	-2.311	3.359
CIL	-25.173	1.013
BAL	10.071	-4.457
MAB	1.353	1.327
POB	3.272	0.711
BAC	-4.972	3.782
M1–3	4.049	0.423
MAL	18.634	-4.209

values, whereas *M. nigricans* and *M.* cf. *nigricans* had low negative to high positive values. Thus, this analysis confirmed the distinctive cranial morphology peculiar to TTU 109227.

Comparing linear measurements of TTU 109227 with *M. nigricans* (*n* = 41–54) and *M.* cf. *nigricans* (*n* = 2–3), TTU 109227 has larger dimensions, without overlap, for most characters (all but M1–3) related to the length of skull (GLS, CCL, CBL, CIL, BAL) and rostrum (MTL, M1–3, MAL, MAN). On the other hand, all width measurements (MAB, BCB, IOB, POB) and rostrum (BAC, BAM) overlap with those from *M. nigricans* and *M.* cf. *nigricans*. These results indicate that TTU 109227 has a skull comparatively longer, but not wider, than the skulls of *M.* cf. *nigricans* and *M. nigricans*.

Combined results from morphological, morphometric, and molecular analyses show that TTU 109227 represents a unique lineage that differs from all species of Neotropical *Myotis* in qualitative and quantitative morphological characters and in its *Cytb* gene sequence. Based on these findings, we recognize TTU 109227 as a representative of an undescribed species, which we here name as:

Myotis clydejonesi sp. nov.
Clyde Jones's Myotis, Myotis de Clyde Jones
Figs. 2, 4, 5; Table 3

Holotype and type locality.—The holotype (TTU 109227) comprises the skin and skull of an adult lactating female (Figs. 4, 5), including tissue (TK 151465), collected by H. H. Genoways (field number 6630) on 23 January 2008 at Raleigh Falls (04°43' N, 56°12' W; obtained from the skin label), Sipaliwini, Suriname. External and craniodental dimensions are in Table 3. The species is known from only the type locality (Fig. 6). This collecting site is located on an island in the Coppername River in the Central Suriname Nature Reserve. Relatively dense, near-mature tropical lowland forest with only a limited understory occupied most of the area. The mist net in which the holotype was captured was placed under the largest tropical trees near the banks of the Coppername River (Genoways and McLaren 2003).

Diagnosis.—Myotis clydejonesi can be distinguished from all other Neotropical species of *Myotis* by the flattened braincase, elongated rostrum, silky fur, and combination of dorsal and ventral pelage colors. The fur is silky; dorsal pelage is blackish, without contrast between bases and tips, and ventral fur is blackish basally (2/3 of the total hair length) and tipped yellowish-red on terminal third. The braincase is flatter and the pelage is silkier than in any other South American species known to us. This combination of the ventral and dorsal pelage colors appears to be unique among Neotropical *Myotis*. The following set of traits also is useful to distinguish *M. clydejonesi* from other *Myotis* that occur on the Guiana Shield: long, silky pelage; absence of a fringe along the trailing edge of uropatagium; low sagittal and lambdoidal crests; and rounded occipital region.

Morphological description and comparisons.—Among South American *Myotis, M. clydejonesi* is a medium-sized species (FA 34.9 mm, other measurements in Table 3). The pelage is silky. Dorsal fur is blackish without contrast between bases and tips. Ventral fur is blackish basally (2/3 of the total fur length) and yellowish-red on the tips (1/3), with strong contrast in color between bases and tips. Membranes are medium-brown. The plagiopatagium is attached to the foot at the level of the toes by a broad band of membrane (see López–González et al. 2001:141, fig. 1a). The dorsal surfaces of elbow and tibia are naked or nearly naked. The uropatagium lacks the fringe of hairs along the trailing edge. Like most species of *Myotis*, its dental formula is 2/3, 1/1, 3/3, 3/3 = 38. The P3 is aligned in the toothrow (not displaced lingually), and visible in lateral view. Frontals are slightly inclined, with a smooth transition from the rostrum to the braincase. The sagittal and lambdoidal crests are low. The occipital region is rounded, and does not project much behind level of occipital condyles. In contrast to other Neotropical *Myotis*, the skull is flattened, but not nearly so flattened as in *M. planiceps* Baker, 1955 (see photo of a *M. planiceps* skull in Haynie et al. 2016:703, fig. 2a).

In addition to the diagnostic traits, *M. clydejonesi* can be distinguished from those species that co-occur on the Guiana Shield (*albescens, keaysi, riparius, oxyotus, nigricans*) as follows: from *M. albescens* by

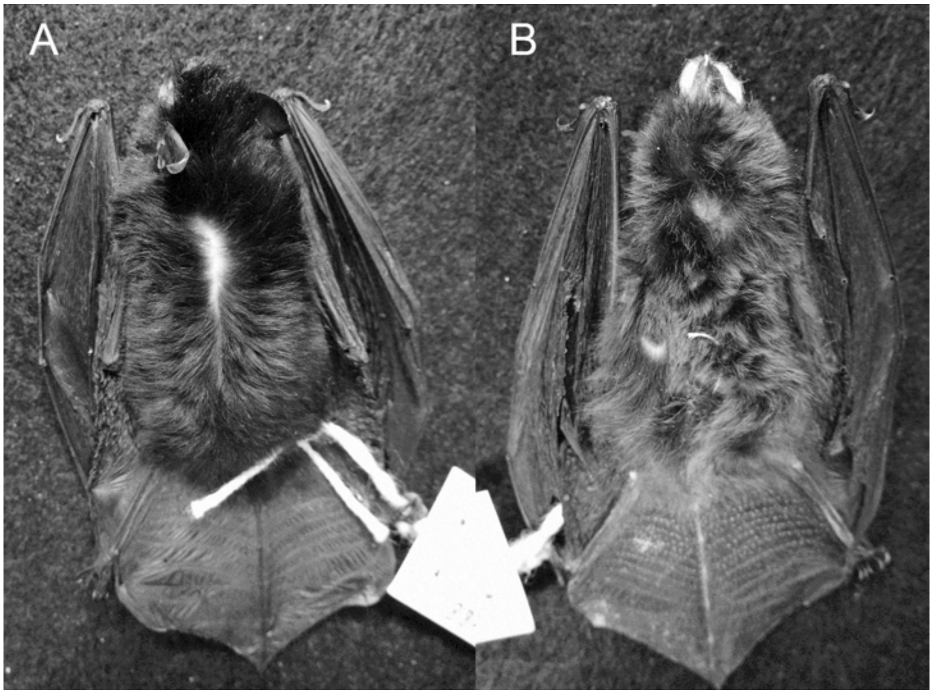

Figure 4. Dorsal (A) and ventral (B) views of the skin of the holotype of *Myotis clydejonesi* (TTU 109227). See Table 3 for measurements.

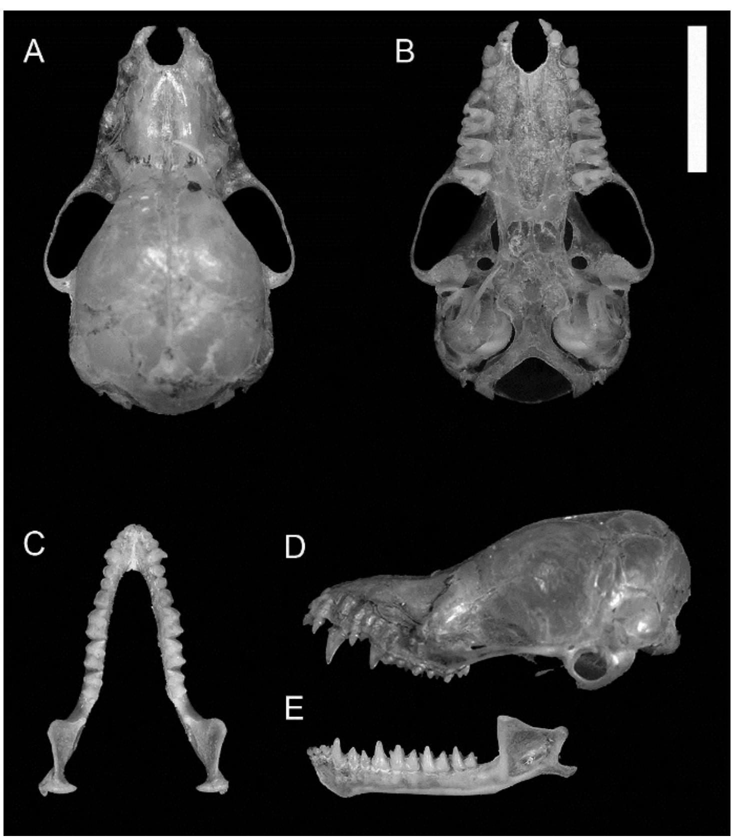

Figure 5. Dorsal (A), ventral (B), and lateral (D) views of the skull, and dorsal (C) and lateral (E) views of the mandible of the holotype of *Myotis clydejonesi* (TTU 109227). Scale bar = 5 mm. See Table 3 for measurements.

Table 3. Selected measurements (mm) and body mass (g) of the holotype of *Myotis clydejonesi* (TTU 109227), and of samples of *M.* cf. *nigricans* from Suriname and *M. nigricans* from Paraguay. Mean calculated for $n \geq 3$; n = sample size (adults only). See Methods for variable abbreviations and Appendix for localities of specimens.

Variable	TTU 109227, ♀ (Suriname) Holotype	*M.* cf. *nigricans* (Suriname) Mean (Range), *n*	*M. nigricans* (Paraguay) Mean (Range), *n*
TL	88	–	–
Tail	38	–	–
Hind foot	6	–	–
Ear	11	–	–
Body mass	4.3	–	–
FA	34.9	35.0, 1	32.9 (30.7–35.6), 54
3ML	33.6	–	31.1 (28.8–34.5), 54
LDH	7.7	5.6, 1	–
LVH	6.1	4.5, 1	–
GLS	14.3	13.9 (13.4–14.2), 3	13.7 (13.2–14.2), 53
CCL	12.8	12.1 (11.7–12.3), 3	12.0 (11.7–12.5), 53
CBL	13.5	12.7 (12.3–13.1), 3	12.7 (12.3–13.1), 52
CIL	13.7	12.9 (12.5–13.2), 3	12.9 (12.5–13.3), 52
BAL	12.3	11.7 (11.5–11.8), 3	11.6 (11.2–12.1), 52
ZB	8.8	8.1, 8.3, 2	–
MAB	7.0	6.9 (6.7–7.2), 3	7.0 (6.8–7.3), 53
BCB	6.4	6.6 (6.4–6.8), 3	6.5 (6.2–6.9), 52
IOB	4.4	4.6 (4.5–4.8), 3	4.5 (4.0–4.8), 53
POB	3.4	3.6 (3.6–3.7), 3	3.6 (3.4–3.8), 53
BAC	3.5	3.5 (3.4–3.7), 3	3.5 (3.2–3.6), 41
BAM	5.7	5.6 (5.5–5.7), 3	5.3 (5.1–5.5), 41
MTL	5.3	5.1 (5.0–5.2), 3	5.0 (4.8–5.2), 52
M1–3	3.0	2.9 (2.8–3.0), 3	2.9 (2.7–3.0), 53
MAL	10.2	9.8 (9.5–10.1), 3	9.6 (9.2–10.0), 53
MAN	5.6	5.4 (5.3–5.5), 3	5.3 (5.2–5.5), 53

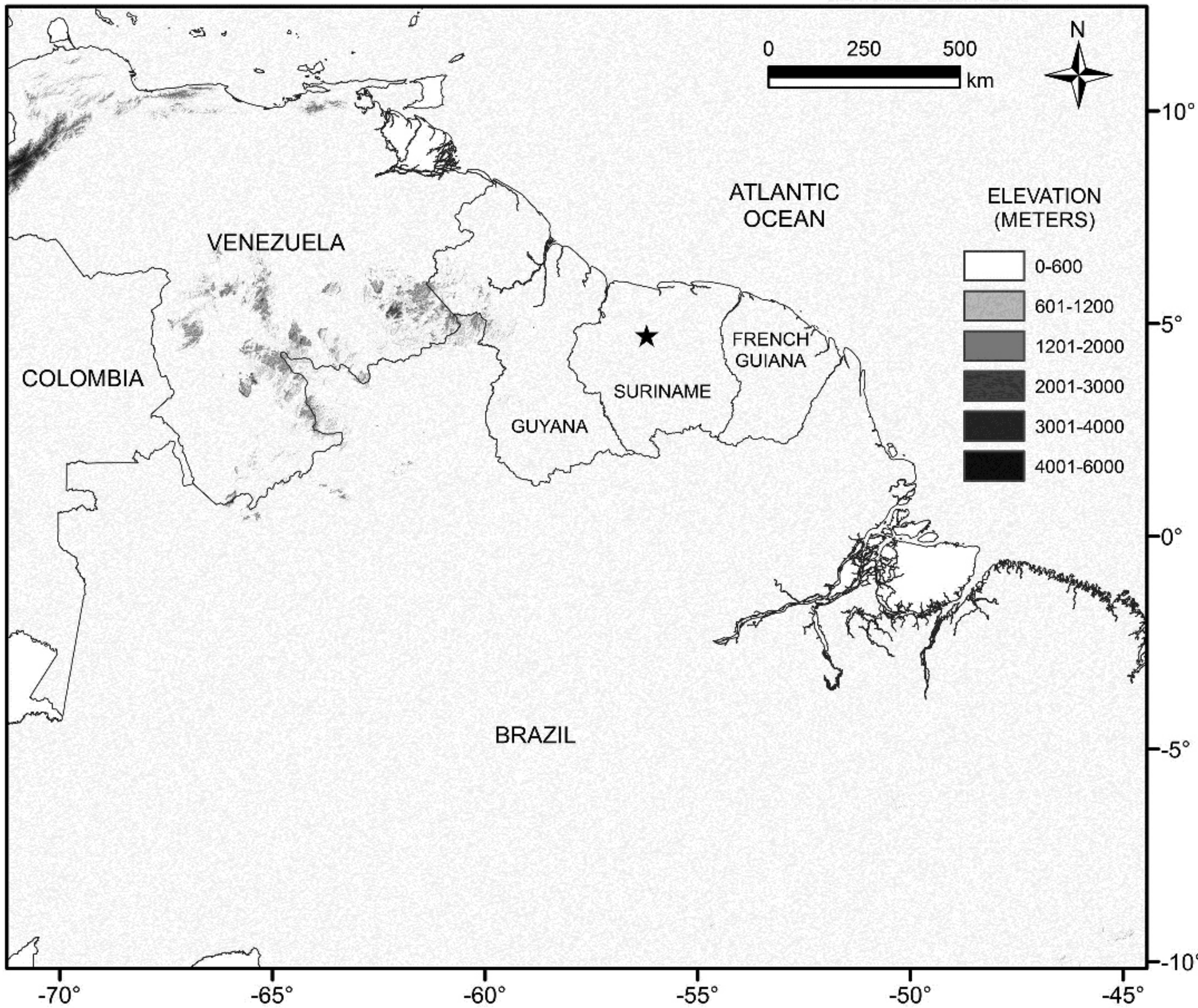

Figure 6. Map of part of South America illustrating the type locality (indicated by star) of *Myotis clydejonesi* at Raleigh Falls (04°43' N, 56°12' W), district of Sipaliwini, Suriname.

the absence of a fringe of hairs along the trailing edge of the uropatagium; from *M. oxyotus* by the frontals smoothly inclined (not steeply sloping as in *oxyotus*), and smaller external and cranial size (see Moratelli et al. 2013); from *M. keaysi* and *M. riparius* by the silky fur, and occipital region rounded; also, from *M. keaysi* by the dorsal fur on the uropatagium not reaching the knee, and the fur on the plagiopatagium along the body either absent or extremely sparse. Comparing *M. clydejonesi* with *M.* cf. *nigricans* from Suriname (using vouchers that were the sources of DNA for our *Cytb* analysis), *M. clydejonesi* also can be distinguished by the flattened skull and elongated rostrum. These characteristics also distinguish *M. clydejonesi* from *M. nigricans* sensu stricto (Bolivia, Paraguay, E Brazil).

Etymology.—Myotis clydejonesi honors Clyde Jones, in recognition of his outstanding contributions to mammalogy (see Jones 2005). Clyde was a mentor, colleague, supervisor, and friend; we find it particularly fitting that the type specimen of *M. clydejonesi* is housed in the Museum at Texas Tech University, the institution that holds a major part of his collections and legacy.

DISCUSSION

With the description of *M. clydejonesi,* 21 formally described Neotropical species of *Myotis* currently are recognized (see Moratelli and Wilson 2014). Husson (1962) recognized three species of *Myotis* from Suriname—*M. albescens, M. nigricans,* and *M. surinamensis* Husson, 1962. The latter he proposed as a replacement name for *Vespertilio ferrugineus* Temminck. However, according to Carter and Dolan (1978:73) and Davis and Gardner (2008:445), the type of *V. ferrugineus* does not represent a South American bat. Subsequently, Lim et al. (2005) reported three species (*albescens*, *nigricans*, *riparius*), and *M. clydejonesi* now represents the fourth species for the country. Beyond the support for recognizing *M. clydejonesi*, our results also indicate that "*M. nigricans*" from Suriname possibly represents another undescribed species.

Our findings also provide additional support for Larsen et al.'s (2012) hypothesis that *M. nigricans* should be restricted to southern South America. The species, as traditionally recognized, is polyphyletic. We suggest retaining the name "*nigricans*" for the haplogroup formed by Bolivian and Paraguayan samples because they are geographically closer to the type locality of the species in southeastern Brazil (see LaVal 1973; Moratelli et al. 2011) than is any of the remaining haplogroups. Based on our results, at least four geographic groups previously assigned to *M. nigricans* may require new names (Suriname, western Ecuador, eastern Peru, and Tobago; see Fig. 1). Our results require additional analyses, and we will return to collections for further morphological comparisons. However, based on the frequency with which we find single museum specimens that we cannot assign to any of the currently recognized species (e.g., TTU 109227 when originally examined), we suspect that the diversity of Neotropical *Myotis* (~ 26 spp.) is still underestimated.

The results of our phylogenetic and morphological analyses unquestionably ally *M. clydejonesi* with other species in the *albescens* group (sensu Moratelli et al. 2013). In northern South America and the Guiana Shield, this group comprises *M. albescens, M. caucensis, M. clydejonesi*, *M. handleyi*, *M. nesopolus larensis*, *M.* cf. *nigricans*, and *M. oxyotus*. Other *Myotis* found in the same region (*M. keaysi*, *M. pilosatibialis*, *M. riparius*, and *M. simus*) are in the *ruber* group. Finally, *M. clydejonesi* can be distinguished from all species in the Neotropical subclade (sensu Ruedi et al. 2013) by its combination of ventral and dorsal pelage color and the depressed braincase. Although not so flattened as in *M. planiceps* Baker, 1955, these two species share this trait (much more accentuated in *planiceps*). The flattened braincase in these two species is an example of convergence; *M. planiceps* is a representative of the Nearctic subclade of *Myotis* (Haynie et al. 2016).

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APPENDIX

Listed below are localities of specimens examined from northern South America, including northern Brazil, French Guiana, Guyana, Suriname, and Venezuela. They are preserved in the American Museum of Natural History (AMNH, New York, USA); Carnegie Museum of Natural History (CM, Pittsburgh, USA); Centre for the Study of Biological Diversity, University of Guyana (M, Georgetown, Guyana); Muséum d'histoire naturelle (MHNG, Geneva, Switzerland); Museum of Texas Tech University (TTU, Lubbock, USA); Museu de Zoologia da Universidade de São Paulo (MZUSP, São Paulo, Brazil); National Museum of Natural History, Smithsonian Institution (USNM, Washington, DC, USA); and Royal Ontario Museum (ROM, Toronto, Canada). Localities are arranged alphabetically by species and major political unities. Specimens marked with asterisks were used in Table 2, and those with two asterisks also were used in the discriminant function analysis.

Myotis albescens.—FRENCH GUIANA (1): Cayenne, Montsinery, Riviere des Cascades (MHNG 1990.017). GUIANA (18): Berbice, Dubulay (M 343); Essequibo, Chodikar River, 55 km SW of Gunn's Strip (ROM 106655); Essequibo, Karanambo (ROM 97922); Potaro-Siparuni, Iwokrama Field Station, Iwokrama Forest (ROM 111997, 112041, 112048, 112625); Potaro-Siparuni, Iwokrama Reserve, Pakatau Mountain, Siparuni River, 42 km WNW of Kurupukari (ROM 107115); Potaro-Siparuni, Kabukalli Landing, Iwokrama Forest (ROM 111658); Rupumini, Kanukumi (M 177); Upper Takutu-Upper Essequibo, Dadanawa Ranch Headquarters (ROM 31892, 31903); Upper Takutu-Upper Essequibo, Dadanawa, Kuitaro River, Mountain on Right Bank (ROM 33002, 33003, 33004, 33005, 33006, 33007). SURINAME (6): Nickerie, Grassalco (CM 63922, 63923, 63924, 63925, 63926); Saramacca, Raleigh Falls (CM 63928). VENEZUELA (39): Amazonas, Belén, 56 km NNW of Esmeralda, Río Cunucunuma (USNM 405790, 405794, 405796); Amazonas, Belén, 56 km NNW of Esmeralda, Cano Essa (USNM 405792); Amazonas, Capibara, 106 km SW of Esmeralda, Brazo Casiquiare (USNM 409392, 409395, 416579); Amazonas, Cerro Neblina Base Camp (USNM 560807, 560808); Amazonas, Paria, 25 km S of Puerto Ayacucho (USNM 409416, 409420, 409422, 409425); Amazonas, Río Mavaca, 108 km SSE Esmeralda (USNM 405798); Amazonas, San Juan, 163 km ESE Puerto Ayacucho, Río Manapiare (USNM 409403, 409404, 409406–409408, 409410–409415, 409454, 416581); Amazonas, San Juan, Río Manapiare (USNM 416580, 416582); Apure, Río Cinaruco, 38 km NNW Puerto Páez (USNM 373909, 373913–373917, 374008); Apure, Nulita, 29 km SSW Santo Domingo, Selvas de San Camilo (USNM 441714–441716); Bolívar, Río Supamo, 50 km SE El Manteco (USNM 387693); Miranda, 7 km E Río Chico, near Puerto Tuy (USNM 387697–387701, 387703); Miranda, 10 km SE Río Chico, near Tacariquade La Laguna (USNM 387702); Trujillo, Valera, 23 km NW Valera, Río Motatán (USNM 370933); Zulia, El Rosario, 42 km NW Encontrados (USNM 441718).

Myotis clydejonesi.—SURINAME (1): Sipaliwini, Raleigh Falls (TTU 109227** [holotype]).

Myotis handleyi.—VENEZUELA (27): Aragua, Rancho Grande Biological Station, 13 km NW Maracay (USNM 517503, 562923, 562924, 562925, 562926, 562927, 562928, 562929, 562930, 562931, 562932, 562933, 562934, 562935, 562936, 562937); Distrito Federal, Pico Ávila, 5 km NE Caracas, near Hotel Humboldt (USNM 370932 [holotype]); Distrito Federal, Pico Ávila, 5 km NE Caracas, near Hotel Humboldt (USNM 370891 [paratype]); Miranda, Curupao, 5 km NW Guarenas (USNM 387723); Monagas, 3 km NW Caripe, near San Agustín (USNM 409391, 409429, 409430, 409431, 409433, 409435, 409437, 409438).

Myotis keaysi.—VENEZUELA (45): Aragua, Rancho Grande Biological Station, 13 km NW Maracay (USNM 370893–370895, 370898–370902, 370911–370913, 370915–370922, 370924, 370926, 370929); Aragua, Rancho Grande Biological Station, 13 km NW Maracay (USNM 370927, 370928, 370930, 370931); Aragua, Pico Guayamayo, 13 km NW Maracay (USNM 521564); Aragua, Rancho Grande, Portachuelo (USNM 562920, 563005, 563006); Aragua, Rancho Grande (USNM 562921); Bolívar, Gran Sabana (USNM 130625, 130626); Carabobo, Montalban, 4 km NW Montalban, La Copa (USNM 441741, 441742); Distrito Federal, Los Venados, 4 km NW Caracas (USNM 370889); Distrito Federal, Pico Ávila, 5 km NNE Caracas, near Hotel Humboldt (USNM 370890); Distrito Federal, junction Puerto Cruz Highway and Colonia Tovar Highway, 0.5 km W (USNM 562984); Guarico, Hacienda El Vira, 10 km NE Altagracia (USNM 387707); Miranda, San Andres, 16 km SE Caracas (USNM 373920); Miranda, Curupao, 5 km NW Guarenas (USNM 387714–387716, 387718); Monagas, Caripe (USNM 534265).

Myotis nesopolus.—CURAÇAO (1): Punda area, Willemstad (USNM 101849 [holotype of M. nesopolus]). VENEZUELA (9); Falcón, Capatarida (USNM 441710, 441735–441737, 441740); Falcón, 6 km SW Capatarida (USNM 441711); Falcón, Capatarida (USNM 441728); Lara, Río Tucuyo (AMNH 130709 [holotype of M. larensis]); Zulia, Near Cojoro, 35 km NNE Paraguaipoa (USNM 441721).

Myotis nigricans.—PARAGUAY (54): Presidente Hayes, 227 km NW Villa Hayes by road (MVZ 144707*, 144708*, 144710*, 144711*, 144713*, 144714*, 144715*, 144716*, 144717*, 144719*, 144720*, 144722*, 144726*, 144727*, 144728*, 144729*, 144730*, 144731*, 144732*, 144735*, 144738*, 144739*, 144741*, 144743*, 144744*, 144746*, 144747*, 144748*, 144749*, 144750*, 144752*, 144753*, 144755*, 144756*, 144757*, 144761*, 144762*, 144763*, 144764*, 144766*, 144767*, 144768, 144769, 144770**, 144771**, 144772**, 144773**, 144774**, 144775**, 144776**, 144777**, 144778**, 144779*, 144780*).

Myotis cf. *nigricans*.—FRENCH GUIANA (7): (MHNG 1983.75, 1983.76, 1983.77, 1983.79, 1984.03, 1984.05, 1990.54). GUYANA (35): Cuyuni-Mazaruni, Paruima (ROM 108263); Demerara-Mahaica, Ceiba Biological Center (ROM, 113797, 112532, 112572, 112665); Upper Demerara-Berbice, Dubulay Ranch (USNM 582351, USNM 582352); Upper Demerara-Berbice, Tropenbos, 20 km SSE of Mabura Hill (ROM 103479, 103483); Upper Takutu-Upper Essequibo, Achimeriwau River, Mabi Wau, Near Achamere Wau (ROM 34042, 34043, 34044, 34045, 34046, 34047, 34048, 34049); Upper Takutu-Upper Essequibo, Chipirari Wau Mouth, 15 mi E of Dadanawa (ROM 34020); Upper Takutu-Upper Essequibo, Courchiwin Mountain, 10 mi E of Dadanawa (ROM 32890, 32892, 32893, 32894, 32896, 32897, 32900); Upper Takutu-Upper Essequibo, Essequibo River, 7 km S of Gunn's Strip (ROM 106738); Upper Takutu-Upper Essequibo, Gunn's Strip (ROM 106772); Upper Takutu-Upper Essequibo, Karanambo (ROM 97931); Upper Takutu-Upper Essequibo, Komawariwau River, Comiwari Wau Mouth, 15 mi E of Dadanawa (ROM 34023, 34027, 34035, 34036); Upper Takutu-Upper Essequibo, Kuma River, 5 mi E, 5.5 mi S of Lethem, Kanuku Mountain (ROM 97827, 97828, 97879). SURINAME (3): Para, Zanderij (CM 63933**, 69053**, 77699**). VENEZUELA (64): Amazonas, Boca Mavaca, 84 km SE Esmeralda, 7 km up Río Mavaca (USNM 405801); Amazonas, Paria, 25 km S Puerto Ayacucho (USNM 409424, 409455); Apure, Nulita, 29 km SW Santo Domingo, Selvas de San Camilo (USNM 441722); Aragua, 3 km S Ocumare de La Costa (USNM 517504, 517505); Bolívar, Maripa (AMNH 17069 [holotype of *M. maripensis*]); Carabobo, 10 km NW Urama, El Central (USNM 373921, 373922, 373923, 373924, 373925, 373926, 373927, 373928, 373929, 373930, 373931, 373932, 373933, 373934, 373935, 373936, 373937–373941, 373942, 373943, 373944, 373945, 373946, 373947, 373948, 373949, 373950, 373951–373959, 373989–374004); Carabobo, 6 km N Urama (USNM 374012); Trujillo, 11 km NW Urama, El Central (USNM 387708).

Myotis oxyotus.—VENEZUELA (9): Amazonas, Cerro Duida, Cano Culebra, 50 km NW Esmeralda (USNM 405799); Amazonas, Cerro Neblina, Camp VII (USNM 560809–560811); Bolívar, Km. 125, 85 km SE El Dorado (USNM 387712); Bolívar, El Pauji, 21 km NE Icabaru, El Pauji (USNM 441750); Distrito Federal, Alto Ño León, 33 km SW Caracas (USNM 409427); Merida, La Mucuy, 4 km E Tabay (USNM 373919, 387705).

Myotis riparius.—FRENCH GUIANA (2): Paracou, near Sinnamary (AMNH 266376, 268591). GUYANA (6): Barima-Waini, North West District (USNM 568021); Potaro-Siparuni, Iwokrama Field Station, Iwokrama Forest (ROM 112049); Potaro-Siparuni, Iwokrama Reserve, Burro Burro River, 25 km WNW of Kurupukari (ROM 107278, 114620); Potaro-Siparuni, Mount Ayanganna, First Plateau Camp (ROM 114688, 114689); Upper

Takutu-Upper Essequibo, Gunn's Strip (ROM 106773). VENEZUELA (12): Amazonas, Boca Mavaca, 84 km SSE Esmeralda, 7 km up Río Mavaca (USNM 405803, 405804); Amazonas, Capibara, 106 km SW Esmeralda, Brazo Casiquiare (USNM 409457); Amazonas, ca. 2 km SE Cerro Neblina Base Camp (USNM 560625); Amazonas, Tamatama, Río Orinoco (USNM 405806); Apure, Nulita, 29 km SW Santo Domingo, Selvas de San Camilo (USNM 416584, 441746, 441748); Aragua, Rancho Grande (USNM 562940); Barinas, 7 km NE Altamira (USNM 441743); Bolívar, Río Supamo, 50 km SE El Manteco (USNM 387721); Bolívar, San Ignacio de Yhuruani (USNM 448544).

Myotis simus.—BRAZIL (42): Amazonas, Borba (AMNH 91886–91892, 94224, 94225, 94227, 94230–94234); Amazonas, Itacoatiara (MZUSP 4372); Amazonas, Manaus (AMNH 79534, 91472–91478, 91500); Amazonas, Parintins (AMNH 92983, 93489–93497, 93922–93925); Amazonas, Rio Juruá (MZUSP 638, 1074).

Non-volant Mammals of Ash Meadows National Wildlife Refuge, Nevada

Richard W. Manning and Martin R. Heaney

Abstract

Ash Meadows National Wildlife Refuge is located within the Mojave Desert ecoregion of southern Nevada. We conducted a mammal survey, across all habitat types, for two years using Sherman live-traps and pitfall traps. We comment on habitat associations (or preferences) and estimates of relative abundance for each species captured. Also, we comment on other large-bodied mammals of the Refuge. Three rodent species were especially abundant and accounted for approximately three-fourths of all live-trap and pitfall trap captures: Merriam's Kangaroo Rat (*Dipodomys merriami*); Western Harvest Mouse (*Reithrodontomys megalotis*); and Cactus Deermouse (*Peromyscus eremicus*).

Key words: Ash Meadows National Wildlife Refuge, habitat preference, mammals, Nevada, rodent relative abundance

Introduction

During 2007–2009, a 2-year baseline wildlife inventory was conducted at Ash Meadows National Wildlife Refuge (hereafter, the Refuge or AMNWR) in Nye County, Nevada. This particular study is focused on the results of that survey that pertain to non-volant mammals on the Refuge. The main purposes of this study were to: 1) establish permanent sampling sites on the Refuge, including pitfall drift fence arrays (PDFAs) and Sherman® live-trap transects; and 2) collect baseline information on small ground-dwelling mammals on the Refuge.

Study Site

The AMNWR occurs entirely within the Mojave Desert ecoregion, which covers an area of approximately 38,360 km^2 (14,811 mi^2) in southern Nevada (Fig. 1). Average annual precipitation is 65–190 mm (3–7 in). The flora is dominated by Creosotebush (*Larrea tridentata*), Allscale (*Atriplex polycarpa*), Brittlebush (*Encelia farinosa*), Desert Holly (*Atriplex hymenelytra*), White Burrobush (*Hymenoclea salsola*), and Joshua Tree (*Yucca brevifolia*), as well as a number of common associated species.

Ash Meadows National Wildlife Refuge is located in Nye County, Nevada, approximately 145 km (90 mi) northwest of Las Vegas (Fig. 2). Several prominent physiographic features, often mentioned in text, are depicted in Figure 2. The Refuge was established during June of 1984, protecting nearly 9,300 ha (23,000 ac) of spring-fed wetlands and alkaline desert habitat. Ash Meadows Refuge supports at least 26 endemic plants and animals, five of which are Federally listed as Endangered. The Refuge is thought to harbor the largest concentration of terrestrial endemism in the continental United States (http://www.fws.gov/desertcomplex/ashmeadows/).

The Refuge consists of a complex mosaic of communities characterized by unique conditions related to small-scale variations in floristic assemblages, topography, soil characteristics, drainage patterns, and other physical features of the landscape. Following the

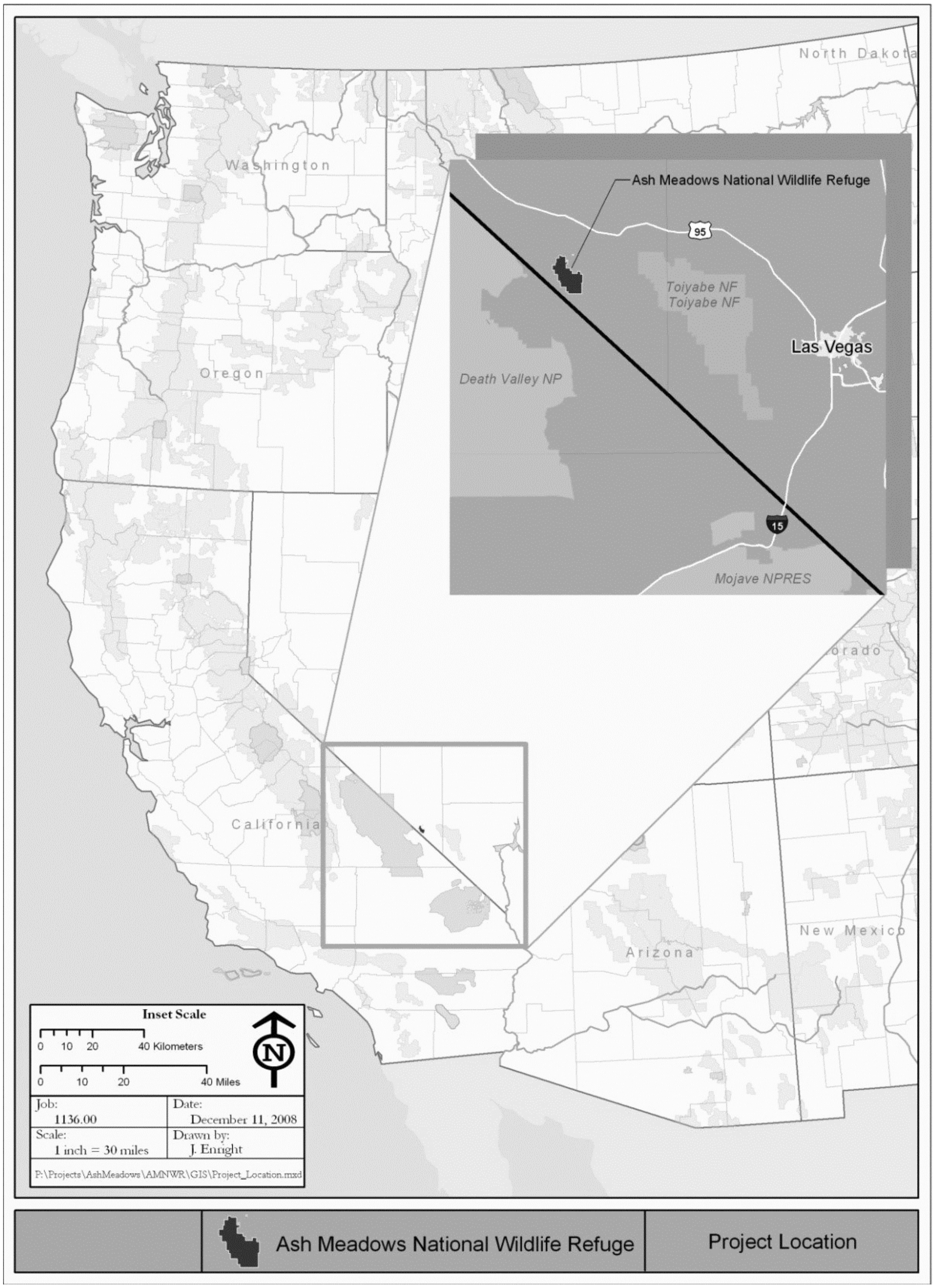

Figure 1. Map depicting research area, Ash Meadows National Wildlife Refuge, within the state of Nevada.

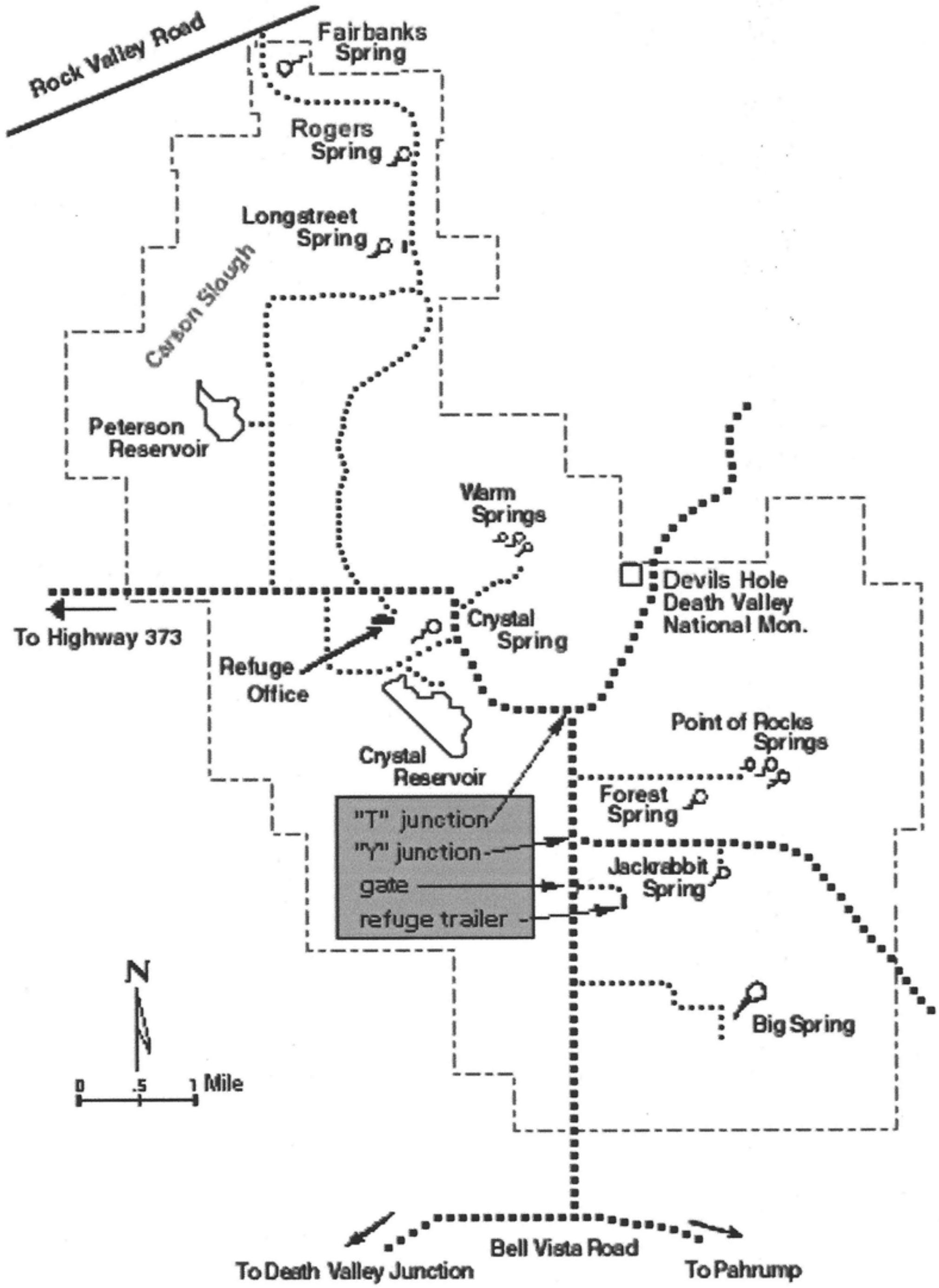

Figure 2. Schematic map of Ash Meadows showing major springs and points of interest. [Bostic, Joseph. Ash Meadows. 2000. miniQuest adventures for the part time explorer. http://www.miniquest.com/blog/2000/11/4/ash-meadows. Accessed December 2015].

completion of vegetation mapping by the BIO-WEST botanical team, all habitat types were identified based on vegetation characteristics.

Habitat Types

Alkali Meadow.—Alkali Meadows exist in areas with a shallow water table (1–2 m) throughout the growing season. This community most often is located in a valley depression or at the bottom of alluvial fans throughout arid deserts of the Southwest. The typical elevation range of Alkali Meadows at Ash Meadows NWR is 1,070–2,130 m (CNPS 2009). Soils consist of alkaline clays and silts that often produce a salt 'crust' on the surface (Jones & Stokes Associates 1993; UCSB 2009). Vegetation is low growing and consists of perennial grasses and sedges such as Alkali Sacaton (*Sporobolus airoides*), Saltgrass (*Distichlis spicata*), Beardless wildrye (*Leymus triticoides*), and Arctic Rush (*Juncus arcticus*). Common shrubs within Alkali Meadows include Rubber Rabbitbrush (*Ericameria nauseosa*) and Big Saltbush (*Atriplex lentiformis*) (CNPS 2009).

The most concentrated alkali communities occur in Carson Slough, the Crystal Reservoir and lower Crystal Marsh areas, and west of Big Spring. Throughout the Refuge, hydrology varies from saturated in the winter months to saturated year-around. Alkali Meadow is the transitional habitat between Alkali Shrub-Scrub communities and the wetter habitat types such as Wet Meadow, Alkali Sink, Alkali Seep, and sometimes Emergent Marsh communities. Although Alkali Meadows may share many species in common with bordering communities, they are unique in hydrology, species densities, and species composition. Alkali Meadows differ from Alkali Seeps in that they have a much higher percentage of vegetation cover, and they differ from Wet Meadows in that they rarely, or for only a short time, have surface water. A salt crust is associated with Alkali Meadow habitats and appears to be more pronounced in depressions and areas with drastic annual hydrologic changes. More Black-tailed Jackrabbit (*Lepus californicus*) activity was observed in Alkali Meadow habitat than in any other habitat within the Refuge. Vegetation is moderate to dense with usually more than 50% cover of herbaceous species. The two most common plant species here are Alkali Sacaton and Saltgrass. In some cases, both form monotypic stands. Other common plants not listed above but associated with Alkali Meadow on the Refuge are Sandburg Bluegrass (*Poa secunda*), Mojave Thistle (*Cirsium mojavense*), Copperweed (*Oxytenia acerosa*), Whiteflower Rabbitbrush (*Chrysothamnus albidus*), and Mojave Seablite (*Suaeda moquinii*).

Alkali Playa.—Alkali Playas occur throughout the arid Southwest in the lowest elevations of desert basins where the topography is level to concave, and barren to sparsely vegetated (<10% cover) (NatureServe 2009). Playas form during periods of intermittent flooding and evaporation, which occur in high-groundwater years or after flash flood events (NatureServe 2009; USGS 2009). Because of water evaporation, some playas maintain varying amounts of surface salt crust that limits the types of vegetation that can grow there. Soils have a characteristic clay layer or hard pan, which limits water drainage (NatureServe 2009). Plants common to Alkali Playas include spikerush (*Eleocharis* sp.), Iodinebush (*Allenrolfea occidentalis*), Mojave Seablite, Saltgrass, Alkali Sacaton, and *Atriplex* species (NatureServe 2009). Polygonal surface cracking is a common feature in Alkali Playas (USGS 2009).

This habitat covers the least amount of area on the Refuge. It occurs in only one location, directly below Crystal Reservoir Dam. It appears that playa formation may be caused in part by seepage from Crystal Reservoir Dam, as well as groundwater and seasonal rains. A salt crust with moderate to low thickness is associated with the Alkali Playa, as are scattered surface gravels. Vegetation density is low; the most common species are scattered sparsely throughout this habitat and concentrated on its margins. These species are Shadscale (*Atriplex confertifolia*), Arctic Rush, Saltgrass, Mojave Thistle, Whiteflower Rabbitbrush, and Alkali Sacaton.

Alkali Seep.—Alkali Seep communities occur in unique areas across Southwestern deserts. The water table must be at or near the surface throughout the year for an Alkali Seep to form. Soils are slightly to heavily alkaline and do not allow ponding water during rain events (Nuzum 2005; UCSB 2009). Alkali Seeps often are found bordering or within larger Alkali Meadow communities (NNHP 2009; UCSB 2009). Alkali Seeps occur on flats, sloping terrain, and drainages.

Vegetation cover usually is low (Nuzum 2005; UCSB 2009). Some common species in this habitat are Velvet Ash (*Fraxinus velutina*), Mesquite (*Prosopis* sp.), Saltgrass, Shadscale, Arctic Rush, and Mojave Thistle (NNHP 2009).

This habitat occurs at low to mid elevations where the water table is near the surface. A moderate to high thickness of evaporated salt crust surface exists, which limits vegetative cover in comparison with neighboring Alkali Meadows. Soils are clay and saturated for most of the year. Small pockets of Alkali Seep occur within Alkali Meadow communities and near spring channels. Alkali Seeps may also transition into Wet Meadow and Emergent Marsh habitats. Alkali Seeps often form at the bottom of topographic breaks. Common species found in this habitat on the Refuge include those listed above, as well as Desert Polygala (*Polygala acanthoclada*), Whiteflower Rabbitbrush, Copperweed, and Alkali Sacaton.

Alkali Shrub-scrub.—Alkali Shrub-scrub is a common habitat type found throughout the Mojave and Sonoran Deserts (Brown 1994), as well as in small stands in the Colorado and Great Basin Deserts (Rowlands 1988). It occurs from below sea level to 1,800-m elevations and has deep soils high in silt and clay content that hold more water than soils of Creosote Shrublands. Alkali Shrub-scrub is described as occurring in two phases, a xerophytic phase and a halophytic phase. The distribution of each phase is influenced by groundwater availability, which in turn is based on topography and climate. The xerophytic phase is located at higher elevations and is composed of xeric shrubs, subshrubs, and few forbs or grasses. The halophytic phase occurs at lower elevations and often borders Alkali Playa, Alkali Sink, and Alkali Seep habitats. Because groundwater is more available, a higher variety of plants are found in this phase, although they must be able to tolerate higher levels of alkalinity (Brown 1994). In both phases the plant community is dominated by plants in the goosefoot (Chenopodiaceae) family. The xerophytic phase is mostly dominated by *Atriplex* sp. The most common species are Four-wing Saltbush (*Atriplex canescens*), Allscale, Desert Holly, and Shadscale (Rowlands 1988; CNPS 2009). In the halophytic phase the dominant species are still Chenopods but include more varieties such as *Suaeda* sp., *Nitrophila* sp., and *Sarcobatus* sp., as well as the introduction of grasses such as Alkali Sacaton and Saltgrass (Rowlands 1988; Brown 1994).

The most common habitat type within the Refuge is Alkali Shrub-scrub. It occurs throughout the mid-elevations. It is found throughout the central and southern portions of the Refuge with both xerophytic and halophytic types. The halophytic phase is the most common on the Refuge and occurs at lower to mid elevations, often bordering washes, Alkali Meadows, Alkali Seeps, Alkali Sinks, or riparian areas. The most common dominant species in the halophytic phase are Alkali Goldenbush (*Isocoma acradenia*), Shadscale, Rubber Rabbitbrush, Mojave Seablite, Mesquite (*Prosopis pubescens*) and Honey Mesquite (*Prosopis glandulosa*). Soils are not well drained in either of the types because of high silt and clay content, but they are never saturated to the surface. Elevation change in the eastern section of the Refuge often is rapid and, therefore, the xerophytic type does not always develop; instead it transitions quickly to Salt Desert Scrub habitat or Creosote Shrubland. Other than the *Atriplex* species listed above, common species in the xerophytic phase are Desert Pepperweed (*Lepidium fremontii*) and Threadleaf Snakeweed (*Gutierrezia microcephala*). It is only in the driest of the xerophytic phase that some cactus species appear sparsely, such as Beavertail Pricklypear (*Opuntia basilaris*) and Silver Cholla (*Cylindropuntia echinocarpa*). The xerophytic phase of Alkali Shrub-scrub may have species in common with Salt Desert Scrub, but it has a higher vegetation density, occurs at a slightly lower elevation, does not have well-drained soils, and exhibits a more prominent forb and grass layer (see the Salt Desert Scrub habitat description). Although forb and grass species are more prominent in Alkali Shrub-scrub habitat than in Salt Desert Scrub, they are still a minor component. Common species include Buckwheat (*Eriogonum* sp.), Desert Globe-mallow (*Sphaeralcea ambigua*), and Indian Rice Grass (*Achnatherum hymenoides*).

Alkali Sink.—Alkali Sinks are found at low elevations with high salinity and shallow water tables, typically less than three meters deep (Barbour et al. 1977; CNPS 2009). Alkali Meadow and Alkali Shrub-scrub share many species in common with Alkali Sink habitats but differ in hydrology and soil. The surface of

Alkali Sinks is impermeable and, therefore, water pools there during rain events. As pools evaporate, a salt crust often develops (CNPS 2009). Mojave Seablite is the most common shrub in this habitat, and it can exist in large stands. Other common species include Greasewood (*Sarcobatus vermiculatus*), Parry's Saltbush (*Atriplex parryi*), Tamarisk (*Tamarix* sp.), Shadscale, Whiteflower Rabbitbrush, Alkali Sacaton, Saltgrass, Arrowweed, and Screwbean Mesquite. *Allenrolfea* species commonly occupy highly saline areas that other plants cannot tolerate (Barbour et al. 1977; CNPS 2009). Alkali Sinks have many species in common with Alkali Playa; however, Alkali Playa have significantly less vegetation cover (<10%) (NatureServe 2009).

Within the AMNWR, Alkali Sink habitats occur at mid-elevation west and southwest of Peterson Reservoir, south of Crystal Marsh, and in scattered areas in the southern portion. Soils are clay and fine silt that are poorly drained with evidence of pooling water at the surface. There is no associated surface salt crust. Mojave Seablite is strongly dominant (≥ 50% coverage) in all Alkali Sink communities throughout the Refuge. Species found in Alkali Sink communities within the Refuge are less diverse than those found in regional habitats. Other than Mojave Seablite, common species associated with Alkali Sinks are Big Saltbush, Shadscale, Allscale, and Saltgrass.

Ash.—Velvet Ash is a deciduous tree that prefers fine-textured soils and occurs in riparian areas throughout the Southwest (USDA 2009). Although it is generally considered a riparian species, Velvet Ash is found both within and outside of the Refuge's riparian habitats. For this reason, and because of the number of rare and endemic species found in Ash habitat, the Ash communities have been separated from Riparian Woodland (see Riparian Woodland habitat description) and assigned a separate habitat type. Ash habitat occurs throughout the low and mid-elevations of the Refuge, often within or bordering larger Alkali Meadow, Wet Meadow, Alkali Seep, and riparian habitats. The largest Ash communities within the Refuge occur on Collins Ranch, Mary Scott Spring, Scruggs Springs, and southeast of Crystal Reservoir. On the Refuge, Ash habitat most often occurs in small patches near springs and seeps, with one major exception, a community southeast of Crystal Reservoir that occurs within a larger Alkali Meadow community. This is the largest Ash population on the Refuge. Ash communities have a varying understory based on the surrounding habitat type in which they occur. Some common understory species are Alkali Sacaton, Big Saltbush, and Alkali Goldenbush. Other overstory trees that may be found within Ash habitat are Goodding's Willow (*Salix gooddingii*) and Screwbean Mesquite.

Cottontop Dry Ridge.—Within the Mojave Desert, Cottontop Dry Ridge habitat is commonly described within Creosote Shrubland habitat based on similar species composition and environmental conditions (see Creosote Shrubland habitat description). The Cottontop Dry Ridge habitat classification is based on the 2006 Ash Meadows Geomorphic and Biological Assessment final report (Otis Bay and Stevens Ecological Consulting 2006), which distinguishes Cottontop Dry Ridge as a habitat type within the Refuge based on a lower vegetative cover than in Creosote Shrubland, as well as the unique steep slopes and ridges that it occupies. Soil is poor and supports a low density of vegetation including Creosote Bush, White Bursage, *Eriogonum* species, Barrel Cactus (*Ferocactus cylindraceus*), and Silver Cholla. Cottontop Dry Ridge habitat occupies the highest elevations of the Refuge, the high slopes and ridges of the Specter Range bordering the eastern boundary of the Refuge. These Cambrian limestone and dolomite ridges rise steeply from the valley floor and transition quickly from Creosote Shrubland or Salt Desert Scrub into Cottontop Dry Ridge habitat (Otis Bay and Stevens Ecological Consulting 2006).

Creosote Shrubland.—Creosote Shrubland is the single most dominant plant community found in the Mojave Desert (Brooks et al. 2007). It occurs at less than 1,220 m in elevation above the "saltbush zone," which is dominated by *Atriplex* species, and below the "Blackbrush Zone," which is dominated by Blackbrush (*Coleogyne ramosissima*) (Brown 1994). Creosote Shrubland often occupies broad valleys, plains, low hills, and lower bajadas. The characteristic soil is well-drained sand with large surface gravels often forming desert pavement (NatureServe 2009). Creosotebush is the dominant shrub and most often associated with white bursage; however, other shrubs may occupy and dominate the community at varying elevations. Some common, co-dominant species are Shadscale, Desert

Holly, *Ephedra* species, *Encelia* species, and Desert-thorn (NatureServe 2009). These communities are highly prone to fire damage (Brooks et al. 2007).

The highest elevations on the Refuge are occupied by Creosote Shrubland habitat. It is distributed on the east of the Refuge and is similar to Creosote Shrubland found throughout the Southwest. Creosote Shrubland habitat differs from Salt Desert Scrub in that it occurs at slightly higher elevation. Although they may have some species in common, Creosote Shrubland habitat is dominated by Creosotebush and White Bursage, with a minor component of Shadscale, Desert Holly, Button Brittlebush (*Encelia frutescens*), White Ratany (*Krameria grayi*), and Rusty Molly (*Bassia californica*). Soil is well drained with dark cobbles on the surface that often form desert pavement. The herbaceous layer is sparse but may include Desert Trumpet (*Eriogonum inflatum*), Rigid Spineflower (*Chorizanthe rigida*), and winter annuals such as *Phacelia* species.

Dunes.—Stabilized Dunes and Coppice Dunes are found in warm, semi-arid regions of the Southwest. Soils commonly associated with dunes are quartz or gypsum very fine- to medium-grained sands (NatureServe 2009; USACE 2009). Within a given area, dune size is mostly uniform and can range from 0.5 to 3 m high and 1 to 15 m wide. Dunes form in areas where vegetation acts as nets, catching sands that build up in mounds. Vegetation that stabilizes dunes must be able to tolerate having its branches and roots continually covered with sand. In the Southwest the most common stabilizing species is Honey Mesquite (Rango et al. 2000). Other species found in dune communities are Mormon Tea (*Ephedra* sp.), Four-wing Saltbush, *Acacia* species, *Tamarix* species, White Bursage, Desert Sand Verbena (*Abronia villosa*), Sand Sagebrush (*Artemisia filifolia*), Dune Buckwheat (*Eriogonum deserticola*), *Sporobolus* species, and Creosotebush (Rango et al. 2000; NatureServe 2009; USACE 2009).

Within the Refuge there are two types of dune; Mesquite Dunes and Shrub Dunes. Both are Coppice Dunes, each with different plants acting as the stabilizing species. Mesquite Dunes are stabilized by honey mesquite and are the most common dunes found on the Refuge. Shrub Dunes are stabilized by four-wing saltbush and are less abundant than Mesquite Dunes. Heavy winds form dunes at mid-elevations across the Refuge with a concentration on the western side. Soils are well drained and sandy. Dune communities, especially Mesquite Dunes, are highly productive areas where much animal activity and cultural resources (lithic scatter) have been observed. The largest acreage of Mesquite Dunes is found west of Horseshoe Marsh and west of Cold Spring. Because of the high winds and xeric conditions on the Refuge, dune-forming honey mesquite are low and shrub-like in most areas. Elsewhere in the Southwest, nondune-forming Honey Mesquite are mostly upright with a clear central stem. Common species within a Mesquite Dune community are Honey Mesquite, *Atriplex* species, Alkali Goldenbush, Rubber Rabbitbrush, Mojave Seablite, and Alkali Sacaton. Habitat interlaced within dunes most commonly resembles Alkali Shrub-scrub. Dune communities support a variety of winter annuals including *Eriogonum* species and Booth's Primrose (*Camissonia boothii*). The largest area of Shrub Dunes is found at the western edge of Horseshoe and Crystal marshes, as well as west and south of Peterson Reservoir. Vegetation usually is less dense than in Mesquite Dunes, and these communities support a lower diversity of plants. Common species include Four-wing Saltbush, Thurber's Sandpaper Plant (*Petalonyx thurberi*), shadscale, and Alkali Goldenbush.

Emergent Marsh.—Emergent Marshes are distributed widely throughout all elevations in the arid West but are most concentrated below 2,270 m (Kramer 1988; NatureServe 2009). Emergent Marshes occur on all slopes but most often occur in depressions on the landscape or across level or rolling terrain. Frequent to continual inundation of Emergent Marshes, with water 1–2 m deep, results in hydric silt and clay soils that may display gleyed coloring, high amounts of organic matter, and/or redoximorphic features (NatureServe 2009). This vegetation community is dominated by perennial hydrophytic herbaceous genera such as *Schoenoplectus, Typha, Juncus,* and *Phalaris*. Species differ by region (NatureServe 2009). Emergent Marshes often are bordered by Wet Meadows marked by the transition from hydrophytic to mesophytic vegetation. Deep-water habitat may occur within an Emergent Marsh when the water level reaches more than two meters and emergent vegetation can no longer survive (Kramer 1988). The amount of open water within an Emergent Marsh will vary from season to season (Kramer 1988).

Habitat designated as Emergent Marsh within the AMNWR is most abundant at lower Crystal and Horseshoe marshes. Area of Emergent Marsh will vary from year to year based on annual rainfall and temperature. Crystal and Peterson reservoirs also support Emergent Marsh habitat. Carson Slough has a lattice of Emergent Marsh vegetation that is dominated by Common Reed (*Phragmites australis*). Much of the common reed stands appeared to be drying out because of changing hydrology in the area. Other Emergent Marsh communities on the Refuge are associated with spring outflows including Bradford, Big, and Kings springs. Common species are *Typha* species, Chairmaker's Bulrush (*Schoenoplectus americanus*), and Common Reed, with Arctic Rush, Beaked Spikerush (*Eleocharis rostellata*), and Saltgrass bordering the edge of Emergent Marsh communities as they transition to Wet Meadows.

Mesquite Bosque.—Mesquite Bosque communities are found along rivers in the Southwest, including, but not limited to, the Colorado River, Gila River, Santa Cruz River, and Rio Grande (NatureServe 2009). Although Mesquite Bosques are considered riparian habitat, they often occur somewhat distant from streams on sites with less reliable hydrology (e.g., alluvial terraces, washes, and alkali sinks) but are dependent on the seasonal rise in groundwater (NatureServe 2009; UCSB 2009). Stands are distributed on toe slopes or valley bottoms at elevations below 1,100 m (NatureServe 2009). The canopy consists of *Prosopis* species, including Honey Mesquite, Velvet Mesquite (*Prosopis velutina*), and Screwbean Mesquite. Common species occupying the shrub layer, when one exists, are *Baccharis* species and Coyote Willow (*Salix exigua*). The herbaceous layer is generally open but may contain grass species and *Atriplex* species (NatureServe 2009; UCSB 2009). Mesquite Bosques are important habitat for many mammals, birds, insects, and reptiles throughout the Southwest, providing shade and food resources (Plagens 2009).

Within the Refuge, Mesquite Bosques are distributed throughout low elevations with higher concentrations occurring near springs, seeps, and washes. Because of the high groundwater table in the Refuge's low elevations, Mesquite Bosques are not restricted to riparian areas. Areas near spring channels dominated by screwbean mesquite have been designated as Riparian Woodland habitat to highlight their proximity to water and distinguish them from mesquite stands not associated with a channel. All mesquite stands not directly adjacent to spring channels have been designated as Mesquite Bosque habitat. Screwbean Mesquite is the most common dominant species, with honey mesquite comprising a portion of the canopy in some areas. Other associated tree species are Tamarisk, Velvet Ash, and Fremont Cottonwood (*Populus fremontii*). The most common understory species are Saltgrass, Big Saltbush, Golden Alkalibush, Alkali Sacaton, and Shadscale. Canopy height of this community averages 3–6 m and provides important habitat for animals in the area.

Nonnative/Weed.—Nonnative/Weed habitat is assigned to communities dominated by species that are not native to the Refuge. This excludes Tamarisk, which has been placed in its own habitat type because of the unique management challenge it poses for the Refuge. Transitioning Agricultural habitat also may be dominated by nonnative species; however, Transitioning Agriculture occurs only on historic agricultural fields, whereas Nonnative/Weed habitat occurs in other disturbed areas such as roadsides, historic restoration areas, and on former private property. Some Nonnative/Weed habitat, such as Carson Slough, falls within historic agricultural fields but no longer shows evidence of agriculture in the field. Nonnative/Weed communities exist mostly in wet areas across the low to mid-elevations of the Refuge, including the west side of Carson Slough, Bradford Springs area, and south of Kings Spring. Dominant plants include Fivehook Bassia (*Bassia hyssopifolia*), Russian Knapweed (*Acroptilon repens*), Redstem Stork's Bill (*Erodium cicutarium*), Common Sunflower (*Helianthus annuus*), and Spreading Alkaliweed. Russian Knapweed was being actively controlled during mapping. Habitat designations represent community composition at time of data collection and may not reflect current conditions. Common Sunflower and Spreading Alkaliweed are native species that have been included because of their apparent preference and success on disturbed surfaces.

Riparian Woodland and Shrubland.—Desert Riparian Woodlands and Shrublands are important habitats located along perennial streams and spring outflows throughout the Mojave and Sonoran deserts (Laundenslayer 1988). Riparian zones are dependent on seasonal flooding provided by the streams they occupy (NatureServe 2009). The soils range from rocky, sandy, well-drained soil to silty alluvial deposits (Laundenslayer 1988). Desert Riparian Woodlands and Shrublands occur at low elevations of less than 1,200 m in canyons or valley bottoms. Tree canopy commonly is dominated by Fremont Cottonwood, Goodding's Willow, Velvet Ash, *Prosopis* species, and Tamarisk. The shrub layer, which may be an understory to the tree layer or form unique stands along stream channels, often is composed of Big Saltbush, Narrowleaf Willow (*Salix exigua*), arrowweed, or Mojave Seablite (Laundenslayer 1988; NatureServe 2009; USFS 2009). Desert Riparian areas average 7.5–24.5 mm (3.1–9.8 in) precipitation a year, but communities may survive in much drier conditions if the water table is seasonally available (Laundenslayer 1988).

Riparian Woodlands on the Refuge are associated with spring discharges and their surrounding areas. The Riparian Woodlands classification includes two types, those dominated by *Prosopis* species and those dominated by *Salix* and/or *Populus* species. Because Mesquite Bosque communities are found throughout the Refuge in non-riparian areas, communities dominated by *Prosopis* species in riparian areas were designated as Riparian Woodland, and those dominated by *Prosopis* species in non-riparian areas were designated as Mesquite Bosque (see Mesquite Bosque habitat description). Common tree species are the same as above with the exception of velvet ash, which has been placed in a unique habitat type (see Ash habitat description). The largest amount of Riparian Woodland occurs along the channel corridor of Kings Spring and other nearby springs, as well as in the Scruggs Springs area, Crystal Spring channel, and southwest of Bradford Springs. Canopy cover is dense with varying understory composition. The most common understory plants are Big Saltbush and Alkali Sacaton. Riparian Woodland most often transitions into Riparian Shrubland or Alkali Shrub-Scrub communities.

Riparian Shrublands are associated with spring outflow in the same areas as or independently of Riparian Woodlands throughout the Refuge. They are either the understory of Riparian Woodlands or occur in independent stands. When the two habitats occur together, the Riparian Woodlands will be nearest to the spring channel and transition to Riparian Shrublands farther back from the spring channel. Riparian Shrublands in the vicinity of Big Spring occur independently of Riparian Woodlands. Common shrubs are as indicated above with the addition of Emory's Baccharis (*Baccharis emoryi*), which is common in the Refuge both within and outside of riparian areas.

Salt Desert Scrub.—Salt Desert Scrub, also known as Shadscale Scrub, occurs throughout the Mojave and Great Basin deserts on low slopes of alluvial fans. The soils generally are poorly drained and slightly alkaline. Plant density is low and canopy height ranges from 0.3 to 1 m. Salt Desert Scrub occurs below Creosote Shrubland, which is dominated by Creosotebush, in the Mojave Desert and below Sagebrush Scrub, which is dominated by *Artemisia* species, in the Great Basin Desert (Smith 2000). Some of the most common species associated with this community are Shadscale, Blackbrush, Budsage (*Artemisia spinescens*), Desert Alyssum (*Lepidium fremontii*), Four-wing Saltbush, Fremont's Dalea (*Psorothamnus fremontii*), Threadleaf Snakeweed, *Ephedra* species, Spiny Hopsage, Spiny Menodora, and Winterfat. Salt Desert Scrub has many species in common with Alkali Shrub-Scrub but is found at slightly higher elevations and in more xeric conditions (Smith 2000).

Salt Desert Scrub is one of the driest habitat types in the Refuge, second only to Creosote Shrubland. It occurs on the eastern edge of the Refuge on toe slopes, alluvial fans, and badlands, transitioning quickly from the xerophytic phase of Alkali Shrub-Scrub. Salt Desert Scrub also can be found southwest of Cold Spring on the westernmost boundary of the Refuge. The most notable difference between Salt Desert Scrub and Alkali Shrub-Scrub communities are that Salt Desert Scrub has well-drained soils, which often form desert pavement, along with low vegetation density, minimal forb and grass layer, and a slightly higher elevation. Common species within the Refuge are as above with the exception of Blackbrush, which was only observed once on the refuge. The herbaceous layer is sparse. The two most common species are Desert Trumpet and rigid Spineflower, which occur along with other winter annuals.

Tamarix.—*Tamarix* communities form dense (60–100% cover) stands along riparian corridors throughout the Southwest. Communities often are monotypic with few non-*Tamarix* species contributing to overall cover (Hart 2009; USFS 2009). *Tamarix* is most successful below sea level to 2,000 m but has been found at elevations up to 3,350 m (USFS 2009). *Tamarix* has the ability to occupy non-riparian areas because of its extensive root system, which may reach deep groundwater otherwise unavailable to native vegetation (Hart 1999). These communities are tolerant of a wide variety of soil conditions and can withstand high salt concentrations. *Tamarix* often occurs in previously disturbed areas. The two main *Tamarix* species widespread throughout the Southwest are Small Flower Saltcedar (*T. parviflora*) and Saltcedar (*T. ramosissima*). Other species that may occur in *Tamarix* stands are Arrowweed, Fremont Cottonwood, Narrowleaf Willow, Goodding's Willow, *Prosopis* species, and Big Saltbush. Annual grasses may occupy the understory (Hart 1999; USFS 2009). *Tamarix* is a non-native species that was introduced to the United States in the 1800s. It has since become one of the most common riparian species in the Southwest. Some of the effects of *Tamarix* communities include displacement of native species, increased soil salinity, increased water consumption, increased fire frequency due to the high amount of fuel load, and increased flood events (Hart 1999).

Tamarix habitat within the Refuge ranges from a few individuals along washes to large stands composing 100% of the canopy. *Tamarix* was found throughout the Refuge in varying soil conditions in proximity to open water, ephemeral washes, or areas of high groundwater. Carson Slough, southeast of Jackrabbit Spring, south of Kings Spring, and around Peterson and Crystal reservoirs had the most *Tamarix*. The period of data collection often did not correspond to *Tamarix* flowering time and, therefore, *Tamarix* was not identified to the species level. Throughout the mapping process the Refuge was actively controlling the presence of *Tamarix*. Habitat designations were made based on the dominant vegetation at the time of data collection, and they may or may not represent current conditions. In many areas where *Tamarix* has been removed, it was observed that *Tamarix* seedlings were resprouting or old stumps were greening from the base. Common species associated with *Tamarix* are Screwbean Mesquite, Fivehook Bassia, Emory's Baccharis, Shadscale, Saltgrass, and common sunflower. Continued control of *Tamarix* is needed throughout the Refuge, especially in active restoration areas such as Peterson and Crystal reservoirs.

Transitioning Agriculture.—Transitioning Agriculture habitat was assigned when a community occurred on a historic agricultural field but did not yet resemble or function as any other habitat type. Transitioning Agriculture was scattered throughout the mid elevations of the Refuge in areas such as Bradford Springs, west of Point of Rocks Springs, southwest of Jackrabbit Spring, west of the Refuge office, and in the southern portion of Carson Slough. Most Transitioning Agriculture areas were at varying levels of succession, and many still had plow lines or planting rows visible on the ground and in aerial photographs. Vegetative cover is low profile and often has a nonnative component. Other historic agricultural fields within the Refuge that are not assigned as Transitioning Agriculture are further along in transition and resemble an appropriate habitat type. Composition varies based on surrounding communities and location on the Refuge. Some native species that appear to prefer (or are successful on) the disturbed surfaces of Transitioning Agriculture are Brownplume Wirelettuce (*Stephanomeria pauciflora*), Emory's Baccharis, Big Saltbush, and Honey Mesquite. Nonnative species include Desert Indianwheat (*Plantago ovata*) and Redstem Stork's Bill. As succession and restoration continue, these areas may become more naturalized and act as functioning habitat types.

Wet Meadow.—Wet Meadows occur throughout the western United States and are characterized by a dense herbaceous layer (60–100% cover) and little to no tree or shrub layer (Ratliff 1988). The hydric soil associated with Wet Meadows is poorly to moderately drained with a texture of clay loams to fine sands (MTNHP 2009). The water table is at the surface for most of the growing season but can fall to as much as a meter below the surface during the dry season, especially in the Southwest. Wet Meadows occupy seeps, alluvial terraces, stream benches, overflow channels, and areas near springs on level to slightly undulating surfaces; they also often transition to Emergent Marsh communities (Ratliff 1988; MTNHP 2009). Associated species are Arctic Rush, Sedge (*Carex* sp.), Tufted Hairgrass (*Deschampsia caespitosa*), Saltgrass, Bulrush (*Schoenoplectus* sp.), *Eleocharis* species, Foxtail Barley (*Hordeum jubatum*), and Alkali Sacaton (Ratliff 1988; MTNHP 2009).

Wet Meadows occur throughout low elevations of the AMNWR where the water table is at or near the surface during most of the season, in open meadows, and in drainages associated with spring outflow. Carson Slough, southwest of Crystal Reservoir, and west of Big Spring are the largest areas of Wet Meadow habitat within the Refuge. Wet Meadows often are the transition between mesic Alkali Meadow and hydrophytic Emergent Marsh habitats. Where Wet Meadows occur in topographically low areas or drainages, they may be bordered by Alkali Shrub-Scrub or other, more mesic habitat types. Although Wet Meadows may share many species in common with Alkali Meadow, Wet Meadow soils are saturated to the surface for much of the growing season. Plant species associated with Wet Meadows must be able to tolerate inundation as well as short dry periods. The most common species associated with Wet Meadows within the Refuge are *Eleocharis* species, *Juncus* species (most commonly Arctic Rush), Sandburg Bluegrass, and Saltgrass, with scattered Chairmaker's Bulrush and Sturdy Bulrush (*Schoenoplectus robustus*). Shrubs and trees mostly are absent from Wet Meadows with the occasional Emory's Baccharis, Big Saltbush, Screwbean Mesquite, and Velvet Ash at the edges.

Materials and Methods

Pitfall drift fence arrays.—Pitfall drift fence arrays (PDFAs) were the primary method used to sample amphibians and reptiles on the Refuge and incidentally take small mammals. Bury and Corn (1987), Corn and Bury (1990), and Corn (1994) suggest that PDFAs are an effective way to sample species richness and determine cryptic and rare species. The PDFAs consisted of a central 6-gallon plastic bucket with the rim buried flush with the ground and three 10-m spans of galvanized sheet metal flashing placed as vertical barriers radiating out (hereafter, "arms"). The configuration of PDFAs varied slightly with location, depending on the surrounding vegetation and topography; however, the main design was in the shape of a "Y," with one arm extending due north and the remaining arms radiating out from the center with equal angles of approximately 120 degrees (Fig. 3). In addition to the center, pitfall traps were placed in the middle and at the end of each 10-m arm. All pitfall trap buckets had snap-on removable lids. Funnel traps were placed between the middle and end of each arm. Loose soil, sand, and debris were placed at the bottom of each pitfall to provide protection for captured specimens. The number of PDFAs by habitat type are presented in Table 1.

Waypoints (UTM NAD 83, Zone 11) were collected for the location of every PDFA (see PDFA locality map, Fig. 4) installed on the AMNWR and entered into the database. Each pitfall trap open for one night was considered one trap-night.

Field efforts were conducted over two years during three seasons: spring (6–11 April 2008 and 5–10 April 2009); summer (1–6 June 2008 and 31 May–4 June 2009); and fall (19–24 October 2008 and 18–23 October 2009). Prior to starting the second-year field efforts, a PDFA repair trip was conducted 25–27 February 2009. Repairs consisted of replacing pitfall bucket lids, reattaching flashing to rebar or wooden lathes, and replacing galvanized flashing that was fatigue-cracked by strong winds.

Sherman live-trapping.—Sherman live-traps were the primary trap used to survey small mammals on the Refuge (see Jones et al. 1996; Wemmer et al. 1996). Trap-nights are defined as one trap set for one night. Two field teams each deployed approximately 180–200 traps per night along transects located in various habitat on the Refuge. Traps were retrieved the following morning and deployed at another location. Traplines consisted of approximately 30–40 traps per line with individual trap stations positioned approximately 10 m (33 ft) apart. One or two traps were set at each station and baited with oatmeal. In many cases, trapline starting points were associated with a terminal PDFA pitfall bucket. Waypoints were collected for each trapline end point.

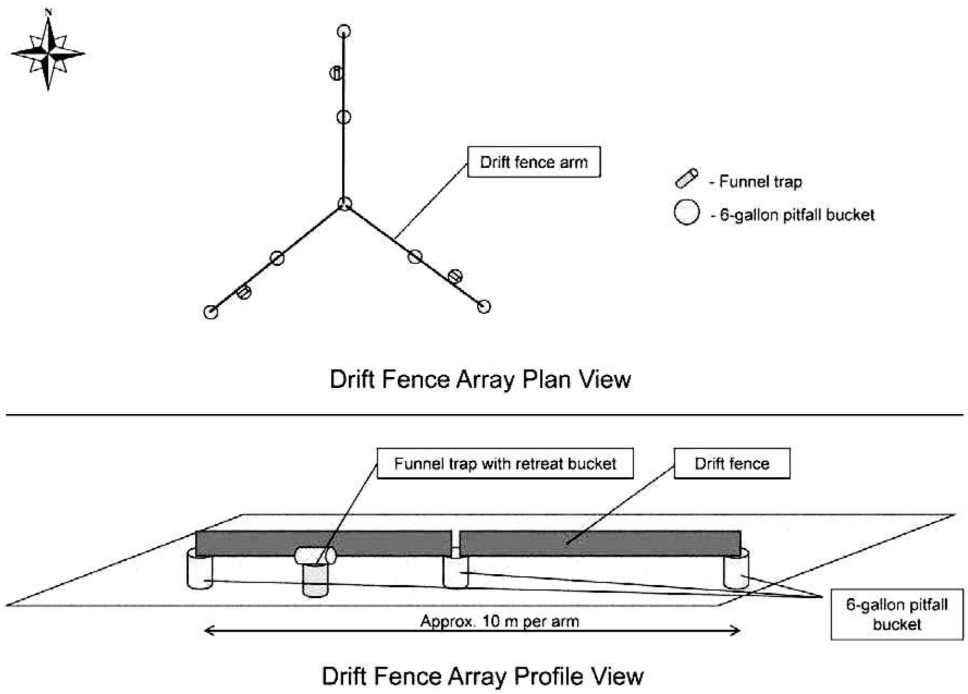

Figure 3. Schematic of the pitfall drift fence arrays (PDFAs) installed at Ash Meadows National Wildlife Refuge, Nevada.

Table 1. The number of pitfall drift fence arrays (PDFAs) in each habitat type at Ash Meadows National Refuge, Nevada, 2008–2009.

Habitat Type	Number of PDFAs
Alkali Shrub Scrub	11
Creosote Shrubland	5
Dune (Mesquite)	3
Alkali Meadow	2
Transitioning Agriculture	2
Alkali Sink	1
Ash	1
Dune (Shrub)	1
Mesquite Bosque	1
Riparian Shrubland	1
Riparian Woodland	1

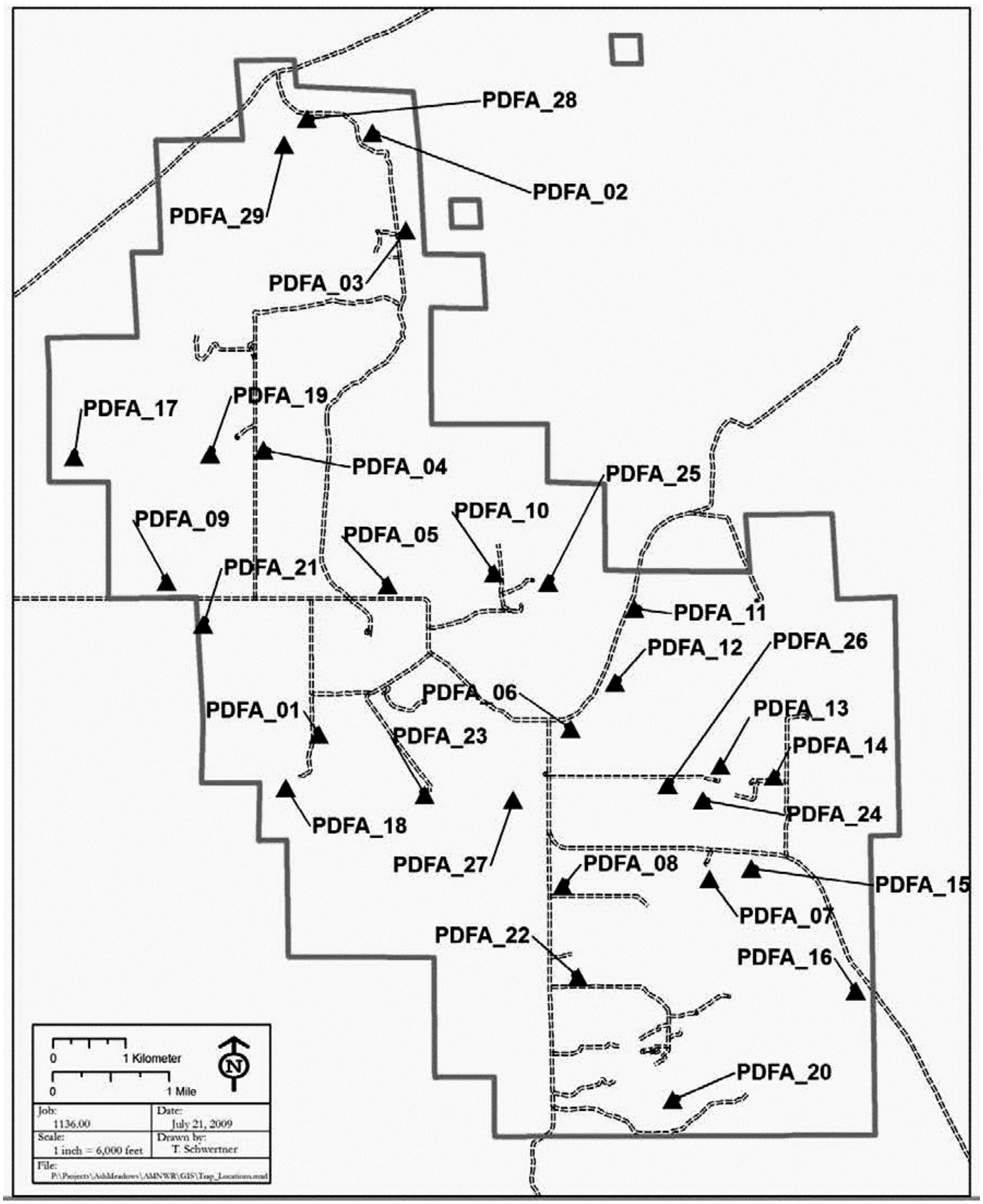

Figure 4. Location of pitfall drift fence arrays (PDFAs) on Ash Meadows National Wildlife Refuge. These locales served as the foci of Sherman live-trap transect lines.

All live specimens captured were identified to species and sex, released on-site, and the data were recorded. Ambient environmental data also were collected at each sampling location, including temperature, wind speed, wind direction (using handheld Kestrel anemometer), percent cloud cover, and precipitation.

Game cameras.—Four motion-activated Moultrie i40 digital game cameras were used to inventory additional medium to large mammals. Cameras were rotated among habitats each season. Cameras were mounted on steel T-posts and left in habitat types between seasonal sampling events. Each camera station was treated with scent attractants to increase the likelihood of mammal observation. Mammal species observed with the game cameras were recorded. Ambient environmental data were collected by the game camera, which included start and stop times, date, and temperature.

Incidental observations.—A number of qualitative efforts were employed in addition to the Sherman live-trap sampling efforts. All small mammals captured in PDFAs were recorded. Small mammal incidental observations were recorded and waypoints collected at each encounter. Road cruises were conducted near dawn and dusk to document mammal species. A GPS waypoint was collected for each mammal encounter.

Tissue samples.—Prior to release of live specimens, tissue samples (ear clips) were collected using a 2 mm (0.1 in) diameter punch. No more than 30 samples per species were collected. Tissues were placed in a Nunc® tube and stored in 95% ETOH. Any trap-dead mammal was prepared as a voucher specimen (usually skin and skull); skeletal muscle, heart, and liver tissue also were collected. All tissue samples were deposited at the Natural Science Research Laboratory of the Museum of Texas Tech University (TTU) in Lubbock, Texas.

Analysis of relative abundance.—Quantitative population and community metrics for small mammals were calculated using only Sherman live-trap data. Observed relative abundance is defined as the number of individuals captured per trap-night.

Known collection specimens.—We know of mammal material in three museum collections from Ash Meadows: United States Museum of Natural History (NMNH), Smithsonian Institution; Museum of Vertebrate Zoology at Berkeley (MVZ); and the Natural Science Research Laboratory of the Museum of Texas Tech University (TTU). These specimens are listed after the individual species accounts.

RESULTS

During our small mammal trapping survey (representing 10,910 trap-nights) the overall trap success rate was 10.4% (i.e., 10.4 animals per 100 trap-nights) across all habitat types. A total of 1,130 individuals representing 15 species were captured in Sherman traps (Table 2). Three species accounted for 72.3% of all captures. Merriam's Kangaroo Rat (*Dipodomys merriami*) was the most commonly captured small mammal (n = 276, or 24.4% of all captures); Western Harvest Mouse (*Reithrodontomys megalotis*) was the second most numerous small mammal taken (n = 275, or 24.3% of all captures); and the Cactus Deermouse (*Peromyscus eremicus*) ranked as the third most commonly trapped rodent (n = 267, or 23.6% of all captures).

A total of 225 individuals representing 14 species (1 soricomorph, 1 lagomorph, and 12 rodents) were captured in pitfall traps (Table 3). The three most frequently captured species were the Cactus Deermouse (n = 112, or 49.8% of captures); Western Harvest Mouse (n = 31, or 13.8% of captures); and Southern Grasshopper Mouse (*Onychomys torridus*) (n = 25, or 11.1% of captures). These three species accounted for 74.7% of all PDFA small mammal captures.

Accounts of Species

Common and scientific names follow Bradley et al. (2014) and Mantooth and Riddle (2005) unless otherwise noted.

Table 2. Number of small mammals captured in Sherman traps (along with total trap-nights) by habitat type, at Ash Meadows National Wildlife Refuge, 2008–2009.

	Habitat Type																		
Species	Alkali Meadow	Alkali Seep	Alkali Shrub Scrub	Alkali Sink	Ash	Cottontop Dry Ridge	Creosote Shrubland	Dune (Mesquite)	Dune (Shrub)	Emergent Marsh	Mesquite Bosque	Nonnative/Weed	Riparian Shrubland	Riparian Woodland	Salt Desert Scrub	*Tamarix*	Transitioning Agriculture	Wet Meadow	Grand Total
Ammospermophilus leucurus			11				3												14
Chaetodipus formosus	1		2			24	21												48
Dipodomys deserti	1		3	4				11	28										47
Dipodomys merriami	6	1	84	21			63	63	7	3	13		1	3	3		8		276
Dipodomys microps			9				1								3				13
Mus musculus	37		2	4				1		15		11		5		12		43	130
Neotoma lepida	1		7			10	2	3		7	1			3			3		37
Onychomys torridus								3	4										7
Perognathus longimembris			4					1							1		1		7
Peromyscus crinitus						5													5
Peromyscus eremicus	8		18		7	13	9	16	4	57	5	2	1	102		1	18	6	267
Peromyscus maniculatus				1													1		2
Reithrodontomys megalotis	90		14		1			1		44	4	20		5		26	11	59	275
Spermophilus tereticaudus				1															1
Thomomys bottae	1																		1
Total captured	145	1	154	31	8	52	99	99	43	126	23	33	2	118	7	39	42	108	1,130
Trap-nights	1,988	40	2,006	311	145	360	622	755	265	813	379	170	60	656	94	496	686	1,062	10,910

Table 3. Number of small mammals captured in pitfall drift fence arrays (along with total trap-nights) by habitat type, at Ash Meadows National Wildlife Refuge, 2008–2009.

	Habitat Type																		
Species	Alkali Meadow	Alkali Seep	Alkali Shrub Scrub	Alkali Sink	Ash	Cottontop Dry Ridge	Creosote Shrubland	Dune (Mesquite)	Dune (Shrub)	Emergent Marsh	Mesquite Bosque	Non-Native/Weed	Riparian Shrubland	Riparian Woodland	Salt Desert Scrub	Tamarix	Transitioning Agriculture	Wet Meadow	Grand Total
Ammospermophilus leucurus							1												1
Chaetodipus formosus			2				12												14
Dipodomys merriami			9					3											12
Dipodomys microps			1				1												2
Mus musculus			1				1						1						3
Neotoma lepida								1						7					8
Notiosorex crawfordi														1					1
Onychomys torridus			7					7	11										25
Perognathus longimembris			6				1												7
Peromyscus eremicus			18		19		4	3	6		1		11	27			23		112
Peromyscus maniculatus			1	1			1												3
Reithrodontomys megalotis	1		8	2	1			4	3		3		1	1			7		31
Sylvilagus audubonii								2											2
Thomomys bottae	2						1										1		4
Total captured	3	0	53	3	20	0	22	20	20	0	4	0	13	36	0	0	31	0	225
Trap-nights	480	0	2,640	240	240	0	1,200	720	240	0	240	0	240	240	0	0	480	0	6,960

ORDER LAGOMORPHA – Pikas, Hares, and Rabbits
Family Leporidae
***Sylvilagus audubonii arizonae* (Allen, 1877)**
Desert Cottontail

The Desert Cottontail is broadly distributed across most of the arid southwestern United States and northern Mexico. Like most other rabbits and hares, it tends to be crepuscular (Chapman 1999). The biology and natural history of this species was summarized by Chapman and Willner (1978). In Nevada, the species is known only from creosote and sagebrush habitats in the southern tip of Nevada in Clark, Nye, Esmeralda, White Pine, and Lincoln counties (Hall 1946). Two Desert Cottontail (young-of-the-year) were captured in PDFAs in Dune (Mesquite) habitat in 2008.

Additional records.—"At Pahrump Ranch, Indian Springs, and St. Thomas, cottontails were even more numerous than jack rabbits [sic]" (Burt 1934:423).

Known museum specimens.—Ash Meadows, 4.8 mi NW of Devil's Hole (2, MVZ).

***Lepus californicus deserticola* Mearns, 1896**
Black-tailed Jackrabbit

The Black-tailed Jackrabbit is a conspicuous part of the mammalian fauna of the desert Southwest. It is known to occur in very diverse habitats from near sea level to montane elevations (North and Marsh 1999). The biology and natural history of this species was summarized by Best (1996). It occurs throughout Nevada and is more likely to be seen than other rabbit and hare species (Hall 1946). Although Black-tailed Jackrabbits were commonly observed on the Refuge, none was trapped or collected during field efforts.

Additional records.—"Jack rabbits [sic] were abundant about the farming districts. There were hundreds of them at Pahrump Ranch, Indian Springs, Corn Creek Station, Las Vegas, and St. Thomas" (Burt 1934:423).

Known museum specimens.—None.

ORDER SORICOMORPHA – Insectivores
Family Soricidae
***Notiosorex crawfordi crawfordi* (Coues, 1877)**
Crawford's Desert Shrew

This small-bodied insectivore is considered rare in Nevada (Mantooth and Riddle 2005) and has been reported from only three southern counties in the state (Clark, Nye, and Mineral). A single Crawford's Desert Shrew was captured in a pitfall trap set in Riparian Shrubland habitat along the outflow below King's Pool in 2009. This is the first known record of the species from the Refuge and only the seventh record of its occurrence in Nevada (Manning et al. 2013). The biology and natural history of this shrew was reviewed by Armstrong and Jones (1972) and Armstrong (1999a).

Additional records.—None.

Known museum specimens.—1, TTU.

ORDER CARNIVORA – Carnivores
Family Canidae
***Canis latrans mearnsi* Merriam, 1897**
Coyote

The Coyote is a common, widely distributed canid of the United States. It is often heard more than seen. On the Refuge 8–10 individuals were recorded and they were heard nearly every time we were on the Refuge after dark. Most sightings were in Alkali Shrub-Scrub or Creosote Shrubland. The biology and natural history of this predator were reviewed by Bekoff (1977, 1999).

Additional records.—None.

Known museum specimens.—None.

***Urocyon cinereoargenteus scottii* Mearns, 1891**
Common Gray Fox

The Common Gray Fox is far less common on the Refuge than the Coyote. During the 2-year study, two sightings were recorded for this canid—one near

Crystal Reservoir and another on the north end of the Refuge in an Alkali Scrub area. Haroldson (1982) and Fritzell (1999) reviewed the biology of this small fox.

Additional records.—None.

Known museum specimens.—None.

Family Felidae
***Puma concolor kaibabensis* (Nelson and Goldman, 1931)**
Mountain Lion

The Mountain Lion is often associated with montane habitat in desert regions. Refuge personnel relayed a reported sighting of a Mountain Lion in the southeast portion of the Refuge. Several people also reported seeing a large cat in the area a few years prior to the initiation of this study. Currier (1983) and Beier (1999) reviewed the biology and natural history of this large felid.

Additional records.—None.

Known museum specimens.—None.

***Lynx rufus baileyi* Merriam, 1890**
Bobcat

The bobcat is a fairly common predator in the desert Southwest. Refuge staff report several sightings each year. During the study we documented one individual crossing the road on the southern end of the Refuge. It was seen in an area of low mesquite. Lariviere and Walton (1997) and Layne (1999) summarized the biology of this nocturnal felid.

Additional records.—None.

Known museum specimens.—None.

Family Mustelidae
***Taxidea taxus berlandieri* Baird, 1857**
American Badger

The American Badger is a semi-fossorial carnivore. One of its preferred dietary items is the pocket gopher. Long (1973, 1999) reviewed the natural history and biology of this species. Only one American Badger was observed on the Refuge by one of us during the 2-year study. This animal was seen from a helicopter on the north end of the Refuge west of Longstreet Spring. In addition, an American Badger was reported at the west entrance of the Refuge on Spring Meadows Road in March 2010. Finally, two skulls were found by Refuge staff, one in sandy habitat on the north end of the Refuge, and one in a cattail marsh along Fairbanks Outflow.

Additional records.—None.

Known museum specimens.—None.

ORDER ARTIODACTYLA – Even-toed Ungulates
Family Antilocapridae
***Antilocapra americana americana* (Ord, 1815)**
Pronghorn

Pronghorn occur over much of the western and southwestern United States, including much of the State of Nevada. Although no Pronghorns were observed during the field study, there is at least one observation of the species from the Refuge: "…we have confirmed sightings of pronghorn (1) and mule deer" … on the Refuge (Cristi Baldino, USFWS, Ash Meadows NWR). O'Gara (1978, 1999) reviewed the biology of this unique artiodactyl.

Additional records.—None.

Known museum specimens.—None.

Family Bovidae
***Ovis canadensis nelsoni* Merriam, 1897**
Desert Bighorn Sheep

The Desert Bighorn Sheep is the state mammal of Nevada. Of the three subspecies of desert bighorns known to occur in the state, *O. c. nelsoni* is the smallest and palest (Hall 1995). Shackleton (1985) reviewed the biology of this species. Bighorn Sheep were observed on the Refuge during this study along the higher and lower elevations near Point of Rocks in September and October.

Additional records.—None.

Known museum specimens.—None.

Family Cervidae
Odocoileus hemionus hemionus **(Rafinesque, 1817)**
Desert Mule Deer

The Desert Mule Deer occurs over most of the western United States, including most of Nevada. It is a big game animal over much of its range. Although no Desert Mule Deer were documented during the field study, there is at least one reported observation of the species from the Refuge: "…we have confirmed sightings of pronghorn and mule deer" … on the Refuge (Cristi Baldino, USFWS, Ash Meadows NWR, personal communication). McCullough (1999) and Anderson and Wallmo (1984) reviewed the biology of this taxon.

Additional records.—None.

Known museum specimens.—None.

ORDER RODENTIA – Rodents
Family Cricetidae – New World Mice, Rats, and Voles
Neotoma lepida lepida **Thomas, 1893**
Desert Woodrat

The Desert Woodrat (also known as the Desert Packrat) is found in the Great Basin, southern California, and Baja California. It has a vegetarian diet and usually constructs rather large nests that may be used by many generations of Desert Woodrats (MacMillen 1999). The biology and natural history of this species were summarized by Verts and Carraway (2002). It occurs statewide in Nevada, except for the north-central part of Nevada.

A total of 37 Desert Woodrats were taken during our trap efforts. These rats tended to be rather broadly distributed across the Refuge, and individuals were captured in a variety of habitats: Cottontop Dry Ridge (*n* = 10); Emergent Marsh (*n* = 7); and Alkali Shrub-Scrub (*n* = 7). These three habitats accounted for 24 individuals (64.9% of all captures). Only eight Desert Woodrats were captured in pitfall traps, seven in Riparian Shrubland and one in Dune (Mesquite) habitat.

Additional records.—None.

Known museum specimens.—Ash Meadows (5, NMNH).

Onychomys torridus longicaudus **Merriam, 1889**
Southern Grasshopper Mouse

This is a small, territorial, carnivorous rodent of the Sonoran and Mojave deserts of North America. Insects and scorpions are a main staple of its diet (Riddle 1999). The Southern Grasshopper Mouse has a shorter white-tipped tail than similarly sized rodents found in the same areas. It is most often associated with sandy habitats, and its "sand bathing" behavior keeps its pelage clean and in prime condition. The biology and natural history of this species were summarized by McCarty (1975). In Nevada it is known only from the southernmost regions.

Only seven of these carnivorous rodents were taken in Sherman live-traps. Four grasshopper mice were captured in Dune (Scrub) habitat, and the other three individuals were taken in Dune (Mesquite) habitat. Many Southern Grasshopper Mice (*n* = 25) were taken in pitfall traps. Most individuals (*n* = 11) were taken in Dune (Scrub) habitat, whereas seven each were captured in Alkali Shrub-Scrub and Dune (Mesquite) habitat. All habitats in which grasshopper mice were captured had a fine sand substrate as a major component.

Additional records.—None.

Known museum specimens.—Ash Meadows, 2.5 mi NW of Devil's Hole (1, MVZ); Ash Meadows, 4.8 mi NW of Devil's Hole (2, MVZ); Ash Meadows (2, NMNH).

Peromyscus crinitus stephensi Mearns, 1897
Canyon Deermouse

The Canyon Deermouse usually is found in habitat that has large amounts of exposed rock, vertical or horizontal, with only scant vegetation. Often this is the only mammal species living on isolated mesas or buttes (Armstrong 1999b). The biology and natural history of this species was summarized by Johnson and Armstrong (1987). There are three known subspecies of the Canyon Deermouse in Nevada (Hall 1946).

Only five Canyon Deermice were taken in Sherman live-traps. All of these mice came from higher elevations in rocky areas in Cottontop Dry Ridge habitat. No individuals were taken in a pitfall trap.

Additional records.—None.

Known museum specimens.—Ash Meadows, 4.8 mi NW of Devil's Hole (1, MVZ); Ash Meadows (2, NMNH).

Peromyscus eremicus eremicus (Baird, 1847)
Cactus Deermouse

This denizen of desert environs prefers low rocky slopes with scattered vegetation and is distributed from western Texas to southern California and northern Mexico. Its diet consists of plant material and insects. The Cactus Deermouse may enter daily torpor or seasonal aestivation during the hottest months of the summer (Caire 1999). In Nevada, this species is known only from the extreme southern tip of the state in Nye, Clark, and Lincoln counties (Hall 1946).

The Cactus Deermouse was third only to Merriam's Kangaroo Rat and Western Harvest Mouse in terms of individuals taken ($n = 267$). It was captured in nearly every habitat sampled on the Refuge. The four habitats with highest numbers of captured individuals were Riparian Woodland ($n = 48$), Emergent Marsh ($n = 57$), Transitioning Agriculture ($n = 18$), and Alkali Shrub-Scrub ($n = 18$). The Cactus Deermouse was the most frequently taken rodent in pitfall traps ($n = 112$, or 49.7% of all captures). Four habitat types had especially high numbers of captures: Riparian Woodlands, Transitioning Agriculture, Alkali Shrub-Scrub, and Ash. Veal and Caire (1979) reviewed the biology of this species.

Additional records.—"Pahrump Ranch" (Burt 1934:416).

Known museum specimens.—Ash Meadows, 4.8 mi NW of Devil's Hole (2, MVZ); Ash Meadows (17, NMNH).

Peromyscus maniculatus sonoriensis (LeConte, 1853)
North American Deermouse

This deermouse is one of the most ubiquitous mice in the United States. It occurs from the Pacific Coast to the Atlantic Coast, except for the southeastern states, and from southern Alaska and Canada to Mexico. It is also one of the more geographically and ecologically variable species of the genus (Handley 1999). In southern Nevada, this deermouse often is restricted to riparian habitats (Hall 1946). Two subspecies are known to occur statewide in Nevada (Hall 1946).

No North American Deermice were captured in 2008. The following year five individuals were captured. Two were taken in Sherman live-traps, one from Transitioning Agriculture and one from Alkali Sink habitat. Three individuals were taken in pitfall traps, one each from Alkali Shrub-Scrub, Creosote Shrubland, and Alkali Meadows habitats.

Additional records.—None.

Known museum specimens.—Ash Meadows (10, NMNH).

Reithrodontomys megalotis megalotis (Baird, 1857)
Western Harvest Mouse

The Western Harvest Mouse is rather broadly distributed over the central grasslands and southwestern deserts of North America. It is usually associated with thick, mesic vegetation on firm soils (Webster 1999). The biology and natural history of this species were summarized by Webster and Jones (1982). *Reithro-*

dontomys is somewhat smaller in body size than other sympatric peromyscine rodents (Hall 1946).

Two hundred seventy-five Western Harvest Mice were taken in Sherman live-traps. Most individuals (*n* = 90) were trapped in Alkali Meadows habitat, frequently in areas where the house mouse (*Mus musculus*) was a common inhabitant. Other individuals were taken across the Refuge in areas with short dense vegetation, especially wet areas (e.g., Wet Meadow, *n* = 59; and Emergent Marsh habitat, *n* = 44). Western Harvest Mice also were taken in pitfall traps (*n* = 31). Most of these individuals (*n* = 8) were captured in Alkali Shrub-Scrub habitat, with the remainder coming from nearly all other habitat types, albeit in low numbers. This species was not taken in areas devoid of ground vegetation (e. g., Creosote Shrubland, Salt Desert Scrub, and Cottontop Dry Ridge).

Additional records.—"Pahrump, Indian Springs, Las Vegas, Wheeler Well, Willow and Cold Springs, Mormon Well, and St. Thomas" (Burt 1934:416).

Known museum specimens.—Ash Meadows, 2.5 mi W of Devil's Hole (2, MVZ); Ash Meadows (28, NMNH).

Family Geomyidae

***Thomomys bottae centralis* Hall, 1930**

Botta's Pocket Gopher

Botta's Pocket Gopher is found throughout the southwestern deserts of the United States and northern Mexico. This fossorial rodent is highly variable in body size and pelage color, and there is marked sexual dimorphism in many populations across its known range (Patton 1999). In Nevada, four species of *Thomomys* are known to occur (Hall 1946). Specimens at NMNH were identified as *T. b. perpallidus* by J. Patton (R. Fisher, NMNH, personal communication). From an e-mail communication with Dr. Patton, the following was received: "Whether or not *centralis* itself (type locality in White Pine Co., eastern Nevada) is a synonym of *perpallidus* awaits analyses of Nevada samples of *T. bottae*." Further, he stated, "I curated all of the pocket gophers in the USNM [United States National Museum] collection back in 1993 and at that time believed, and still do, that those samples from Nye and Clark counties that Hall listed as *centralis* were best considered *perpallidus*."

Until the Nevada material has been studied in detail, especially using molecular techniques, the conservative stance is taken for this report; therefore, *centralis* is retained as the correct subspecific name at this time. It is understood that with study, what is referred to as *centralis* in this report may indeed be assigned to *T. b. perpallidus* in the future.

Only one pocket gopher was trapped during the first year of the study. It was taken using a Baker-Williams gopher trap in Emergent Marsh habitat adjacent to a saltcedar (*Tamarix* sp.) removal site next to a cattail (*Typha* sp.) marsh at Crystal Reservoir. During 2009 a single young-of-the-year, presumably dispersing from natal burrow systems, was taken in a Sherman live trap in Alkali Meadows habitat. Four individuals were captured in pitfall traps, one each in four habitat types: Alkali Shrub-Scrub, Alkali Meadow, Transitioning Agriculture, and Emergent Marsh. Evidence of gopher burrowing activity commonly was seen on the Refuge. Most frequently the burrows and diggings were seen in areas with loose, sandy-loamy soils, frequently on slightly elevated surfaces such as berms.

Additional records.—"At Pahrump Ranch, Indian Springs, Las Vegas, and St. Thomas" (Burt 1934).

Known museum specimens.—Ash Meadows, 2.5 mi W of Devil's Hole (18, MVZ); Ash Meadows, 4.8 mi W of Devil's Hole (11, MVZ); Ash Meadows (41, NMNH).

Family Heteromyidae

***Chaetodipus formosus mojavensis* Huey, 1938**

Long-tailed Pocket Mouse

A saxicolous species, the Long-tailed Pocket Mouse occurs in the Great Basin, Mojave, and Colorado deserts of western North America. This medium-size pocket mouse is often associated with creosotebush, shadscale, and various sagebrush species (Geluso 1999). In Nevada, this mouse is most frequently is found in the Lower Sonoran Zone (creosote) and lower part of the Upper Sonoran Zone (sagebrush) (Hall 1946).

A total of 48 Long-tailed Pocket Mice were taken in Sherman live-traps during this study. Most individuals (*n* = 24) were taken in Cottontop Dry Ridge habitat and Creosote Shrubland (*n* = 21). Both habitat types possess rocky soils or desert pavement. Fourteen Long-tailed Pocket Mice were taken in pitfall traps. Ten individuals were taken in Creosote Shrubland habitat; the other four were taken in Alkali Shrub-Scrub habitat.

Additional records.—None.

Known museum specimens.—None.

Dipodomys deserti deserti Stephens, 1887
Desert Kangaroo Rat

The Desert Kangaroo Rat is a large-bodied, four-toed, sand dune-dwelling species. It constructs an extensive burrow system with numerous entrances (Best 1999). The biology and natural history of this species was summarized by Best et al. (1989). This is the largest and palest of the *Dipodomys* species in Nevada.

A total of 47 Desert Kangaroo Rats were captured during this study, with most individuals taken in areas of fine, windblown sand. Twenty-eight individuals were captured in Dune (Shrub) habitat, eleven in Dune (Mesquite), four in Alkali Sink, three in Alkali Shrub-Scrub, and one in Alkali Meadows. None were taken in pitfall traps.

Additional records.—"Pahrump, Indian Springs, Corn Creek, and St. Thomas" (Burt 1934:415).

Known museum specimens.—Ash Meadows (39, NMNH).

Dipodomys merriami merriami Mearns, 1890
Merriam's Kangaroo Rat

This four-toed kangaroo rat occupies a rather broad range of habitat and soil types. When found with congeners, it primarily occurs on rocky soils (Rogers 1999); however, it also occurs on sandy and clayey soils. Merriam's Kangaroo Rat ranges farther out onto alkali flats than other species of *Dipodomys* (Hall 1946).

This was the most frequently trapped rodent during the study, with a total of 276 individuals captured. Three habitats accounted for most (*n* = 210, or 76%) of the captures: Alkali Shrub-Scrub (*n* = 84), Creosote Shrubland (*n* = 63), and Dune (Mesquite) (*n* = 63). Only 12 Merriam's Kangaroo Rats were taken in pitfall traps; nine specimens were captured in Alkali Shrub-Scrub habitat and three were captured in Dune (Mesquite).

Additional records.—None.

Known museum specimens.—Ash Meadows, 2.5 mi NW of Devil's Hole (2, MVZ); Ash Meadows, 4.8 mi NW of Devil's Hole (1, MVZ). Ash Meadows (35, NMNH).

Dipodomys microps occidentalis Hall and Dale, 1939
Chisel-toothed Kangaroo Rat

The Chisel-toothed Kangaroo Rat is named for its flattened chisel-like incisors, which differ from the rounded awl-like incisors of other kangaroo rats. It has five toes and is somewhat unusual in that it feeds primarily on plant leaves rather than on seeds. A key plant in its diet is shadscale. The known distribution of the Chisel-toothed Kangaroo Rat is the arid Great Basin between the Sierra Nevada and Rocky Mountains (Hayssen 1999). The biology and natural history of this species were summarized by Hayssen (1991). This taxon is found in western and southern Nevada (Hall 1946).

This was the least common of the three kangaroo rat species found on the Refuge. Fifteen Chisel-toothed Kangaroo Rats were captured during the 2-year study. Nine were captured in Alkali Shrub-Scrub, one in Creosote Shrubland, and three in Salt Desert Scrub. Only two Chisel-toothed Kangaroo Rats were taken in pitfall traps, both in Alkali Shrub-Scrub habitat.

Additional records.—None.

Known museum specimens.—Ash Meadows (3, NMNH).

***Perognathus longimembris panamintinus* Merriam, 1894**
Little Pocket Mouse

This small heteromyid is fairly common throughout the southwestern United States. It ranges from southern Oregon through most of Nevada, southern California, and northern Baja California (French 1999). In Nevada, this pocket mouse usually is found on "…the fine sandy soil in the center of valleys, but is found more often, and more abundantly, on firmer soils of the slightly sloping margins of the valleys" (Hall 1946:358).

Only seven Little Pocket Mice were captured in our Sherman live-traps. Four were taken in Alkali Shrub-Scrub and one each was taken in Salt desert Scrub, Transitioning Agriculture, and Dune (Mesquite). Seven individuals were taken in the pitfall traps, all in Alkali Shrub-Scrub habitat.

Additional records.—None.

Known museum specimens.—None.

Family Muridae
***Mus musculus* Linnaeus, 1758**
House Mouse

This invasive, non-native rodent usually is considered a commensal of humans. It generally is found in or near man-made structures, although some survive in native habitats. The House Mouse frequently is found in the same habitat (mesic areas with dense vegetation, where it is considered abundant) as harvest mice (Hall 1946). These moist habitats are a central component of the Refuge's conservation efforts for the Ash Meadows Montane Vole. Competition with native mice may contribute to the possible demise of the Montane Vole.

One hundred thirty of these mice were taken in Sherman live traps during the 2-year study. Two habitats were particularly noted to harbor House Mice; Wet Meadow (*n* = 43) and Alkali Meadow (*n* = 37). This species usually was taken in areas with rather dense ground cover on moist soils. Only three House Mice were captured in pitfall traps, one each, in Alkali Shrub-Scrub, Creosote Shrubland, and Riparian Shrubland habitats.

Additional records.—"Pahrump Ranch" (Burt 1934:422).

Known museum specimens.—Ash Meadows, 4.8 mi NW of Devil's Hole (2, MVZ).

Family Sciuridae
***Ammospermophilus leucurus leucurus* (Merriam, 1889)**
White-tailed Antelope Squirrel

The White-tailed Antelope Squirrel is a heat-tolerant diurnal sciurid. Unlike other squirrels, this desert rodent is active throughout the year. In addition to eating plant material, it also consumes insects and small rodents (Hafner 1999). The biology and natural history of this species was summarized by Belk and Smith (1991). This squirrel can be found in areas with sandy soils, as well as on firmer, even rocky, soils (Hall 1946).

Fifteen White-tailed Antelope Squirrels were taken in this 2-year study. Most individuals (*n* = 12) were captured in Alkali Shrub-Scrub habitat (one in a pitfall trap), whereas three were taken in Creosote Shrubland; individuals occasionally were seen along roadways on the Refuge while driving through various habitat types.

Additional records.—None.

Known museum specimens.—Ash Meadows (16, NMNH).

***Xerospermophilus tereticaudus tereticaudus* Baird, 1857**
Round-tailed Ground Squirrel

Round-tailed Ground Squirrels are found primarily in sandy areas of relatively flat desert habitat, especially near mesquite, creosotebush, and saltbush. The biology and natural history of this desert rodent was reviewed by Ernest and Mares (1987). Like the

White-tailed Antelope Ground Squirrel, this species is heat tolerant and may remain active when temperatures exceed 45ºC (113ºF) (Ernest 1999). In Nevada, the Round-tailed Ground Squirrel is known only from southern Clark and Nye counties (Hall 1946).

There are four specimens from the Death Valley Biological Survey of 1891 from Ash Meadows. This species was captured only once during our 2-year study on the Refuge, in Alkali Sink habitat.

Additional records.—None.

Known museum specimens.—Ash Meadows (4, NMNH).

Mammals of Possible Occurrence

ORDER CARNIVORA
Family Canidae
***Vulpes macrotis arsipus* Elliot, 1903**
Kit Fox

This small fox has been united systematically and taxonomically with the Swift Fox, which is known to occur farther to the east and north. Most authorities now consider the Kit Fox to be a separate species. McGrew (1979) and Thacker and Flinders (1999) reviewed the biology and natural history of this taxon. No Kit Foxes were observed on the Refuge, but a single kit fox was seen crossing the road between the Refuge and Pahrump, Nevada.

Family Mephitidae
***Mephitis mephitis estor* Merriam, 1890**
Striped Skunk

We had no encounters with the Striped Skunk while conducting field work at the Refuge. Wade-Smith and Verts (1982) and Bixler (1999) reviewed the biology and natural history of this skunk.

***Spilogale gracilis gracilis* Merriam, 1890**
Western Spotted Skunk

The Western Spotted Skunk frequently is associated with rocky, somewhat vertical habitat. This species was not encountered during the field work on the Refuge. Crooks (1999) and Verts and Carraway (2001) reviewed the biology and natural history of this small skunk.

Family Procyonidae
***Bassariscus astutus nevadensis* Miller, 1913**
Ringtail

This procyonid frequently is associated with rocky outcrops and cliffs, often near permanent water sources. It was not observed during the study at Ash Meadows NWR. Poglayen-Neuwald and Toweill (1988) and Baker (1999) summarized the biology of this species.

ORDER RODENTIA
Family Cricetidae
***Microtus montanus nevadensis* Bailey, 1898**
Montane Vole

The Montane Vole is a common and widely distributed rodent of the intermountain western United States. It is found in a variety of mesic habitats, including grasslands, wet meadows, and streamside vegetation (Jannett 1999). Anderson (1959) revised and summarized the biogeography and taxonomy of North American Montane Voles. Hoffmann and Koeppl (1985) discussed the zoogeography of New World microtines. The biology and natural history of this species was summarized by Sera and Early (2003). In Nevada, the species occurs mostly in montane habitats in the northern half of the state. Montane Voles are active throughout the day during the growing seasons, but peak activity is at dusk and dawn (Jannett 1999; Sera and Early 2003). The vole frequently is associated with habitats dominated by graminoid vegetation and can be found in well-drained, arid, and wet habitats (Getz 1985). Montane Voles are semi-fossorial and their nests can be found both aboveground and belowground; however, brood nests always occur belowground. In addition to the nests they dig, male Montane Voles may also use and occupy gopher burrows. Currently, 15 subspecies of Montane Moles have been described (Anderson 1959; Hall 1981; Sera and Early 2003). Most subspecies of the Montane Vole have not been studied thoroughly due to their limited distribution

(Sera and Early 2003). Hall (1946) and Mantooth and Riddle (2005) both reported six subspecies of the Montane Vole in Nevada, one of which was the Ash Meadows Montane Vole.

Bailey (1898) first described the Ash Meadows Vole as *Microtus nevadensis*. Bailey (1900) later revised the genus (*Microtus*). Hall (1935) suggested that it was a subspecies of the *montanus*-group and applied the trinomial *Microtus montanus nevadensis*. This taxon (known from 30 specimens and minimal field data) was collected at "…a big salt marsh below Watkins Ranch, Ash Meadows, Nye County, Nevada" (Hall 1946:549).

The Nevada Natural Heritage Program lists the Ash Meadows Montane Vole as "SH" state rank, which denotes that the species is known from historical records and could be rediscovered (Mantooth and Riddle 2005). Historically, the Ash Meadows Montane Vole was known to occur on the Refuge. We were not able to locate this vole during our field trapping efforts. In addition to our live-trap study (this report), we sampled select mesic habitats (on the northern part of the Refuge). None was found. The species appears to be extirpated from the Refuge.

Additional records.—None.

Known museum specimens.—Ash Meadows, 4.8 mi NW of Devil's Hole (13, MVZ); Ash Meadows (17, NMNH).

Family Muridae
***Rattus norvegicus norvegicus* (Berkenhout, 1769)**
Norway or Brown Rat

This introduced rodent is found statewide in Nevada. The Norway Rat is a commensal with man and is generally found in and around human habitation. No individuals were taken at the Refuge.

DISCUSSION

The Refuge supports a diverse terrestrial mammalian fauna dominated by a few species. In this study, the Cactus Deermouse, the Western Harvest Mouse, and Merriam's Kangaroo Rat dominate the rodent community in terms of relative abundance. The mammalian community of the Refuge appears to be representative of the region, at least in terms of species diversity. Of the 18 native, non-volant small mammal species (soricimorphs, lagomorphs, and rodents) whose distribution includes the Refuge, 17 (94%) were documented during this study. Only the Ash Meadows Montane Vole was not documented to occur there during our study. Other species not observed on the Refuge were carnivores, and one of these (Kit Fox) was observed just outside the Refuge boundary. The Ringtail, Western Spotted Skunk, and Striped Skunk were not observed during the study. Moreover, the methods employed during this study targeted primarily smaller ground foraging mammals.

The success of future trapping efforts for small mammals using Sherman live-traps could be maximized by seasonal timing. Trapping efforts conducted in early autumn would coincide with peak rodent populations, following spring and summer recruitment. Additional efforts could also be implemented to target the Desert Shrew (e.g., by installing much smaller pitfall traps placed at higher densities). Such efforts could provide better insight to the range and density of the Desert Shrew.

Based upon the results of this study, it appears likely that Ash Meadows Montane Vole has been extirpated from the Refuge. This conclusion is supported by the lack of success by other researchers since the vole last was reported in 1933. Moreover, because most potential habitat in the Ash Meadows marsh complex is located on the Refuge, it is unlikely that populations exist in areas not searched during this or previous studies.

Competition with introduced rodent species also might have played a role in inhibiting Ash Meadows Montane Vole populations. We found that the House Mouse was abundant in areas of potential vole habitat on the Refuge. Some authors have suggested that invasion by introduced species has negative population-level consequences for native rodent species (Simberloff 2009).

We were anxious to document the mammals that eke out a living in this region. The Mojave Desert is in one of the hottest and driest, habitats in North America. What we found helps us define or understand the niche of these desert-adapted species.

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A Resurvey of Bats at Dinosaur National Monument

Michael A. Bogan and Tony R. Mollhagen

Abstract

Between 1982 and 1990, biologists associated with the U.S. Fish and Wildlife Service (FWS) conducted inventories for mammals, including bats, at Dinosaur National Monument (DINO) in Colorado and Utah. These studies by FWS were the first systematic attempts to survey for bats throughout the monument. In 2008, park managers asked for a resurvey of the resident bat fauna. The basic premise was to re-visit localities where bats had been captured between 1982 and 1990 and again use mist nets to assess the general distribution and abundance of bats on the monument and determine if there were any obvious trends in species occurrences, numbers, or distribution. In the original study, we netted a total of 60 nights and captured 468 individuals of 14 species at 26 localities. Our average capture rate was 7.8 individuals of three species per sampling event. In 2008–2009, we netted a total of 51 nights and captured 909 individuals of 15 species at 23 localities. The average capture rate was 17.8 bats of 4.4 species per netting event. Examination of the two data sets, separated by more than two decades, reveals far more similarities than differences. Recent work yielded almost twice as many bats as the former study, yet the inventory of species is essentially unchanged. In both time periods, a large majority of the total number of bats was taken at higher elevations, and male bats of two-thirds of the species dominated the composition at higher elevations. From a faunal perspective, the 15 resident bat species at DINO can be divided into three classes: abundant (> 10% of total captures); common (2–10% of captures); and uncommon (< 2% of captures). Bats that were abundant at DINO included *Myotis evotis, M. volans, M. yumanensis, Lasionycteris noctivagans*, and *Eptesicus fuscus*. Bats that were common included *M. californicus, M. ciliolabrum, M. thysanodes, Lasiurus cinereus, Corynorhinus townsendii*, and *Antrozous pallidus*. Uncommon species at DINO included *M. lucifugus, Parastrellus hesperus, Euderma maculatum*, and *Tadarida brasiliensis*. There is one record for *Nyctinomops macrotis* from the monument, but we did not capture one in either time period. Most species were in the same classes in the earlier study, suggesting the bat fauna is relatively stable over time. We consider most of the resident species to be stable in numbers given the results of the two studies. For two species, *M. ciliolabrum* and *M. evotis*, the capture numbers indicate they might be increasing slightly. For three others, *M. lucifugus, L. cinereus,* and *E. fuscus,* the numbers suggest that there might be some evidence of a downward trend.

Key words: bats, Colorado, Dinosaur National Monument, distribution and abundance, population, resurvey, trends, Utah

Introduction

Originally established in 1915 to protect paleontological resources on 32 hectares, Dinosaur National Monument (DINO) was expanded in 1938 to include the Green and Yampa river corridors. The present

85,446-hectare monument is rich in geological and biological resources, and its singular landscapes of river canyons and upland benches are unique among lands managed by the National Park Service (NPS). The monument includes among its biological resources a possible 16 species of bats. Bats are subjects of conservation concern due to habitat destruction, use of insecticides, low reproduction rates, and vulnerability due to colonial roosting habits (O'Shea and Bogan 2004). Western bats in particular also may be affected by land management practices such as grazing, logging, lowering of water tables, and destruction of reservoirs. In addition, ongoing changes in the area surrounding DINO may conceivably impact bats or resources upon which they depend. Such changes include: perceived decline of cottonwood gallery forests; grazing, oil and gas development; increases in recreational use; invasion of exotic species; and attempts to remove one such exotic (tamarisk, *Tamarix*). Finally, ongoing global changes, such as climate warming, may affect bats (Humphries et al. 2002; LaVal 2004; Rebelo et al. 2010).

Between 1982 and 1990, biologists associated with the Fish and Wildlife Service (FWS) conducted inventories for mammals, including bats, in the monument. Initially, we surveyed the river corridors in DINO in support of a reserved water rights case that later proceeded through the court system. Subsequent survey efforts were expanded to upland areas in the monument, many of which proved rich in numbers of bats. Although some of the oldest records of bats in Colorado are from the area around DINO (e.g., Cary 1911, summarized by Armstrong 1972), these studies by FWS were the first systematic attempts to survey for bats throughout the monument (Bogan et al. 1983, 1988). The work resulted in the capture of more than 450 individuals from 26 localities on or very near the park; many captured individuals were saved as voucher specimens and deposited in the Biological Survey Collections, Fort Collins, CO [now located in the Museum of Southwestern Biology (MSB), University of New Mexico]. Efforts by other investigators also resulted in a variety of new information for the monument and Moffat County, including work by Freeman (1984), who surveyed throughout the state of Colorado but worked extensively in Moffat County, Navo et al. (1992), who conducted the first acoustic survey at the park, and Storz (1995), who obtained interesting new data on *Euderma maculatum* (Spotted Bat). Although most information comes from the Colorado (Moffat County) portion of the monument, there also is information from the Utah (Uintah County) side. In 2008–2009, we conducted a "resurvey" effort of bats at DINO. The basic premise was to re-visit localities where bats had been captured between 1982 and 1990, assess the general distribution and abundance of bats, and determine if there were changes in species occurrences, numbers, or distributions on the monument.

The state of Colorado is known to have 19 species of bats (Chiroptera) (Armstrong et al. 1994; Fitzgerald et al. 1994; Hayes et al. 2009). Of these 19, two are species that have recently invaded from the east, *Lasiurus borealis* (Eastern Red Bat) and *Perimyotis subflavus* (Tricolored Bat); these two species are not known to occur on the western slope of Colorado. Another species, *Idionycteris phyllotis* (Allen's Big-eared Bat) was recently confirmed from acoustic data in southwestern Colorado (Hayes et al. 2009). For much of western Colorado there are records for 16 species. Utah is known to have 18 species, 16 of which occur in northeastern Utah (Uintah Co.). Only *L. blossevillii* (Western Red Bat) and *I. phyllotis* are absent from Uintah County. Overall, there are verified records of 16 species from DINO, including an enigmatic record of *Nyctinomops macrotis* (Big Free-tailed Bat) from the parking lot at the Dinosaur Quarry on the Utah side of the monument (Table 1).

We suspect that it is the complex geological, topographical, and biological features of the park that, in part, produce the diverse bat fauna of DINO (e.g., Humphrey 1975). Additionally, the characteristics of each species, coupled with their biogeographic history and location on the Colorado Plateau, contribute to this rich fauna. Indeed, the bat faunas of DINO and Canyonlands National Park (CANY), about 190 km SW DINO, for example, are remarkably similar (Bogan et al. 2006). Each park has 16 species but whereas there are records for *Myotis lucifugus* (Little Brown Myotis) but not for *I. phyllotis* at DINO, the converse is true for CANY. Another well-known area, the Henry Mountains in south-central Utah, is known to have 16 species as well (Mollhagen and Bogan 1997).

At the time of Durrant's (1963) surveys for mammals in DINO, shooting was the common method of obtaining specimens of bats in the field. As no shooting

Table 1. Bats (Chiroptera) known to occur in the region of Dinosaur National Monument (Durrant 1952; Hall 1981; Fitzgerald et al. 1994; Mollhagen and Bogan 1997; Bogan et al. 2006; O'Shea et al. 2011). Scientific and common names follow Baker et al. (2003) except for *Parastrellus*, which follows Hoofer et al. (2006). The acronyms for the species names are those used in tables elsewhere in this report.

Scientific Name	Acronym	Common Name
Myotis californicus	Myca	California Myotis
M. ciliolabrum	Myci	Western Small-footed Myotis
M. evotis	Myev	Long-eared Myotis
M. lucifugus	Mylu	Little Brown Myotis
M. thysanodes	Myth	Fringed Myotis
M. volans	Myvo	Long-legged Myotis
M. yumanensis	Myyu	Yuma Myotis
Lasiurus cinereus	Laci	Hoary Bat
Lasionycteris noctivagans	Lano	Silver-haired Bat
Parastrellus hesperus	Pahe	Canyon Bat
Eptesicus fuscus	Epfu	Big Brown Bat
Euderma maculatum	Euma	Spotted Bat
Corynorhinus townsendii	Coto	Townsend's Big-eared Bat
Antrozous pallidus	Anpa	Pallid Bat
Tadarida brasiliensis	Tabr	Brazilian Free-tailed Bat
Nyctinomops macrotis	Nyma	Big Free-tailed Bat

was allowed in the monument, Durrant and his crew obtained no bats. However, Durrant listed 14 species of bats that he presumed occurred on the monument, based on his knowledge of mammals of the Colorado Plateau (e.g., Durrant 1952). Indeed, all 14 of these species are known today, along with *M. californicus* (California Myotis) and the Big Free-tailed Bat. Armstrong (1972), in his study of Colorado mammals, found specimens in collections for just eight species of bats in Moffat County: *M. yumanensis* (Yuma Myotis), *M. evotis* (Long-eared Myotis); *M. volans* (Long-legged Myotis); *M. ciliolabrum* (Small-footed Myotis); *Eptesicus fuscus* (Big Brown Bat); *L. cinereus* (Hoary Bat); *Corynorhinus townsendii* (Townsend's Big-eared Bat); and *Antrozous pallidus* (Pallid Bat). Armstrong et al. (1994) had records of 14 species from Moffat County, excluding the molossids *Tadarida brasiliensis* (Brazilian Free-tailed Bat) and *N. macrotis*. Distribution maps in Fitzgerald et al. (1994) likewise indicated the presence of 14 species in Moffat County, again excluding only the molossids. There are records for both molossids from DINO, although only from the Utah side of the monument.

Four of the 16 species of bats occurring within DINO are state species of concern for Colorado and/or Utah. These are *C. townsendii* in both states, and *M. thysanodes* (Fringed Myotis), *E. maculatum*, and *N. macrotis* in Utah. In Colorado, all bats are protected as nongame animals. Management Policies (2006:45) state that the NPS will inventory native species that are of special management concern (such as rare, declining, sensitive, or unique species and their habitats) and will manage them to maintain their natural distribution and abundance.

The primary objective of this resurvey was to attempt to document the occurrence of at least 90% of the bats documented in the previous studies at DINO by means of a two-year field effort using mist nets, as in the original field efforts. New, pertinent records and specimens were examined as necessary. The work involved re-visiting sites netted in 1982–1990, setting nets, collecting data on bats, and spending about 30 days per year in the field over two years.

METHODS

Most methods used in the study were consistent with original methods and with methods currently approved by bat biologists for such work (e.g., Kunz and Kurta 1988; Kunz et al. 2009) and are detailed in a written capture and handling protocol approved annually by the Institutional Animal Care and Use Committee (IACUC) at the University of New Mexico. All bats captured were released unharmed as rapidly as possible. No voucher specimens were taken nor were there any bat mortalities during our work in 2008–2009. We obtained a research permit from the monument (DINO-2008-SCI-0013) to allow the survey. Although annual reports were provided to DINO during our work from 1982 to 1990, no overall synthesis of the data was ever completed. To provide a database for comparison with the recent work, we entered the earlier data into a spreadsheet. We included data from specimens in the MSB collected by us during this time period as well as capture numbers from field notes that we deemed reliable. As a part of this phase, we also re-examined the museum specimens to verify identifications.

Mist-net surveys.—Mist nets (Avinet Inc., Dryden, NY) were deployed across and around bodies of water (e.g., Haystack Rock Reservoir) and in perceived flyways (e.g., Hog Canyon, Split Mountain) usually, but not always, at sites and in patterns similar to the original surveys. Lengths of mist nets ranged from 3 to 20 m and numbers of nets deployed on any single evening varied from one to five, depending on the area and shape of the body of water. Mist nets were set up shortly before sunset and tended for several hours until activity declined. Nets were never left untended. Effort was recorded as total horizontal meters of standard nets deployed and net nights (total nets x nights). We attempted to approximate the number of nights in the original sampling; we tallied 60 separate netting events in 1982–1990 and 51 in 2008–2009.

We removed bats from nets immediately following capture and recorded time of capture, species, sex, reproductive condition, and any miscellaneous comments on standardized field data sheets and then released the bats. We later summarized the data from field data sheets in Excel spreadsheets for tabulation of data, calculation of the number of species and individuals captured, relative abundance of species (percent of all bats captured), and prevalence value (the percent occurrence among all possible dates and locations sampled). For the purpose of comparison, the same treatment was given to data from the earlier survey. Copies of field data sheets were provided to the monument.

Location data.—Each of the 23 sites where we sampled in 2008–2009 was given a waypoint name and a more descriptive name. Geographic coordinates, elevation, and estimated position error were acquired for each locality with Garmin GPS units set to record coordinates in decimal degrees using NAD27 as a datum. The NAD1927 datum was used because that is the datum for USGS quad maps we employed for orientation. Elevations obtained by GPS units were reconciled against the USGS quad maps and when there was a discrepancy between sources, values were interpolated.

RESULTS AND DISCUSSION

During the two-summer study, we set out 2,480 meters of bat nets and accrued a total 195 net nights (Table 2). In 2008 we made three trips to DINO, encompassing 83 total person-days of travel, to recon-

Table 2. Level of effort at all sites in 2008–2009 showing number and size of nets at each netting event, total horizontal meters of net deployed at each event, and net nights (nets x nights).

Location	Date	3m	6m	10m	14m	20m	Total Meters	Net Nights
Chew Reservoir	8-Aug-08					3	60	3
Snow Reservoir	9-Jul-09					5	100	5
Buffham Reservoir	8-Jul-08				1	3	74	4
	9-Jul-08			1	1	2	64	4
Massey Pond	1-Jul-08		1		1	1	40	3
Massey Reservoir	30-Jun-08			2		2	60	4
	18-Jul-09				1	3	74	4
Bear Draw Reservoir	5-Aug-08					4	80	4
	17-Jul-09		1	1	1	1	50	4
Dry Woman Reservoir	6-Jul-08				2	1	48	3
	4-Aug-08					4	80	4
	17-Jul-09			2	1	2	74	5
Haystack Rock Reservoir	4-Jul-08			1	1	2	64	4
	5-Jul-08				1	3	74	4
	3-Aug-08					4	80	4
	4-Jun-09					5	100	5
	16-Jul-09				1	4	94	5
Ely Creek	14-Jul-09		2		1		26	3
Vermillion Creek	7-Jul-08		3				18	3
Hog Canyon	1-Jun-08				2	1	48	3
Pool Creek Ranch	12-Aug-08		1			3	66	4
Morris Ranch	31-May-08		1	1		2	56	4
	2-Jul-08				3	2	82	5
	1-Aug-08					4	80	4
	10-Aug-08					4	80	4
	3-Jun-09					5	100	5
	17-Jun-09				2	2	68	4
Big Joe Campground	9-Jun-09	2	2	1			26	5
	10-Jun-09	1	3	1			30	5
Pool Creek Petroglyphs	3-Jun-08	3	1				12	4

Table 2. (cont.)

Location	Date	3m	6m	10m	14m	20m	Total Meters	Net Nights
	10-Jul-08	3					6	3
	11-Aug-08	2			1	1	38	4
	15-Jun-09	2	1	1	1		34	5
	8-Jul-09	2	1				10	3
Pot Creek	12-Jul-09			1	1	2	64	4
Harding Hole	11-Jun-09	2	2	1			26	5
	12-Jun-09	4		1			18	5
Pool Creek at Echo Park	2-Jun-08		4	1			34	5
	11-Jul-08	1	2				14	3
	6-Aug-08		1				6	1
	16-Jun-09	1	2	1			24	4
Cub Creek	3-Jul-08		3				18	3
	2-Aug-08		3				18	3
	7-Jun-09		4				24	4
	10-Jul-09		3				18	3
Laddie Park	13-Jun-09			1	2	2	78	5
Rippling Brook	13-Jul-09	1	2		1		28	4
Jones Hole Campground	14-Jul-09		2				12	2
Split Mountain	9-Aug-08				1		14	1
	6-Jun-09				2	1	48	3
	10-Jul-09			2		1	40	3
						Total	2,480	195

noiter netting sites and to net bats. We were in DINO during 29 May to 5 June, 30 June to 12 July, and 1–13 August for a total of 68 person-days. During this time we netted a total of 27 nights at 15 different localities (Table 2) for a total of 95 net-nights. Inclement weather precluded netting on several occasions. Four of the 15 localities were new ones that were not netted in the earlier work. We netted the following localities in 2008: Chew Reservoir (1 time); Buffham Reservoir (2 times); Massey Pond (1, new); Massey Reservoir (1); Bear Draw Reservoir (1, new); Dry Woman Reservoir (2); Haystack Rock Reservoir (3); Vermillion Creek (1); Hog Canyon (1, new); Morris Ranch (4); Pool Creek Ranch (1); Pool Creek Petroglyphs (3); Pool Creek at Echo Park (3); Cub Creek (2); and Split Mountain (1, new).

In 2008, we captured 517 bats of 15 species (Table 3), more individual bats than we captured in the original survey. Earlier, we averaged 7.8 bats of 3.0 species per night, whereas in 2008 we averaged 19.1 bats of 4.8 species per night. Included in the 2008 averages are two nights when we set nets but captured no bats (Hog Canyon and Split Mountain). The best

Table 3. Localities, dates, and bat species captured in Dinosaur National Monument in the summer of 2008. Data are arranged by highest elevation and earliest netting date. The columns on the right side indicate the total number of bats and total bat species captured by locality and date. Summaries at the bottom include the total individuals of each species (Sum), the percentage that species comprises of the 517 total bats captured (% Total Bats), and the percentage of times at least one individual of that species was captured among the 27 separate combinations of sampling locations and dates (% Prevalence). The identities of the acronyms for the 15 bat species are given in Table 1. Descriptions and coordinates of the capture localities are in locality accounts available from the authors.

Elev. (m)	Location	Date	Myca	Myci	Myev	Mylu	Myth	Myvo	Myyu	Laci	Lano	Pahe	Epfu	Euma	Coto	Anpa	Tabr	Total Bats	Total Species
2,263	Chew Reservoir	8-Aug-08	-	-	3	-	1	2	1	-	-	-	-	-	2	-	-	9	5
2,182	Buffham Reservoir	8-Jul-08	1	2	9	-	2	6	1	-	5	-	2	-	2	3	-	33	10
		9-Jul-08	-	4	-	-	1	2	1	-	1	-	1	-	-	1	-	11	7
2,095	Massey Pond	1-Jul-08	-	2	1	1	-	-	2	2	3	-	-	-	-	-	-	11	6
2,078	Massey Reservoir	30-Jun-08	-	-	-	6	-	-	1	2	5	-	-	-	-	-	-	14	4
1,979	Bear Draw Reservoir	5-Aug-08	-	-	8	-	-	2	1	3	-	-	-	-	-	-	-	14	4
1,975	Dry Woman Reservoir	6-Jul-08	-	4	2	-	-	4	1	-	1	-	2	-	-	-	-	14	6
		4-Aug-08	-	3	19	2	5	5	4	2	-	-	6	-	2	3	-	51	10
1,974	Haystock Rock Reservoir	4-Jul-08	-	5	8	-	-	5	9	-	40	-	22	3	-	4	-	96	8
		5-Jul-08	-	3	4	-	-	2	3	2	4	1	14	1	-	2	-	36	10
		3-Aug-08	-	3	11	-	-	6	-	-	3	-	16	1	10	6	-	56	8
1,635	Vermillion Creek	7-Jul-08	-	3	1	-	-	-	-	1	-	-	-	-	-	-	-	5	3
1,634	Hog Canyon	1-Jun-08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
1,634	Pool Creek Ranch	12-Aug-08	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	1
1,631	Morris Ranch	31-May-08	2	-	-	-	-	-	1	-	-	-	3	-	1	1	-	8	5
		2-Jul-08	-	-	3	-	1	-	3	1	-	-	-	-	-	2	-	10	5
		1-Aug-08	1	-	2	-	-	5	-	1	-	-	8	-	2	28	-	47	7
		10-Aug-08	-	-	1	-	-	2	-	-	-	-	6	-	-	13	-	22	4
1,593	Pool Creek Petroglyphs	3-Jun-08	-	-	-	-	1	1	6	-	4	-	-	-	-	-	-	12	4
		10-Jul-08	-	2	-	-	-	1	-	-	-	-	-	-	-	-	-	3	2
		11-Aug-08	-	-	-	-	1	-	-	1	-	1	-	-	-	1	-	4	4
1,571	Pool Creek at Echo Park	2-Jun-08	5	-	1	-	-	-	32	-	1	-	-	-	-	-	-	39	4
		11-Jul-08	-	2	-	-	2	3	1	-	1	-	-	-	-	-	-	9	5
		11-Aug-08	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	1

Table 3. (cont.)

Elev. (m)	Location	Date	Myca	Myci	Myev	Mylu	Myth	Myvo	Myyu	Laci	Lano	Pahe	Epfu	Euma	Coto	Anpa	Tabr	Total Bats	Total Species
1,565	Cub Creek	3-Jul-08	-	-	1	-	-	-	-	-	-	2	2	-	-	-	1	6	4
		2-Aug-08	-	-	-	-	-	-	-	-	-	-	2	-	-	3	-	5	2
1,459	Split Mountain	9-Aug-08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
		Sum	9	33	74	9	15	46	68	15	68	4	84	5	19	67	1	517	15
		% Total Bats	1.7	6.4	14.3	1.7	2.9	8.9	13.2	2.9	13.2	0.8	16.2	1.0	3.7	13.0	0.2		
		% Prevalence	14.8	40.7	55.6	11.1	33.3	51.9	59.3	33.3	40.7	11.1	44.4	11.1	22.2	44.4	3.7		
																	Avg.	19.1	4.8

one-night captures came from Haystack Rock Reservoir (96 and 56), Dry Woman Reservoir (51), Morris Ranch (47), Pool Creek at Echo Park (39), Haystack Rock Reservoir (36), and Buffham Reservoir (33). Our earlier efforts convinced us that Haystack Rock Reservoir was an important resource for bats and based on our netting there in July 2008 this continued to be true. Even in August 2008, when the pond was mostly mud and the surrounding area showing the effects of large numbers of cattle, nets set around the periphery still captured bats attracted by an insect hatch from the mud.

We captured all species of bats known from DINO except for *N. macrotis*, known only by a salvaged specimen from the Quarry area but presumed to be a member of DINO's bat fauna. Among the other three species of concern, numbers from the original surveys versus those from 2008 are: *M. thysanodes* 5, 15; *E. maculatum* 5, 5; and *C. townsendii* 14, 19. Great caution should be used in extrapolating from these numbers, but they seem to demonstrate that these species of concern are still a part of the bat fauna of DINO and in roughly the same or greater numbers as in the past based on our netting data from 2008 (Table 3).

The most abundant species we captured in 2008 were: *E. fuscus*, 84; *M. evotis*, 74; *M. yumanensis*, 68; *L. noctivagans*, 68; *A. pallidus*, 67; and *M. volans*, 46. Total captures of the other species ranged from one (*T. brasiliensis*) to 33 (*M. ciliolabrum*). Also of note was the capture of four Canyon Bats (*Parastrellus hesperus*) in 2008. This species is on the edge of its range at DINO and previously was known by only two individuals from the monument.

We made two trips to DINO in 2009, with an emphasis on netting at some of the sites in the river corridors that were netted in 1982 (Table 4). Our total travel was 70 person-days and we worked on the monument 3–18 June and 8–19 July for a total of 56 person-days. During our time on the monument, we netted 24 nights at 17 different sites for a total of 100 net-nights. Specifically, we netted at Snow Reservoir (1 night, new), Massey Reservoir (1), Bear Draw Reservoir (1), Dry Woman Reservoir (1), Haystack Rock Reservoir (2), Split Mountain (2), Morris Ranch (2), Cub Creek (2), Pool Creek at Echo Park (1), Pool Creek Petroglyphs (2), Big Joe Campground (2, Yampa River), Harding

Table 4. Localities, dates, and bat species captured in Dinosaur National Monument in the summer of 2009. Data are arranged by highest elevation and earliest netting date. The columns on the right side indicate the total number of bats and total bat species captured by locality and date. Summaries at the bottom include the total individuals of each species (Sum), the percentage that species comprises of the 392 total bats captured (% Total Bats), and the percentage of times at least one individual of that species was captured among the 24 separate combinations of sampling locations and dates (% Prevalence). The identities of the acronyms for the 15 bat species are given in Table 1. Descriptions and coordinates of the capture localities are in locality accounts available from the authors.

Elev. (m)	Location	Date	Myca	Myci	Myev	Mylu	Myth	Myvo	Myyu	Laci	Lano	Pahe	Epfu	Euma	Coto	Anpa	Tabr	Total Bats	Total Species
2,244	Snow Reservoir	9-Jul-09	2	3	2	-	-	9	1	-	3	-	-	-	7	-	-	27	7
2,078	Massey Reservoir	18-Jul-09	-	2	-	1	1	-	2	2	1	-	1	-	-	-	-	10	7
1,979	Bear Draw Reservoir	17-Jul-09	-	8	7	-	-	4	-	7	32	-	4	3	-	-	-	65	7
1,975	Dry Woman Reservoir	17-Jul-09	1	7	18	-	1	5	1	5	17	1	9	2	1	2	1	71	14
1,974	Haystack Rock Reservoir	4-Jun-09	2	8	1	-	-	1	5	-	16	-	5	-	-	-	-	38	7
		16-Jul-09	-	2	8	-	-	11	1	2	46	-	25	1	1	4	-	101	10
1,639	Ely Creek	14-Jul-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
1,631	Morris Ranch	3-Jun-09	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	2	2
		17-Jun-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
1,600	Big Joe Campground	9-Jun-09	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	2	1
		10-Jun-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
1,593	Pool Creek Petroglyphs	15-Jun-09	1	1	-	-	1	1	2	1	3	-	4	-	-	-	-	14	8
		8-Jul-09	1	-	-	-	-	4	1	-	-	-	3	-	-	-	-	9	4
1,586	Pot Creek	12-Jul-09	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1
1,576	Harding Hole	11-Jun-09	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	1
		12-Jun-09	1	-	3	-	-	2	-	-	-	-	-	-	-	-	-	6	3
1,571	Pool Creek at Echo Park	16-Jun-09	2	-	2	-	-	-	3	-	1	-	-	-	-	-	-	8	4
1,565	Cub Creek	7-Jun-09	-	-	-	-	-	-	2	-	-	-	2	-	-	-	-	4	2
		10-Jul-09	1	-	-	-	3	1	1	-	-	2	9	-	-	-	-	17	6

Table 4. (cont.)

Elev. (m)	Location	Date	Myca	Myci	Myev	Mylu	Myth	Myvo	Myyu	Laci	Lano	Pahe	Epfu	Euma	Coto	Anpa	Tabr	Total Bats	Total Species
1,562	Laddie Park	13-Jun-09	1	-	1	-	2	-	-	-	-	-	-	-	-	3	-	7	4
1,558	Rippling Brook	13-Jul-09	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	2	2
1,533	Jones Hole Campground	14-Jul-09	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	2	2
1,459	Split Mountain	6-Jun-09	-	-	-	-	-	-	2	-	-	-	1	-	1	-	-	4	3
		10-Jul-09	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	1
		Sum	12	31	47	1	9	38	23	17	119	3	64	6	10	11	1	392	15
		% Total Bats	3.1	7.9	12.0	0.3	2.3	9.7	5.9	4.3	30.4	0.8	16.3	1.5	2.6	2.8	0.3		
		% Prevalence	37.5	29.2	50.0	4.2	25.0	37.5	54.2	20.8	33.3	8.3	45.8	12.5	16.7	20.8	4.2		
																	Avg.	16.3	4.0

Hole (2, Yampa River), Laddie Park (1, Yampa River), Pot Creek (1, Green River), Rippling Brook (1, Green River), Jones Hole Campground (1, Green River), and Ely Creek (1, at Jones Hole, Green River).

In 2009, we netted a total of 392 individuals of 15 species (Table 4). On average, we captured 16.3 individuals of four species each night we netted, down slightly from the 2008 averages (19.1; 4.8). Included in these averages are three nights when we captured no bats. The most productive localities were Haystack Rock Reservoir (101 individuals), Dry Woman Reservoir (71), Bear Draw Reservoir (65), Haystack Rock Reservoir (38), and Snow Reservoir (27), all upland sites south of the Yampa River Corridor. Among the river sites, Laddie Park (7) and Harding Hole (6) were the most productive. In general, our captures at the river sites were disappointingly low, perhaps because of some combination of low temperatures in June, netting sites cluttered by vegetation, and abundant water. Among the species of concern, we captured seven *M. thysanodes,* six *E. maculatum,* and 10 *C. townsendii,* numbers similar to captures in 2008. Again, these species were captured at roughly the same proportion as in years past.

The most frequently captured species in 2009 included 119 *L. noctivagans,* 64 *E. fuscus*, 47 *M. evotis*, 38 *M. volans*, and 31 *M. ciliolabrum*. Total captures of other species ranged from one (*T. brasiliensis*) to 23 (*M. yumanensis*; Table 4). The most notable difference between captures in the two years was the near-doubling of numbers of *L. noctivagans*, the large reduction in numbers of *A. pallidus,* fewer *M. evotis* and *M. yumanensis*, and the slight reduction in numbers of *E. fuscus* and *M. volans*. Although there are multiple biases in using mist nets, we are more inclined to suspect that many, or all, of the between-year differences are the result of more mundane factors including somewhat lower temperatures in June 2009 as well as random chance in our choice of when to net a given site. For example, on 2 June 2008 we captured a large number of female *M. yumanensis*, likely from a maternity colony, at Pool Creek at Echo Park. Similarly, we captured 28 *A. pallidus* at the Morris Ranch one night (Table 3). Although we netted both sites in 2009, it was at different times and we did not encounter such numbers. Adult male *L. noctivagans* are common to abundant in midsummer at DINO and at times may account for up to 50% of all bats captured on the Yampa Bench (Tables 3, 4). The large number caught in 2009 reflects this abundance.

We and our associates netted on or very near the park in six different years: June and July 1982; August 1985; July 1987; August 1988; June 1989; and July 1990. In 1982, all localities were in either the Yampa or Green river canyons, areas where we suspected that bat netting was not very productive due to the abundance of available water. Most netting from 1985 to 1990 was conducted primarily at upland sites, including several productive sites on the Yampa Bench and in or near northern areas of the monument. The exact times of our visits were generally determined by a variety of factors (e.g., work scheduled elsewhere) rather than by phenomena such as moon phase or expected temperatures.

Between 1982 and 1990, we captured 468 individuals of 14 species (Table 5); no molossids were taken. Our average capture rate was 7.8 individuals of 3.2 species per sampling event. On eight of 60 (13%) separate combinations of locations and dates, we captured no bats. We captured relatively high numbers of individuals at Massey Reservoir (21.4 average), Big Joe Campground (19.5), Dry Woman Reservoir (18), Haystack Rock Reservoir (15.4), Canyon Overlook (11.3), Pool Creek Petroglyphs (11), and Cub Creek (6.8). Most of the productive sites ranged in elevation from 1,974 m to 2,346 m, although Big Joe, Pool Creek Petroglyphs, and Cub Creek ranged only from 1,566 m to 1,600 m.

In terms of average number of species, the most productive netting sites were Massey Reservoir (7 species), Haystack Rock Reservoir (6.7), Canyon Overlook (4.7), Dry Woman Reservoir (4.5), Big Joe Campground (4.5), Pool Creek Petroglyphs (4), and Cub Creek (2.8, Table 5). At most other sites we usually captured 1–3 species per night. Typically, the best of these sites were above 1,974 m, had moderately large, still waters that allowed many species to use them, and pools were often isolated from other water resources. The small pools upstream from Big Joe Campground on the Yampa River were an exception, perhaps due to an abundant insect resource or nearby favorable roosting sites.

Among the species of concern, we captured seven *M. thysanodes* (1.5% of total bats), five *E. maculatum* (1.1%), and 14 *C. townsendii* (3%) between 1982 and 1990 (Table 5). By comparison, the most abundant species were *E. fuscus* (112, 24%), *L. noctivagans* (69, 15%), *M. volans* (55, 12%), *M. yumanensis* (52, 11%), and *M. evotis* (41, 9%), and *L. cinereus* (41, 9%). Most of these more abundant species are known to be common at higher elevations, although *M. yumanensis* also are common at lower elevations (e.g., Pool Creek at Echo Park). It is worth noting that some species were uncommon or missing among our captures. For example, between 1982 and 1990 we took only two *P. hesperus* (0.4%) and no molossids (Table 5) although we obtained a salvaged *T. brasiliensis* taken in 1985 from the Green River Housing Area on the Utah side of the monument. The *N. macrotis* was salvaged from the Dinosaur Quarry (Utah, Uintah Co., R23E, T4S, Sec. 26) by W. Dye on 9 December 1996 and is now in the MSB.

Among the 26 sites where we worked from 1982 to 1990 (Table 5), we were able to net at 17 of these sites in 2008–2009 (Table 6). The nine sites we did not net included two where bats were shot (Massey Camp and Haystack Rock on Yampa River); among the seven nettable sites were three that were dry (Buffham Place, Old Bassett Cabin, Massey Troughs), two sites on private property (Five Springs, Canyon Overlook), one on the river could not be scheduled (Alcove Brook), and one was deemed too large and deep to net (Cottonwood Creek near Canyon Overlook). Of the seven nettable sites, six were upper elevation sites (above 2,134 m) but accounted for less than 10% of all captures from 1982 to 1990 ($n = 45$). Only one of these sites, Canyon Overlook, was very productive; we netted a total of 34 bats of nine species there in July 1990.

Among the historic sites, the 17 we did net in 2008–2009 were Chew Reservoir, Buffham Reservoir, Massey Reservoir, Bear Draw Reservoir, Dry Woman Reservoir, Haystack Rock Reservoir, Vermillion Creek, Pool Creek Ranch, Ely Creek, Morris Ranch, Big Joe Campground, Pool Creek Petroglyphs, Pot Creek, Harding Hole, Pool Creek at Echo Park, Cub Creek, and Rippling Brook. We added six new sites to compensate for those no longer available or usable. These included Snow Reservoir, Massey Pond (dry in 2009), Hog Canyon, Laddie Park, Jones Hole Campground,

Table 5. Localities, dates, and bat species captured in Dinosaur National Monument, 1982–1990. Data are arranged by highest elevation and earliest netting date. The columns on the right side indicate the total number of bats and total bat species captured by locality and date. Summaries at the bottom include the total individuals of each species (Sum), the percentage that species comprises of the 468 total bats captured (% Total Bats), and the percentage of times at least one individual of that species was captured among the 60 separate combinations of sampling locations and dates (% Prevalence). The identities of the acronyms for the 15 bat species are given in Table 1. Descriptions and coordinates of the capture localities are in locality accounts available from the authors.

Eleve. (m)	Location	Date	Myca	Myci	Myev	Mylu	Myth	Myvo	Myyu	Laci	Lano	Pahe	Epfu	Euma	Coto	Anpa	Tabr	Total Bats	Total Species
2,355	Five Springs	7-Aug-88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
		8-Aug-88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
2,346	Canyon Overlook	17-Jul-90	1	3	4	1	-	2	4	3	-	-	6	-	1	-	-	25	9
		18-Jul-90	-	-	-	-	-	1	2	1	-	-	1	-	-	-	-	5	4
		19-Jul-90	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	4	1
2,317	Cottonwood Creek	19-Jul-90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
		20-Jul-90	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	1
2,263	Chew Reservoir	20-Jul-90	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1
2,235	Buffham Place	4-Aug-88	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	8	1
		5-Aug-88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
2,194	Old Bassett Cabin	2-Aug-88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
		3-Aug-88	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	1
2,182	Buffham Reservoir	6-Aug-88	-	1	-	-	-	1	4	-	2	-	-	-	-	1	-	9	5
2,164	Massey Camp	15-Jul-90	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	2	2
2,134	Massey Troughs	11-Jul-90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
		12-Jul-90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
2,078	Massey Reservoir	11-Jul-90	-	1	-	8	-	1	2	3	4	-	3	-	-	-	-	22	7
		12-Jul-90	-	1	1	2	-	-	7	5	8	-	3	-	2	1	-	30	9
		13-Jul-90	-	2	-	3	1	-	4	1	11	-	1	2	-	-	-	25	8
		14-Jul-90	-	-	2	2	-	5	-	2	8	-	3	-	-	-	-	22	6
		15-Jul-90	-	2	-	-	-	2	2	-	1	-	1	-	-	-	-	8	5

Table 5. (cont.)

Eleve. (m)	Location	Date	Myca	Myci	Myev	Mylu	Myth	Myvo	Myyu	Laci	Lano	Pahe	Epfu	Euma	Coto	Anpa	Tabr	Total Bats	Total Species
2,002	Bear Draw	5-Jul-87	-	-	6	-	-	4	-	-	-	-	-	-	1	-	-	11	3
1,975	Dry Woman Reservoir	6-Jul-87	1	2	4	-	-	3	-	3	8	-	5	-	-	-	-	26	7
		7-Jul-87	-	-	-	-	-	5	-	-	-	-	5	-	-	-	-	10	2
1,974	Haystack Rock Reservoir	12-Aug-85	-	1	4	-	-	1	2	-	1	-	2	-	3	-	-	14	7
		2-Jul-87	1	-	1	-	-	4	1	1	14	1	14	-	-	-	-	37	8
		3-Jul-87	1	-	-	-	-	1	-	1	5	-	1	1	-	-	-	10	6
		4-Jul-87	-	1	2	-	-	1	-	-	-	-	5	1	-	-	-	10	5
		15-Jun-89	4	-	2	-	-	1	-	2	2	-	5	1	1	-	-	18	8
		17-Jun-89	-	1	2	-	-	2	1	-	-	-	5	-	-	1	-	12	6
1,659	Haystack Rock	6-Jun-82	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	2	2
1,635	Vermillion Creek	9-Aug-85	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	1
1,634	Pool Creek Ranch	11-Aug-88	-	-	1	-	-	2	3	-	-	-	-	-	-	-	-	6	3
		12-Aug-88	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	1
		18-Jun-89	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1
		20-Jun-89	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	3	2
1,633	Ely Creek	14-Jun-82	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	2	2
		26-Jul-82	-	-	-	-	-	-	1	1	-	-	-	-	-	1	-	3	3
		27-Jul-82	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
1,631	Morris Ranch	23-Jun-89	-	-	1	-	1	-	-	-	-	-	-	-	-	1	-	3	3
		9-Jul-90	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1
		10-Jul-90	-	-	-	-	-	-	-	-	-	-	3	-	-	3	-	6	2
1,600	Big Joe Campground	19-Jul-82	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	3	1
		20-Jul-82	9	-	1	-	1	4	9	-	-	-	4	-	6	2	-	36	8

Table 5. (cont.)

Eleve. (m)	Location	Date	Myca	Myci	Myev	Mylu	Myth	Myvo	Myyu	Laci	Lano	Pahe	Epfu	Euma	Coto	Anpa	Tabr	Total Bats	Total Species
1,593	Pool Creek Petroglyphs	12-Aug-88	-	-	-	-	1	5	-	1	1	-	4	-	-	-	-	12	5
		19-Jun-89	1	-	-	-	-	4	1	-	1	-	11	-	-	-	-	18	5
		20-Jun-89	1	-	-	-	-	-	-	-	-	-	2	-	-	-	-	3	2
1,586	Pot Creek	12-Jun-82	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	3	2
1,576	Harding Hole	7-Jun-82	1	-	-	-	-	1	-	-	-	-	-	-	-	1	-	3	3
		8-Jun-82	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
1,571	Pool Creek at Echo Park	10-Jun-82	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	2	1
		22-Jul-82	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-	4	2
1,566	Cub Creek	22-Jun-89	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1
		6-Jul-90	-	-	-	-	-	-	-	1	-	-	6	-	-	-	-	7	2
		7-Jul-90	-	-	-	-	-	1	1	1	-	-	7	-	-	-	-	10	4
		8-Jul-90	-	-	-	-	-	1	2	2	-	-	3	-	-	1	-	9	5
		9-Jul-90	-	-	-	-	-	-	-	9	-	-	1	-	-	1	-	11	3
		10-Jul-90	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	2	2
1,558	Rippling Brook	13-Jun-82	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1
1,553	Alcove Brook	11-Aug-85	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1
		Sum	24	17	41	16	7	55	52	41	69	2	112	5	14	13	0	468	14
		% Total Bats	5.1	3.6	8.8	3.4	1.5	11.8	11.1	8.8	14.7	0.4	23.9	1.1	3.0	2.8	0.0		
		% Prevalence	20.0	18.3	26.7	8.3	10.0	40.0	30.0	33.3	26.7	3.3	53.3	6.7	10.0	16.7	0.0		
																	Avg.	7.8	3.2

Table 6. Localities, dates, and bat species captured in Dinosaur National Monument, 2008-2009. Data are arranged by highest elevation and earliest netting date. The columns on the right side indicate the total number of bats and total bat species captured by locality and date. Summaries at the bottom include the total individuals of each species (Sum), the percentage that species comprises of the 909 total bats captured (% Total Bats), and the percentage of times at least one individual of that species was captured among the 51 separate combinations of sampling locations and dates (% Prevalence). The identities of the acronyms for the 15 bat species are given in Table 1. Descriptions and coordinates of the capture localities are in locality accounts available from the authors.

Elev. (m)	Location	Date	Myca	Myci	Myev	Mylu	Myth	Myvo	Myyu	Laci	Lano	Pahe	Epfu	Euma	Coto	Anpa	Tabr	Total Bats	Total Species
2,263	Chew Reservoir	8-Aug-08	-	-	3	-	1	2	1	-	-	-	-	-	2	-	-	9	5
2,244	Snow Reservoir	9-Jul-09	2	3	2	-	-	9	1	-	3	-	-	-	7	-	-	27	7
2,182	Buffham Reservoir	8-Jul-08	1	2	9	-	2	6	1	-	5	-	2	-	2	3	-	33	10
		9-Jul-08	-	4	-	-	1	2	1	-	1	-	1	-	-	1	-	11	7
2,095	Massey Pond	1-Jul-08	-	2	1	1	-	-	2	2	3	-	-	-	-	-	-	11	6
2,078	Massey Reservoir	30-Jun-08	-	-	-	6	-	-	1	2	5	-	-	-	-	-	-	14	4
		18-Jul-09	-	2	-	1	1	-	2	2	1	-	1	-	-	-	-	10	7
1,979	Bear Draw Reservoir	5-Aug-08	-	-	8	-	-	2	1	3	-	-	-	-	-	-	-	14	4
		17-Jul-09	-	8	7	-	-	4	-	7	32	-	4	3	-	-	-	65	7
1,975	Dry Woman Reservoir	6-Jul-08	-	4	2	-	-	4	1	-	1	-	2	-	-	-	-	14	6
		4-Aug-08	-	3	19	2	5	5	4	2	-	-	6	-	2	3	-	51	10
		17-Jul-09	1	7	18	-	1	5	1	5	17	1	9	2	1	2	1	71	14
1,974	Haystack Rock Reservoir	4-Jul-08	-	5	8	-	-	5	9	-	40	-	22	3	-	4	-	96	8
		5-Jul-08	-	3	4	-	-	2	3	2	4	1	14	1	-	2	-	36	10
		3-Aug-08	-	3	11	-	-	6	-	-	3	-	16	1	10	6	-	56	8
		4-Jun-09	2	8	1	-	-	1	5	-	16	-	5	-	-	-	-	38	7
		16-Jul-09	-	2	8	-	-	11	1	2	46	-	25	1	1	4	-	101	10
1,639	Ely Creek	14-Jul-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
1,635	Vermillion Creek	7-Jul-08	-	3	1	-	-	-	-	1	-	-	-	-	-	-	-	5	3
1,634	Hog Canyon	1-Jun-08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0

Table 6. (cont.)

Elev. (m)	Location	Date	Myca	Myci	Myev	Mylu	Myth	Myvo	Myyu	Laci	Lano	Pahe	Epfu	Euma	Coto	Anpa	Tabr	Total Bats	Total Species
1,634	Pool Creek Ranch	12-Aug-08	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	1
1,631	Morris Ranch	31-May-08	2	-	-	-	-	-	1	-	-	-	3	-	1	1	-	8	5
		2-Jul-08	-	-	3	-	1	-	3	1	-	-	-	-	-	2	-	10	5
		1-Aug-08	1	-	2	-	-	5	-	1	-	-	8	-	2	28	-	47	7
		10-Aug-08	-	-	1	-	-	2	-	-	-	-	6	-	-	13	-	22	4
		3-Jun-09	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	2	2
		17-Jun-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
1,600	Big Joe Campground	9-Jun-09	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	2	1
		10-Jun-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
1,593	Pool Creek Petroglyphs	3-Jun-08	-	-	-	-	1	1	6	-	4	-	-	-	-	-	-	12	4
		10-Jul-08	-	2	-	-	-	1	-	-	-	-	-	-	-	-	-	3	2
		11-Aug-08	-	-	-	-	1	-	-	1	-	1	-	-	-	1	-	4	4
		15-Jun-09	1	1	-	-	1	1	2	1	3	-	4	-	-	-	-	14	8
		8-Jul-09	1	-	-	-	-	4	1	-	-	-	3	-	-	-	-	9	4
1,586	Pot Creek	12-Jul-09	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1
1,576	Harding Hole	11-Jun-09	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	1
		12-Jun-09	1	-	3	-	-	2	-	-	-	-	-	-	-	-	-	6	3
1,571	Pool Creek at Echo Park	2-Jun-08	5	-	1	-	-	-	32	-	1	-	-	-	-	-	-	39	4
		11-Jul-08	-	2	-	-	2	3	1	-	1	-	-	-	-	-	-	9	5
		6-Aug-08	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	1
		16-Jun-09	2	-	2	-	-	-	3	-	1	-	-	-	-	-	-	8	4

Table 6. (cont.)

Elev. (m)	Location	Date	Myca	Myci	Myev	Mylu	Myth	Myvo	Myyu	Laci	Lano	Pahe	Epfu	Euma	Coto	Anpa	Tabr	Total Bats	Total Species
1,565	Cub Creek	3-Jul-08	-	-	1	-	-	-	-	-	-	2	2	-	-	-	1	6	4
		2-Aug-08	-	-	-	-	-	-	-	-	-	-	2	-	-	3	-	5	2
		7-Jun-09	-	-	-	-	-	-	2	-	-	-	2	-	-	-	-	4	2
		10-Jul-09	1	-	-	-	3	1	1	-	-	2	9	-	-	-	-	17	6
1,562	Laddie Park	13-Jun-09	1	-	1	-	2	-	-	-	-	-	-	-	-	3	-	7	4
1,558	Rippling Brook	13-Jul-09	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	2	2
1,533	Jones Hole Campground	14-Jul-09	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	2	2
1,459	Split Mountain	9-Aug-08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
		6-Jun-09	-	-	-	-	-	-	2	-	-	-	1	-	1	-	-	4	3
		10-Jul-09	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	1
		Sum	21	64	121	10	24	84	91	32	187	7	148	11	29	78	2	909	15
		% Total Bats	2.3	7.0	13.3	1.1	2.6	9.2	10.0	3.5	20.6	0.8	16.3	1.2	3.2	8.6	0.2		
		% Prevalence	25.5	35.3	52.9	7.8	29.4	45.1	56.9	27.5	37.3	9.8	45.1	11.8	19.6	33.3	3.9		
																	Avg.	17.8	4.4

and Split Mountain (Table 6). Technically, Bear Draw Reservoir was a new site. It was less than a mile from the original site in Bear Draw yet it provided more surface area for drinking by bats than the original pool.

Overall, we captured almost twice as many bats (909) in the recent work (Table 6) as in the original surveys (468; Table 5). We captured 17.8 bats of 4.4 species per netting event in the recent work compared to 7.8 bats of 3.0 species per event in the original survey. Among higher-elevation sites, the most productive sites were: Haystack Rock Reservoir (65.4 bats/night); Dry Woman Reservoir (45.3); Bear Draw (39.5); Snow Reservoir (27 on one night); and Buffham Reservoir (22). The more productive lower-elevation sites were: Morris Ranch (14.8); Pool Creek at Echo Park (14.3); Pool Creek Petroglyphs (8.4); and Cub Creek (8.0). Many of these sites were productive in the earlier study as well (Dry Woman, Haystack, Pool Creek Petroglyphs, and Cub Creek), although Massey Reservoir and Big Joe Campground yielded far fewer captures. Several performed better than in previous visits (Buffham Reservoir, Bear Draw, Morris Ranch, and Pool Creek at Echo Park).

The reasons for increased capture rates are unknown, as we did not attempt to increase our numbers and in fact netted fewer nights (60 vs. 51). One difference between the two periods is that in the earlier work we also conducted rodent surveys and prepared specimens, so perhaps our efforts on bats were diluted to some extent. Countering this is that in much of the earlier work we left nets set throughout the night, a practice we no longer conduct or condone. In the recent work, we also made some attempt to schedule our work at the time of the dark (new) moon, because in our experience bat captures increase under these conditions. However, in 2009 we were less able to do this due to river trip schedules. There is the possibility that we deployed more long (20 m) nets in 2008–2009 but we cannot reconstruct data from the original study to facilitate this comparison. Finally, we suspect we might be very slightly better at netting bats as we have had 20-plus years of additional experience.

During our work in 2008–2009 (Table 6), we netted a total of 15 species at DINO. We believe this number represents the number of resident species at the monument and consider *N. macrotis* as occasionally present. For most of the 15 species, we obtained evidence of reproduction (data available from authors). In terms of numbers of species per site, the higher-elevation sites demonstrating greater diversity were: Dry Woman Reservoir (10 species/night); Haystack Rock Reservoir (8.6); Buffham Reservoir (8.5); and Snow Reservoir (7, one night). Lower-elevation sites tended to have fewer species: Morris Ranch (4.6); Pool Creek Petroglyphs (4.4); and Cub Creek and Pool Creek at Echo Park (3.5 per site). Again, several of these were diverse in 1982–1990 (Dry Woman, Haystack, Pool Creek at Petroglyphs, and Cub Creek), although Massey Reservoir and Big Joe failed to meet the diversity observed in the earlier survey.

It seems axiomatic that sites that have high diversity (and numbers) are important to the bats that occur there and are an important source of food, water, and perhaps social interactions. We recommend that these sites be placed on a list of "high-priority" sites for wildlife at DINO and consideration be given to protecting them. This does not mean that sites with low diversity are not important as well; they may have lower diversity because not all species can obtain a given resource there (e.g., too small for large bats to maneuver over but an excellent site for smaller bats). We do not know why two sites (Massey Reservoir and Big Joe Campground) that were previously productive in numbers or species were not as productive in 2008–2009. In the case of Massey, it was our subjective opinion that there were many more cattle present than in 1990. Perhaps there have been detrimental changes in insect populations, roosting sites, or water quality, or maybe it was merely a consequence of timing. Additional work at the site might clarify this situation. In the case of Big Joe Campground, there is the possibility that our memories and notes failed us and we did not net far enough upstream in Starvation Valley in 2009.

In terms of numbers of the species of concern, we were reassured by our captures of three species. We caught over three times as many *M. thysanodes* and twice as many *E. maculatum* and *C. townsendii* as in the previous study. Among these three species, the percent of total captures went up for *M. thysanodes* but stayed about the same for the other two species. Prevalence values for all three went up, suggesting they were more widespread than before. We did not net any *N. macrotis* so their status at DINO remains unclear.

One clear similarity between the two periods was the preponderance of bats captured at high-elevation sites. Between 1982 and 1990, we captured 311 (66%) bats at sites above 1,800 m and 157 (34%) at sites below that elevation. There were 13 sites both above and below 1,800 m. In 2008–2009, eight sites were above 1,829 m and 15 sites were below that elevation (Table 6). Nonetheless, sites above 1,800 m yielded 657 (72% of the total) bats in 2008–2009, whereas 252 (28%) came from the 15 lower sites. Are bats really more common at higher elevations in the monument or are these numbers a result of other factors?

For example, did we spend more time or effort at the higher elevations? In terms of net-nights, in 2008–2009 we expended 69 (35.3%) net-nights above 1,800 m and 126 (64.6%) net-nights below that elevation. In terms of effort, we deployed 1,112 m (48.5%) of net at sites above 1,829 m elevation and 1,178 m (51.4%) of nets below that elevation. Thus, we had a slightly greater effort at lower elevations than at higher sites, a fact influenced to some degree by revisiting the sites on the rivers. We could not reliably calculate net-nights or net feet deployed for the earlier work but assume it was similar. Thus, time or effort would not seem to account for greater numbers of captures at the high-elevation sites.

Are there inherent differences between the low- and high-elevation sites? Here, there may be some definite trends. DINO is a land of large, rolling, sagebrush-covered benches at the upper elevations dissected by multiple small drainages and canyons that ultimately, for the most part, drain into the canyons of the Yampa and Green rivers. Cattle grazing is an historic land-use pattern in the upper areas; although some grazing occurs at lower elevations (e.g., Cub Creek), it seems less common and intense. One of the consequences of grazing the benches has been the construction and maintenance of "stock ponds" or reservoirs for livestock. Although such reservoirs are sometimes controversial, and we know of instances where land-management agencies have destroyed such impoundments, many bat biologists see them as a vital resource for bats, especially in areas where the water table has dropped (e.g., Mollhagen and Bogan 1997; Rabe and Rosenstock 2005; Jackrel and Matlack 2010; Chambers et al. 2011).

These scattered, moderate to large, reservoirs on the benches are desirable sites for bat netting as bats seem to congregate at such places. It is possible that such nutrient-rich stock ponds increase aquatic insect biomass, and thus increase forage for bats. They tend to be larger in size than most lowland sites and thus have more surface area for foraging bats. They also may be closer to roosting sites. Virtually all lower-elevation sites are smaller in size. Many are located on small streams that are often subject to flash flooding (which may affect in situ insect biomass) or are sites where we could not place nets over water (e.g., Morris Ranch and Laddie Park) due to interference by vegetation. In turn, most netting sites along the rivers are compromised by the abundance of water where bats can forage or drink, a phenomenon that may dilute concentrations of bats. Whatever the biological reasons may be for apparent concentrations of bats at the high-elevation sites, they are clearly sites that biologists can use to obtain information on bats.

Are there detectable trends among bats taken at the higher elevation sites? During our earlier work, we had the impression that we captured more males than females at high-elevation sites. Our database for 2008–2009 gave us an opportunity to examine if this might be true. We again used an elevation of 1,800 m in elevation to separate low and high elevation sites. Although this division is somewhat arbitrary, there is a clear separation among our study sites with 15 sites ranging from 1,459 m (Split Mountain) to 1,639 m (Ely Creek), each differing from the adjacent site by 30–60 m in elevation. The eight high-elevation sites begin 335 m above the Ely Creek site at 1,974 m (Haystack Rock Reservoir) and range up to 2,263 m (Chew Reservoir), each differing from adjacent sites by 30–90 m elevation.

Our captures of bats at high-elevation sites indeed reveal a preponderance of males over females (Table 7). We netted 511 males (80%) and only 127 females (20%). Conversely, at lower sites the numbers were more similar although we netted slightly more females (151, 59%) than males (103, 41%; Table 8). Numbers in these tables are slightly different than those shown

Table 7. Captures of males and females at capture sites above 1,800 meters elevation in 2008-09. Data are arranged by highest to lowest elevations and earliest to latest netting dates. For each net event the number of males captured is given first, then the number of females. The combined total numbers of bats shown captured in this table and Table 8 is slightly less than the total number shown in Table 6. A few bats escaped before the sex could be determined. The identities of the acronyms for the 15 bat species are given in Table 1.

Elev. (m)	Location	Date	Myca	Myci	Myev	Mylu	Myth	Myvo	Myyu	Laci	Lano	Pahe	Epfu	Euma	Coto	Anpa	Tabr
2,263	Chew Reservoir	8-Aug-08	-	-	3/0	-	1/0	2/0	0/1	-	-	-	-	-	0/2	-	-
2,244	Snow Reservoir	9-Jul-09	1/1	3/0	2/0	-	-	8/1	1/0	-	3/0	-	-	-	0/7	-	-
2,182	Buffham Reservoir	8-Jul-08	1/0	2/0	8/1	-	0/2	3/3	1/0	-	5/0	-	2/0	-	0/2	3/0	-
		9-Jul-08	-	4/0	-	-	1/0	2/0	0/1	-	1/0	-	1/0	-	-	1/0	-
2,095	Massey Pond	1-Jul-08	-	2/0	0/1	0/1	-	-	0/1	2/0	3/0	-	-	-	-	-	-
2,078	Massey Reservoir	30-Jun-08	-	-	-	0/6	-	-	0/1	2/0	5/0	-	-	-	-	-	-
		18-Jul-09	-	2/0	-	0/1	1/0	-	1/1	2/0	1/0	-	1/0	-	-	-	-
1,979	Bear Draw Reservoir	5-Aug-08	-	-	4/4	-	-	0/2	0/1	2/1	-	-	-	-	-	-	-
		17-Jul-09	-	6/1	3/4	-	-	2/2	-	6/0	28/0	-	4/0	1/2	-	-	-
1,975	Dry Woman Reservoir	6-Jul-08	-	4/0	0/2	-	-	0/3	0/1	-	1/0	-	2/0	-	-	-	-
		4-Aug-08	-	2/1	15/4	2/0	5/0	3/2	4/0	2/0	-	-	6/0	-	2/0	0/3	-
		17-Jul-09	1/0	7/0	13/4	-	1/0	4/1	-	5/0	17/0	0/1	8/0	1/1	0/1	0/2	0/1
1,974	Haystack Rock Reservoir	4-Jul-08	-	5/0	7/1	-	-	2/3	4/5	-	40/0	-	20/1	2/0	-	4/0	-
		5-Jul-08	-	3/0	2/2	-	-	1/1	0/3	2/0	4/0	1/0	12/0	1/0	-	2/0	-
		3-Aug-08	-	2/1	7/4	-	-	2/4	-	-	3/0	-	14/0	1/0	1/9	6/0	-
		4-Jun-09	2/0	7/1	1/0	-	-	1/0	1/4	-	15/0	-	4/1	-	-	-	-
		16-Jul-09	2/0	-	7/1	-	-	5/6	1/0	1/0	46/0	-	24/1	0/1	0/1	4/0	-
		Sum M/F	7/1	49/4	72/28	2/8	9/2	35/28	13/19	24/1	172/0	1/1	98/3	6/4	3/22	20/5	0/1
																Total M/F	511/127

Table 8. Captures of males and females at capture sites below 1,800 meters elevation in 2008-09. Data are arranged by highest elevation and earliest netting date. For each net event the number of males captured is given first, then the number of females. The combined total number of bats shown captured in tables 7 and 8 is slightly less than the total number shown in Table 6. A few bats escaped before the sex could be determined. The identities of the acronyms for the 15 bat species are given in Table 1.

Elev. (m)	Location	Date	Myca	Myci	Myev	Mylu	Myth	Myvo	Myyu	Laci	Lano	Pahe	Epfu	Euma	Coto	Anpa	Tabr
1,639	Ely Creek	14-Jul-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,635	Vermillion Creek	7-Jul-08	-	2/1	0/1	-	-	-	-	1/0	-	-	-	-	-	-	-
1,634	Hog Canyon	1-Jun-08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,634	Pool Creek Ranch	12-Aug-08	-	-	-	-	0/1	-	-	-	-	-	-	-	-	-	-
1,631	Morris Ranch	31-May-08	0/2	-	-	-	-	-	1/0	-	-	-	0/3	-	0/1	0/1	-
		2-Jul-08	-	-	3/0	-	1/0	-	3/0	1/0	-	-	-	-	-	2/0	-
		1-Aug-08	1/0	-	2/0	-	-	1/4	-	1/0	-	-	1/7	-	1/1	12/15	-
		10-Aug-08	-	-	1/0	-	-	0/1	-	-	-	-	1/5	-	-	11/2	-
		3-Jun-09	-	-	-	-	0/1	-	-	-	-	-	-	-	-	1/0	-
		17-Jun-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,600	Big Joe Campground	9-Jun-09	-	-	1/1	-	-	-	-	-	-	-	-	-	-	-	-
		10-Jun-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1,593	Pool Creek Petroglyphs	3-Jun-08	-	-	-	-	1/0	0/1	0/6	-	4/0	-	-	-	-	-	-
		10-Jul-08	-	1/0	-	-	0/2	2/1	0/1	-	1/0	-	-	-	-	-	-
		11-Aug-08	-	-	-	-	0/1	-	-	0/1	-	-	-	-	-	1/0	-
		15-Jun-09	0/1	0/1	-	-	0/1	0/1	0/2	1/0	3/0	-	0/4	-	-	-	-
		8-Jul-09	0/1	-	-	-	-	2/2	0/1	-	-	-	1/2	-	-	-	-
1,586	Pot Creek	12-Jul-09	-	-	-	-	-	-	-	-	-	-	1/0	-	-	-	-
1,576	Harding Hole	11-Jun-09	-	-	0/1	-	-	-	-	-	-	-	-	-	-	-	-
		12-Jun-09	0/1	-	2/1	-	-	1/1	-	-	-	-	-	-	-	-	-

Table 8. (cont.)

Elev. (m)	Location	Date	Myca	Myci	Myev	Mylu	Myth	Myvo	Myyu	Laci	Lano	Pahe	Epfu	Euma	Coto	Anpa	Tabr
1,571	Pool Creek at Echo Park	2-Jun-08	2/3	-	0/1	-	-	-	2/30	-	1/0	-	-	-	-	-	-
		11-Jul-08	-	1/0	-	-	0/2	2/1	0/1	-	1/0	-	-	-	-	-	-
		6-Aug-08	-	-	-	-	-	-	1/0	-	-	-	-	-	-	-	-
		16-Jun-09	1/1	-	1/1	-	-	-	2/1	-	1/0	-	-	-	-	-	-
1,565	Cub Creek	3-Jul-08	-	-	1/0	-	-	-	-	-	-	0/2	0/2	-	-	-	1/0
		2-Aug-08	-	-	-	-	-	-	-	-	-	-	1/1	-	-	0/3	-
		7-Jun-09	-	-	-	-	-	-	1/1	-	-	-	2/0	-	-	-	-
		10-Jul-09	0/1	-	-	-	2/1	0/1	1/0	-	-	0/2	4/5	-	-	-	-
1,562	Laddie Park	13-Jun-09	0/1	-	0/1	-	0/2	0/1	-	-	-	-	-	-	-	1/2	-
1,558	Rippling Brook	13-Jul-09	-	-	-	-	-	-	0/1	-	-	-	-	-	-	1/0	-
1,533	Jones Hole	14-Jul-09	-	-	0/1	-	-	-	0/1	-	-	-	-	-	-	-	-
1,459	Split Mountain	9-Aug-08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		6-Jun-09	-	-	-	-	-	-	2/0	-	-	-	1/0	-	0/1	-	-
		10-Jul-09	-	-	1/0	-	-	-	-	-	-	-	-	-	-	-	-
		Sum M/F	4/11	4/2	12/8	0/0	4/11	8/14	13/45	4/1	11/0	0/4	12/29	0/0	1/3	29/23	1/0
															Total M/F 103/151		

in Tables 3–6, because Tables 7–8 exclude bats that we identified upon capture but that escaped before all data could be gathered.

Myotis evotis and *M. volans*, known to be common at higher elevations (Fitzgerald et al. 1994), had the largest numbers of females taken at the higher sites (28 for both species; Table 7), presumably reflecting this habitat bias. We were surprised by the relative abundance of female *M. yumanensis* (19) at the higher sites. This is a species that typically is more common near open water (Barbour and Davis 1969) and perhaps the large reservoirs on the benches attract them to these sites. Another anomaly was the number of reproductive female *C. townsendii* that we captured at Snow Reservoir on the cool night of 9 July. When these bats began to drink and forage over the pool we were initially surprised, but we soon concluded they had been attracted by a large accumulation of small, white moths over the reservoir itself. We observed several individuals capture moths. The predilection of *L. noctivagans* to be common at higher-elevation sites was mentioned previously.

Only two species exceeded 28 female captures at low-elevation sites (Table 8). At the lower sites we took 45 female *M. yumanensis*, more in keeping with known habitat predilections of this species, and 29 female *E. fuscus*, a species we often regard as an "elevational" generalist. However, in 2008–2009, female *E. fuscus* were more abundant at lower elevations. We also took 23 female *A. pallidus*, mostly at the Morris Ranch in early August (Table 8).

At low-elevation sites, where males comprised 41% of the captures, the numbers of captured males exceeded the numbers of captured females in six of 15 species (Table 9). Conversely, at high-elevation sites, where males made up 80% of the catch, captured males exceeded captured females in 10 of 15 species (Table 9). At the higher sites, females outnumbered males only for *M. lucifugus, M. yumanensis, C. townsendii,* and *T. brasiliensis* (n = 1). One species, *P. hesperus,* had equal captures.

There are compelling reasons for male and female bats to occupy different areas, roosts, or habitats during the summer (Cryan et al. 2000). Cooler temperatures at higher elevations may cause bats to enter torpor. In much of the montane West, pregnant females seem to select low-elevation habitats as it is important that they maintain a constant body temperature to allow either embryos or dependent young to develop in the narrow window of time before food supplies begin to decline. As a part of this strategy, females tend to form maternity colonies in sites where their body heat warms the roost. By contrast, males are common at higher elevations where their strategy is to roost solitarily and enter torpor during the day. Among the bats at DINO, females in general are more common at lower elevations whereas males clearly are more common at higher elevations. Female *M. evotis* and *M. volans* are an exception to this generalization and we assume they are either making nightly migrations from low- to high-elevation sites or they are roosting at the upper elevations. Both species seem adapted to higher elevations. Telemetry studies would shed light on the roosting habits of female bats at the monument.

About 37% (98/267) of the females we captured in 2008–2009 showed some form of reproductive activity: pregnancy, lactation, or sign of recent lactation (post-lactation). Our netting schedule each year precluded any attempt to monitor reproductive cycles in detail. The presumption is that most females are pregnant early in the summer, but it can be difficult during this time to discern definite signs of pregnancy. The earliest date we noted gravid bats was 4 July in 2008 and 16 July in 2009. We captured lactating females from 11 July 2008 and 14 July 2009 and as late as 5 August in 2008. We netted 32 flying young-of-the-year but only in 2008, beginning on 3 August and as late as 12 August that year. We probably did not work late enough in summer 2009 to catch young. During the two years, we tallied 113 reproductive males (vas deferens swollen and intruding into the uropatagium); the earliest dates were 4 July in 2008 and 16 July in 2009. We continued to net reproductive males until we left the monument each year (10 August in 2008 and ca. 17 July in 2009). Species-specific data on reproduction are available from the authors.

Our data suggest that low temperatures in June 2009 likely affected bat captures. In June 2008, the average temperature when we started a netting event was 23° C and ending temperature was 15° C; in June

Table 9. Numbers of males and females for low- and high-elevation sites for all bats captured 2008-2009. High sites (*n* = 8) are those above 1,800 meters are shown on the left side of the table. Low sites (*n* = 15) are below that elevation. Data presented are the numbers of each sex of each species and the percent each sex represents of the total captures of each species. Bats that escaped before sex determination are not shown. The identities of the acronyms for the 15 bat species are given in Table 1.

	Low Sites				High Sites			
Species	Males	% Male	Females	% Female	Males	% Male	Females	% Female
Myca	4	26.7	11	73.3	7	87.5	1	12.5
Myci	4	66.7	2	33.3	49	92.5	4	7.5
Myev	12	60.0	8	40.0	72	72.0	28	28.0
Mylu	0		0		2	20.0	8	80.0
Myth	4	26.7	11	73.3	9	81.8	2	18.2
Myvo	8	36.4	14	63.6	35	55.6	28	44.4
Myyu	13	22.4	45	77.6	13	40.6	19	59.4
Laci	4	80.0	1	20.0	24	96.0	1	4.0
Lano	11	100.0	0	0.0	172	100.0	0	0.0
Pahe	0		4	100.0	1	50.0	1	50.0
Epfu	12	29.3	29	70.7	98	97.0	3	3.0
Euma	0		0		6	60.0	4	40.0
Coto	1	25.0	3	75.0	3	12.0	22	88.0
Anpa	29	55.8	23	44.2	20	80.0	5	20.0
Tabr	1	100.0	0		0		1	
Total	103		151		511		127	

2009, starting temperatures were about 4° C lower (19° C); ending temperatures were approximately the same as in 2008. In June 2008, we captured an average of almost 15 bats/night over four nights. In June 2009, we averaged less than half that number (7 bats/night), even with more nights of effort and a good catch at Haystack Rock Reservoir. Three of the 2009 localities were river sites, accounting for five of 12 nights of effort and this may have influenced our captures. It is not clear how the presence of a moon in early June 2009 affected these captures.

Results during the other three capture periods were roughly similar with starting temperatures above 23° C and ending temperatures around 15–20° C. Nonetheless, July 2009, the period with the highest average start and end temperatures, had the highest average capture rate (25.5 bats/night). Both July efforts included productive nights at Haystack Rock Reservoir (96 and 101 bats), although the 2009 effort also had good nights at Bear Draw and Dry Woman reservoirs. In our only August effort (2008) our best capture numbers were in the dark of the moon.

To look for additional patterns we ranked all sites by number of bats captured and then looked at various attributes of the sites. Not surprisingly all the Yampa Bench (upland) sites rank in the top 20 sites in number of captures. Additionally, the top eight sites, all with captures greater than 39/night, were all made when no moon was present. During nights that we characterized as “no moon” we captured a total of

661 (73%) bats, whereas on nights with some or full moon we captured 248 bats. Interestingly, three of five nights when we caught no bats also had no moon, although all five nights were in river or riparian, not upland, sites. Sites we characterized as "upland," but excluding the Morris Ranch, accounted for 657 (72%) of all bats captured. Sites characterized as "riparian," "river," and the Morris Ranch accounted for just 252 bats. Other variables, such as cloud cover and presence of large trees, also probably influence capture rates but perhaps in a more subtle fashion.

CONCLUSIONS

In terms of species diversity, the two time periods are very similar. From 1982 to 1990, we captured 14 species in nets and obtained a fifteenth, a salvaged *T. brasiliensis*. In 2008–2009 we captured all 15 species in nets. One of the least common species in the earlier work was *P. hesperus*. We have two specimens from that period (one of which was shot), but in 2008–2009, we netted a total of seven *P. hesperus*. In the recent study we also netted two *T. brasiliensis* (including one in Colorado). Both of these species are on or near the margin of their respective geographic ranges. These slight increases suggest to us that the two species are clearly surviving in the area, and may be slowly becoming more abundant (Bogan and Cryan 2000; Genoways et al. 2000). Other species on or near the edge of their ranges include *M. californicus*, known only to the north from adjacent Sweetwater County, Wyoming; *M. yumanensis*, known by us from Big Horn, Lincoln, and Sheridan counties, Wyoming (also see Buskirk 2016); and *E. maculatum* and *A. pallidus*, whose ranges are attenuated to the east although more expansive to the south, west, and north (Reid 2006).

When we began this work we had some expectations that we would capture a *N. macrotis* as there is a salvaged specimen from the Quarry. We are familiar with this species from our work in New Mexico and Utah and have found reproductive females to be moderately common in some places. We have observed their roosts in slickrock canyon walls with large, incised cracks and have netted them over long, linear pools in streambeds in isolated canyons. The species may occur at DINO but it is possible that we did not net in locations where they occur. Alternatively, they may be absent because some resource is not present or in short supply. Bogan and Cryan (2000) report an isolated individual (MSB 122221) from West Gros Ventre Butte near Jackson, Wyoming, but the northernmost maternity roosts with females and young are at the latitude of Moab, Utah (Bogan, unpubl.). For the present, we are inclined to conclude that *N. macrotis* occurs occasionally at DINO.

A comparison of data from both studies (Table 10) suggests that in general, bat species and numbers are doing well at DINO. Although we caught about twice as many bats in the recent study, we do not believe that bats are twice as abundant as they were in 1982–1990. For most species we did capture more individuals, but there are exceptions. For example, we took slightly fewer *M. californicus* and *M. lucifugus* and about three-fourths the number of *L. cinereus*. Given the relatively small sample sizes, these differences may not be real. Alternatively, possible reasons for the declines are that we may have misidentified a few *M. californicus* as *M. ciliolabrum*; we were less successful at Massey Reservoir where *M. lucifugus* was common in the earlier study; and perhaps we simply were not in the right spot at the right time to net more *L. cinereus*. For all three species, the proportion that each species represented out of total bats also declined by about 50%. Interestingly, their general occurrence or distribution on the monument, as measured by percent total captures and percent prevalence, remained about the same (Table 10). We consider the three species to be somewhat less common but as widespread as before.

Among those species for which we captured more individuals, a few increased by factors of three to six times. We captured almost three times as many *M. evotis* and *L. noctivagans*, four times as many *M. ciliolabrum*, and six times as many *A. pallidus*. It is difficult to ignore the possibility that these numbers do not represent some real increase in numbers of these species (Table 10). Geluso and Geluso (2012) demonstrated, for example, that bat abundance can fluctuate

Table 10. A comparison of all bats captured in the periods 1982-1990 and 2008-09. Data tabulated for each period, for each species, are the total captures, the percent of total captures, and the percent prevalence of occurrence. The rightmost columns are a comparison of the populations as expressed as by the percent of total captures and the percent prevalence for each species. The last column is a subjective assessment of population trends. The identities of the acronyms for the 15 bat species are given in Table 1.

	1982-90			2008-09					
Species	Total Captures	% Total Captures	% Prevalence	Total Captures	% Total Captures	% Prevalence	% Total Captures Difference	% Prevalence Difference	Trend
Myca	24	5.1	20.0	21	2.3	25.5	-2.8	5.5	Stable
Myci	17	3.6	18.3	64	7.0	35.3	3.4	17.0	Increasing?
Myev	41	8.8	26.7	121	13.3	52.9	4.6	26.2	Increasing?
Mylu	16	3.4	8.3	10	1.1	7.8	-2.3	-0.5	Decreasing?
Myth	7	1.5	10.0	24	2.6	29.4	1.1	19.4	Increasing?
Myvo	55	11.8	40.0	84	9.2	45.1	-2.5	5.1	Stable
Myyu	52	11.1	30.0	91	10.0	56.9	-1.1	26.9	Increasing?
Laci	41	8.8	33.3	32	3.5	27.5	-5.2	-5.8	Decreasing?
Lano	69	14.7	26.7	187	20.6	37.3	5.8	10.6	Stable
Pahe	2	0.4	3.3	7	0.8	9.8	0.3	6.5	Stable
Epfu	112	23.9	53.3	148	16.3	45.1	-7.6	-8.2	Decreasing?
Euma	5	1.1	6.7	11	1.2	11.8	0.1	5.1	Stable
Coto	14	3.0	10.0	29	3.2	19.6	0.2	9.6	Stable
Anpa	13	2.8	16.7	78	8.6	33.3	5.8	16.6	Increasing?
Tabr	0	0.0	0.0	2	0.2	3.9	0.2	3.9	Stable

greatly with precipitation. Nonetheless, such an apparent increase might have resulted from a few very successful nights of netting, such as for *L. noctivagans* at Haystack Rock and *A. pallidus* at Morris Ranch. The same may be true for *M. evotis*, as we had two or three very successful nights for that species. However, for *M. ciliolabrum*, the general pattern is different as we had many nights of fair to moderate captures (3–8 animals). The proportion each species made of the total catch also increased, as did the prevalence value for all. These four species may represent the best evidence that some species have increased in numbers. There is the possibility that such increases result from subtle habitat changes not noticed by us.

Another suite of species increased by about one and one-half to two times in abundance (Table 10). These species include *M. volans*, *M. yumanensis*, *E. fuscus*, *E. maculatum*, and *C. townsendii*. Total numbers of each of these species in 2008–2009 vary from 11 to 91 and some caution is advised in dealing with smaller samples (e.g., *E. maculatum*). But, for some of these species (e.g., *C. townsendii*, *E. fuscus*, and *M. yumanensis*) we again had a night or two of exceptional captures that influenced total numbers. Interestingly, the percent each species represented of the total remained about the same or decreased slightly. Prevalence values increased in most cases, markedly so in one case (*M. yumanensis*), and decreased in one case (*E. fuscus*; Table 10). We are persuaded that the small change in proportions and the slight increase in prevalence suggest these species are healthy at DINO.

From a faunal perspective, we subjectively divided resident bat species at DINO into three classes: abundant (> 10% of total captures), common (2–10% of captures), and uncommon (< 2% of captures). Bats that are abundant at DINO include *M. evotis*, *M. volans*, *M. yumanensis*, *L. noctivagans*, and *E. fuscus*. Bats that are common include *M. californicus*, *M. ciliolabrum*, *M. thysanodes*, *L. cinereus*, *C. townsendii*, and *A. pallidus*. Uncommon species at DINO are *L. lucifugus*, *P. hesperus*, *E. maculatum*, and *T. brasiliensis*. Most species were in the same categories for the earlier work, suggesting the fauna is relatively stable over time. The exceptions are slight differences in percentages for *M. evotis*, *M. thysanodes*, and *L. lucifugus*.

In many ways, we found DINO unchanged after all these years and, reassuringly, the bat fauna of the monument still seemed healthy. Nonetheless, we urge that our current results be interpreted cautiously at this juncture. Why is DINO so "good" for bats? Our guess would be that it is a combination of the presence of good foraging and roosting sites, coupled with a fortuitous distribution of water sources, especially in the uplands. The relative paucity of visitors (and their activities) to large, wild parts of the monument also may play a role, as may the general lack of intensive agriculture near the monument. Grazing continues to be a visible land use in and near the monument and it was our subjective opinion that in some areas, in spite of what appeared to be a year of good winter precipitation in 2007–2008, the effects of grazing pressure were more obvious than during our earlier work.

Bats at DINO face a variety of local pressures, but like all organisms they also face global threats. In particular, most climate scientists are convinced that global warming is occurring. How would warming temperatures affect bats at DINO? Depending on the degree of warming, the summer habits of many bats, especially males that use torpor at upper elevations, could change. How warmer temperatures would affect female bats in the summer at DINO is more conjectural but presumably some of them would move upward in elevation. We know almost nothing about the wintering habits of most bats at DINO other than that some (*L. noctivagans, L. cinereus, T. brasiliensis*) migrate to other, warmer, areas where food remains available, whereas the other species probably make, at most, local migrations to hibernacula to overwinter. Again, depending on the degree of warming, some hibernacula might become too warm to be used by bats. Although this study provides two benchmarks across time comparing bat assemblages in one geographic region, the data will be informative in comparing future bat assemblages, especially in light of threats such as white-nose syndrome, should it spread west across the Great Plains.

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Distribution Records and Reported Sightings of the White-nosed Coati (*Nasua narica*) in Texas, with Comments on the Species' Population and Conservation Status

David J. Schmidly, John Karges, and Robert Dean

Abstract

The status of the White-nosed Coati (*Nasua narica*) in Texas has been an enigma for decades. Herein, we review documentation of the historical records as well as numerous reports of recent sightings, very few of which are "confirmed" with specimens or photographs; most come from amateur naturalists and must be considered "anectodal." Long-term mammal surveys by professional mammalogists and camera trap studies from within the range of the coati in Texas have not produced any specimens or other documentation of the species. Almost all of the sightings are of solitary individuals from within 100 miles of the borderlands and/or of released pets. The most numerous sightings are from Big Bend National Park just across the river from the Maderas del Carmen/Sierra del Carmen Mountains of northern Coahuila, Mexico, where a small breeding and permanently established population has now become established. We know of no evidence that a breeding population of wild coatis now live in Texas, although a recent conservation corridor established along the borderlands could eventually result in the species expanding its range into the State.

Key words: conservation, distribution, *Nasua narica*, Texas, White-nosed Coati

Introduction

White-nosed Coatis (*Nasua narica*) are procyonid carnivores closely related to raccoons and ringtails. They are often indiscriminately called coatimundis, though the latter term properly refers only to solitary adult males. The White-nosed Coati (hereafter simply coati) ranges from Panama through Mexico. It reaches the limits of its breeding range in the United States (U.S.), where it has been recorded in southeastern Arizona, southwestern New Mexico, and southwestern Texas. The species is uncommon or at low abundance throughout its U.S. distribution and especially Texas, where it is thought to be rare. The breeding range of *N. narica* in the U.S. extends from the Animas Mountains in southwestern New Mexico to the Baboquivari Mountains in south-central Arizona, and north to the Gila River (Kaufmann et al. 1976).

Although coatis superficially resemble raccoons, they have a more slender, flexible snout and a long, slender tail that is often carried erect (Kaufmann 1987). They are intermediate in size between raccoons and ringtails, with adults typically weighing 4–6 kg (9–13 pounds) and having a total length of 85–134 cm (33.5–53 inches), about half of which is tail. Generally, female coatis are slightly smaller than males. The color, usually chocolate brown, varies from pale sandy brown to reddish to almost black. Indistinct dark tail-rings, a white snout, broken white-eye rings, and a yellowish wash on the chest and shoulders are among the most distinguishable characteristics.

Coatis are thought to be the largest native animal to invade the U.S. Borderlands in the last 135 years

(Gehlbach 1981). Their northward movement initially corresponded with post-pluvial times in a fashion similar to that of the nine-banded armadillo (*Dasypus novemcinctus*). There is a lack of pluvial fossil records for both of these mammals, and they do not appear north of the Border until historic times or at archeological sites no earlier than a few thousand years Before Present (B.P.). More recent expansions have been characterized as "culturally induced"—resulting from opportunistic individuals who have responded to situations created by human conditions such as the heaps of carrion beef that littered Arizona in 1891–1893 (Gehlbach 1981).

In the U.S. and northern Mexico, coatis live mostly in the pine-oak and riparian woodlands of scattered mountain ranges, chiefly at elevations of 1,400 to 2,000 m (4,600–6,500 feet), in a type of vegetation known as Madrean Evergreen Woodland (Brown 1973). They also range higher into coniferous forests and occasionally down into desert grassland and scrub. They can move easily across intermontane valleys through grassland and desert by following wooded riparian corridors. They may even cross some treeless stretches in their northern push, but tree-sized vegetation is a requisite for resident populations (Gehlbach 1981).

In contrast to most procyonids, coatis are mainly diurnal in activity and maintain a matriarchal social system with the females and young males in bands and the adult males usually solitary (Kaufmann 1962). Population densities are highly variable within years, but are lower in the southwestern U.S. than in the tropics, and there is some suggestion that at *Nasua narica's* northern range limit the populations may be nomadic or migratory (Kaufmann et al. 1976). Like any species at the edge of their range, coati populations exhibit extraordinary flux, as natural and cultural factors exert unusually stressful limiting or powerful enhancing effects. In 1960–1961, an epidemic of canine distemper reduced coati populations throughout Arizona, while a 32-inch snowfall in 1967–1968 drove the recovering Peloncillo-Guadalupe mountains population out of the southern part of that mountain range (Gehlbach 1981). For these reasons, there has been concern about the conservation status of the species in the U.S. with suggestions that the species likely warrants complete legal protection.

Marginal records for coatis in the U.S. generally fall into two categories—occasional wanderers, and released or escaped captives. Most of the records are based only on sightings, and some of them are questionable. Most of the marginal records are of single animals. Coatis also commonly are acquired as pets because of their intelligence, inquisitiveness, and the charismatic appeal of the young. However, by their third year, coatis often become quarrelsome and destructive, and often are released back into the wild, where feral breeding populations may become established in more or less suitable habitat (see Kaufmann et al. 1976 for a thorough discussion).

Herein we review the status of the coati in Texas with the following objectives: (1) to review and annotate published historical records of the coati; (2) to present notes and other appropriate documentation concerning recent sightings of coatis made by professional and amateur naturalists as assembled and summarized by the authors; (3) to assess these observations and records with regards to the natural history of the species at the northern limits of its range; and (4) to use this information base to make more accurate forecasts and assessments about the population and conservation status of *N. narica* in the state.

Even though much of the information presented in this publication is not confirmed with "concrete" documentation, and especially in consideration of how little information is available about the coati in Texas, we believe the reported observations have value in suggesting areas of the state where vigilance should be exerted to determine if coati populations are present and/or possibly becoming established. Many natural history reports at the end of the 19th and beginning of the 20th centuries made use of observations and records provided by local landowners or naturalists, and field agents were instructed to seek out such information (for example, see Bailey 1905 and other publications of the *North America Fauna* series published by the U.S. Biological Survey). This was deemed a necessary practice because specimen collecting was scattered and incomplete, especially for many of the more charismatic and rare species, and local residents were considered a valuable resource to fill-in distribution records when actual specimens could not be obtained. As we demonstrate, this situation is similar with regard to the coati in Texas.

Historical Specimen and Sighting Records from the Literature

There are 13 historical accounts in the literature representing 22 reports of coatis in Texas, but only three of these, representing four individuals, have been documented with scientific specimens. Most, but not all, of these records should be regarded as "confirmed" as discussed below.

(1) The first published report of a coati in Texas, and the U. S., was reported in 1905 by Vernon Bailey who documented a specimen collected in 1877 at Brownsville, Cameron County, by J. C. Merrill. In a footnote to the species account, Bailey commented that this individual might have been an imported animal that escaped from captivity. This specimen is deposited in the mammal collection of the U.S. National Museum in Washington, D.C.

(2) The next documented report of a Texas coati did not appear until 61 years later, when Taber (1940) reported a Mexican trapper catching a coati or "chulo" in July 1938, near Eagle Pass in Maverick County on the American side of the Rio Grande. With regard to the provenance of this record, Taber (1940) speculated "that the specimen probably was a pet that had escaped from captivity in Piedras Negras, just across the border, to which place they often are brought for sale to American tourists." A third record also was included in the report by Taber (1940). It was obtained 10 January 1939, some 20 miles below Boquillas in the Dead Horse Mountains of Trans-Pecos Texas in what is likely now Big Bend National Park (BBNP). A game warden had mistaken the skin for an illegally taken river otter and confiscated it from a Mexican trapper before subsequently presenting it to the Texas Cooperative Wildlife Collection (now Biodiversity Research and Teaching Collections) at Texas A&M University (catalogued as number 1412, skin & skull, prepared by R. L. Peterson and P. Goodrum, but missing since November 1966).

(3) A fourth record was reported by Davis (1943): "In late February, 1943, Archie Kelly a resident of Concan, Texas, encountered a large coati, which his three collie dogs had treed, on the Rio Frio, about 40 miles north of Uvalde, Uvalde County." However, 40 miles north of Uvalde is in Real and not Uvalde County and, therefore, we follow Goetze (1998; see below) in listing the record from Real County. The animal was an adult male measuring 142.2 cm (56 inches) in total length. Mr. Kelly was of the opinion that at least one other coati ranged in that locality, which led Davis (1943) to speculate that "this typically Mexican species is definitely extending its range into southern Texas and that it will likely become established." When Taylor and Davis (1947) published the first edition of *The Mammals of Texas*, they described the distribution of the coati as "southern Texas from Brownsville to the Big Bend region of the Trans-Pecos."

(4) Another gap of almost two decades occurs before three additional records were reported by National Park Service personnel in BBNP—one from the U.S. side of the Rio Grande at Boquillas, a second from the Chisos Mountains in 1959, and the third from the Chisos Basin in 1966. These records were characterized as representing "occasional pioneers from Mexico" (Kaufmann et al. 1976).

(5) In the 1960 edition of *The Mammals of Texas*, Davis listed the coati as occurring in five Texas counties—Aransas, Brewster, Cameron, Maverick, and Uvalde counties. The basis for the Aransas county record was not explained in the species account, and the same five county records were listed in the 1966 edition of the book. It has been common practice in the various editions of *The Mammals of Texas* not to give specific details of records, many of which were provided to Davis and subsequent authors by game wardens and other personnel of the Texas Parks and Wildlife Department or by experienced local naturalists.

(6) Halloran (1961) reported two sightings of coatis on the Aransas National Wildlife Refuge in Aransas County: "J. Clark Salyer II and former Refuge Manager James O. Stevensen saw a coati at Mustang Lake April 28, 1939. Another coati was seen on May 15 of the same year." It is possible these two reports represented the source of Davis' 1960 inclusion of Aransas County as part of the coatis range in Texas.

(7) The 1974 edition of *The Mammals of Texas* listed a record from Kerr County, again without including details, thus increasing the number of coati

county records to six. Similarly, the 1988 edition of this book listed the same six counties. To date there has not been any confirmation of the provenance for the Kerr County record.

(8) In August 1975, I. Poglayen reported in a personal communication to John Kaufmann a road-killed coati 50 kilometers (km) west of Abilene in Taylor County (Kaufmann et al. 1976). Given the distance from Abilene to the Mexican border (about 400 km or 240 mi), the authors speculated that "the animal was probably an escaped captive."

(9) Another gap of almost two decades occurred before two records were documented and reported from Victoria County along the Texas coast (Henke and Young 1997). The first sighting occurred on 27 July 1994, in riparian habitat approximately 1 mile southwest of the Guadalupe River and 2.7 miles east of U.S. Highway 77. The second sighting occurred on 29 April 1995, when a coati was seen crossing State Road 175 approximately 2 miles north of the intersection of Highway 77 and State Road 175 (now State Highway 91). These sightings constituted the northernmost occurrence of coatis in the Gulf Prairies and Marshes vegetational area of Texas (Henke and Young 1997). The authors of this report offered the following interpretation of these records: "We believe it unlikely that the observed coatis were escaped pets or zoo specimens. The only zoo in South Texas that has coatis is the Texas Zoo, which is located in Victoria, Texas. They reported no missing specimens. Regional game officials were not aware of individuals keeping or breeding coatis locally." Interestingly, these two records are from the same river-bottom habitat patch that is currently intact.

(10) The 1994 edition of *The Mammals of Texas* by Davis and Schmidly listed nine counties with records of coatis, including the previous six counties mentioned, plus new records of occurrence in Hidalgo, Starr, and Webb counties. Again, the details for the new records were not provided in the publication. The records for Webb County became available to Schmidly in 1982 when he examined two specimens collected in 1901 at Laredo, Webb County, and housed in the mammal collection of the Philadelphia Academy of Natural Sciences. The two Laredo specimens (ANSP 6096 and 6233) were donated to the collection by the Zoological Society of Philadelphia, which means they were zoo animals. ANSP 6096 is a skin with skull and skeleton but no sex indicated. External measurements are: total length, 42 inches (106.7 cm); tail 20.25 inches (51.4 cm); and hind foot 3.5 inches (8.9 cm). ANSP 6233 is a male preserved as a skull and body mount. The skin tags for both read "Texas, Webb County, Laredo" with a date of "February 11, 1901." These animals could have easily been pets purchased across the border in Nuevo Laredo, Mexico, for display at the zoo and then later donated to the collection. Two of us (Schmidly, DJS; and Karges, JK) recall from field-work in the borderlands not far from the U.S./Mexican border that roadside vendors commonly sold wild animals, including coatis, which potentially could constitute a source of transported and subsequently released pet animals.

(11) Jones and Frey (2013), in their report on the mammals of Padre Island National Seashore (PAIS), described four reliable reports of coatis on the island: on the west side of the island adjacent to beach mile 20, and at the entrance to PAIS in the early 1990s; a second report in January 1996 of an individual digging for crabs in the fore-dunes at beach mile 29; and photographs of a group of coatis sighted in 2005 at the Best Western Hotel (14050 South Padre Island Drive) adjacent to Packery Channel at the northern edge of North Padre Island (Nueces County, 4.62 kilometers south and 5.84 kilometers east of Flour Bluff). From these records the authors concluded, "although coatis are probably present within PAIS, their status is unknown."

(12) In the 2004 edition of *The Mammals of Texas*, Schmidly added a record from Real County and described the distribution of the coati in Texas as follows: "they are only known from the southern part of the state, from Brownsville northwest to the Big Bend region of the Trans-Pecos and east to Kerr and Victoria counties." The provenance of the record from Real County came from Goetze (1998). A careful review of his species account for the coati reveals the basis of the record to be Davis' (1943) publication of the record from Uvalde County that now has been determined to have been taken in Real County (see above).

(13) In the most recent edition of *The Mammals of Texas*, Schmidly and Bradley (2016) summarized the distribution of coatis in the state as follows: "His-

torically, they were known from the southern part of the state, from Brownsville northwest to the Big Bend region of the Trans-Pecos and east to Kerr and Victoria counties. Today they are known only from the Big Bend and Padre Island areas." The distribution map for the species (p. 278) encompassed 12 counties: Brewster, Maverick, Kerr, Real, Uvalde, Webb, Victoria, Aransas, Starr, Hidalgo, Cameron, and Nueces. The record from near Abilene in Taylor County was not depicted on the map. From the records presented below in this paper, it is clear that the Lower Rio Grande Valley should have been included as a part of the coati's range in Texas.

OTHER OBSERVATIONS OF COATIS IN TEXAS

We have compiled a number of recent reports of coati sightings in the Big Bend region, in the area between Big Bend and Del Rio, and from several locations in the Lower Rio Grande Valley. These sightings constitute the basis for the information presented in this section of the paper along with some additional reports from personnel of the Texas Parks and Wildlife Department (TPWD) as well as other naturalists working along the Mexico-Texas boundary (see Acknowledgments).

The provenance of the various sightings includes "confirmed" documented records and others that are more tenuous and lack "concrete" supporting information and therefore can only be considered as "anecdotal" sightings or reports. Many of the "anecdotal" accounts come from second-hand reports of sightings made by amateurs without formal experience or training and lack physical evidence (specimens or photographs) or detailed, accurate descriptions. Confirmed sightings are well documented with specimens, photographs, or were made directly by professional naturalists-mammalogists with experience observing coatis.

Big Bend Basin and Big Bend National Park (BBNP)

The observations described below were gathered by Rob Dean (RD) from the official park natural history field observation records that are maintained on-site at BBNP headquarters in Panther Junction. The forms available for this purpose are completed and submitted by individuals who believe they have seen an unusual animal worth documenting; the "record form" includes several categories of information—species observed, observer (with contact information), date and time of observation, weather, and space for comments about the description, behavior, or other pertinent information regarding the sighting.

According to RD, the wildlife sighting forms are available at each visitor center in BBNP and are offered to individuals upon request. National Park Service (NPS) staff often will ask a visitor to fill out a form if the sighting is deemed significant. The completed form is then checked by staff and the reporting party is thanked for contributing to the park wildlife database. For rare or unusual sightings, NPS staff will "quiz" the reporting party to ensure as much of a degree of certainty as possible. The card is then photocopied and placed in a public binder at park headquarters. Both the original and the copy are incorporated into the permanent files of the Park's Science and Resource Management Office. All visitor sightings are considered to be "anecdotal" unless verified by a photograph or by NPS confirmation; sightings by professionals, such as researchers or other experts in the field, are considered to be "confirmed" (personal communication, Raymond Skiles, Wildlife Biologist and Wilderness Coordinator at BBNP, to DJS).

Rob Dean provided copies of the observation records for coatis to DJS, who studied the species observation descriptions and arranged them into three categories—none (no physical description of the animal; simply stated "saw coati"); vague (some mention of defining features but not enough for complete confirmation); and accurate (sufficient detail provided so there can be little doubt of identification). An example of an "accurate" description would be, "pointed face, white eye rings, white across nose, small ears, tail without evident rings; compared to photo of coati, no doubt of identity." An example of a "vague" description would be, "adult crossing road from west to east; walking very slow; tail dragging ground; healthy, full coat." The breakdown of the 40 sightings according to these categories was as follows: "accurate" (8 sightings); "vague" (23 sightings); and "none" (9 sightings).

Thirty-five of the sightings came from within the boundaries of BBNP and five were from just outside the boundary of the park. The latter group included sightings from: U.S. Highway 385, just north of the park entrance (February 2009 and December 2011); north of Study Butte, State Highway 118 (no date); 10 miles north of Terlingua, State Highway 118 (October 1988); and Contrabando Canyon in Big Bend Ranch State Park. Of these only the latter record can be considered as confirmed (see below).

Sightings from inside the park included the following (with dates):

a. Vicinity of Rio Grande Village (7): January 2013; August 2008; December 2006; February 1987; September 1998; May 1978; August 1977.

b. Vicinity of Panther Junction (7): August 2008; November 2002; January 2000; July 1998; April 1987; January 1983; November 1978.

c. The Basin (7): December 2000; November 1999; August 1998; March 1998; January 1998; June 1994; September 1987.

d. Boquillas Canyon (3): March 1986; November 1977; November 1964.

e. Santa Elena Canyon (2): January 2010; November 1998.

f. Castolon (2): March 2006; May 1988.

g. Single locations: Sam Nail Ranch (February 2009); Hot Springs (March 2002); Burro Mesa (February 1999); Lower Canyons (June 1998); Laguna Meadows (May 1989); Dugout Wells (September 2014).

The sightings occurred over a 50-year period (1964–2014) with observations recorded in 20 of those years: 1964 (1 sighting); 1977 (2); 1978 (3); 1983 (1); 1986 (1); 1987 (3); 1988 (2); 1989 (1); 1992 (1); 1994 (1); 1998 (6); 1999 (3); 2000 (2); 2002 (2); 2006 (2); 2008 (2); 2009 (2); 2010 (2); 2011 (1); 2013 (1); and 2014 (1). More than 25% (11 of 40) of the sightings occurred during a three-year period from 1998 to 2000. There have been no sightings since 2014. Combining all of the records, sightings were made in every month of the year according to the following breakdown: November, 7; January, 6; March and September, 5; February, 4; June and December, 3 each; April and August, 2 each; and 1 each in May, July, October. Twenty-seven of the sightings (67%) were made during daylight hours, and all but two of these involved single, solitary individuals. There were two sightings of two animals made in April and February 1987, respectively, from Route 13, 14 miles west of Panther Junction (at 2 p.m.), and from the Rio Grande Village Nature Trail at 8 a.m. A sighting made on 8 August 2008, in a tree at the Rio Grande Village Store, by Imre Karafiath (experienced bird observer in the park) was "confirmed" by an excellent photograph (see Fig. 1).

The coati is regarded as "an occasional migrant, not a resident, with credible reports in BBNP occurring on a less than annual basis" (RD and Raymond Skiles, personal communication).

Sightings in the Trans-Pecos Outside of BBNP

These sightings typically lack precise locality information and dates, much less any form of confirmation such as photos, and therefore are considered anecdotal, even though for the most part they were made by individuals known to be reliable naturalists, unless noted otherwise. These sightings are reported as told to Karges (JK) or Schmidly (DJS), including discussion of the basis for species identification.

Presidio County.—Details of a young coati seen in a roadside boulder field along the state highway adjacent to Big Bend Ranch State Park (BBRSP) were provided by Mark Lockwood, Natural Resource Specialist with TPWD, to Clyde Jones (Texas Tech University) when he was working on mammals in that area. Big Bend Ranch State Park staff have now confirmed the sighting with a photograph from their archives. The animal was seen 1 mi. east of Contrabando Canyon on State Highway 170 on 29 September 2000 (M. Lockwood, TPWD, in litt.). This is the same sighting that was included in the official sighting records maintained at BBNP headquarters (see above).

Michael Huston, a mammalogist in the Department of Biology at Texas State University who studies mammals in the Big Bend region, recently informed DJS (6 September 2016) of coati sightings made by a local resident who works for a bentonite mining company

Figure 1. A White-nosed Coati in a tree at the Rio Grande Village Store in Big Bend National Park, 8 August 2008. Photo courtesy of Imre Karafiath.

in the Terlingua Creek drainage in the southernmost part of the county. According to the report, the man claims to have regularly seen two coatis over the past several years near Agua Fria, which is a spring-fed pool in the upper, generally dry reaches of Terlingua Creek. According to Huston, the man is known to be "very observant with birds and animals."

Lower Canyons of the Big Bend (Brewster, Terrell and Val Verde counties).—Bill Russ, a Texas Parks and Wildlife Department district biologist who lived and worked in Terrell County in the early 1990s, reported coati troop sightings along the Rio Grande made from boating (rafting and canoe) trip participants, and from the descriptions provided both JK and Russ agreed these were coati sightings. There was no indication of how many sightings, how many animals, dates, or any other details or natural history specifics.

Recently, we were informed of two additional sightings of coatis just below Boquillas Canyon. Bonnie McKinney (personal communication to DJS) reported a close-up sighting of a single individual under the cane of a sand bar along the river in 1985. In the fall of 2011, Marcos Paredes, then an NPS river ranger for BBNP, and a party of companions floating the river told JK of seeing multiple coatis on the Coahuilan side of the riverbank at International Water and Boundary Commission (IBWC) mile marker 791 at Rabbit Ears Canyon (Cañón El Guerro). One was photographed and JK has obtained a copy of that image. We consider both of these records to represent "confirmed" sightings.

Pecos County/Crockett County (near the Interstate 10 bridge over the Pecos River).—In the late 1990s, Dean Hendrickson, an ichthyologist at the University of Texas, reported to JK that he saw three adult coatis run across the interstate highway in the vicinity of the Pecos River bridge and valley near Sheffield. Hendrickson has years of field experience in Arizona and the Sierra Madre Occidental in adjacent Chihuahua and Sonora, Mexico, with lots of familiarity and encounters with coatis. For this reason, we consider this to be a "confirmed" sighting.

Crockett County.—Jim Mueller, then on the Biology Department faculty at Sul Ross State University and now the U.S. Fish and Wildlife Service (USFWS) Refuge Zone Biologist based at the Balcones Canyonlands National Wildlife Refuge, told JK that Josh Avey, a Texas Tech graduate student studying mule deer on a hunting ranch east of Iraan in northwest Crockett County, sighted a troop of 12 to 15 coatis while conducting spotlight surveys on the ranch in 1999. The ranch in question had bank-side property with the Pecos River which would lend some credence to a possible corridor for movement up the river.

Terrell County.—At Cedar Station, between Langtry and Dryden, two teenage sons of Pat and Glenn Merkord (friends of JK) reported seeing two coatis feeding at daybreak as they watched from a deer stand near a baited corn feeder. The animals were feeding as it got light enough to see. According to JK, the whole family, including the sons, would have been able to discern between coatis and raccoons, gray foxes, or ringtails but we still consider the record "anecdotal."

Davis Mountains, Jeff Davis County.—Chris Durden (a lepidopterist then in the Biology Department at the University of Texas) told JK that he saw a coati in the upper Davis Mountains Resort region (east of Mt. Livermore) of the Davis Mountains on 21 October 1974. In April 2012, Louis Harveson from the Borderlands Research Institute at Sul Ross State University, as part of a study of mountain lions in the mountains, reported that a coati was found attacked by a lion or coyote after having been caught in one of their traps. According to Jonah Evans (personal communication to DJS), the identification was based on inspecting the fur at an old lion kill site. Recently, on 11–12 June 2016, Chris Mallery, a herpetologist from the University of North Texas camping in Davis Mountains State Park, reported to JK sighting an animal matching the description of a coati on State Highway 118 just outside of the park. Finally, Bryan Hughes, a biologist from Arizona familiar with coatis, informed DJS that he observed a coati on 19 August 2012 just before dark (7:30 pm) on Ranch-to-Market road 1832, in the northern part of the Davis Mountains. With the exception of the latter record, we do not regard any of the records as "confirmed."

Val Verde County.—Multiple anecdotal sightings, covering drainages of the Rio Grande, Pecos and Devils rivers, have been reported to JK from this county. In July 2014, a naturalist's sighting came to JK's attention of a reported solitary coati, followed a few months later by a second sighting from a ranch near Pumpville on tributaries of the Pecos River. The stewards for The Nature Conservancy (Jim and Bea Harrison) at the Dolan Falls Preserve provided documentation that some members of the Texas Ornithological Society's board, while attending a meeting/retreat at the preserve in the late 1990s, saw a coati crossing the road in daylight hours just as they were departing the Devils River State Natural Area. When JK mentioned the sighting to Jim Finegan, former TPWD state natural area staffer and descendent of the original landowner family, he too mentioned casually that he had seen a coati on the natural area but without date or details. Joe Joplin, current TPWD Superintendent of the Devils River State Natural Area, reported that another TPWD employee familiar with coatis from previous Arizona experience told him about sighting a juvenile coati crossing Dolan Creek Road near the old Fawcett/Finegan Ranch headquarters at 6:55 a.m. on 21 April 2015. Rob Klockman, a graduate of the Department of Wildlife and Fisheries Sciences at Texas A&M University, reported two additional sightings from the county—in May 2005, from Loma Alta on U.S. Highway 277; and in May 2010 on U.S. Highway 90 just west of Langtry. Finally, Nathan Wells, another naturalist friend of JK, reported sighting a juvenile coati on 4 July 2015 near a road-cut along U.S. Highway 277 north of Del Rio.

Observations in South Texas and the Lower Rio Grande Valley

Fewer sightings have been reported in southern Texas than in the Big Bend and regions to the east along the border with Mexico, but the number of sightings has been increasing recently, including a recent capture of a coati and its subsequent release by TPWD officials. These reports are documented as communicated by various individuals to JK or DJS and unless noted otherwise are regarded to be anecdotal sightings.

Cameron County.—Tony Henehan, currently a TPWD biologist in Weslaco, reported to JK that a former TPWD biologist told him of sighting a coati crossing a road within the Las Palomas Wildlife Management Area along the Arroyo Colorado at the Arroyo Colorado Unit north of Rio Hondo. No dates or other details concerning the sighting were recorded.

Hidalgo County.—Javier de Leon, TPWD Superintendent of the Estero Llano Grande State Park, told JK that in 2011 or 2012 (he could not be sure of the specific year) a maintenance worker reported 4–5 coatis on TPWD property a few miles east of the state park. The employee, who the Superintendent claimed knew the difference between coatis, raccoons, or opossums, saw the animals among tepeguaje and anacua trees within the IBWC floodway. Also, in 2012, Javier de Leon reported that a Bensen-Rio Grande Valley State Park volunteer told him that maintenance workers at Benson Grove RV Park (approximately 3 mi. directly north of the state park) captured a coati while trying to trap nuisance opossums, describing the animal as possessing "a long nose and long brown tail with rings." That animal was released unbeknownst to park staff at Bentsen-Rio Grande Valley State Park, southwest of Mission (de Leon in litt.).

Jonah Evans, the state mammalogist with TPWD, told DJS about a coati that was captured in a residential backyard in Alamo, Hidalgo County, on 17 April 2016 by municipal animal control personnel. The animal was brought to the Gladys Porter Zoo in Brownsville where it lived for some time before TPWD personnel became aware of the circumstances. TPWD officials later released the animal at the Anacua Unit of Las Palomas Wildlife Management Area near Santa Maria, Cameron County, on 26 July 2016. This record is regarded as a "confirmed" sighting.

Maverick County.—Kathy Pine, at the time a staff member of The Nature Conservancy in Houston, told JK in the early 2000s that while spending time on a ranch in this county, she saw of troop of coatis. She was emphatic they were coatis.

McMullen County (Tilden).—In July 1994, Rob Klockman (see above) reported seeing a coati at Tilden, which is the county seat and lies at the intersection of State Highways 16 and 72 in the north-central part of the county.

Western Willacy County/Eastern Hidalgo County.—Tony Henehan, a TPWD biologist responsible for Wildlife Management Areas, reported that a scorched/road-killed coati carcass was obtained following "the burning of a sugar cane field in Willacy County a couple of miles north of La Villa, Texas." The specimen was salvaged and will be deposited in an academic museum research collection. The animal was reported as coming from Willacy County, although La Villa is in eastern Hidalgo County near the county line. Although this is considered by us to represent a "confirmed" record, the wildlife technician who assisted with the recovery of the specimen unfortunately could not recall the exact year of the discovery, only that it was in either the month of August or September.

Webb County.—Jim Goetze, a mammalogist in the Science Department at Laredo Community College, reported to DJS (9 September 2016) that a live coati is currently on display at the Lamar Bruni Vergara Environmental Science Center on the campus at the community college. According to the report, the animal (a male) was procured from a family who had imported and raised it for at least two years. Also, Goetze reported to DJS that he receives occasional reports of coati sightings from U. S. Border Patrol personnel and hunters, but that in 21 years of biological work in Webb County and the surrounding area he has never seen a coati.

SURVEYS CONDUCTED BY PROFESSIONAL MAMMALOGISTS WITHIN THE RANGE OF COATIS

Several long-term field surveys of mammals have been conducted by professional mammalogists working in the geographic regions where many of the aforementioned sightings were made. These studies involved extensive trapping (cage traps and in some instances camera traps) for carnivores as well as day-light and nocturnal excursions to search for mammals. These are listed here along with appropriate comments regarding the presence of coatis in the survey areas. The results of these studies have been reported in scientific publications, agency reports, or made as personal communications to DJS.

Big Bend National Park (1974–1976).—David Schmidly and Robert Ditton (1976), along with their graduate students, spent two years assessing riparian sites in BBNP. They visited 64 separate sites along the river between the park boundaries, traveling by vehicle along the River Road and spent dozens of days and nights "river-rafting" in Santa Elena, Mariscal, and Boquillas canyons. Their efforts included trapping for both small and large mammals as well as day-light and night-time observations for large mammals. They never saw a coati or received a report of one in the park during this time frame. Both Rio Grande Village and Santa Elena Canyon, where coati sightings were subsequently made, were visited and sampled by them on multiple occasions.

Harte Ranch, Big Bend National Park, Brewster County (1991–1993).—Clyde Jones, Frank Yancey, and Richard Manning conducted an extensive field survey of mammals in this newly acquired parcel (57,000 acres) along the northern boundary of the Park. Despite considerable effort to capture and observe carnivores, they never captured, sighted nor received any reports of coatis in the area (Jones et al. 1993; Yancey et al. 2006).

Big Bend Ranch State Park, BBRSP (1994–1995).—This large state park (one of the largest state-managed land areas in North America) is located in southeastern Presidio County just west of BBNP. Frank Yancey and Clyde Jones collected and observed mammals at more than 300 localities throughout the state park. The published report (see Yancey 1997) included this statement about coatis: "Local residents have reported the occurrence of *N. narica* in BBRSP, but these reports are unsubstantiated. The species prefers woodlands and rocky areas…both present in BBRSP, so an occasional individual may wander into the park from Mexico." The incidental observation of a coati was confirmed by a photograph taken after the Yancey publication (discussed earlier).

Chinati Mountains State Natural Area, Presidio County (2002–2010).—Clyde Jones, his students, and colleagues surveyed mammals in this area over a period of almost a decade. Located just up river and northwest of BBRSP, they collected throughout the mountains, but found no evidence of coatis and made no mention of them in their published report (Jones et al. 2011).

Davis Mountains, Jeff Davis County (1998–2002).—For four years, Robert DeBaca (2008) surveyed mammals in the Davis Mountains, including The Nature Conservancy's (TNC) Davis Mountains Preserve, Davis Mountains State Park, Balmorhea State Park as well as Phantom Spring and Sandia Springs Preserve. He also examined museum and literature records and found no reports of coatis in the area. As explained above, there have been a few unconfirmed sightings of coatis in the Davis Mountains proper since the study by DeBaca. A camera trap study on the TNC's Davis Mountain Preserve by staff of the Borderlands Research Institute at Sul Ross State University apparently has not produced any sightings of coati.

Indio Mountains Research Station, Hudspeth County (1993–present).—The University of Texas at El Paso (UTEP) has maintained a field station since 1993 in these mountains, which are about 40 miles southwest of Van Horn. Jerry Johnson, Professor of Biology at UTEP and a long-time colleague of DJS, provided these comments to DJS about coatis in the region: "I have been actively engaged in field work in that area since 1973 during both daylight and nighttime hours, and have never seen a live or road-killed coati, nor has any local ever mentioned seeing them around here".

Amistad National Recreation Area, Val Verde County (1976–1977; 2006–2007).— Several extensive surveys of mammals in this area did not produce any records or sightings of coatis. Robert Ditton and DJS (1977) surveyed selected sites with high human activity, collecting both small and large mammals as well as conducting daytime and nighttime observational surveys. J. M. Mueller and his students at Sul Ross State University conducted an extensive trapping survey of mammals in the Recreation Area in 2006–2007, and they did not report any sign of coatis in the area (Bahm et al. 2008).

Devil's River State Natural Area (2001, north unit).— Brant and Dowler (2001) surveyed mammals, including mesocarnivores, at the Natural Area for several years and did not sight or report any records of coatis.

Edwards Plateau (1989–1994).—Jim Goetze (1998) actively collected and searched for mammals on the Edwards Plateau over a 5-year period and never recorded any sightings of coati in the area. His published report included a reference to the record from the border of Uvalde and Real County published by W. B. Davis in 1943 (see above).

CAMERA TRAP SURVEYS

In recent years, camera traps have become an important tool in wildlife research and management, especially for surveying carnivore species (Foster and Harmsen 2012). Camera traps provide tools to more thoroughly survey species over a larger area than may be possible with other survey techniques, particularly in remote areas with rough terrain (Silveira et al. 2003). We have become aware of a number of camera trap surveys in areas where coati sightings have been reported and provide details below.

Dennison et al. (2016) placed paired trail cameras at 38 locations throughout the Davis Mountains on TNC's Davis Mountain Preserve and two adjacent private ranches in Jeff Davis County. The habitat is very similar to that preferred by coatis at the northern edge of their range (montane evergreen forests, woodlands and savannah, and riparian gallery woodlands). Cameras were activated at each site for a minimum of three months between June 2012 and March 2013. Feral hogs (*Sus scrofa*) and gray fox (*Urocyon cinereoargenteus*) were the most widespread species, each observed at 33 of 38 camera locations. Mountain lions (*Puma concolor*) were observed at 22 of the 38 camera locations. Mesocarnivores recorded included coyote (*Canis latrans*), skunk (no species designation), bobcat (*Lynx rufus*), raccoon (*Procyon lotor*), and ringtail (*Bassariscus astutus*). There were no camera observations of coatis.

James Eddy (personal communication to DJS), a graduate research assistant in the Borderlands Research Institute at Sul Ross State University, placed 10 cameras over about 600 acres at Elephant Mountain Wildlife Management area from April 2015 until August 2016. This area is about 26 miles south of Alpine in Brewster County. The objective of the project was to study quail, but several mesocarnivores, including badger (*Taxidea taxus*), black bear (*Ursus americanus*), bobcat, coyote, gray fox, raccoon, and skunk (no species given), were detected but no coatis.

Raymond Willis (personal communication with DJS), Director of the Dalquest Research Station of Midwestern State University, and some of his students have placed 20 camera traps on Terlingua Ranch in southern Presidio and Brewster counties since 2013. This 3,000-acre property is located on the northeast border of BBRSP about 20 miles from the Mexican border. Their cameras have produced regular sightings of mountain lion, coyote, raccoon, bobcat, gray fox, a few ringtails, and one or two black bear but no sightings of coati.

Michael Huston (personal communication with DJS) and his students in the Wildlife Biology program at Texas State University have had an array of 8 camera traps in the canyons on the west side of the Christmas Mountains just north of BBNP since February of 2015. Their traps also produced no sightings of coatis.

In 2014 and 2015, Skyler Stevens (2016), a graduate student in the Department of Natural Resources Management at Sul Ross University, conducted an extensive camera trap study in BBNP. Fifty-eight cameras were deployed over a 450 square kilometer grid covering the Chisos Mountains, parts of the Sierra Quemada, Burro Mesa, and some of the flats north and east of the Chisos. The purpose of the project was to document occurrences of mountain lions and their prey. The cameras were placed in areas expected to capture animal movement such as washes, saddles in ridges, canyons, and at convergences of game trails. Over 14,000 trap nights produced 500,000 pictures that were sorted and analyzed. The results produced more captures of mesocarnivores than big cats; among the procyonids, a few raccoons and several ringtails were noted but coatis were never observed, not even a suspicious photograph. In addition to the Sul Ross project, BBNP has maintained six cameras in diverse habitats throughout the part for six years with no sightings of coatis (Raymond Skiles personal communication to DJS).

Marc Cancellare (personal communication to DJS), a graduate student with Richard Kazmaier at West Texas A&M University, placed 16 cameras at Black Gap Wildlife Management Area in southeastern Brewster County from September 2014 to October 2015 (total of 6003 camera days and 360,934 images) and, to date, has not recorded any photos of coatis. Over the same time-frame, camera traps also were placed on the privately-owned Buckhollow Ranch (Real and Uvalde counties) and TNC's Independence Creek Preserve (Terrell County) with no reported observations of coatis at either site.

Dowler et al. (2016) made extensive use of camera traps to sample mesocarnivores on the recently acquired Dan A. Hughes Unit at the Devil's River State Natural Area, located 35–45 km north of Del Rio in Val Verde County, between February 2013 and August 2015. Twenty-two camera traps were placed along dry washes or in areas where animals were thought to be passing between February 2013 and August 2015 (total of 3,547 camera days). Also, camera traps were accompanied by 996 cage-trap nights using Tomahawk Live Traps. Mammals recorded by the camera traps included: opossum (*Didelphis virginiana*), jackrabbit (*Lepus californicus*), porcupine (*Erethizon dorsatum*), gray fox, bobcat, mountain lion, hog-nosed skunk (*Conepatus leuconotus*), ringtail, and raccoon. There were no captures or photographs of coatis made during this period even though previous anecdotal sightings of coatis existed for this area (see above).

Mike Tewes (personal communication to DJS), a Research Professor at the Caesar Kleberg Wildlife Research Institute at Texas A&M Kingsville, has conducted extensive camera trapping and observation studies for ocelots (*Felis pardalis*) in the South Texas brushlands and Lower Rio Grande Valley since 1985. He has never encountered a coati "after probably 50,000 cage-trap nights and over 50,000 camera nights in south Texas." He went on to comment that he has trapped and collared coatis in northeast Mexico as well as photographed them in different locations. Elaborating further, Tewes told DJS he talked with Mr. Jimmy McAllen, who owns several large ranches just north of the Rio Grande Valley, and who keeps track of wildlife oddities or unusual sightings. McAllen said he had never found a coati, but that he did know of one person who had released a captive animal.

Discussion and Recommendations

What can be made of all of this—a handful of published historical records over a 139 year period, several of which appear to represent "escaped pets," with a few recent confirmed sightings; numerous "anecdotal" sightings over decades from scattered areas along the Texas border with Mexico but mostly adjacent to the Rio Grande and Devils River and recently from the Lower Rio Grande Valley; the absence of any coati sightings during extensive field collecting surveys made over the past 40 years by professional mammalogists; and a complete lack of coati photos from seven camera trap studies conducted over the past five years in areas where coatis have been incidentally sighted during that time?

Although much of the documentation assembled and discussed herein is "anecdotal" and not accompanied by "hard evidence" of occurrence, it does provide a basis for some useful interpretations that can be refined over time as more detailed and accurate information becomes available. Some studies advocate use of anecdotal data, whereas others demand more stringent evidentiary standards such as only accepting records verified by physical evidence, at least for rare or elusive species. Frey et al. (2013) demonstrated that occurrence datasets based on anecdotal records can be useful when inferring species distributions, provided that data are used only for easily-identifiable species and are based on robust modeling methods. In the American Southwest (New Mexico and Arizona), they were able to demonstrate that the predicted distribution of the coati based on anecdotal occurrence records was similar to datasets that only included physical occurrence.

Coatis are highly distinctive in appearance and behavior and are unlikely to be misidentified by careful or knowledgeable observers. Because coatis are diurnal and mostly active during the day, anecdotal reports are more likely to represent accurate identifications than would be expected for carnivore species that typically are nocturnal (e.g., opossums, raccoons, and ringtails). In addition, because coatis are an unusual and relatively rare species in Texas, encounters are likely to be remembered. For these reasons, we propose that many sightings of coatis in Texas, as documented in this paper, represent valid observations and provide useful information. Although some of these observation records may be considered doubtful, others are definitely reliable and are too numerous to ignore. Some of the included sight records undoubtedly represent exceptional wanderings by wild individuals, most likely adult males, but many of these animals appear to be released or escaped captives.

Fortunately, there is a good knowledge of the natural history of the coati at the northern margin of its range in Arizona where there are resident, breeding populations (see Kaufmann et al. 1976 for details). This provides a useful background for interpreting the status of the species in Texas.

Observations of coatis in Texas are scattered over time and highly periodic. Gaps in observations, representing spans of several years and even decades, are evident. Records, represented by specimens, photographs, documented sightings, and recent anecdotal sightings included in this paper, are now available from 19 counties in the state including 13 counties with "confirmed" records (see Fig. 2). With a few exceptions, most of the sightings have been made along the Texas-Mexico borderlands (within 100 miles of the border) from Big Bend east to Del Rio and south to Brownsville.

Most of the documented sightings in Texas have been of single animals. Sightings of multiple individuals or troops are among the most poorly documented of the records. Such a pattern would suggest the observations primarily represent marginal records of occasional wanderers and released or escaped pets. Of the scattered records from Texas, only those from the Big Bend's Rio Grande area and perhaps from the Devils River basin likely represent true wanderers from Mexico. These two rivers, together with the Pecos River, represent possible dispersal corridors for wandering coatis from Mexico to make their way further inland as they are known to use river and stream corridors as well as springs.

Unlike Arizona, where coatis have been resident year round for over a century and exist as breeding populations, there is no evidence that a breeding population of coatis has been established or exists in Texas. While young have been sighted, they do not appear in troops as would be expected if a breeding population had been established—coatis breed annually so mixed age populations would be expected. Hundreds of troop sightings, including adult females with young males and females, are available from Arizona. In Arizona most mating apparently takes place in April, the bands break up before the young are born in June, and the females with their new litters re-gather with the yearlings of both sexes in August.

Our observations are consistent with the interpretation of Fred Gehlbach (1981), who spent several years observing coatis along the U.S.-Mexico Borderlands, and concluded "all of the Texas records represented solitary, wandering males or escaped and released pets and that there were no family bands of this species within a hundred miles of the Texas border." This interpretation is reinforced by the fact that numerous long-term surveys by professional mammalogists, as well as several recently conducted camera trap studies,

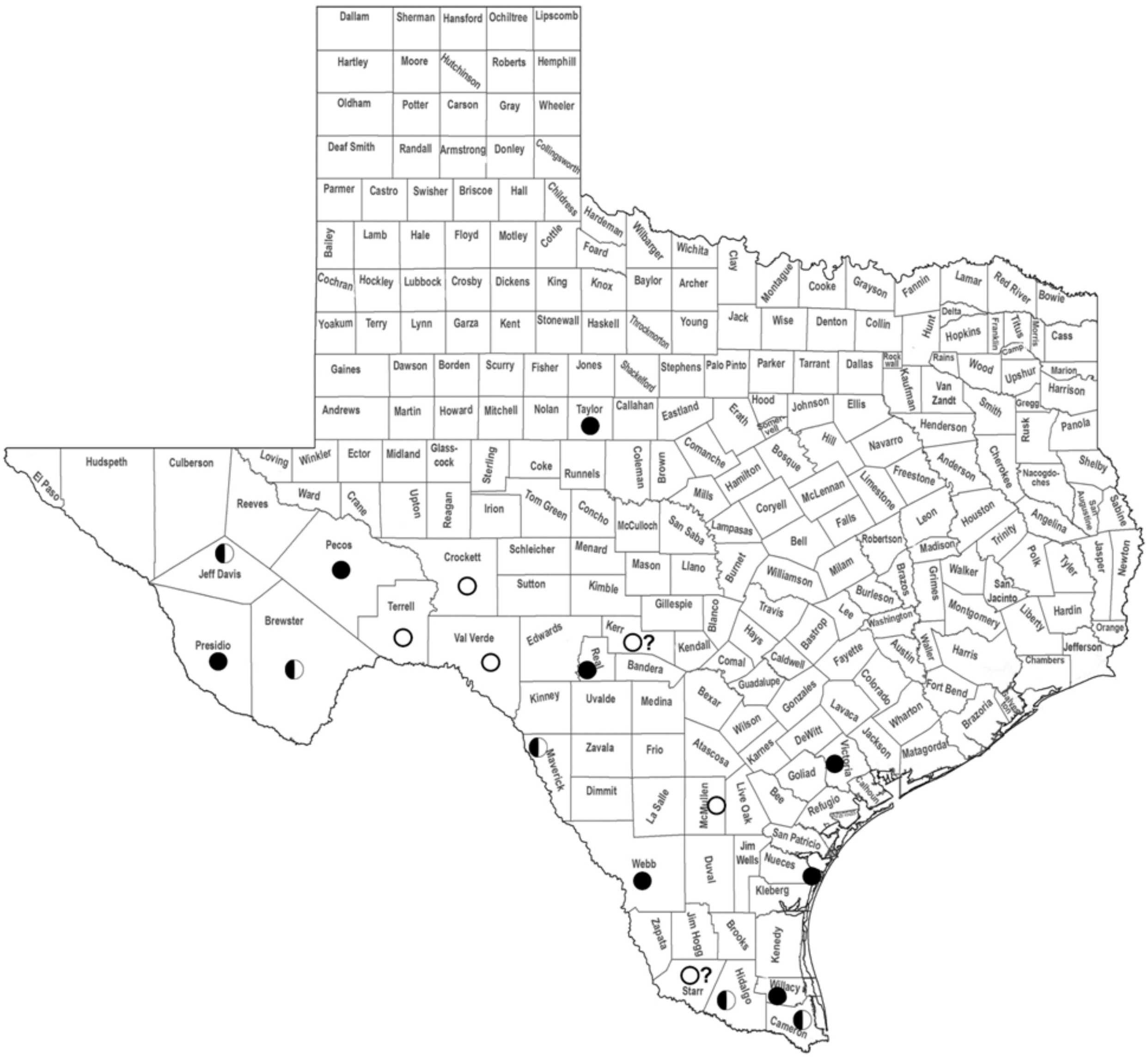

Figure 2. County records of coatis in Texas. Closed circles represent counties with "confirmed records"; open circles represent counties with only "anecdotal" sightings; open circles followed by a question-mark are from counties with questionable documentation; half-filled circles represent counties with both "confirmed" and "anecdotal" records.

in the areas where many of the confirmed/anecdotal sightings have been reported failed to document any evidence of established coati populations. Perhaps in some of the areas where clusters of sightings have been made over decades, such as BBNP, rare populations have temporarily flourished beyond their normal breeding range but did not persist in marginal habitat and likely were killed off by periods of drought and cold that eliminated them in relatively short intervals.

Surveys from southeastern Arizona and southwestern New Mexico show that the distribution of coatis corresponds almost exactly to that of the Encinal and Mexican Oak-Pine Woodland as mapped by Brown (1973). They also are known from lower elevations in cottonwood-sycamore-willow associations near streams and springs, and marginal records have been recorded in Chihuahuan Desert scrub and grassland habitat and in riparian areas surrounded by desert.

This pattern matches very well with the observations from BBNP where the most numerous sightings were in Rio Grande Village (cottonwood-willow), the Basin (pinyon-oak-juniper), and the vicinity of Panther Junction (desert scrub habitat).

Several of the sightings in BBNP were from places popular with campground campers along the River Road adjacent to the Rio Grande (e.g., Rio Grande Village, Santa Elena Canyon, Castolon, and Hot Springs). Gehlbach (1981) noted that solitary coatis are prone to beg marshmallows and raid garbage cans at night. Also, at such places he noted they often shift from diurnal to nocturnal habits in apparent response to nocturnally unattended trash cans and diurnal campground hassle. He reported at Chiricahua National Monument seeing a coati "table" seven campers in five seconds one evening.

The source population for Texas coatis is most likely the mountains along the northern border of the Mexican states of Coahuila, Nuevo Leon, and Tamaulipas. Coatis have not been documented east of the Rio Grande in New Mexico nor or there any observations along the Texas border from El Paso to Presidio making it highly unlikely that animals from Arizona and western Chihuahua, Mexico, would ever disperse into Texas.

Baker (1956) in his study of Coahuila, Mexico, mammals wrote that he had "received no definite records of the coati along the Rio Grande in Coahuila." However, McKinney and Villalobos (2004) and McKinney (2012), who have conducted wildlife studies for almost 20 years in the Maderas del Carmen/Sierra del Carmen mountains of northern Coahuila on the border with BBNP, are confident that the coati has become established there through recent range expansions and is now a permanent resident. McKinney and her associates have made numerous sightings of coatis, including several troops in the piñon-juniper, pine-oak, and fir woodlands from 4,500 to 6,000 feet, always in or near riparian areas, going back to 2002 and 2003. They consider the coati to be a rare resident of the mountains; significantly all of their sightings were of groups and not solitary individuals. According to McKinney (personal communication to DJS): "I am 100 percent confident this is a resident breeding population that is not large but widely scattered over the landscape,… and I suspect that the coati people have seen in the Big Bend area are for sure from the Carmens."

The Rio Grande, although probably a barrier to small mammals where it flows through deep canyons along part of the northern boundary of Coahuila, seems not to bar the passage of most mammals where the river's banks are low (Baker 1956; Schmidly 1977). We have confirmed sightings from both sides of the Rio Grande in the Boquillas region of BBNP clearly supporting the interpretation that coatis are able to cross the river.

In Chihuahua, coatis are known only from the western Sierras where they undoubtedly are a source population for Arizona and New Mexico, but they have not been recorded from the mountains nearest to the border of Texas (Anderson 1972). Similarly, the nearest mountains to the Pecos and Devils rivers, east of the Big Bend area, with possible coati habitat are the Serranias del Burro in northern Coahuila. Coatis have not been recorded there although no extensive mammal survey has ever been attempted from that mountain range which represents the northernmost sky island of the Sierra Madre Oriental in the state of Coahuila, Mexico. The area does include habitat similar to that in the Sierra del Carmen/Maderas del Carmen where coatis are known to occur.

Source populations for coati in south Texas and the lower Rio Grande Valley would likely come from isolated mountain ranges near the border in the Mexican states of Nuevo Leon or Tamaulipas. In Tamaulipas, just below Brownsville, coatis have been recorded from the San Carlos Mountains, about 200 km (120 miles) south of the Texas border (Schmidly and Hendricks 1984), and these mountains could be a potential source for animals to wander north and enter the lower Rio Grande Valley. But, an even more likely source population would be the Sierra Picachos between Roma, Texas, and Monterrey, Nuevo Leon. A Mexican biologist and colleague of JK, Enrique Guadarrama, who has been studying black bears in these mountains, reports that coatis are common there which would make those mountains a much more likely proximal source of wandering animals (single males or troops) to enter the western Lower Rio Grande Valley. The Sierra Picachos are only 90 km (56 miles) from Roma, Texas.

The conservation status of the coati in Texas remains enigmatic. The species was listed as state endangered in Texas in 1993 but has since been downgraded to threatened by TPWD and ranked as an "S2" species. Such a ranking is used to designate imperiled populations at high risk of extinction, or elimination due to very restricted range, very few populations, steep declines, or other factors. The coati is listed as a Species of Greatest Conservation Need (SGCN) in Texas according to the Texas Conservation Plan (TCAP) [http://tpwd.texas.gov/land/tcap/sgcn.phtml] for the Chihuahuan Desert, Arizona-New Mexico Mountains, Edwards Plateau, and South Texas Plains ecoregions, and therefore warrants conservation attention and additional information on status and distribution in those areas.

Coatis would be seriously impacted by degradation of riparian woodland habitat in these areas because they require a sizeable area of habitat to maintain a viable population (Schmidly 2002). Given their tenuous status, John H. Kaufmann, who at one time was the coordinator of the Coati Study Project in the United States, recommended complete legal protection for these animals although no official listing was ever made and the species is not currently included on the endangered species list by the USFWS (Kaufmann 1987). In New Mexico, the coati is an endangered species, under legal protection, and it may not be hunted or trapped. In Arizona, it is considered a nongame mammal and may be taken during an open season, with a bag limit of one per calendar year. In Mexico it is not considered endangered and there is practically no information on the status of its populations even where it is abundant (Ceballos 2014). In northern Mexico, hunting apparently has caused significant reductions in their populations (Gompper 1995).

Additional study and information will be required in order to better predict the conservation status and long-term viability of the species in Texas. A more formal system for documenting and following up on verified sightings should be developed and implemented. Observers should be encouraged to document incidents with photography and salvaged specimens (for road-killed animals) with accurate localities and circumstances of the sightings. The same system should be put in place for observers utilizing camera traps. State agencies (TPWD, State Land Office), NGOs (The Nature Conservancy and Audubon Society), academic institutions (perhaps through the Texas Mammal Society) and interested landowners could cooperate in such efforts. If a troop of coatis is documented, professional, experienced naturalists should be funded to conduct ecological and behavioral studies that might include radio-collaring of individuals, obtaining tissue samples through non-lethal means to conduct genetic assessments of population structure and taxonomic affinity, and gathering other basic natural history information (food habits, reproductive patterns, movements, etc.).

The success of the El Carmen—Big Bend Conservation Corridor project (see McKinney 2012) offers much hope for the eventual establishment of a permanent, breeding coati population in Texas. This program is a cooperative effort by the U. S. and Mexican governments, private conservation groups and area ranchers to provide and protect a corridor on both sides of the Rio Grande in the Big Bend region that will allow wildlife to move freely within an intact ecosystem (McKinney 2006). Currently, the corridor includes over 400,000 acres of land in the Sierra del Carmen and Maderas del Carmen and 47,000 acres of "wilderness" with no development at all along the Rio Grande. The corridor from Mexico literally comes across the border at the eastern end of Boquillas Canyon and follows the big valley to the north. The American black bear (*Ursus americanus*) population has increased substantially on both sides of the border as a result of this habitat protection plan, and presently efforts are underway to re-establish bighorn sheep (*Ovis canadensis*), mule deer (*Odocoileus hemionus*), and pronghorn (*Antilocapra americana*). According to McKinney (email communication to DJS) the coati is also considered a critical species in their project. This effort could eventually result in the establishment of a viable, sustainable coati population in the Chisos Mountains of the Big Bend region.

Coatis wandering north along regions to the east of the Big Bend and the lower Rio Grande Valley would have to cross a broad area of desert-scrub habitat to become established in Texas, and while a few of them may continue to wander into this region along riparian woodland corridors they probably will not be able to permanently occupy such marginal habitat. However, there could be some corridor potential in the Lower Rio Grande Valley, where recent and numerous sightings have been reported, from adjacent source populations in Tamaulipas and Nuevo Leon in Mexico and the units of protected TPWD and USFWS lands, as well as Audubon Texas' Sabal Palm Sanctuary and The Nature Conservancy's Southmost Preserve.

Finally, there is one other aspect of the natural history of the coati—subspecific assignment of populations—that also requires clarification. Historically, Bailey (1905) assigned Texas specimens to the subspecies *N. n. yucatanica* (Allen 1904; type locality, Chichen Itza, Yucatan, Mexico) and that assignment remained in effect until Goldman (1942) described *N. n. tamaulipensis* (type locality, Cerro de la Silla, near Monterrey, Nuevo Leon, Mexico) and assigned the Texas populations to that subspecies. Specimens from Arizona and New Mexico were assigned to the subspecies *N. n. pallida* (type locality, Guadalupe y Calvo, Chihuahua, Mexico) that also was described by Allen (1904). All of these subspecies were combined in 1951 by Phillip Hershkovitz into a single subspecies, *N. n. molaris* (type locality, Manzanillo, Colima, Mexico), which had been described in 1902 by Merriam and had taxonomic priority. Hershkovitz's taxonomic assignment was based solely on color, reflecting the presence of a major shift in color across the Isthmus of Tehuantepec. Hoffmeister (1986) called for a detailed analysis, employing cranial features as well as color and other characters, to clarify the relationships of coati populations. We agree with Hoffmeister's assessment but also would suggest a genetic analysis should be added to better determine if the Arizona and Texas populations are part of the same population or represent distinct population clades.

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Ecological Distribution and Foraging Activity of the Ghost-faced Bat (*Mormoops megalophylla*) in Big Bend Ranch State Park, Texas

Franklin D. Yancey, II

Abstract

Data from a two and one-half year study of bats in Big Bend Ranch State Park (BBRSP), Texas, along with those from subsequent monitoring work were used to ascertain the distribution of the Ghost-faced Bat (*Mormoops megalophylla*) within the park. In addition, habitat affinities and periods of foraging activities were assessed. A GIS-generated map of the distribution of *Mormoops megalophylla* within BBRSP indicated that this species was relatively widespread throughout BBRSP. *Mormoops megalophylla* was found to occur in both flatlands and canyonlands, but favored the latter. In addition, the Ghost-faced Bat was found to prefer riparian areas with little or no vegetation, as opposed to areas with dense vegetation. Females appear to reside in the park only during late spring and summer, whereas adult males apparently are absent from the area throughout the year. Prey items of *M. megalophylla* consisted mostly of lepidopterans, with coleopterans, dipterans, hemipterans, homopterans, and neuropterans being consumed at a much lesser degree. Individuals were found to forage above standing or slow-moving water between 2154 h and 0700 h, but were most active the first two hours following sunset.

Key words: Big Bend Ranch State Park, diet, distribution, foraging activity, Ghost-faced Bat, habitat, *Mormoops megalophylla*, Texas

Introduction

The Ghost-faced Bat (*Mormoops megalophylla*) ranges from northern South America, northward through parts of Central America, on up to northern Mexico. It reaches its northern limits in the extreme southern United States, where it is known only from southern Arizona and southwestern Texas (Beatty 1955; Smith 1972; Hall 1981; Hoffmeister 1986; Rezsutek and Cameron 1993). Although *Mormoops megalophylla* is not particularly uncommon throughout much of its range, data on the life history of this species are nearly unknown. For example, Rezsutek and Cameron (1993) summarized the biology of *M. megalophylla* throughout its range, but presented little information on its habitat affinities and foraging patterns and activities. Yancey (1997) made some general comments regarding habitat preferences, but did not quantify foraging habitat affinities. Bateman and Vaughan (1974) presented some general information on mormoopid periods of activity, however most of their observations were of bats traveling to and from foraging areas. This study details the distribution of *M. megalophylla* within Big Bend Ranch State Park (BBRSP), Texas, and provides insight into the habitat affinities and foraging activities of this poorly understood bat.

MATERIALS AND METHODS

This study was conducted entirely within the boundaries of BBRSP, which lies within the Trans-Pecos region of the extreme western part of Texas (see Fig. 1). The park is located just north of the Mexican state of Chihuahua, from which it is separated by the Rio Grande. The town of Lajitas and Big Bend National Park occur to the east, and the city of Presidio is found to the west. The major portion of BBRSP is situated in the southeast corner of Presidio County, whereas a small part of the park occurs in the southwest corner of Brewster County. Initially the park consisted of approximately 113,000 ha (Alloway 1995), but with land acquisitions over the past 20 years the park has increased in size to more than 125,000 ha (M. W. Lockwood personal communication; unreferenced). Most of the park is composed of scrub habitat dominated by typical Chihuahuan Desert plants such as Creosote-bush (*Larrea tridentata*), acacia (*Acacia* sp.), Lechuguilla (*Agave lechuguilla*), and a variety of cacti (*Echinocereus* sp., *Mammalaria* sp., *Opuntia* sp.). However, with more than 100 springs and several permanent streams, the park also contains many localities with riparian habitat dominated by cottonwoods (*Populus* sp.), willows (*Salix* sp.), and seepwillows (*Baccharis* sp.). These numerous water-associated habitats within the park were the focal points for sampling bats during this study.

This study was done concurrently with a general assessment of the mammalian fauna of BBRSP that occurred from 1994 to 1996 (see Yancey 1997), with subsequent follow-up field work conducted in 2015. Bats were sampled using mist nets as outlined by Kunz and Kurta (1988) and Kunz et al. (1996). At dusk, nets were strung across selected springs, streams, stock tanks, or other small bodies of water that occur throughout BBRSP, and monitored throughout the night. Each night that an individual net was set and monitored was considered one net-night. Localities sampled varied by the density of riparian vegetation in the immediate area, as well as the surrounding topography. Vegetation was considered closed if it formed a closed canopy or was dense and tall enough to obstruct the edges of the body of water at the net site. If the immediate vegetation was short and sparse to the point where the net was unobstructed and/or no canopy formed, it was considered open. Localities were labeled as canyonlands if the site was within a canyon greater than 5 m deep, whereas they were considered flatlands if the site was situated on level terrain or within a shallow arroyo.

Localities of sample sites were obtained with a Magellan hand-held global positioning system (GPS). Each individual captured was measured, sexed, and examined for reproductive condition, and when feasible, time of capture was noted. Following collection of data, bats were released, or, in some instances, retained as voucher specimens; those specimens are deposited in the Natural Science Research Laboratory of the Museum of Texas Tech University. Stomachs (along with contents) of some bats were collected and analyzed following Whitaker (1988). Data were recorded in an Excel-based database and downloaded into ArcView GIS software for generation of the distribution map.

Habitat associations were analyzed by calculating chi-square values and then plotting those values against a resampled distribution obtained at 1,000 iterations (Bruce 1992; Simon 1992). The alpha level was set at 0.05. Habitat variables (vegetation density and topography) were analyzed independently and combined. Because there were only two treatment groups for each independent test, there was no need for further analysis if a significant difference was noted. Because there were four treatment groups in the combined variable test, if a significant difference was detected then a multiple comparison chi-square test was used to determine which habitats differed from one another (Glantz 1992). The alpha level of rejection for this test was determined using the Bonferroni inequality formula,

$$\alpha = \alpha_x^2 / k$$

where α_x^2 is the original alpha level, and k is the number of individual treatment groups considered in the original test (Glantz 1992). Therefore, for the multi-comparison test used in this study the alpha level was 0.0125. A binomial test against equal proportions with an alpha level of 0.05 was used to determine peak period of activity (Dowdy and Wearden 1991).

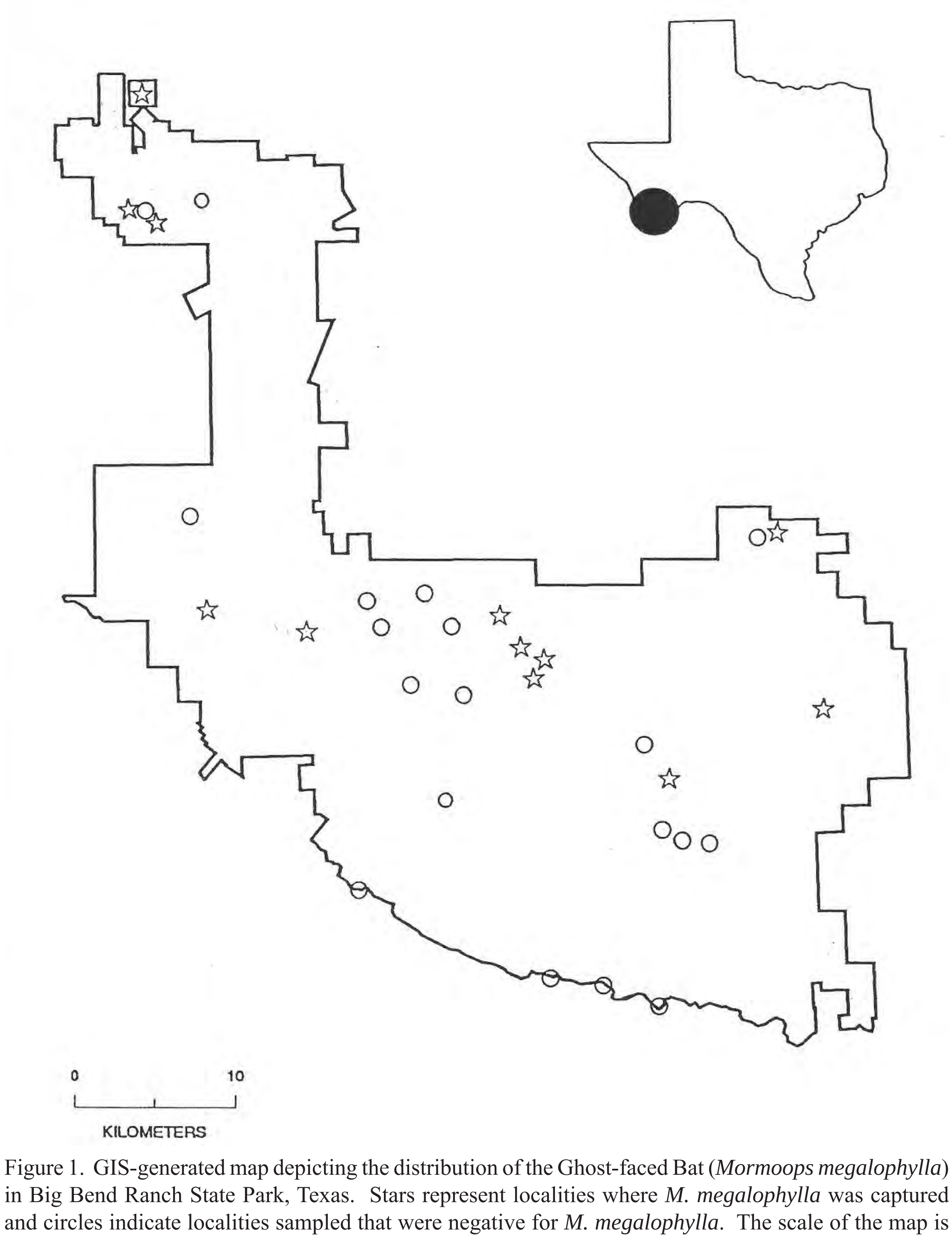

Figure 1. GIS-generated map depicting the distribution of the Ghost-faced Bat (*Mormoops megalophylla*) in Big Bend Ranch State Park, Texas. Stars represent localities where *M. megalophylla* was captured and circles indicate localities sampled that were negative for *M. megalophylla*. The scale of the map is such that if all symbols representing localities were plotted, there would be considerable overlap, thus confounding the map. Therefore, where overlap would occur, a single symbol has been plotted that represents multiple localities in the same general area.

RESULTS AND DISCUSSION

Distribution and abundance.—From January 1994 to June 1996, 339 mist nets were set at 108 localities throughout BBRSP. A total of 550 bats representing 14 species was captured during this time, 131 of which were Ghost-faced Bats. They accounted for 24% of all bats captured, second in abundance only to the American Parastrelle (*Parastrellus hesperus*), which accounted for 34% of bats taken. Of the 108 sites sampled, *M. megalophylla* was encountered at 16 sites scattered throughout the park. On 5 September 2015, a 109th locality was netted. This site is situated in the isolated Solitario region of the park, and was not sampled during the original study period due to the absence of water sources. During the recent sampling of this new locality, six Ghost-faced Bats were captured, bringing the total number of sites in BBRSP where *M. megalophylla* has been documented to 17. These results indicate that this bat is relatively common and widespread in the park. The general pattern of distribution of *M. megalophylla* within BBRSP is depicted in Figure 1.

That Ghost-faced Bats were found to be common and widespread in the Big Bend region is in contrast to previous reports by Easterla (1973) and Scudday (1976), who listed this bat as uncommon in Big Bend National Park and BBRSP, respectively. The occurrence of *M. megalophylla* at specific sites is known to be highly variable and unpredictable (Ammerman et al. 2012), and discrepancies in the previously reported abundance of this bat in the area indicate the possible existence of temporal fluctuations. On 4, 5, and 6 September 2015, three sites in BBRSP were sampled to gain insight into the stability of this species in the park. During this time, six nets were set yielding a total of 103 bats, 47 of which were Ghost-faced Bats, making them the most frequently encountered bats (45.6%) during this abbreviated sampling period. The results of the follow-up work suggest that the population of *M. megalophylla* at BBRSP has remained stable over the past two decades.

Ghost-faced Bats are reported to reside in Trans-Pecos Texas only during the warmer months (Schmidly 1977; Ammerman et al. 2012), and that was found to be the situation at BBRSP during this study. Individuals were encountered only between 29 March and 18 September. Interestingly, *M. megalophylla* resides on the Edwards Plateau just to the east during winter (Eads et al. 1957; Goetze 1998). This suggests seasonal migration between these two areas, although this has yet to be documented (Ammerman et al. 2012). Of the 184 individuals examined during this study, 182 were adult females, the only two males being juveniles. Most of the females were either gravid, lactating, or in post-lactating condition (see Yancey 1997). It appears that prior to or during migration from wintering grounds, females segregate themselves from males, then arrive at BBRSP to set up nursery colonies. Young are born and nursed during the summer at these nursery colonies, and then the onset of fall migration leads to exodus from the park in late summer or early autumn.

Ecological affinities.—Specimens of *M. megalophylla* were acquired from water-associated sites with a variety of surroundings. Because *M. megalophylla* was found to occur in the park only from late March through September, only net-nights from this time period ($n = 260$) were considered in the analyses of ecological affinities. Ghost-faced Bats occasionally were taken among dense stands of plants that often formed a closed canopy, but were more often encountered in open areas with sparse vegetation ($P < 0.001$; Table 1). They also were captured in both canyons and level flatlands, but were more often netted in the former ($P < 0.001$; Table 1). When considering these two features collectively (amount of vegetation and topography), a difference between observed and expected numbers of bats was detected ($P < 0.001$), and therefore pairwise comparisons were made ($\alpha = 0.0125$ based on the Bonferroni inequality adjustment). These comparisons indicate that *M. megalophylla* in BBRSP has affinities for the various habitats in the following order (highest to lowest): canyons with open/sparse vegetation (Fig. 2); flatland areas with open/sparse vegetation (Fig. 3); canyons with closed/dense vegetation (Fig. 4); and flatland areas with closed/dense vegetation (Fig. 5; Table 2). Each habitat was significantly favored over the one below it ($P < 0.001$).

Apparently, both density of vegetation and topography play important roles in the selection of foraging

Table 1. Results for two independent habitat variables; amount of vegetation and topography. Only nets set (n = 260) and individuals caught (n = 131) from late March through mid-September (1994–1995) were considered, as this is the time period that *M. megalophylla* is known to occur in Big Bend Ranch State Park.

	Vegetation		Topography	
	Sparse	Dense	Canyon	Level
Net-nights	111	149	91	169
Ghost-faced Bats caught	126	5	97	34
Ghost-faced Bats caught/net-night	1.135	0.034	1.066	0.201

Figure 2. Example of canyonland with open/sparse vegetation. This habitat was the type that *Mormoops megalophylla* had the highest affinity for at Big Bend Ranch State Park, Texas.

habitat of *M. megalophylla* in BBRSP, but the former seemingly more so than the latter. The habit of avoiding densely vegetated areas probably is in response to the high aspect wings of this species, as these relatively long wings would be a hindrance in thick vegetation (Norberg 1994). This bat's affinity for canyons probably is due to the abundance of small caves on the sides of many canyon walls at BBRSP. Caves reportedly are a primary roosting structure of this bat (Schmidly 1977; Graham and Barkley 1984; Ammerman et al. 2012), and individuals have been collected from caves in the adjacent Mexican states of Coahuila (Baker 1958) and Chihuahua (Anderson 1972). Foraging near a night roost would reduce the amount of time and energy spent traveling from roost to foraging grounds as compared to foraging some distance from the roost site.

It has been suggested that windy conditions may reduce the effectiveness of mist nets in capturing bats, and thus possibly introduce a sampling bias in favor of less windy areas (Kunz and Kurta 1988). The canyons sampled during this study certainly provided some protection from wind that was not present for the flatlands sampled. However, wind does not appear to alter the effectiveness of mist nets until wind speed reaches 14.5 km per hr (O'Farrell and Bradley 1970).

Figure 3. Example of flatland with open/sparse vegetation. This habitat was the second most frequently used habitat by *Mormoops megalophylla* at Big Bend Ranch State Park, Texas.

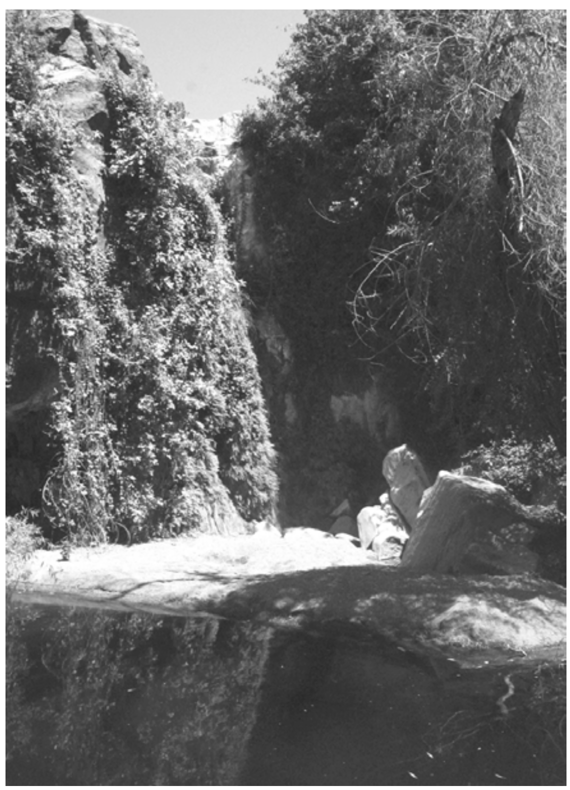

Figure 4. Example of canyonland with closed/dense vegetation. This habitat was used only sparingly by *Mormoops megalophylla* at Big Bend Ranch State Park, Texas.

Figure 5. Example of flatland with closed/dense vegetation. This habitat was the type that *Mormoops megalophylla* had the lowest affinity for at Big Bend Ranch State Park, Texas.

Table 2. Results for habitat variables combined. Only nets set (*n* = 260) and individuals caught (*n* = 131) from late March through mid-September (1994–1995) were considered, as this is the time period that *M. megalophylla* is known to occur in Big Bend Ranch State Park.

	Vegetation:Topography			
	Sparse:Canyon	Sparse:Level	Dense:Canyon	Dense:Level
Net-nights	67	44	24	125
Ghost-faced Bats caught	93	33	4	1
Ghost-faced Bats caught/net-night	1.388	0.750	0.167	0.008

As nets were not typically set during such conditions during this study, a sampling bias due to wind should be considered minimal at most.

Diet and foraging activity.—The stomach contents of 45 Ghost-faced Bats were analyzed to determine the food items that *M. megolophylla* forages on in BBRSP. Insects made up 100% of the diet. At 100% frequency of occurrence, lepidopterans were by far the most common type of insect consumed, followed by coleopterans (including at least some scarabids and some carabids), dipterans, hemipterans, homopterans, and neuropterans (Table 3). The majority (> 50% by volume) of stomach contents for 44 of the 45 individuals examined was lepidopteran, whereas one individual had coleopterans (carabids and others) comprising the majority of its stomach contents. Of the 45 stomachs examined, 37 contained only lepidopteran elements. Black (1974) set a percent frequency of occurrence level of 65 or greater to classify a bat species as a particular type of insect strategist. With a 100% percent frequency of occurrence for lepidopterns, *M. megalophylla* clearly warrants classification as a moth strategist at BBRSP.

Table 3. Prey items recovered from the stomachs of 45 Ghost-faced Bats (*Mormoops megalophylla*) from Big Bend Ranch State Park. All prey items recovered were of insect material from six insect orders.

	Insect Order					
	Lepidoptera	Coleoptera	Diptera	Hemiptera	Homoptera	Neuroptera
Number of stomachs recovered from	45	3	3	1	1	1
Percent frequency of occurrence	100	6.7	6.7	2.2	2.2	2.2

Bateman and Vaughan (1974) summarized the period of activity of *M. megalophylla* in Sinaloa, Mexico, and determined that this bat was active between 1930 h and 0630 h. However, this assessment was based on the capture times of only 20 individuals in nets that, in many cases, were left unattended throughout the night until 0600–0630 h, in which case time of capture was vague at best. In other instances, nets were attended, but monitored only until 2230 h at the latest, in which case the majority of the night was left unsampled. Therefore they were able to establish a broad range of activity time, but were unable to comment on peak periods of activity. During this study, the capture time intervals of 69 individuals taken in 10 nets that were monitored throughout the night were recorded. These nets were set above standing or slow-moving water where bats were visibly noted to be foraging on the wing, as is typical of mormoopids (Hill and Smith 1984). Based on times of capture, *M. megalophylla* was found to be actively foraging from just after dusk (2154 h) to just after sunrise (0700 h). The first two hours following dusk appear to be the peak period of activity for this bat, as it was captured significantly more often during this time (56 individuals) than at all other times combined (13 individuals; $P < 0.001$). The first two hours following dusk also seems to be a peak period of foraging for many other species of moth-strategist bats in the southwestern United States (Jones 1965; Black 1974).

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Pleistocene/Holocene Faunas from the Trans-Pecos

Arthur H. Harris

Abstract

There are only two extensive Pleistocene fossil faunas known from Trans-Pecos Texas: Fowlkes Cave and Sierra Diablo Cave. The fauna from Sierra Diablo Cave is compared to those from Fowlkes Cave and the Guadalupe Mountains. Both the Fowlkes Cave and Sierra Diablo Cave faunas are shown to be mixed Holocene-Pleistocene deposits.

Key words: faunas, fossil, Holocene, Pleistocene, vertebrates, Wisconsin age

Introduction

The Guadalupe Mountains represent the southernmost high ground more or less in continuity with the southern Rockies of northern New Mexico. Ranges immediately to the south are of notably lower elevation. Wisconsin-age faunas are well documented from the Guadalupe Mountains region of southeastern New Mexico and adjacent Trans-Pecos Texas. Until recently, only Fowlkes Cave (Dalquest and Stangl 1984) had produced extensive faunal remains of this age from south of that region. Sierra Diablo Cave, roughly 75 km W of Fowlkes Cave, recently produced a large fauna. The purpose of this paper is to document the Sierra Diablo Cave fauna and its contribution to our knowledge of late Pleistocene paleobiology in relation to the Guadalupe Mountains late Pleistocene sites and to the Fowlkes Cave fauna (Fig. 1).

The Late Pleistocene in southeastern New Mexico and adjacent Trans-Pecos Texas.—The Wisconsin is the last glacial age, lasting from about 75 kya (thousands of years ago) until 11.7 kya. The Wisconsin has been divided into early, middle, and late phases. The mid Wisconsin is considered to have ended at about 29,000 kya.

A variety of late Pleistocene sites occur in the Guadalupe Mountains region of southeastern New Mexico and adjacent Texas. The most extensive of these, Dry Cave in Eddy County, New Mexico, is used herein for comparison with sites to the south (Morgan and Harris 2015). Radiocarbon dates from the younger Dry Cave sites range from 10,730 ± 150 to 15,030 ± 210 BP (Harris 1989), with older but undated deposits extending into the middle Wisconsin.

Sierra Diablo Cave.—Sierra Diablo Cave is a small horizontal cave in the limestone rim rock of the Diablo Plateau (Fig. 2). Elevation is approximately 1,645 m and the exposure is to the south. The Rio Grande is about 50 km to the southwest. Seventeen Draw, which may have had permanent water during the Pleistocene, approaches to within about 1.5 km of the cave. The landscape supports typical desert vegetation of the region.

Although snakes and some small mammals almost certainly voluntarily utilized the cave, most specimens likely were brought in by predators and scavengers. The rugged topography would make it difficult for horses and the larger artiodactyls to access the cave; however, presence of at least two large felids is sufficient to explain their presence. Smaller predators and avian scavengers undoubtedly account for many of the other remains.

Figure 1. Location of fossil sites in relation to several political boundaries and place names.

Figure 2. Sierra Diablo Cave is located a bit to the right of center, near the base of the massive limestone outcrop. The foreground vegetation is largely creosotebush. View approximately north. Photograph by A. H. Harris.

Materials and Methods

A small collection of faunal remains was donated to the University of Texas at El Paso (UTEP) from presumably surface collections in 1966. More recently, the owners of Circle Ranch invited me to initiate faunal studies at the cave, and exploratory collections were hand-picked or sieved from disturbed matrix in 2007 and 2009. More formal collections were made under a memorandum of understanding between the ranch owners and UTEP. Because of the presence of archaeological material, formal excavation has been by archaeologists. University of Texas at El Paso archaeologist David Carmichael held a field school at the site in 2010, and Javier Vasquez continued with field parties in 2011–2013; all faunal material during these years was recovered by the archaeologists during screening for artifacts. Small matrix samples also were taken. Most faunal material from 2011–2013 was collected by hand by the archaeological field crews from ¼-inch or window-screen mesh.

To date, I have identified and catalogued 1,666 specimens into the UTEP Biodiversity Paleobiology Collection. These form the basis for interpretation of the Sierra Diablo Cave fauna.

Stratigraphy and chronology.—Basic stratigraphic information was established by Vasquez (2010). The cave has been extensively pot hunted, with excavations extending into Pleistocene deposits. Much of the fauna comes from an overburden of disturbed sediments. Although various sizes of limestone roof-fall occur, the basic matrix is of powdery fill, possibly of eolian origin. Because of pot hunting, aboriginal activity, the softness of the fill, and animal burrowing, mixing between levels has occurred, especially in the upper portions. During excavation, attempts were made to separate disturbed overburden from the original surface, but the division point was not always apparent. Faunal material labeled by the archaeologists as from disturbed areas is given separately in Table 1; material not so labeled is given as reported by the excavators, but may not have been recognized as from disturbed sediments by the archaeological crew.

A datum level was established 0.69 m above ground surface. The archaeological excavations have revealed seven recognizable strata, or zones: A through G (uppermost to lowest). Zones E and G are limited in scope; the latter lacked fossil remains and is not further considered here. Several of the strata were subdivided into levels by the excavators.

The surface fill (A), excavated in three levels and ranging from 0.54 to 0.75 m below datum (thicknesses measured at the same point for all strata), contained much plant material and produced artifacts of archaic cultural age as well as of the 20th century; however, occurrences of Pleistocene taxa such as horse (*Equus*) and Conkling's Pronghorn (*Stockoceros conklingi*) indicate strong contamination (Table 1). Judging from the fauna, zone A (Holocene, based on cultural material and presence of modern fauna) may lie on a Pleistocene surface (zone B) with much mixing between A and the upper portions of B.

Stratum B ranged from 0.76 to 1.03 m below datum. Consisting largely of compacted sediments, there was little in the way of plant material. Some cultural material was present. Stratum C ranged in depth from 1.03 to 1.54 m below datum. There is a sharp break between B and C, the latter being a loose deposit of coarse silt to fine-grained sand. Some cultural material was present.

Stratum D, 1.54 to 1.88 m below datum, consisted of silt-sized particles. The only cultural material present was flake debitage. Stratum E was shallow and pinched out in places, allowing stratum D to contact stratum F. Except for color, composition was essentially the same as F, which consisted of carbon-stained sediments ranging from 1.93 to 2.06 m below datum.

A radiocarbon date of 32,770 ± 38 years BP (AA94457) was determined on charcoal from stratum F. Because of excavation conditions at the time, it is unclear whether the date actually appertains to stratum F, but supports the presence of mid Wisconsin deposits. The only other date available to me is 34,970 ± 640 (about 40,000 radiocarbon kya) years BP (AA97732), determined on charcoal from stratum F. The sample was taken 30 cm from a bone of an extinct pronghorn and 20 cm from a chert biface. Under microscopic

Table 1. List of taxa recovered from the late Pleistocene of the Guadalupe Mountains region (GM), the older fossil deposit of Fowlkes Cave, and the Holocene to mid Wisconsin of Sierra Diablo Cave by stratigraphic zone. "Disturb" indicates taxa from disturbed sediments of Sierra Diablo Cave; "cf." indicates a degree of uncertainty in identification; "?" indicates a questionable identification; "*" indicates presence in the terminal Pleistocene only; † indicates an extinct species. Birds, unrecorded from Fowlkes Cave, are placed last in the table and only those present in Sierra Diablo Cave are compared to those from the GM. Nomenclature of Dalquest and Stangl (1984), Parmley (1988, 1990), and Parmley and Bahn (2012) is updated to current usage (original names in parentheses).

Taxon	GM	Fowlkes	A	B	C	D	E	F	Disturb
Osteichthyes	x								x
Ambystoma mavortium	x				x				x
Anaxyrus	x		x	x			x	x	x
Anaxyrus cognatus	x								
Anaxyrus punctatus	x							x	x
Anaxyrus woodhousii (*Bufo woodhousei*)	x	x							
Anaxyrus microscaphus/woodhousii	x			cf.					
Incilius nebulifer (*Bufo valliceps*)		x							
Pseudacris triseriata	x								
Lithobates (*Rana*)	x	x							?
Lithobates pipiens	x								
Scaphiopus/Spea	x		x						
Scaphiopus couchii	x				cf.				x
Spea bombifrons	x								cf.
Spea multiplicata	x								x
Terrapene	x			cf.					
Gopherus morafkai			x	x		x		x	x
Crotaphytus collaris (*Crotaphytus*)	x	x	x	x	x	x	x	x	x
Gambelia wislizenii									?
Holbrookia maculata	x								
Phrynosoma cornutum	x*	x		x				x	x
Phrynosoma hernandesi	x		x	x	x		x		x
Phrynosoma modestum	x*	x	x	x		x	x		x
Sceloporus	x			x	cf.	cf.		x	x
Sceloporus cowlesi	x								
Plestiodon cf. *P. obsoletus* (*Eumeces* cf. *E. obsoletus*)		x							
Plestiodon multivirgatus	x								

Table 1. (cont.)

Taxon	GM	Fowlkes	A	B	C	D	E	F	Disturb
Aspidoscelis (*Cnemidophorus*)	x*	x	x						
Arizona elegans		x	x						x
Bogertophis subocularis	x	x	x	x		x		x	x
Coluber/Masticophis	x	x	x	x	x			x	x
Gyalopion canum		x							
Lampropeltis alterna (*L. mexicana*)		x							
Lampropeltis getula	x	x	x	x	x				x
Lampropeltis triangulum		x							
Opheodrys aestivus		x							
Pantherophis emoryi (*Elaphe* cf. *E. guttata*)	x	x	x	x					x
Pituophis catenifer (*P. melanoleucus*)	x	x	x	x	x	x			x
Rhinocheilus lecontei		x	x	x		cf.			x
Salvadora	x		x	x					x
Sonora		x							
Tantilla		x							
Trimorphodon vilkinsonii									x
Crotalus	x	x	x	x	x			x	x
Crotalus atrox	x			cf.					
Diadophis punctatus		cf.							
Heterodon nasicus									x
Hypsiglena	x								
Hypsiglena jani (*H. torquata*)		x							
Nerodia erythrogaster		x							
Thamnophis	x	x							
Thamnophis marcianus		cf.							
†*Nothrotheriops shastensis*	x		x						
Cynomys	x	x	x	x	x		x	x	x
Cynomys gunnisoni	x			x					cf.
Cynomys ludovicianus	x	x	x	x					x
Ictidomys/Xerospermophilus	x	x	x	x				x	x
Ictidomys tridecemlineatus	x								
Xerospermophilus spilosoma (*Spermophilus spilosoma*)		x							

Table 1. (cont.)

Taxon	GM	Fowlkes	A	B	C	D	E	F	Disturb
Marmota flaviventris	x	x	x	x					x
Otospermophilus variegatus (*Spermophilus variegatus*)	cf.	x		x				x	x
Tamias (*Eutamias*)		x			x				
Urocitellus elegans	x								
Chaetodipus	x	x		x	cf.			x	x
Chaetodipus hispidus	x	x		x	x				
Dipodomys merriami/ordii		x		x					x
Dipodomys merriami		x	x						
Dipodomys ordii	x	x	x						
Dipodomys spectabilis	x	x	x	x	x		x	x	x
Perognathus	x	x	cf.						
Perognathus flavus/merriami		x	x	x					
Perognathus flavus		x							
Cratogeomys castanops (*Pappogeomys castanops*)	x	x	x	x	x	x		x	x
Geomys arenarius			x	x	x	x	x	x	x
Thomomys bottae	x	x		x					x
Thomomys talpoides	x				x	x			
Lemmiscus curtatus	x								
Microtus	x	x				x		x	x
Microtus longicaudus	x								
Microtus mogollonensis (*Microtus mexicanus*)	x	x	x	x	x	x		x	x
Microtus ochrogaster	x								
Microtus pennsylvanicus	x								x
Ondatra zibethicus	x								
Neotoma cinerea	x		x	x	x	x			x
Neotoma floridana	x								
Neotoma leucodon (*Neotoma albigula*)	x	x	x	x	x	x	x	x	x
Neotoma mexicana	x	x							
Neotoma micropus	x	x							cf.
Onychomys arenicola (*Onychomys torridus*)		x	x	x					x
Onychomys leucogaster	x	x	x	x					

Table 1. (cont.)

Taxon	GM	Fowlkes	A	B	C	D	E	F	Disturb
Peromyscus	x	x	x	x	x	x	x	x	x
Peromyscus boylii	cf.	x							
Peromyscus crinitus	x								cf.
Peromyscus eremicus		x	x						
Peromyscus leucopus	x	x							
Peromyscus maniculatus	x	x				x			
Peromyscus nasutus (*P. difficilis*)	x	x			x	x		x	x
Peromyscus laceianus (*P. pectoralis*)		x	x						
Reithrodontomys	x	x	x	x					
Reithrodontomys fulvescens		cf.							
Reithrodontomys megalotis		x	x	x					
Reithrodontomys montanus		x							
Sigmodon hispidus	x	x	x	x			x	x	x
Sigmodon ochrognathus		x		x		x			x
Erethizon dorsatum	x	x							x
†*Aztlanolagus agilis*				x	x			x	x
Lepus	x	x	x	x		x	x	x	x
Lepus californicus	x	x	x						x
Lepus townsendii	x								
Sylvilagus audubonii	x	x	x	x	x	x		x	x
Sylvilagus floridanus/robustus	cf.	x	x	cf.					x
Sylvilagus nuttallii	x			cf.					cf.
Cryptotis parva	x								
Notiosorex crawfordi		x							
†*Notiosorex dalquesti*	x			x					cf.
†*Notiosorex harrisi*	x								
Sorex merriami	x								
Sorex neomexicanus (*S. vagrans*)	x	x							
Sorex palustris	x	x							
Sorex preblei	x								
†*Desmodus stocki*				x					x
Tadarida brasiliensis	x								x

Table 1. (cont.)

Taxon	GM	Fowlkes	A	B	C	D	E	F	Disturb
Antrozous pallidus	x		x	x		cf.		cf.	x
Corynorhinus townsendii	x			x					
Eptesicus fuscus	x	x	x			x			x
Lasiurus cinereus	cf.								
Myotis californicus	x								
Myotis californicus/ciliolabrum	x								
Myotis evotis	x								
Myotis lucifugus	x	x							
Myotis thysanodes			x	x					
Myotis velifer	x	x							
Lynx rufus (Felis rufus)	x	x	x	x	x	x		x	x
†*Panthera atrox*	x								x
Puma concolor	x				x	x		x	x
Canis latrans	x		x	x				x	x
Canis dirus/lupus									x
Canis dirus	cf.								
Canis lupus	x								
Urocyon cinerioargenteus	cf.		cf.	cf.					
Vulpes macrotis/velox	x			x	cf.				x
Vulpes macrotis	x								
Vulpes velox	x								
Ursus americanus	x								x
Mustela erminea	x								
Mustela frenata	x								x
Taxidea taxus	x		x					x	x
Mephitis	x		cf.	x	cf.	x		x	x
Spilogale gracilis/putorius	x			x				x	x
Bassariscus astutus	x			cf.					x
Equus	x		x	x	x	x		x	x
†*Equus conversidens*	x						x		x
†*Equus francisci*	x								
†*Equus occidentalis*	x								

Table 1. (cont.)

Taxon	GM	Fowlkes	A	B	C	D	E	F	Disturb
†*Equus scotti*	x								cf.
†*Mylohyus*		x							
†*Camelops hesternus*	x								
†*Hemiauchenia macrocephala*	x								x
Odocoileus	x		x	cf.					x
Odocoileus hemionus	cf.		x						x
Antilocapra americana	x		x	x				x	x
†*Capromeryx furcifer*	x	x	x	x		x		x	x
†*Stockoceros conklingi*	x		x	x	x	x		x	x
†*Bison antiquus*	cf.			cf.					cf.
†*Oreamnos harringtoni*	x								x
Ovis canadensis	x		x					x	cf.
Callipepla	cf.								x
†*Meleagris crassipes*	x			cf.					
Cathartes aura			cf.					?	x
†*Coragyps occidentalis*	x		x	x	x	x	cf.		x
†*Gymnogyps amplus*	x			cf.	x			cf.	x
Geococcyx californianus	x			x					
Bubo virginianus	x								x
Falco sparverius	x			x				x	x
Corvus corax	x			x	x				x
Corvus cryptoleucus						x			
Pica hudsonia	x								x
Petrochelidon fulva/pyrrhonota			x	x		x		x	x

examination, the sample was found to be composed of plant remains and rodent dung. This suggests that the material was a packrat midden used as fuel. Thus, although the age of the midden was ~35,000 14^{C} years old, the date of the burning could have been much later.

Occurrence of some cultural material, though decreasing with depth, suggests some contamination through at least stratum D, and probably below.

Pleistocene faunal elements are widespread within the sediments, and discovery of the extinct Stock's Vampire Bat (*Desmodus stocki*) and the extinct Aztlán Rabbit (*Aztlanolagus agilis*), species believed to have become eradicated from the Southwest by the end of the mid-Wisconsin, indicate deposition commenced before the late Wisconsin.

Fowlkes Cave.—Fowlkes Cave is critical for interpretation of the Pleistocene faunas south of the

Guadalupe Mountains in the western Trans-Pecos. The Pleistocene fauna of Sierra Diablo Cave differs significantly from that of Fowlkes Cave (Table 1). Dalquest and Stangl (1984) interpreted the recovered fauna as indicating environmental conditions such that microhabitats suitable for taxa now found only far to the north were contemporaneous with warm desert conditions. This interpretation is incompatible with the interpretation of the Sierra Diablo Cave fauna.

SELECTED SPECIES ACCOUNTS FOR SIERRA DIABLO CAVE

Order of presentation follows the Center for North American Herpetology for herptiles, American Ornithologists' Union Birds of North and Middle America (http://checklist.aou.org/) for birds, and Wilson and Reeder (2005) for mammals. † indicates an extinct species.

Crotaphytus collaris (Eastern Collared Lizard).—This is the most common lizard recovered. It was present in all zones. Parmley and Bahn (2012), with an abundance of caution, took *Crotaphytus* only to the generic level at Fowlkes Cave; I have assumed that the taxon represented is of this species and record it as such in Table 1.

The species is widespread in the Southwest today and is common in southwestern mid and late Wisconsin fossil faunas, though not recorded in the higher-elevation faunas of the Guadalupes. Both rocks and some open areas appear to be requirements, according to Applegarth (1979).

Phrynosoma cornutum (Texas Horned Lizard).—This is a warm-climate lizard absent from the late Wisconsin Dry Cave faunas until warming at the very end of the Pleistocene. It also occurs in the mid Wisconsin fauna. It was recovered from zones B and F.

Phrynosoma hernandesi (Mountain Short-horned Lizard).—This horned lizard is by far the most common of the genus, with 44 identified elements compared to three Texas Horned Lizards and 13 Round-tailed Horned Lizards. Occurrences were in zones A, B, C, and E.

It is absent from the desert-scrub lowlands, but occurs in higher grasslands into open forest. It is distributed from southern Canada south well into Mexico. Applegarth (1979) hypothesized that only this species of lizard was able to thrive at Dry Cave under full glacial conditions because it is ovoviparous, retaining the eggs internally and giving birth to living young. Warming of body and eggs is accomplished by behavioral means (e.g., basking), whereas soil temperatures in much of their range may be marginal for egg development.

Occurrence appears continuous through mid and late Wisconsin faunas in southern New Mexico, thus suggesting that summer temperatures were relatively cool throughout the mid and later Wisconsin.

Phrynosoma modestum (Round-tailed Horned Lizard).—This is another warmclimate horned lizard apparently absent from all but the Guadalupe Mountains terminal Pleistocene deposits. It was recovered from zones A, B, D, and E.

Aspidoscelis sp. (whiptail lizards).—Although present rarely in the mid Wisconsin of the Guadalupe Mountain sites, whiptail lizards apparently were extirpated during the late full glacial, reentering the region only at the tail end of the Wisconsin. It was identified from zone A.

Gopherus morafkai (Morafka's Desert Tortoise).—This tortoise currently is limited to the Sonoran Desert; however, it is known from several localities and times within the Chihuahuan Desert (Van Devender et al. 1976; Harris 2003). At least two eastward pulses occurred, one in mid Wisconsin time and one in late Wisconsin. Remains were recovered from zones A, B, D, and F. The stratigraphic occurrences at Sierra Diablo Cave indicate that the mid Wisconsin is represented; occurrences in B suggest possible presence in the late Wisconsin, also.

This tortoise appears to be limited geographically today by harsh winter temperatures, implying winters at the times of occurrence lacked the extreme cold outbreaks seen today. Contemporaneous vegetation from Late Wisconsin woodrat middens at Shelter Cave in south-central New Mexico indicates the tortoise there was living in xerophilous woodlands (Van Devender et al. 1976).

†*Nothrotheriops shastensis* (Shasta Ground Sloth).—This rather regionally common sloth is represented in the fauna by a single tooth fragment from zone A. These sloths seemingly utilized caves for shelter and thus remains commonly are found in caves that have accessible entrances. They would be expectable in caves with vertical entrances only by rare accident.

A study by McDonald and Jefferson (2008:321) suggested that the “lower limiting temperature falls in the range of 10 to 20°C,” thus indicating mild winter temperatures. It appears that these sloths were absent in the Guadalupe Mountains region during full glacial times, but present in the mid Wisconsin and again after full-glacial conditions.

Cynomys gunnisoni (Gunnison’s Prairie Dog).—The cave currently is within the ranges of *C. ludovicianus*, the Black-tailed Prairie Dog, with a presence only a few hundred meters away. The only specimen in presumed undisturbed sediments was retrieved from zone B. Gunnison’s Prairie Dog is known as a late Wisconsin fossil at sites in the region. The nearest contemporary occurrence is in the northwestern third of New Mexico, where it may thrive at relatively high elevations.

Cynomys ludovicianus (Black-tailed Prairie Dog).—Occurrence was limited to zones A and B. Several specimens were from the surface. In general, Black-tailed Prairie Dogs require greater expanses of open, low vegetation than does Gunnison’s Prairie Dog.

Tamias sp. (chipmunk).—Chipmunks have not been identified from the extensive Dry Cave late Wisconsin faunas, while present in the earlier Wisconsin fauna and the mid Wisconsin Big Manhole Cave (Morgan and Harris 2015). They have been identified from the late Wisconsin of two higher elevation caves (ca. 2000 m) in the Guadalupe Mountains (Logan 1983; Harris and Hearst 2012). Seemingly, they occurred only in the higher elevations during the late Wisconsin, but descended to lower sites in the mid Wisconsin. However, the gray-footed chipmunk currently does occur in the Sierra Diablo and Guadalupe Mountains (Schmidly 1977).

Marmota flaviventris (Yellow-bellied Marmot).—Now occurring no closer than northern New Mexico, this large sciurid was wide-spread over the Southwest in the late Pleistocene. Lundelius (1979) suggested that this taxon (and the Bushy-tailed Woodrat, *Neotoma cinereus*) lingered on into the Holocene in a mesic canyon of the Guadalupe Mountains. It also is possible that the remains are Pleistocene in age.

Remains were recovered from zones A and B. It is hypothesized that current absence from sites south of northern New Mexico is due scanty winter precipitation and the long spring drought common to the region, resulting in lack of green fodder during the time the marmots awaken from hibernation (Harris 1970).

Dipodomys merriami (Merriam’s Kangaroo Rat).—Dalquest and Stangl (1984) reported 14 *D. merriami* jaws from Fowlkes Cave. As they noted, “Wherever found, *D. merriami* is an indicator of true, arid, desert conditions” (p. 443). Although a number of identifications of *D. merriami/ordii* (that is, either one or the other species) have been made within the region, there is not one other identification specific to this species from Pleistocene levels. Both the two specifically identifiable specimens from Sierra Diablo Cave are from zone A and obviously Holocene. Thus it appears that *D. merriami* is a true indicator of the Holocene in our region.

Cratogeomys castanops (Yellow-faced Pocket Gopher).—Whenever three species of pocket gophers occur in a region (as apparently was the case at Sierra Diablo Cave), the landscape is divided into mutually exclusive tracts. This species tends to inhabit relatively deep, silty or sandy soils with few rocks, whereas *Geomys* takes to sandy soils and *Thomomys* to shallow rocky soil. In the absence of other species, the deeper soils may be inhabited by any species.

This species seems well adapted to relatively arid habitats and is widespread in mid and late Wisconsin faunas of the region. Its presence implies relatively deep soils within predator range, perhaps along Seventeen Draw. At Sierra Diablo Cave, it was recovered from all zones except E.

Geomys cf. *arenarius* (Desert Pocket Gopher).—The specific designation is on the basis of current distribution; *G. knoxjonesi* (Jone's Pocket Gopher) ranges fairly close and is an alternative possibility. No *Geomys* occurrences are reported from the eastern side of the Guadalupe Mountains region, but the genus is common at Pendejo Cave to the west. At Sierra Diablo Cave, it is recorded from all zones. Occurrence on the flats immediately south of the cave is suggested.

Thomomys bottae (Botta's Pocket Gopher).—*Thomomys bottae* was rare. Only one specimen is relatable to a zone (zone B), although seven specimens are known from disturbed areas. This is a common species in a number of late Wisconsin regional sites and common in the area today. Current conditions suggest that soils likely were relatively shallow and rocky on the flats above the cave and inhabitable by *T. bottae*.

Thomomys talpoides (Northern Pocket Gopher).—Only a single specimen identifiable as *T. talpoides* (plus a queried identification) has been recovered. The sample containing the specimen spanned two zones: C and D. The species is not known from the mid Wisconsin of the Guadalupe Mountains area.

Since two species of pocket gopher are almost always allopatric on a fine scale, presumably different ecological habits were inhabited by the two species of *Thomomys*. One likelihood is that the cooler northern slopes were preferred by *T. talpoides*; since this habitat is lacking near the cave, the scarcity of *T. talpoides* is explained.

Lemmiscus curtatus (Sagebrush Vole).—Although the number of microtine rodents from the site is small, the absence of this vole could be significant. This is one of the more common voles in the late Wisconsin Dry Cave sites, making up 37% of the voles identified from the Balcony Room site, for example. Although not strictly limited to sagebrush grasslands, the vole is commonly associated with sagebrush; its absence suggests Sierra Diablo Cave may be south of late Wisconsin sagebrush distribution.

Microtus mogollonensis (Mogollon Vole).—This is the most forgiving of dry conditions of the regional voles, in places descending down into pinyon-juniper habitat. If Sierra Diablo Cave was of a somewhat more arid aspect than the Guadalupe region to the north, it would make sense that *Microtus longicaudus* (Long-tailed Vole) would be absent. Ten of 11 identifiable *Microtus* elements recovered from Sierra Diablo Cave are of this species. This vole survived well into the Holocene in the Davis Mountains (Kennedy and Jones 2006).

Microtus pennsylvanicus (Meadow Vole).—A single partial palate with left M1 and M2 from overburden sediments was identified on the basis of a fifth ''button-shaped'' element at the posterior end of M2 (Semken and Wallace 2002). Also, a visible suture between the maxillary and palatine rules out *M. mogollonensis* (which, alone among southwestern species of *Microtus*, has these elements fused). The assumption is made that species, such as *M. longicaudus*, that require more mesic conditions and occasionally show the "button," are absent; this is strengthened by only *M. mogollonensis* being represented among other identifiable elements.

Although the Meadow Vole occurs in mesic montane habitats, it also inhabits lower-elevation marshy areas. Occurrence at Sierra Diablo Cave may indicate former habitat in Seventeen Draw or, failing that, in the Rio Grande Valley to the southwest. The latter retained a population in southern New Mexico at least into the early Holocene (Smartt 1977), and there is no reason to not suspect occurrence in the Rio Grande Valley nearer to Sierra Diablo Cave.

Neotoma cinerea (Bushy-tailed Woodrat).—This northern woodrat is nearly ubiquitous in late Wisconsin sites in the region. It was present in zones A, B, C, and D. It may have survived into the Holocene in a mesic canyon in the Guadalupe Mountains (Lundelius 1979), but there is no indication of survival into the Holocene elsewhere in the Southwest.

Neotoma mexicana (Mexican Woodrat).—These woodrats occurred in prepleniglacial and post-pleniglacial deposits at Dry Cave, but apparently were absent during the full glacial impact. They also survived into the early Holocene at Dry Cave. It was represented by a single element at Fowlkes Cave (Dalquest and Stangl 1984), but has not been identified from Sierra Diablo Cave.

Onychomys arenicola (Mearn's Grasshopper Mouse).—This mouse is found in a warm-climate, arid habitat. It appears in the zones A and B at Sierra Diablo Cave and is the current common species of the area. It does not appear in the Dry Cave faunas, but does at Fowlkes Cave (as *Onychomys torridus*, Southern or Long-tailed Grasshopper Mouse).

Peromyscus crinitus (Canyon Mouse).—Canyon mice occur in the arid West east to northwestern New Mexico at present. It has been identified as a fossil in the Guadalupe Mountains region (Morgan and Harris 2015). A single specimen is tentatively identified from disturbed sediments at Sierra Diablo Cave, but might represent the deer mouse (*Peromyscus maniculatus*).

Peromyscus eremicus (Cactus Mouse).—This is a lowland mouse unidentified for sure from the Guadalupe region late Wisconsin sites. An identification from Upper Sloth Cave in the Guadalupe Mountains apparently was based solely on the absence of accessory cusps (Logan and Black 1979), a trait known to occur in other species of *Peromyscus*. A single Sierra Diablo Cave specimen was identified by discriminant analysis from zone A.

Reithrodontomys megalotis (Western Harvest Mouse).—Unfortunately, only two specimens of *Reithrodontomys* of a total of five are identified to species. The western harvest mouse is widespread geographically and ecologically.

Sigmodon hispidus (Hispid Cotton Rat).—This is a relatively warm-climate rodent absent from the Guadalupe Mountains late Wisconsin sites until close to the terminal Pleistocene. However, west of the Guadalupes, Pendejo and U-bar caves produced both mid and late Wisconsin records. This rodent should occur near Sierra Diablo Cave at present and is recorded from zones A, B, E, and F.

†*Aztlanolagus agilis* (Aztlán Rabbit).—This small leporid apparently became extinct before the height of late Wisconsin full-glacial conditions (Russell and Harris 1986), though specimens from U-bar and Dust caves could possibly be late Wisconsin. At Dry Cave, this rabbit is associated with radiocarbon dates between about 25 and 33 kya, though those dates are on bone carbonate and likely too young. At Pendejo Cave, it disappears after zone K, which likely places disappearance at a bit younger than 41 kya. Specimens seem fairly securely associated with level 2 of zone B and level F.

The chronological range of this species spans the Pleistocene until its extinction. It ranged geographically from eastern Arizona to central Texas and from Colorado into Chihuahua.

Sorex palustris (Water Shrew).—Despite large samples of shrews regionally, the water shrew is recorded only from Muskox and Fowlkes caves in the region. As the name indicates, this shrew is associated with water and high elevation streams in the Southwest. Nearest present-day approaches are the high mountains of eastern Arizona and northern New Mexico.

†*Desmodus stocki* (Stock's Vampire Bat).—Very similar to the living *D. rotundus* except for its larger size, *D. stocki* survived well into the Holocene on San Miguel Island off the coast of California (Guthrie 1998). However, mainland southwestern records apparently are all mid Wisconsin or earlier. Two of the four specimens (all partial humeri) from Sierra Diablo Cave are assignable to stratigraphic levels: B, level 4, and "B or possibly C?". This would seem to place level B1 as mid Wisconsin. This bat has also been recorded in the Trans-Pecos at Terlingua (Cockerell 1930) and in New Mexico at U-Bar Cave (Harris 1987).

Judging from the temperature tolerances of the living *Desmodus rotundus* (Common Vampire Bat), presence indicates relatively mild climatic conditions, and McDonald and Jefferson (2008) suggested temperature limitations similar to those they found for *Nothrotheriops shastensis*.

Eptesicus fuscus (Big Brown Bat).—At least one specimen, not attributable to a zone, is of the large size typical of late Wisconsin big brown bats in the Southwest. Zones A and D also produced this species.

†*Panthera atrox* (American Lion).—Although *Smilodon* cannot be entirely ruled out, measurements seem to better fit *P. atrox*. The single specimen is a distal right humerus retrieved, presumably from the cave surface, in 1966.

Large cats likely were responsible for presence of large mammals such as horses. This species must have been an awesome predator, and even *Puma concolor* (Mountain Lion) can handle fairly large artiodactyls.

Equus sp. (Horse).—Horse remains unidentifiable to species are common from the surface to the lowest fossiliferous layer. Most are fragments of teeth or post-cranial elements.

†*Equus conversidens* (Mexican Horse).—Several specimens are recognizable as this small Mexican Horse. Recognition primarily is by size, but a well preserved first phalanx has the typical proportions of this species. All but one specimen identified to this species were from disturbed sediments; the exception was from D/F (recorded as E in Table 1).

†*Hemiauchenia macrocephala* (Big-headed Llama).—Four specimens are recognized as belonging to this camel; all are from disturbed sediments. The species is roughly the size of a Dromedary Camel, but with the proportions of a llama. It is difficult to envision it reaching and entering the cave other than as parts carried in by predators or scavengers. As a cursorial animal, it seems best fit for relatively open country. It is widespread as a fossil in the southwestern Pleistocene.

Odocoileus sp. (deer).—With the exception of remains from level A, specimens are labeled as from disturbed sites. A fresh apparent Mountain Lion kill was on the surface at the beginning of a field session.

Antilocapra americana (Pronghorn).—Pronghorn remains were relatively rare (8 confident identifications, 10 at the cf. level of certainty). Zones A, B, and F produced remains, but most specimens came from disturbed sediments. Pronghorn currently inhabit scrub-grassland on the flats above the cave.

†*Capromeryx furcifer* (Matthew's Pronghorn).—Following White and Morgan (2011), Rancholabrean *Capromeryx* are considered to belong to *C. furcifer*. Some 25 elements of this small pronghorn are scattered through the site, zones A, B, D, and F. Remains are common in mid and late Wisconsin cave sites across southern New Mexico and into Chihuahua. A mixed diet and a habitat with clumps of shrubs and trees is suggested by several researchers (Bravo-Cuevas et al. 2013).

†*Stockoceros conklingi* (Conkling's Pronghorn).—I follow Furlong (1943) in considering *S. onusrosagris* as a synonym of *S. conklingi*. This is a pronghorn intermediate in size between the diminutive *C. furcifer* and the large *A. americana*. *Stockoceros conklingi* remains are the most numerous of the larger mammals, with approximately 80 elements recovered and with all levels except E represented.

From the common occurrence of numerous remains in caves, it is generally assumed that these antilocaprids used caves and shelters for protection against the elements.

†*Meleagris* cf. *M. crassipes* (Big Foot Turkey).—A fragment of a tarsometatarsus bearing a spur too large for North American galliform birds other than *Meleagris* was recovered from zone "B (or possibly zone C)". It is assumed from the labeling that the division between D and C was not clear.

This turkey is somewhat smaller than *M. gallopavo* (Wild Turkey), thus likely represents *M. crassipes*. The specimen shows strong digestive corrosion. This species is known from several Guadalupe Mountains region faunas, including the mid Wisconsin fauna from Dry Cave (Rea 1980).

†*Coragyps occidentalis* (Western Black Vulture).—Quite possibly ancestral to the Black Vulture (*Coragyps atratus*), this large form was the dominant vulture regionally, with the Turkey Vulture (*Cathartes aura*) apparently absent from the Guadalupe Mountains region during the full glacial. Remains were found

in zones A, B, C, and D, with a tentatively identified specimen from E.

†*Gymnogyps amplus* (Pleistocene Condor).—The Pleistocene form of *Gymnogyps* was long considered as a separate species from the California Condor (*G. californianus*), but later considered to be a large chronological subspecies of the modern California Condor. However, Syverson and Prothero (2010) produced evidence that the Pleistocene form was indeed a separate species. From a practical viewpoint, much of the material from inland sites cannot as yet be parceled between the two species. New Mexico, Chihuahua, and Trans-Pecos Texas count 11 other Pleistocene sites containing *Gymnogyps*. It is identified from zone C and tentatively from zones B and F.

†*Geococcyx californianus conklingi* (Conkling's Roadrunner).—The distal one-fourth of a tarsometatarsus from B1, level 4, is assignable to this large chronological subspecies of the Greater Roadrunner. It is considered a creature of the cooler summers of the late Wisconsin and may have survived into the early Holocene (Harris and Crews 1983).

Corvus corax (Common Raven).—This is the common raven in the regional late Pleistocene record (Magish and Harris 1976) and at Sierra Diablo Cave. Zones B and C produced remains. *Corvus corax* occasionally occurs in the regional Chihuahuan Desert now, but is not common.

Corax cryptoleucus (Chihuahuan Raven).—This is the current dominant species of *Corvus* in the vicinity of Sierra Diablo Cave. The Chihuahuan Raven is absent from the Guadalupe Mountains regional fossil record, though present in small numbers farther west in the Pendejo Cave mid and late Wisconsin (Harris 2003). A single element is recognized from zone D.

Pica hudsonicus (Black-billed Magpie).—A partial carpometacarpus from disturbed sediments was recovered. Magpies are common in northern New Mexico and are known to occasionally roam to the south. A single late Wisconsin element is recorded for the Guadalupe Mountains region.

Discussion

The question has been raised as to whether Fowlkes Cave adequately reflects late Pleistocene conditions south of the Guadalupe Mountains region (Harris 2016). The answer is that Fowlkes Cave does not—but also that data from Sierra Diablo Cave only partially clarifies the late Pleistocene faunal situation.

Fowlkes Cave.—Dalquest and Stangl (1984) reported Holocene and Pleistocene mammalian faunas from Fowlkes Cave. Later, anurans (Parmley 1988), snakes (Parmley 1990), a cotton rat (Stangl and Dalquest 1991), and lizards (Parmley and Bahn 2012) were added to the Pleistocene fauna (Table 1). Bird remains have not been published.

As interpreted by Dalquest and Stangl (1984), taxa unknown to coexist in the late Wisconsin faunas of the Guadalupe Mountains or elsewhere likely occurred within about 10 mi of Fowlkes Cave during the late Wisconsin. An example is the coexistence of desert taxa such as *Dipodomys merriami*, *Onychomys arenarius*, and *Peromyscus eremicus* together with non-desert species such as *Sorex palustris*, *Sorex neomexicanus*, and *Marmota flaviventris*.

The cave is a sinkhole with the entrance well up a steep slope (Dalquest and Stangl 1984). The exact locality is unreported, but is about 10 km north of Kent, near the southern terminus of the relatively low (less than 1700 m) Apache Mountains. The elevation at the mouth of the cave was not given. As described by Dalquest and Stangl (1984), the uppermost layer excavated consisted of about 30 cm of black silt. Below this layer was a sterile layer consisting of about 35 cm of rock fragments between 15 and 25 mm diameter (layer 1), then 20 cm of fragments between about 5 and 15 mm in diameter interspersed with fossils (layer 2), below which was a sterile layer of finer material about 30 cm thick (layer 3).

A partial lower jaw of an extinct miniature pronghorn (*Capromeryx*) was recovered in place in about the middle of layer 2, indicating a Pleistocene age. Material from that layer produced what Dalquest and Stangl (1984) thought to be a contemporaneous late Wisconsin fauna. Based largely on the size distribution of the fossil taxa, Dalquest and Stangl (1984) hypothesized that most of the fauna was introduced by Barn Owls (*Tyto alba*) from within about 10 miles of the cave.

The fauna (Table 1) includes both desert taxa and cool-adapted mesic forms. Dalquest and Stangl (1984:454) interpreted the taxa as contemporary and reconstructed the ecological conditions as follows:

> Cool streams with fringing borders of willows and meadowlands existed where there are now only dry washes, 10 km or more from the cave. The hillsides and aluvial [sic] fans supported somewhat more vegetation, including more junipers and perhaps some other trees. The creosote bush flats existed as today, but soils were sandy on terraces closer to the streams. Some of the typical desert mammals, such as Merriam kangaroo rat and long-tailed grasshopper mouse, were just entering the area.... The scarcity of the Merriam kangaroo rat and long-tailed grasshopper mouse suggest that cooler climate of the late Pleistocene was just giving way to the hot, desert climate of modern conditions.

The rational, aside from the occurrence of ecologically mixed taxa in the same stratigraphic level, was that glaciation in the Guadalupe Mountains supplied cold, meltwater streams producing habitat for shrews and a vole, while Chihuahuan Desert habitat ruled the interfluvial areas.

There are several problems with this scenario. For one, the Guadalupe Mountains were not glaciated, the nearest (and small) glacier occurring about 185 km to the NNW of the high peaks of the Guadalupe Mountains. Furthermore, drainage from north of the site originates from the southern end of the low Delaware Mountains, some 60 km south of the Guadalupes. The nearest rivers that would have carried glacial meltwater are the Pecos River some 80 km to the northeast and the Rio Grande about 90 km to the southwest. Also, regional reconstructions of vegetation based on packrat midden data indicates creosotebush rare or absent in the area until well into the Holocene, with woodland in the lowlands until at least 8,000 radiocarbon years before the present (Van Devender and Spaulding 1979).

The dilemma facing Dalquest and Stangl (1984) is appreciated: the choice between a mixed late Wisconsin-Holocene fauna or, as suggested by their stratigraphic interpretation, a contemporaneous late Wisconsin fauna. They chose the latter. For reasons noted above and below, I take the opposite approach: that deposition started in the Pleistocene and continued well into the Holocene.

The critical point revolves around the stratigraphic evidence. Dalquest and Stangl assumed the fossiliferous layer was laid down within a relatively short period of time in the final stages of the late Wisconsin. However, layer 1 and the fossiliferous layer 2 consist of rock fragments and thus are necessarily lag deposits. Such deposits occur when fine particles are winnowed from them over time, concentrating relatively thick sedimentary layers into thinner layers of particles too large to be carried away by the available water flow. The alternative is a soilless, gravel-like surface layer surrounding the cave that nevertheless supported an abundant fauna. If, then, the fossiliferous layer represents an appreciable length of time (evidenced in part by the relative fossil richness due to reduction of a thicker deposit), occurrence of late Wisconsin and Holocene taxa is explained. Absence of fossils in the overlying stratum may indicate relatively rapid deposition under severe Holocene climatic conditions. The black silt top deposits, containing a Holocene fauna (Dalquest and Stangl 1986) may well be of historic age, marking soil erosion due to the destruction of vegetation with the over-stocking of livestock.

The stratigraphic evidence is upheld by the nature of the fauna. The mixture of taxa is not known from the extensive Wisconsin deposits of the Guadalupe Mountains region nor is it considered to be likely due to the more southern position of Fowlkes Cave.

In summary:

- Modern data indicate that such desert mammals as Merriam's Kangaroo Rat occur under hot, dry climatic conditions; even where mesic conditions are nearby, such as along the Rio Grande, taxa typical of the Wisconsin Pleistocene are not found. Appeal to glacial meltwater doesn't work.

- Woodrat midden data indicate that hot, dry conditions did not arrive in the area until after the early Holocene.

- Stratigraphic data strongly indicate that the lower fossiliferous stratum is a lag deposit making it feasible that deposition occurred over an extended span of time (late Pleistocene into mid or late Holocene), thus explaining the incompatible faunas.

Sierra Diablo Cave.—The extensive disturbance of the upper portion of the cave sediments basically renders much of its stratigraphic data useless. Especially in zone A, faunal evidence indicates extensive disturbance even where excavation data do not indicate such. This is true to a slightly lesser degree for the upper portion of zone B. A major drawback to interpretation is the rather obvious bias against recovery of the smaller faunal elements during the archaeological excavations.

Aztlanolagus agilis was present about half way through stratum B and *Desmodus stocki* occurred near the base of that zone. These are thought to be markers of the mid Wisconsin and, as best as can be told, were in place stratigraphically. Taxa found in and below those levels are consistent with a mid Wisconsin age, though some taxa also would be expected to survive into the late Wisconsin and some into the Holocene.

Potentially complicating matters, taxa west of the Guadalupe Mountains, such as at U-Bar Cave in the southwestern corner of New Mexico, show little faunal change between mid and late Wisconsin times as compared to those from Dry Cave (Harris 1989). It is possible that the late Wisconsin fauna at Sierra Diablo Cave, west of the Guadalupe-Delaware axis that presumably helps protect areas to the west from the full impact of Great Plains climate, differed from the mid Wisconsin fauna primarily by the loss of *Aztlanolagus* and *Desmodus stocki*. If so, with many of the same taxa present in both mid and late Wisconsin, there would be little in the Sierra Diablo Cave fauna that is unique to the late Wisconsin as opposed to the mid Wisconsin.

Taxa that occur in the Guadalupe Mountains late Wisconsin that might indicate late (as opposed to mid) Wisconsin times if found at Sierra Diablo Cave include *Pseudacris triseriata* (Western Chorus Frog), *Microtus longicaudus*, *Lepus townsendii* (White-tailed Jackrabbit), *Sorex cinereus* (Masked Shrew), *Sorex palustris*, and *Mustela erminea* (Ermine). The absence of these taxa from Sierra Diablo Cave, however, means little. They may be absent either because of the small sample size or because their geographic ranges did not reach south to Sierra Diablo Cave. Of these, only *Sorex palustris* is known to reach this far south (at Fowlkes Cave).

In summary:

- Strong disturbance of upper sediments prevents clear separation between deposits of different ages.

- Deposition commenced in the mid Wisconsin and probably continued without interruption until the present.

- There are no Pleistocene taxa present that would be expected to occur only in the late Wisconsin, as opposed to the mid Wisconsin. Absence of taxa typical of the Guadalupe Mountains late Wisconsin taxa, such are shrews, may be a result of sample size collecting bias, or may indicate real differences between the faunas.

- Although the Sierra Diablo Cave fauna provides some information regarding the mid Wisconsin fauna in Trans-Pecos Texas south of the Guadalupe Mountains region, characterization of the Pleistocene fauna must await discovery, excavation, and interpretation of a large fossil sample with firm stratigraphic evidence from the region.

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First Documented Record of Nutting's Flycatcher (*Myiarchus nuttingi*) for Texas

Mark W. Lockwood

Abstract

A Nutting's Flycatcher (*Myiarchus nuttingi*) was discovered near the mouth of Santa Elena Canyon, Big Bend National Park, Brewster County, Texas from 31 December 2011 to 11 January 2012, providing a first record for the state. This species previously has been documented in the United States in Arizona and California. This paper discusses and provides context for this first documented and accepted state record for Texas.

Key words: Brewster County, *Myiarchus nuttingi*, Nutting's Flycatcher, state record, Texas

Circumstances of the Occurrence

On 31 December 2011, Brandon Percival and David Bradford discovered a Nutting's Flycatcher (*Myiarchus nuttingi*) at the parking area near the mouth of Santa Elena Canyon in Big Bend National Park, Brewster County. Texas. The bird initially was heard calling from an area of dense mixed desert scrub bordering the parking area. This habitat is dominated by Honey Mesquite (*Prosopis glandulosa*), Salt Cedar (*Tamarix* sp.), Screwbean Mesquite (*Prosopis pubescens*), Roosevelt Weed (*Baccharis neglecta*), and Gregg's Acacia (*Acacia greggii*). Photographs were obtained and diagnostic vocalizations were heard. Recordings of the vocalizations were later obtained to fully document the occurrence. During the 12 days the bird was known to be present it appeared to remain in the vicinity of the initial discovery and was seen by many observers. It would remain in the dense vegetation for long periods of time and then forage through the trees bordering the parking area. The bird was not particularly vocal, calling very irregularly and often for very short periods. It was not particularly wary and allowed close inspection when it was in view. Texas Bird Records Committee accepted the documentation (TBRC 2012-01; TPRF 2971), thus providing the first record for Texas (Carpenter 2013).

Discussion

Identification.—Virtually all of the species in the genus *Myiarchus* share very similar plumage characteristics that make identification of individual taxa more difficult. Nutting's Flycatcher is very similar to the Ash-throated Flycatcher (*M. cinerascens*) and these species were once considered to be conspecific (Lanyon 1961). The individual observed at Big Bend National Park exhibited plumage typical of *Myiarchus* flycatchers with a brownish-olive head contrasting with the gray-brown of the nape and back (Fig. 1). The auriculars were lighter brown that the crown. The chin and breast were pale gray contrasting with a moderately bright yellow belly. The wings were darker brown with the coverts and tertials widely edged with tan. The primaries were widely edged with rufous. The tail was also dark brown with the inner webbing of all but the central rectricies mostly cinnamon with an obviously darker coloration on the outer web widening across the feather shaft towards the tip (Fig. 2). The bill was blackish with a flesh colored base to the lower man-

Figure 1. This Nutting's Flycatcher exhibited plumage characteristics consistent with populations in northwestern Mexico. This is the first accepted record for Texas. Photo by Mark W. Lockwood.

Figure 2. The pattern of the underside of the retricies is an important plumage characteristic for separating Nutting's Flycatcher (shown) from the similar Ash-throated Flycatcher. Photo by Mark W. Lockwood.

dible. The overall size was similar to an Ash-throated Flycatcher, but direct comparison was not made. The bird called very infrequently, but did give the distinctive, sharp *wheeek!*

This plumage pattern of Nutting's Flycatcher is shared with most of the other species in the genus *Myiarchus*. Of particular interest in the identification of this individual is Ash-throated Flycatcher, which is a common summer resident and uncommon and local winter resident along the Rio Grande in Brewster County. The Ash-throated Flycatcher differs very subtly from the Nutting's and is best separated by voice. Ash-throated Flycatchers are very slightly larger and thinner bodied with a generally longer crest and larger bill. The undertail pattern of an adult Ash-throated Flycatcher differs in that the dark coloration of the outer webbing extends across the tip of the rectrices. However, first-winter Ash-throated have a tail pattern that is very similar to that of a Nutting's. In general, Nutting's Flycatchers are browner above with brighter yellow underparts.

Distribution.—The Nutting's Flycatcher ranges from northwestern Mexico southward to northwestern Costa Rica (Howell and Webb 1995, AOU 1998). The northernmost population of this species is found in northeastern Sonora within 75 km of the Arizona border (Howell et al. 2014) (Fig. 3). There has been a northward expansion of this species range during

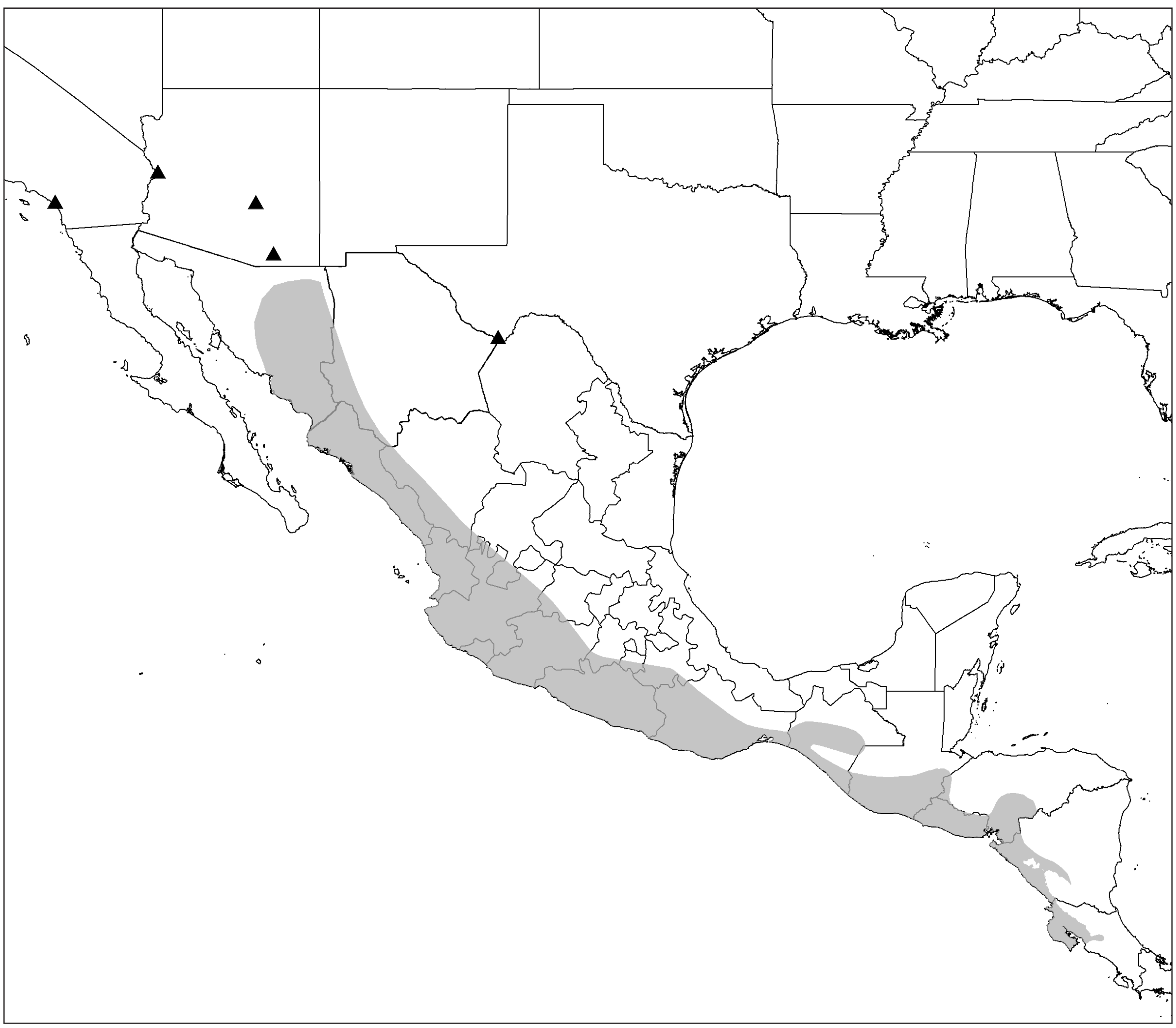

Figure 3. Range of Nutting's Flycatcher and locations (indicated by black triangles) where the species has been documented in the United States. Range map based on Ridgely et al. (2003).

the past 50 years with the northernmost breeding area near Hermosillo in 1960 (Lanyon 1961) to an area in northeastern Sonora that is approximately 160 km farther north (Howell et al. 2014). In Sonora, Nutting's Flycatchers are present year-round and are found in thorn forest habitats between sea level and 1800 m (Howell and Webb 1995). The first record for the United States was a bird collected near Roosevelt, Gila County, Arizona, on 8 January 1952 (Dickerman and Phillips 1953). Subsequent records for Arizona included one at Patagonia Lake State Park, Santa Cruz County, 14 December 1997 (Rosenberg 2001); one at Bill Williams Delta National Wildlife Refuge, Mohave County, 24 September 2008 (Stevenson and Rosenberg 2009); and another was at the latter location in December 2011(Stevenson and Rosenberg 2012). Presumably this same individual was found on 30 November 2012 at the Bill Williams Delta National Wildlife Refuge (Stevenson and Rosenberg 2013), which was followed by the first documented nesting record at the same location in April 2013 (Stevenson and Rosenberg 2014). This species has been found annually since, with six individuals present forming at least two pairs in the summer of 2014 (Stevenson and Rosenberg 2015). Interestingly, this location is approximately 580 km northwest of the northernmost population in Sonora, Mexico. There is also a single record for California, a single bird at Irvine, Orange County, from 11 November 2000 through 26 March 2001 (California Bird Records Committee 2007).

The Texas record may have been expected considering the increase in numbers of Nutting's Flycatchers in Arizona tied with the occurrence of other species of birds found primarily in western Mexico that have been documented in Texas. Species with similar ranges include Ruddy Ground-Dove (*Columbina talpacoti eluta*), Rufous-backed Robin (*Turdus rufopalliatus*), Aztec Thrush (*Ridgwayia pinicola*), and Streak-backed Oriole (*Icterus pustulatus*; Lockwood and Freeman 2014). The distance from known breeding areas to the location of the Texas record is approximately 480 km, which is closer than several of the Arizona records as well as the one from California.

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Bats of Kimball and Cheyenne Counties in the Panhandle of Nebraska

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Abstract

Despite numerous publications on bats throughout Nebraska, only a single record of a bat has been reported from Kimball County and none from Cheyenne County in the southwestern corner of the Nebraska panhandle. With concern about impacts of future wind-energy development on bat populations in the region, we conducted a study to examine the occurrence and seasonal activity of bats in those two counties. In 2010 and 2011, we documented six species of bats in Kimball County—three migratory species (*Lasiurus cinereus*, *Lasiurus borealis*, and *Lasionycteris noctivagans*) and three nonmigratory species (*Eptesicus fuscus*, *Myotis ciliolabrum*, and *Myotis thysanodes*). Only three species were documented in Cheyenne County—*L. noctivagans*, *E. fuscus*, and *M. ciliolabrum*. All six species were captured in the Pine Bluffs area of Kimball County, where pines, junipers, and rock outcrops were present; *M. ciliolabrum* was the only species captured in rocky, treeless areas of Cheyenne County; and *L. noctivagans*, *E. fuscus*, and *M. ciliolabrum* were captured or observed in riparian habitats in both counties. In 2010, a migratory wave of *L. cinereus* and *L. borealis* was documented in early August, and migration for both species seemed to be completed by the beginning of September. In contrast, migration of *L. noctivagans* seemed to begin and end later in the season. Migratory stopover sites in the Nebraska panhandle likely include the Pine Bluffs area as well as the Pine Ridge, Wildcat Hills, and Southern Wildcat Hills. Each stopover site provides an island of coniferous trees that can be used for resting and refuge, while also allowing a place for bats to refuel. In addition, waterways and other places with deciduous trees in the panhandle can be used as stopovers. Wind speeds are favorable for wind-energy development across the panhandle, including grassland areas. Construction of wind turbines in grasslands rather than in wooded areas in western Nebraska likely would reduce negative impacts on bat populations based on our capture success in the various habitats in the region.

Key words: bats, distribution, *Eptesicus fuscus*, *Lasionycteris noctivagans*, *Lasiurus borealis*, *Lasiurus cinereus*, migration, *Myotis ciliolabrum*, *Myotis thysanodes*, Nebraska, reproduction, seasonal activity, wind energy

Introduction

Despite a comprehensive review of Nebraska's bats in 1979 (Czaplewski et al. 1979) and recent surveys of bats in western Nebraska (Benedict et al. 2000; Benedict 2004; Geluso et al. 2004; Geluso et al. 2013), only a single record of a bat has been reported from Kimball County (Silver-haired Bat, *Lasionycteris noctivagans*; Geluso et al. 2004), whereas not a single species is known from Cheyenne County in the southwestern corner of the Nebraska panhandle. However, on the basis of bat distributions and habitat availability in western Nebraska and neighboring states, as many as nine other species might occur in the region. Such species include the Fringed Myotis (*Myotis thysanodes*), Long-legged Myotis (*Myotis volans*), Western Small-footed Myotis (*Myotis ciliolabrum*), Big Brown Bat (*Eptesicus fuscus*), Eastern Red Bat (*Lasiurus borealis*), Hoary Bat (*Lasiurus cinereus*), Pallid Bat (*Antrozous pallidus*), Townsend's Big-eared Bat (*Corynorhinus townsendii*), and American Perimyotis (*Perimyotis subflavus*; Bogan and Cryan 2000; Geluso et al. 2005; Armstrong et al. 2011; Geluso et al. 2013).

Construction of wind turbines for production of electrical energy has known adverse effects on bats (e.g., Kunz et al. 2007; Arnett et al. 2008). In the United States, wind-energy facilities are most detrimental to migratory species, especially *L. noctivagans, L. cinereus,* and *L. borealis* (Kunz et al. 2007; Grodsky et al. 2012). All three species inhabit western Nebraska (Czaplewski et al. 1979; Benedict 2004) and occur in the region during migration (Geluso et al. 2013). Understanding habitat use, relative abundance, and seasonality of migratory and nonmigratory species of bats in Kimball and Cheyenne counties is needed because of the potential for further development of wind power in the region. Thus far, seven operational wind turbines occur in the region (Nebraska Government Website 2016). Here we report our findings of a bat survey in those two counties during summer and early autumn, the time of year that most bat fatalities by wind turbines have been reported in North America (Kunz et al. 2007; Arnett et al. 2008).

STUDY AREA

We conducted our study in Kimball and Cheyenne counties in the southwestern corner of Nebraska's panhandle (Fig. 1). Study sites included coniferous woodlands in western Kimball County, pine-studded and treeless areas in Cheyenne County, and riparian habitats in both counties. Common and scientific names of plants mentioned below follow Kaul et al. (2006).

Pine Bluffs area.—The Pine Bluffs area in western Kimball County is characterized by rolling hills with shallow canyons. The area occurs near the Nebraska border with Wyoming, southeast of the town of Pine Bluffs in Laramie County, Wyoming (Fig. 1). Hilltops and canyonsides contain scattered coniferous trees and occasional rock outcroppings. Common trees consist of Rocky Mountain Ponderosa Pine (*Pinus ponderosa*), Limber Pine (*Pinus flexilis*), and Rocky Mountain Juniper (*Juniperus scopulorum*). Conspicuous shrubs in the area include Yucca (*Yucca glauca*) and Fragrant Sumac (*Rhus aromatica*), whereas common grasses include gramas (*Bouteloua curtipendula, B. gracilis,* and *B. hirsuta*), Little Bluestem (*Schizachyrium scoparium*), and Red Three-awn (*Aristida purpurea*). We sampled six water sources in this area. Two sites were situated on canyon floors (a metal stock tank 8.2 m in diameter [Fig. 2] and an earthen stock tank 44 by 18 m in length [Fig. 3]), and four sites were located in open, flat areas at different distances from canyonsides (an earthen stock tank 6.1 by 1.5 m in length and metal stock tanks 5.5, 6.1, and 9.1 m in diameter).

The Pine Bluffs area only occupies about 6 km^2 in Kimball County, but it is part of a larger wooded area that mostly occurs in southeastern Wyoming. The relatively rugged terrain in the Pine Bluffs area represents the northernmost part of a single, north-south lying escarpment that extends southward along the eastern border of Wyoming and terminates in northern Colorado. The total area in the tri-state region is about 20 km^2.

Pine-studded area in Cheyenne County.—A unique habitat for Cheyenne County exists 4.7 km east of the town of Potter near a place named Point of Rocks (Fig. 1, localities 5–7). This area consists primarily of ponderosa pines and some junipers scattered on ridgetops and slopes of canyons (Fig. 4). Canyonsides also contain horizontal strips of rocky outcrops, yielding a terrace-like appearance. The total area containing trees is about 6 km^2. We sampled a metal stock tank (3.0 m in diameter) in a grassy flat near the head of a canyon and placed a mist net over a large pond (70 by 40 m in length) near a ranch house, 0.25 km from a canyonside. We also erected a net over land at the head of a canyon.

Treeless region of southwestern Cheyenne County.—Most of southwestern Cheyenne County consists of gently rolling hills that are primarily used for grazing cattle; little agricultural land exists in the region compared to the remainder of the county. The landscape is essentially treeless except for occasional

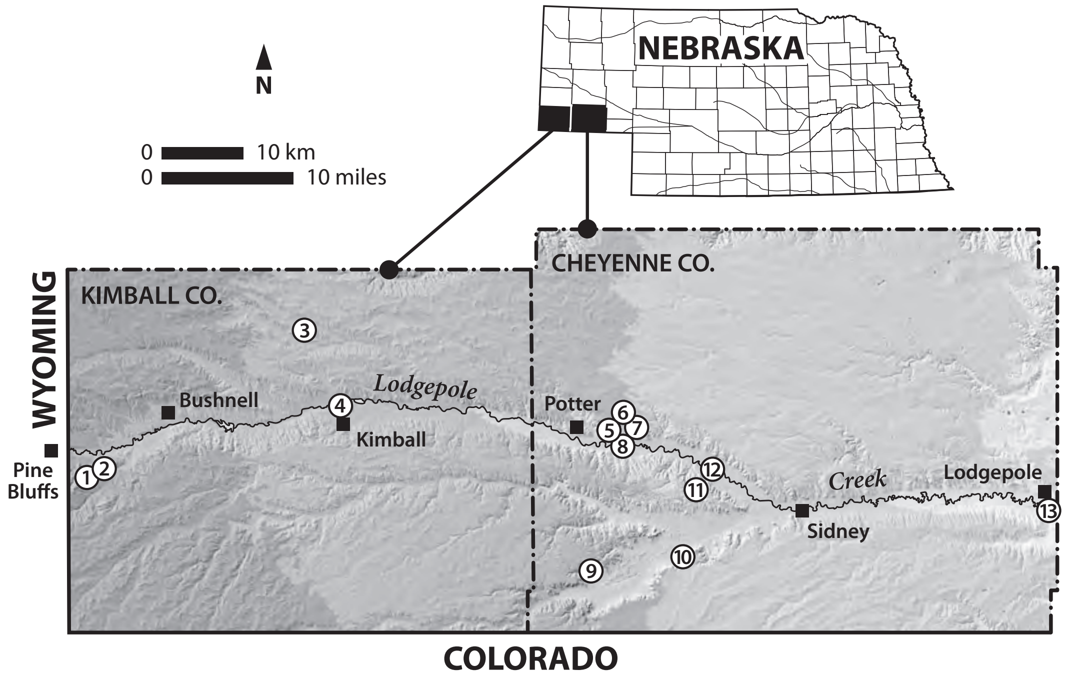

Figure 1. Study sites in Kimball and Cheyenne counties in the southwestern corner of the Nebraska panhandle, where we attempted to capture bats in 2010 and 2011. Also shown are localities of specimens collected prior to our study. Localities in close proximity to each other are represented by the same circled number; for example, locality one represents five sites netted during our study and one site sampled in 2004 (Appendix). Black squares indicate six towns located along Lodgepole Creek.

Figure 2. Over this metal stock tank (8.2 m in diameter) in the Pine Bluffs area of Kimball County, Nebraska, we captured five species of bats, including the only record of Fringed Myotis (*Myotis thysanodes*) from this county.

Figure 3. Over this earthen stock tank (44 by 18 m in length) in the Pine Bluffs area of Kimball County, Nebraska, we captured 32 Hoary Bats (*Lasiurus cinereus*) and 18 Eastern Red Bats (*Lasiurus borealis*) in a single evening (2 August—from dusk to dawn the following morning), in what seemed to be a migratory wave in 2010.

Figure 4. Area of scattered pines with some junipers near a place named Point of Rocks in Cheyenne County, Nebraska. Small maneuverable bats observed in this habitat probably were Western Small-footed Myotis (*Myotis ciliolabrum*).

human-planted windbreaks and trees growing around scattered ranch houses. Common grasses covering the hills include gramas (same three species as above), Red Three-awn, Slender Wheatgrass (*Elymus trachycaulus*), Buffalo Grass (*Buchloë dactyloides*), Needle-and-thread (*Stipa comata*), and Japanese Brome (*Bromus japonicus*). In addition, rocky outcrops break the landscape in many places. We sampled six water sources at different distances from those outcroppings (five metal stock tanks 1.8, 2.4, 6.1, 7.6, and 7.6 m in diameter and an earthen stock tank 25 by 8 m in length, Fig. 5). On two occasions, we placed a net across an open window and door of an abandoned rock house.

Lodgepole Creek.—Lodgepole Creek is an east-west flowing, intermittent stream located in central Kimball and Cheyenne counties (Fig. 1). Lodgepole Creek is a tributary of the South Platte River, and it flows into the South Platte River near the town of Ovid, Sedgwick County, Colorado. Parts of the creek contain deciduous trees, whereas other parts are adjacent to grasslands or agricultural fields that lack trees. We sampled four localities along Lodgepole Creek from central Kimball County near the town of Kimball to eastern Cheyenne County near the town of Lodgepole (Fig. 1). Each site contained Plains Cottonwoods (*Populus deltoides*) and willows (*Salix*, Fig. 6). American Elms (*Ulmus americana*) also were noted along the creek near towns of Potter and Lodgepole, and a few Russian-olives (*Elaeagnus angustifolia*) were observed at the site near Lodgepole. The creek varied in width from 2.7 to 15.2 m at our study sites and was <1 m in depth along most reaches.

Figure 5. One of many rock outcrops in the treeless region of Cheyenne County, Nebraska. We captured Western Small-footed Myotis (*Myotis ciliolabrum*) at this site, when the dry earthen stock tank in the photograph contained water.

Figure 6. Lodgepole Creek between towns of Potter and Sidney in Cheyenne County, Nebraska. We captured Silver-haired Bats (*Lasionycteris noctivagans*), Big Brown Bats (*Eptesicus fuscus*), and Western Small-footed Myotis (*Myotis ciliolabrum*) at this site.

METHODS AND MATERIALS

To capture bats, we used mist nets (Avinet Inc., Dryden, NY, USA) ranging in length from 2.6 to 18 m and set them at ground level over water sources such as metal stock tanks, earthen stock tanks, and streams. On three occasions, nets were placed over land. We attempted to capture bats during 23 nights—21 nights in 2010 (28−30 June; 27 July; 1, 2, 5, and 31 August; 1−6, 9, 29, and 30 September; and 1 and 3−5 October) and two nights in 2011 (29 and 31 July). During our study, eight of 20 sites (40%) were sampled more than once (two to seven times), and on eight of 23 nights (35%), more than one site was sampled at the same time.

Nets were set before evening twilight, and on 18 of 23 nights (78%), they were kept up until dawn the next morning. For each individual captured, we recorded time of capture, species, sex, forearm length, body weight, reproductive condition (i.e., for females—pregnant, lactating, or not noticeably reproductive), and age (young of the year or adult). Females were recorded as lactating if milk could be expressed from mammary glands. An individual was considered a young of the year only if cartilaginous epiphyseal plates in finger joints were visible to the unaided eye when the wing was transilluminated (Anthony 1988). Using that trait, all bats could be aged through August, but beginning in September, it became difficult to age some individuals because cartilage was no longer visible. Thus, beginning in September, some individuals recorded as adults might have been young of the year with ossified epiphyseal joints.

When sampling bats during our survey, the first bats to appear at dusk were always small and highly maneuverable. Upon capture, each of those small bats was a *M. ciliolabrum*. Therefore, in cases where small, maneuverable bats were observed at dusk but not captured, we reported the observation as "*M. ciliolabrum* (observation only)."

Most bats were released after processing at capture sites, but some were kept as voucher specimens and deposited in the natural history collection at the University of Nebraska State Museum in Lincoln (UNSM). Coordinates of localities were determined with a handheld Global Positioning System (GPS 72, Garmin International, Olathe, Kansas), using North American Datum 1983 (NAD 83). We also checked museum databases (The Mammal Networked Information System, using the VertNet portal) and collections at UNSM and at the University of Nebraska at Kearney and Omaha for unpublished records of bats from Kimball and Cheyenne counties. Specific locality descriptions for voucher specimens and for sites where bats were not captured are given in the Appendix.

Results

During 23 nights of netting in the southwestern corner of the Nebraska panhandle, we captured 115 bats representing six species—*L. cinereus*, *L. borealis*, *L. noctivagans*, *E. fuscus*, *M. ciliolabrum*, and *M. thysanodes* (Table 1, Appendix). Bats were captured at four of seven sites in Kimball County (57% success) and at five of 13 sites in Cheyenne County (38% success). In addition, *M. ciliolabrum* was observed but not captured at two additional sites in Kimball County and at one site in Cheyenne County (Table 1). Dates of capture for each species are summarized in Table 2. Reproductively active individuals were observed for *E. fuscus* (pregnant and lactating individuals and volant young), *M. ciliolabrum* (pregnant and lactating individuals), and *L. cinereus* (volant young; Table 3, Appendix).

We captured bats in three of the four habitats sampled—the Pine Bluffs area of Kimball County, the treeless region of Cheyenne County, and Lodgepole Creek in both counties. In the Pine Bluffs area where pines, junipers, and rock outcrops were present, we documented all six species of bats captured in our study (Table 1). In treeless areas of Cheyenne County that contained rock outcroppings, we only documented *M. ciliolabrum* (Table 1). Two individuals were captured over an earthen tank next to a rock outcropping (Fig. 5), and one was captured over a metal stock tank near an abandoned rock house that contained bat feces. Along Lodgepole Creek, we captured *L. noctivagans*, *E. fuscus*, and *M. ciliolabrum* among deciduous trees in Cheyenne County, and along that creek in Kimball County, we captured *L. noctivagans* and *E. fuscus* and observed *M. ciliolabrum* (Table 1). In the pine-studded area of Cheyenne County that contained rocky outcrops, we were unable to capture any bats but suspected that small, maneuverable bats observed at dusk were *M. ciliolabrum* (Table 1).

We captured bats from late June (28th) to early October (5th). Most individuals of *L. cinereus* (36 of 37) and all those of *L. borealis* (19 of 19) were captured in late July and early August 2010 (Table 2). Each was captured in the Pine Bluffs area either over a large, unobstructed earthen tank (two Hoary Bats and one Eastern Red Bat in July; 32 Hoary Bats and 18 Eastern Red Bats in August, Fig. 3) or over a nearby metal tank (two Hoary Bats in August, Fig. 2). Another *L. cinereus* was captured over the metal tank on 31 August. The earthen tank was dry on subsequent visits in 2010 and 2011. Our first captures of *L. noctivagans* occurred in early September in both Kimball and Cheyenne counties, and later captures continued through late September and early October, respectively (Table 2). For nonmigratory species, *E. fuscus* was captured from late June to early September, *M. ciliolabrum* from late June to late September, and our only capture of *M. thysanodes* occurred on 29 September (Table 2).

Besides our captures and observations of *M. ciliolabrum*, we discovered four unpublished records of that species from Kimball County—three from the Pine Bluffs area and one from near the town of Kimball. In the Pine Bluff area, one female each was captured on 15 July, 17 July (lactating), and 4 August 2004; and near Kimball, a male was captured on 16 May 1964 (Appendix).

Table 1. Number of bats captured at seven sites in Kimball County and 13 sites in Cheyenne County, Nebraska, in 2010 and 2011. Numbers in parentheses correspond to those in Figure 1. Detailed locality descriptions for each site are given in the Appendix.

Site description	*Lasiurus cinereus*	*Lasiurus borealis*	*Lasionycteris noctivagans*	*Eptesicus fuscus*	*Myotis ciliolabrum*	*Myotis thysanodes*
Pine Bluffs area, Kimball Co.						
(1) metal tank	--	--	--	--	--	--
(1) small earthen tank	--	--	--	1	1	--
(1) large earthen tank	34	19	--	20	3	--
(1) metal tank	--	--	--	--	--[1]	--
(1) metal tank	3	--	1	1	5	1
(2) metal tank	--	--	--	--	--	--
Pine-studded area, Cheyenne Co.						
(5) large pond	--	--	--	--	--	--
(6) over land	--	--	--	--	--[1]	--
(7) metal tank	--	--	--	--	--	--
Treeless region, Cheyenne Co.						
(9) metal tank	--	--	--	--	--	--
(9) metal tank	--	--	--	--	1	--
(9) next to rock house	--	--	--	--	--	--
(10) metal tank	--	--	--	--	--	--
(11) metal tank	--	--	--	--	--	--
(11) metal tank	--	--	--	--	--	--
(11) earthen tank	--	--	--	--	2	--
Lodgepole Creek, Kimball Co.						
(4) at Kimball	--	--	1	1	--[1]	--
Lodgepole Creek, Cheyenne Co.						
(8) near Potter	--	--	2	--	--	--
(12) between Potter & Sidney	--	--	4	11	2	--
(13) near Lodgepole	--	--	2	--	--	--
Total captured	37	19	10	34	14	1

[1]observation only; see Methods and Materials

Table 2. Dates of capture for bats in Kimball and Cheyenne counties, Nebraska, in 2010 and 2011. Dates also include probable observations of *Myotis ciliolabrum*. For each date, p.m. refers to individuals captured from dusk to midnight, and a.m. refers to those captured after midnight to dawn. All dates refer to 2010, except 29 July, 31 July, and 1 August (a.m.), which refer to 2011.

Date	*Lasiurus cinereus*	*Lasiurus borealis*	*Lasionycteris noctivagans*	*Eptesicus fuscus*	*Myotis ciliolabrum*	*Myotis thysanodes*
28 June (p.m.)	--	--	--	1	--	--
29 June (a.m.)	--	--	--	--	1	--
30 June (p.m.)	--	--	--	6	1	--
1 July (a.m.)	--	--	--	3	--	--
27 July (p.m.)	1	1	--	8	4	--
28 July (a.m.)	1	--	--	3	1	--
29 July (p.m.)	--	--	--	--	--[1]	--
31 July (p.m.)	--	--	--	--	--[1]	--
1 August (a.m.)	--	--	--	1	--	--
1 August (p.m.)	--	--	--	--	2	--
2 August (p.m.)	6	8	--	8	2	--
3 August (a.m.)	28	10	--	1	--	--
31 August (p.m.)	1	--	--	--	--[1]	--
3 September (p.m.)	--	--	1	2	--[1]	--
4 September (p.m.)	--	--	1	1	--[1]	--
5 September (p.m.)	--	--	--	--	--[1]	--
6 September (p.m.)	--	--	--	--	--[1]	--
7 September (a.m.)	--	--	2	--	--	--
29 September (p.m.)	--	--	--	--	1	1
30 September (a.m.)	--	--	1	--	--	--
30 September (p.m.)	--	--	--	--	2	--
1 October (a.m.)	--	--	1	--	--	--
1 October (p.m.)	--	--	2	--	--	--
4 October (p.m.)	--	--	--	--	--[1]	--
5 October (p.m.)	--	--	2	--	--	--
Total captured	37	19	10	34	14	1

[1]observation only; see Methods and Materials

Table 3. Dates of reproductive activity for bats in Kimball and Cheyenne counties, Nebraska, in 2010. None of the dates for lactation extend the period of lactation for a species in the state, and none of the dates for juveniles provide earlier dates when volant young first appear in Nebraska or extend dates in the state when young still can be recognized by cartilage in their finger joints.

Species	June	July	August	September
Eptesicus fuscus				
Pregnant	30[1]	1	--	--
Lactating	30	27, 28	2	--
Volant young	--	--	2, 3	3
Myotis ciliolabrum				
Pregnant	30[2]	--	--	--
Lactating	--	27	1, 2	--
Lasiurus cinereus				
Volant young	--	27	2, 3	--

[1]Female contained a single fetus with a crown-to-rump length of 22 mm.
[2]Female contained a single fetus with a crown-to-rump length of 17 mm.

DISCUSSION

At least six species of bats occur in the southwestern corner of the Nebraska panhandle—three migratory species (*L. cinereus*, *L. borealis*, and *L. noctivagans*) and three nonmigratory species (*E. fuscus*, *M. ciliolabrum*, and *M. thysanodes*). The only previously published record from this region is an *L. noctivagans* that was discovered dead in Kimball County in 1988 (Geluso et al. 2004; Appendix). Thus, our captures of *L. cinereus*, *L. borealis*, *E. fuscus*, *M. ciliolabrum*, and *M. thysanodes* represent new records of occurrence for Kimball County. We only captured three species in Cheyenne County (*L. noctivagans*, *E. fuscus*, and *M. ciliolabrum*), and each represents a new record of occurrence for that county. For each newly reported species in Kimball County, the closest locality of occurrence in Nebraska is from the Southern Wildcat Hills in Banner County, 41 km north for *L. cinereus*, 38 km northwest for *E. fuscus*, and 39 km north for the other species (Geluso et al. 2013). For new records in Cheyenne County, the closest record in Nebraska for *L. noctivagans* is 45 km north-northeast in Morrill County and for *E. fuscus* and *M. ciliolabrum*, 46 km north in Morrill County (Geluso et al. 2013). Because of a lack of historical sampling of bats in the southwestern corner of the panhandle (Jones 1964; Czaplewski et al. 1979; Benedict et al. 2000; Benedict 2004), records reported herein from Kimball and Cheyenne counties are best referred to as range extensions and not expansions in distribution (sensu Frey 2009).

The Pine Bluffs area had the greatest species richness of the four habitats sampled during our study (six species, Table 1), and each of those species also is known from the Southern Wildcat Hills, 37 km north of the Pine Bluffs area (Geluso et al. 2013). Similar to the habitat in the Pine Bluffs area, hilltops and canyonsides of the Southern Wildcat Hills contained ponderosa pines, junipers, and rock outcroppings. However, conifers were denser, canyons were deeper, and rocks were more abundant in the Southern Wildcat Hills. In that wooded and rugged terrain, Geluso et al. (2013) suspected that three additional species might reside in those hills, as we did for the Pine Bluffs area (i.e., *M. volans*, *C. townsendii*, and *A. pallidus*). In both areas, however, none of those species were captured in either survey. Geluso et al. (2013) discussed possible reasons for their seeming absence (e.g., low population densities, lack of certain habitat requirements, or both), which also apply to the Pine Bluffs area.

Our only capture of *M. thysanodes* occurred in the Pine Bluffs area of Kimball County. In Nebraska, *M. thysanodes* is a Tier 1 species of concern due to its limited distribution and rarity in the Wildcat Hills and Pine Ridge regions of the state (Schneider et al. 2011). Our capture in Kimball County, along with recent captures in the Southern Wildcat Hills (Banner County, Geluso et al. 2013), demonstrates that the species has a greater distribution in the state than previously known. In Nebraska thus far, *M. thysanodes* only occurs in areas associated with coniferous woodlands and forests (Czaplewski et al. 1979; Geluso et al. 2013; this study). Our capture on 29 September and another individual captured on that date in the Wildcat Hills (Geluso et al. 2013) represent the latest seasonal date for *M. thysanodes* in Nebraska (Table 2). Although no winter records of *M. thysanodes* are known from Nebraska, hibernating individuals have been reported near the Nebraska panhandle in southwestern South Dakota and southeastern Wyoming (Turner and Jones 1968; Martin and Hawks 1972; Bogan and Cryan 2000; Geluso et al. 2005). Caves and mines in neighboring states might be important shelters for hibernating species of bats that spend summer months in the panhandle of Nebraska. This species and others likely also hibernate within Nebraska in rock fissures or other suitable hibernacula. Information on wintering habits for all species of bats that overwinter in the state is warranted because white-nose syndrome continues to spread westward (Frick et al. 2010), and recently, the fungus associated with the syndrome has been documented in eastern Nebraska (WNS 2015).

Myotis ciliolabrum was the only species captured in the treeless region of southwestern Cheyenne County, and although we did not capture a single bat in the pine-studded area of that county, small bats observed in the canyons likely were that species (Table 1). A common feature in both habitats was the presence of numerous rock outcroppings. Throughout most of its distribution, presence of rocks seems to be an important habitat requirement for *M. ciliolabrum* (Jones et al. 1983), and our captures and observations in southwestern Cheyenne County support that conclusion. Besides *M. ciliolabrum*, we doubt that other species of bats commonly occur in those habitats of the county.

Although we only captured three species in riparian habitats along Lodgepole Creek (*L. noctivagans*, *E. fuscus*, and *M. ciliolabrum*, Table 1), we suspect that *L. cinereus*, *L. borealis*, and possibly other species also periodically inhabit that wooded waterway. In the panhandle, for example, *L. cinereus* has been captured in cottonwood communities along Pumpkin Creek and the North Platte River (Geluso et al. 2013), and *L. borealis* is known from the town of Bridgeport near the North Platte River (Benedict et al. 2000). *P. subflavus* is another species that likely occurs in riparian habitats in Kimball and Cheyenne counties. During summer in the western part of its distribution, *P. subflavus* roosts in areas with isolated deciduous trees surrounded by grasslands or deserts (Geluso et al. 2005; White et al. 2006; Valdez et al. 2009). This species has expanded its distribution across the Great Plains in recent decades (Geluso et al. 2005), and records are now available from northeastern Colorado and southeastern Wyoming (Bogan and Cryan 2000; Armstrong et al. 2006). Lack of captures of *P. subflavus* during our study might be related to (1) minimal netting done by us along the creek, (2) a low population density in the area, (3) difficulty in capturing individuals in mist nets (e.g., White et al. 2016), or (4) some combination of the above.

Migration and migratory stopover sites.—During our study in the southwestern corner of the panhandle, autumn migration of *L. cinereus* and *L. borealis* seemed to have begun in late July/early August (Table 2), a pattern similar to that observed in more northern areas of the panhandle (Benedict 2004; Geluso et al. 2013). Our captures of 34 Hoary Bats and 18 Eastern Red Bats on a single August night likely represent a migratory wave through the Pine Bluffs area. On that night, bats were captured over two nearby stock tanks, but six days prior in late July, only two Hoary Bats and one Eastern Red Bat were captured from dusk to dawn at the same two sites (Table 2). Moreover, 73% of total captures in early August (28 of 34 Hoary Bats and 10 of 18 Eastern Red Bats) occurred after midnight (0004-0448 h), which further suggests the presence of migratory individuals because in temperate climates, relatively few insectivorous bats are captured over water after midnight; on typical summer nights, most individuals are captured < 3 h after sunset (e.g., Jones 1965). In addition, not one female of either species was lactating that night ($n = 26$ adults), indicating a cohort of females free to travel without nursing nonvolant young. Sex ratios of adult migrants were nearly 1:1 for *L. cinereus* (14 females and 16 males) and 2:1 for *L. borealis* (12 females and 6 males). The migratory wave also included four young Hoary Bats (three males and one female), three of which were captured after midnight (female at 0131, male at 0222, and male at 0416 h). Migratory young with and without visible cartilage in their finger joints also have been reported in early August in New Mexico (Findley and Jones 1964; Geluso and Geluso 2004). Findley and Jones (1964) stated that different age groups of *L. cinereus* might migrate at different times during southward migration; however, our captures in the Pine Bluffs area suggest that young and adults sometimes travel together. Although autumn migration of *L. cinereus* and *L. borealis* seemed to be completed by the beginning of September in the Pine Bluffs area (Table 2), migratory individuals have been captured as late as 15 September for Hoary Bats and as late as 29 September for Eastern Red Bats in other parts of the Nebraska panhandle (Geluso et al. 2013).

In the study area, autumn migration of *L. noctivagans* began at least a month later than that of Hoary and Eastern Red bats (Table 2). For example, we captured our first Silver-haired Bats in early September but did not capture a single individual in early August, when many Hoary and Eastern Red bats passed through the area. Similar to those findings, most migratory Silver-haired Bats in the Wildcat Hills and surrounding area also were captured in September, with only a single capture in late August (Geluso et al. 2013). In addition, migratory waves of *L. noctivagans* have been reported in late August and mid September in Ontario, Canada (McGuire et al. 2012). In western Nebraska, autumn migration also ends later for *L. noctivagans*. For example, Silver-haired Bats have been captured on the wing as late as 4 November, whereas late captures for *L. cinereus* and *L. borealis* do not extend beyond September in western Nebraska (Geluso et al. 2013). In Kimball and Cheyenne counties, half of our captures of *L. noctivagans* occurred in October (Table 2). Similar to the sex ratio of migrant Hoary Bats, the ratio for Silver-haired Bats was 1:1 (5 males and 5 females), with some individuals possibly being young of the year with recent epiphyseal ossification (see Methods). Geluso et al. (2013) reported that in the Wildcat Hills and surrounding area, Silver-haired Bats occurred in and around coniferous forests only during spring and autumn migration; however, we discovered that they also use waterways lined with deciduous trees, at least during autumn migration. For example, nine of 10 captures of *L. noctivagans* occurred along Lodgepole Creek, and only one capture occurred in the Pine Bluffs area (Table 1).

All three migratory species were captured during autumn migration in the Pine Bluffs area of western Kimball County (Tables 1 and 2). Similarly, those species have been documented during autumn migration in other coniferous habitats to the north, including the Pine Ridge (Sioux, Dawes, and Sheridan counties), Wildcat Hills (Scotts Bluff, Banner, and Morrill counties), and Southern Wildcat Hills (Banner and Morrill counties, Geluso et al. 2004; Geluso et al. 2013). Those four areas in the panhandle of Nebraska likely provide important stopover sites for migratory bats travelling through a region that is dominated by grasslands. Each area provides an island of trees that can be used for resting and refuge, while also allowing a place for bats to refuel (see McGuire et al. 2012). In addition, waterways and other places with deciduous trees in the panhandle can be used as stopovers during migration (e.g., *L. noctivagans*, Table 1), because each migratory species (*L. cinereus*, *L. borealis*, and *L. noctivagans*) is known to roost in both coniferous and deciduous trees (Ammerman et al. 2012).

Bats and development of wind power in Nebraska.—According to the American Wind Energy Association, Nebraska is the fourth windiest state in the United States and ranks sixth in the nation for the greatest potential to generate electricity from wind power (AWEA 2007; Power Online 2010). As of 2014, Nebraska has 473 operational wind turbines in the state, seven of which are located in a grassland area of Kimball County (4.6 km N, 3.1 km W Kimball; Nebraska Government Website 2016). Not surprisingly, efforts are slated to expand the development of wind energy in Nebraska (Nebraska Legislature 2009).

Observations of bat and avian fatalities beneath wind turbines indicate that wind energy is not as environmentally friendly as once thought (Kunz et al. 2007; Arnett et al. 2008). In the eastern United States, large numbers of bats, mainly *L. borealis*, *L. cinereus*, and *L. noctivagans*, have been killed at utility-scale, wind-energy facilities, especially by turbines situated along forested ridgetops (Kunz et al. 2007). Although wind turbines frequently kill species that migrate long distances, fatalities also have been reported for more sedentary species such as *E. fuscus*, *P. subflavus, M. lucifugus,* and *M. septentrionalis* (Kunz et al. 2007; Grodsky et al. 2012). Thus, development of wind power could impact populations of migratory (*L. cinereus*, *L. borealis*, and *L. noctivagans*) and nonmigratory (*E. fuscus*, *M. ciliolabrum*, and *M. thysanodes*) species in western Nebraska, if wind-energy facilities were constructed in areas frequented by those species.

Unfortunately for the bats, probable stopover sites for many migratory individuals as well as areas used by some nonmigratory species in the panhandle of Nebraska (i.e., Pine Ridge, Wildcat Hills, Southern Wildcat Hills, and Pine Bluffs area) seem to include ideal locations for generating electricity from wind power. Not only are ridgetops and escarpments available, but wind speeds also are ideal on the basis of average speeds 80 m above the ground (NREL 2010; commercial wind turbines range in height from 45 to 100 m, Kunz et al. 2007). Areas with average wind speeds ≥ 6.5 m/s at an 80-m height are generally considered to have a wind resource suitable for wind-energy development (Windexchange 2015), and almost the entire panhandle of Nebraska has wind speeds ≥ 7.5 m/s 80 m above the ground (NREL 2010). Highest wind speeds in the panhandle occur in the Wildcat Hills of Banner County and Pine Bluffs area of Kimball County (≥ 10.0 m/s). Wind speeds also are favorable in the Pine Ridge and in grassland areas of the panhandle (NREL 2010). On the basis of captures of migratory and nonmigratory species of bats in our study (Table 1) and in other areas of the panhandle of Nebraska (Benedict et al. 2000; Benedict 2004; Geluso et al. 2004; Geluso et al. 2013), it seems that construction of wind turbines in open grassland areas would reduce negative impacts on bat populations. After acoustically monitoring bat activity across different landscapes, Baerwald and Barclay (2009) also concluded that bat fatalities probably would be minimized by building wind-energy facilities in prairies rather than in wooded areas that provide stopover sites for migrating tree bats. To assess potential impacts of utility-scale, wind-energy facilities on bat populations, it is necessary to know what species occur and when they occur in areas that might support such facilities.

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APPENDIX

Localities where we attempted to capture bats in Kimball and Cheyenne counties, Nebraska, in 2010 and 2011. Numbers in parentheses before each locality correspond to circled numbers in Figure 1. Localities in close proximity to each other are represented by the same number. Listing of sites follows the order shown in Table 1. A description of the netting site, total number of bats captured, and dates of netting are given after each locality. Dates also include probable observations of *Myotis ciliolabrum*. For each date, p.m. refers to individuals captured from dusk to midnight, and a.m. refers to those captured after midnight to dawn. In addition, the number of males and females captured of each species is given with corresponding information on reproductive condition and age. Voucher specimens are shown in brackets with their museum number at the University of Nebraska State Museum in Lincoln (UNSM) and University of Wyoming, Museum of Vertebrates in Laramie (UWYMV). At the end of the appendix, we also provide information for specimens collected prior to our study.

Pine Bluffs area in Kimball County

(1) 2.79 km S, 0.51 km W Intersection of Stateline Road and Interstate I-80, 41°09.441'N, 104°03.012'W, metal tank 6.1 m in diameter in open, flat area near canyonside, no bats captured on night of 31 July 2011, including after midnight.

(1) 2.8 km S, 0.5 km W Intersection of Stateline Road and Interstate I-80, 41°09.437'N, 104°03.002'W, small earthen tank 6.1 by 1.5 m in length in open, flat area near canyonside, two bats captured: 28 June 2010, p.m.—*E. fuscus* (one adult male [UNSM 30084]); 29 June 2010, a.m.—*M. ciliolabrum* (one adult male [UNSM 30091]); 31 August 2010—none captured including after midnight.

(1) 2.6 km S, 0.1 km W Intersection of Stateline Road and Interstate I-80, 41°09.555'N, 104°02.759'W, large earthen tank 44 by 18 m in length on canyon floor, 76 bats captured: 27 July 2010, p.m.—*E. fuscus* (six lactating females, two adult males), *M. ciliolabrum* (one lactating female), *L. cinereus* (one young-of-the-year female [UNSM 30066]), and *L. borealis* (one adult female [UNSM 30071]); 28 July 2010, a.m.—*E. fuscus* (one lactating female, one adult female, one adult male), *M. ciliolabrum* (one adult male), and *L. cinereus* (one adult female); 2 August 2010, p.m.—*E. fuscus* (three lactating females, three adult females, one adult male, one young-of-the-year male), *M. ciliolabrum* (one lactating female), *L. cinereus* (two adult females, three adult males, one young-of-the-year male), and *L. borealis* (four adult females, four adult males); 3 August 2010, a.m.—*E. fuscus* (one young-of-the-year male), *L. cinereus* (10 adult females, 13 adult males [UNSM 30068], one young-of-the-year female, two young-of-the-year males), and *L. borealis* (eight adult females, two adult males).

(1) 3.2 km S, 0.1 km W Intersection of Stateline Road and Interstate I-80, 41°09.235'N, 104°02.737'W, metal tank 5.5 m in diameter in open, flat area near canyonside, no bats captured on night of 5 September 2010, including after midnight; *Myotis ciliolabrum* observed p.m.

(1) 2.5 km S, 0.1 km E Intersection of Stateline Road and Interstate I-80, 41°09.607'N, 104°02.622'W, metal tank 8.2 m in diameter on canyon floor, 11 bats captured: 27 July 2010, p.m.—*M. ciliolabrum* (one adult female [UNSM 30094], one lactating female, one adult male); 2 August 2010, p.m.—*M. ciliolabrum* (one adult female); 3 August 2010, a.m.—*L. cinereus* (two adult females); 31 August 2010, p.m.—*L. cinereus* (one adult male) and *Myotis ciliolabrum* (observation only); 29 September 2010, p.m.—*M. ciliolabrum* (one adult male) and *M. thysanodes* (one adult male [UNSM 30090]); 30 September 2010, a.m.—*L. noctivagans* (one adult female [UNSM 30079]); 4 October 2010, p.m.—*Myotis ciliolabrum* (observation only); 29 July 2011, p.m.—*Myotis ciliolabrum* (observation only); 31 July 2011, p.m.—*Myotis ciliolabrum* (observation only); 1 August 2011, a.m.—*E. fuscus* (one adult male [UNSM 30097]).

(2) 0.8 km S, 1.5 km E Intersection of Stateline Road and Interstate I-80, 41°10.568'N, 104°01.593'W, metal tank 9.1 m in diameter in open, flat area near canyonside, no bats captured on night of 3 October 2010, including after midnight.

Pine-studded area in Cheyenne County

(5) 0.5 km S, 4.4 km E Potter, 41°12.773'N, 103°15.786'W, large pond 70 by 40 m in length, 0.25 km from a canyonside, no bats captured on night of 29 June 2010, including after midnight.

(6) 0.1 km N, 4.7 km E Potter, 41°13.142'N, 103°15.514'W, over land at canyon head, no bats captured on night of 1 August 2010 (net removed before midnight); *Myotis ciliolabrum* observed.

(7) 5 km E Potter, 41°13.022'N, 103°15.342'W, metal tank 3.0 m in diameter in flat area at canyon head, no bats captured on night of 1 August 2010 (net removed before midnight); no bats captured on night of 5 August 2010, including after midnight.

Treeless region in Cheyenne County

(9) 16.3 km S, 0.5 km E Potter, 41°04.239'N, 103°18.366'W, metal tank 7.6 m in diameter in rolling hills, no bats captured on night of 30 September 2010, including after midnight.

(9) 16.2 km S, 1.5 km E Potter, 41°04.310'N, 103°17.787'W, metal tank 6.1 m in diameter in rolling hills, one bat captured: 9 September 2010—none captured (net removed before midnight); 30 September 2010, p.m.—*M. ciliolabrum* (one adult male [UNSM 30096]).

(9) 16.2 km S, 1.5 km E Potter, 41°04.316'N, 103°17.780'W, adjacent to an abandoned rock house in rolling hills, no bats captured on nights of 9 September 2010 (net removed before midnight) and 30 September 2010, including after midnight.

(10) 14.0 km S, 13.4 km E Potter, 41°05.469'N, 103°09.278'W, metal tank 7.6 m in diameter in rolling hills, no bats captured on night of 2 September 2010, including after midnight.

(11) 6 km S, 13.4 km E Potter, 41°09.785'N, 103°09.300'W, metal tank 1.8 m in diameter in rolling hills, no bats captured on nights of 1 August and 1 September 2010, including after midnight.

(11) 5.2 km S, 13.7 km E Potter, 41°10.342'N, 103°09.045'W, metal tank 2.4 m in diameter in rolling hills, no bats captured on night of 1 September 2010 (net removed before midnight).

(11) 6 km S, 14 km E Potter, 41°09.796'N, 103°08.976'W, earthen tank 25 by 8 m in length in rolling hills, two bats captured: 1 August 2010, p.m.—*M. ciliolabrum* (two lactating females [UNSM 30095]).

Lodgepole Creek in Kimball County

(4) Intersection of Lodgepole Creek and Highway 71, 41°14.889'N, 103°39.767'W, along creek, two bats captured: 4 September 2010, p.m.—*E. fuscus* (one adult female [UNSM 30087]), *L. noctivagans* (one adult male [UNSM 30077]), and *Myotis ciliolabrum* (observation only).

Lodgepole Creek in Cheyenne County

(8) 1.3 km S, 4.5 km E Potter, Lodgepole Creek, 41°12.356'N, 103°15.654'W, along creek, two bats captured: 5 October 2010, p.m.—*L. noctivagans* (two adult females [UNSM 30080]).

(12) 2.9 km S, 14.5 km E Potter, Lodgepole Creek, 41°11.510'N, 103°08.473'W, along creek, 17 bats captured: 30 June 2010, p.m.—*E. fuscus* (two pregnant females [UNSM 30085], two lactating females, two adult females), and *M. ciliolabrum* (one pregnant female [UNSM 30092]); 1 July 2010, a.m.—*E. fuscus* (two pregnant females, one adult female); 3 September 2010, p.m.—*E. fuscus* (one adult female, one young-of–the-year male), *L. noctivagans* (one adult male [UNSM 30076]), and *Myotis ciliolabrum* (observation only); 6 September 2010, p.m.—*Myotis ciliolabrum* (observation only); 7 September 2010, a.m.—*L. noctivagans* (one adult male, one adult female); 30 September 2010, p.m.—*M. ciliolabrum* (one adult male); 1 October 2010, a.m.—*L. noctivagans* (one adult male).

(13) 1.1 km S, 0.7 km E Lodgepole, Lodgepole Creek, 41°08.338'N, 102°37.724'W, along creek, two bats captured: 1 October 2010, p.m.—*L. noctivagans* (one adult female, one adult male [UNSM 30082]).

Specimens collected prior to our study

(1) Kimball County, Gross-Wilkerson Ranch, 7.56 km S, 12.39 km W Bushnell Post Office, T14N, R59W, Sec. 24 SW¼, three specimens: 15 July 2004—*M. ciliolabrum* (one female [UNSM 28970]); 17 July 2004—*M. ciliolabrum* (one lactating female [UNSM 29175]); 4 August 2004—*M. ciliolabrum* (one female [UNSM 30296]).

(3) Kimball County, T16N, R56W, Sec. 26 (center of section is 11.2 km north-northwest of town of Kimball), one specimen: 17 May 1988—*L. noctivagans* (one female [UNSM 19369]).

(4) Kimball County, Kimball area, one specimen: 16 May 1964—*M. ciliolabrum* (one male [UWYMV 124]).

Molecular Systematics and Phylogeography of *Peromyscus nudipes* (Cricetidae: Neotominae)

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Abstract

The taxonomic status of *Peromyscus nudipes* has been problematic, with morphometric studies placing *P. nudipes* in synonymy with *P. mexicanus*, whereas molecular studies have indicated that *P. nudipes* may be an independent evolutionary lineage. To address this conundrum, DNA sequences from the mitochondrial cytochrome-*b* gene, representing all but one of the currently recognized members of the *P. mexicanus* species group, were obtained from GenBank or generated as part of this study. In addition, samples representing closely related species were included as reference and comparative samples. DNA sequences were analyzed under a Bayesian Inference model to infer phylogenetic relationships. Further, genetic distances were estimated and used to determine levels of genetic divergence among taxa. Results indicated that samples formerly recognized as *P. nudipes nudipes* from south-central Costa Rica and northern Panama formed a monophyletic group, whereas samples formerly assigned to *P. nudipes hesperus* and *P. nudipes orientalis* grouped with samples currently recognized as *P. nicaraguae*. Levels of genetic divergence estimated from samples of *P. nudipes nudipes* indicated that it was among the most divergent taxa residing in the *P. mexicanus* species group. Further, differences in distribution and elevation depicted a separation of samples representing *P. nudipes nudipes* and *P. mexicanus*. Together these data suggest that *P. nudipes* is a valid species and that its distribution should be restricted to the high elevation, montane forests of the Cordillera de Talamanca located in south-central Costa Rica and northern Panama.

Key words: cytochrome-*b* gene, Mesoamerica, molecular systematics, *Peromyscus, P. mexicanus* species group, *P. nudipes*

Introduction

The systematic status of *Peromyscus mexicanus* (Rodentia, Cricetidae) and its allies comprising the *P. mexicanus* species group (Osgood 1909; Carleton 1989; Musser and Carleton 2005) has been problematic for several decades. This complex, distributed throughout southern Mexico and Central America, occupies a diversity of habitats and elevation ranges and presumably its evolutionary history has been influenced by numerous biogeographic and climatic events (Pérez Consuegra and Vázquez-Domínguez 2015 and citations therein). The abiotic and biotic features of this region make it one of the most biologically diverse regions in the world and certainly these factors have impacted the diversification of Peromyscine rodents (Dawson 2005).

Since Osgood (1909), numerous authors have revised and improved our understanding of the *P. mexicanus* species complex (Hooper and Musser 1964; Hooper 1968; Musser 1969; Huckaby 1980; Carleton 1989; Rogers and Engstrom 1992; Ordóñez-Garza et al. 2010); however, incomplete sampling from the entire distribution or exclusion of critical taxa has hampered a global assessment of this species complex. Pérez Consuegra and Vázquez-Domínguez (2015) based on findings from analyses of mitochondrial cytochrome-*b* gene (*Cyt*b) sequences, provided the most recent taxonomic assessment of the *P. mexicanus* species group. This extensive study resulted in the proposed elevation of three junior synonyms to species status (*P. nicaraguae, P. salvadorensis,* and *P. tropicalis*), resulting in an increase of the number of species in the group to 11 (*P. grandis, P. guatemalensis, P. gymnotis, P. mexicanus, P. nicaraguae, P. nudipes, P. salvadorensis, P. stirtoni, P. tropicalis, P. yucatanicus,* and *P. zarhynchus*).

Although the study by Pérez Consuegra and Vázquez-Domínguez (2015) resulted in the broadest geographic coverage to date, their study included very few samples located south of Honduras. In particular, only two samples associated with *P. nudipes* were included in their study - one from San José, Costa Rica (GenBank accession number KP284425) and the specimen reported in Miller and Engstrom (2008) from Cartago, Costa Rica (GenBank accession number EF989992). Although *P. nudipes* does not have a broad geographic distribution (see Hall 1981), the geographic features of Costa Rica and Panama (Gutiérrez-García and Vázquez-Domínguez 2013) preclude an in-depth analysis of genetic variation within this species relative to its geographic distribution and to other *P. mexicanus* group members located throughout Mesoamerica.

Allen (1891) described *P. nudipes* based on a single specimen collected from La Carpintera, Costa Rica. Osgood (1909) examined material from additional localities and the data supported Allen's description but it was noted that *P. nudipes* appeared to be intermediate between *P. guatemalensis* and *P. mexicanus*. Several years later, Goodwin (1938) and Harris (1940) described two additional subspecies of *P. nudipes* from Costa Rica; *P. n. orientalis* and *P. n. hesperus*, respectively. Goodwin (1946) examined additional material from Costa Rica and Panama and postulated that the type specimen is not a "typical representative" of *P. nudipes* but that specimens collected from Volcán Irazú (~ 2,850 m) were more reflective examples of the species. In Goodwin's (1946) synopsis, *P. n. orientalis* and *P. n. hesperus* were determined to be smaller in size and appeared to occupy lower elevation habitats than did *P. n. nudipes*. Further, Goodwin (1946) surmised that *P. n. orientalis* and *P. n. hesperus* might be aligned with *P. mexicanus saxatilis*; leaving only *P. n. nudipes* as a representative of the species. Hooper (1968) continued to treat *P. nudipes* as a species although he echoed Osgood's (1909) position that it could fit into either *P. guatemalensis* or *P. mexicanus*. Huckaby's (1980) detailed revision of the *P. mexicanus* species group resulted in *P. nudipes* being synonomized with *P. mexicanus*. Although Hall (1981) recognized *P. nudipes* (and the subspecific divisions), it is likely that he was either unaware of or ignored Huckaby's revisionary study. More recent synopses (Carleton 1989; Musser and Carleton 2005; Trujano-Alvarez and Alvarez-Castañeda 2010) followed Huckaby's recommendation of placing *P. nudipes* in synonymy with *P. mexicanus*.

Although the morphologic data argue for synonymizing all of *P. nudipes* (*hesperus, orientalis,* and *nudipes*), or at least *P. n. hesperus and P. n. orientalis,* with *P. mexicanus*; the genetic data suggest that differentiation exists between the two taxa. For example, despite extreme conservation among autosomes, *P. nudipes* differs from *P. mexicanus* (and some other *P. mexicanus* group members) in the morphology of the X and Y-chromosomes (Hsu and Arrighi 1968; Rogers et al. 1984; Smith et al. 1986). Further, in the allozymic study of Rogers and Engstrom (1992), *P. nudipes, P. mexicanus, P. guatemalensis, P. yucatanicus,* and *P. zarhynchus* were found to be genetically similar but differed based on the presence of autapomorphic alleles. Analyses of mitochondrial DNA sequence data (Miller and Engstrom 2008, Pérez Consuegra and Vázquez-Domínguez 2015) demonstrated that samples historically assignable to *P. n. nudipes* (La Trinidad de Dota, and Cerro de la Muerte, Costa Rica) were strongly differentiated from samples of *P. mexicanus*.

The goals of this study were to: 1) examine genetic variation in the *Cyt*b gene in samples of *P. nudipes* and *P. nicaraguae,* including specimens formerly assigned to *P. n. hesperus* and *P. n. orientalis,* from Costa Rica, Honduras, Nicaragua, and Panama; and 2) attempt to resolve the taxonomic status of *P. nudipes* relative to other members of the *P. mexicanus* species group. DNA sequences generated herein were combined with sequences from Pérez Consuegra and Vázquez-Domínguez (2015) and sequences obtained from GenBank to better assess the genetic variation among members of the *P. mexicanus* group from the more southern portion of its range.

MATERIALS AND METHODS

Samples.—Tissue samples were obtained from 51 specimens collected from naturally-occurring populations in Honduras, Mexico, and Nicaragua or borrowed from museum collections (Localities 1–18, Fig. 1; Appendix). DNA sequences from an additional 173 individuals were included as internal references or used for outgroup comparisons based on the studies of Bradley et al. (2007), Miller and Engstrom (2008), Ordóñez-Garza et al. (2010), and Pérez Consuegra and Vázquez-Domínguez (2015). Specimens were collected following methods outlined in the ASM Guidelines (Sikes et al. 2016) and approved by the Texas Tech University Animal Care and Use Committee. Specimen numbers and collection localities are listed in the Appendix.

Sequence data.—Methods for obtaining DNA sequencing data follow that of Bradley et al. (2007, 2015) with minor modifications; as summarized below. Mitochondrial DNA was isolated from approximately 0.1 g of tissue using a DNeasy kit (Qiagen, Valencia, California). The entire *Cyt*b gene (1,143 bp) was amplified using the polymerase chain reaction method (PCR, Saiki et al. 1988) and the following primers: MVZ05

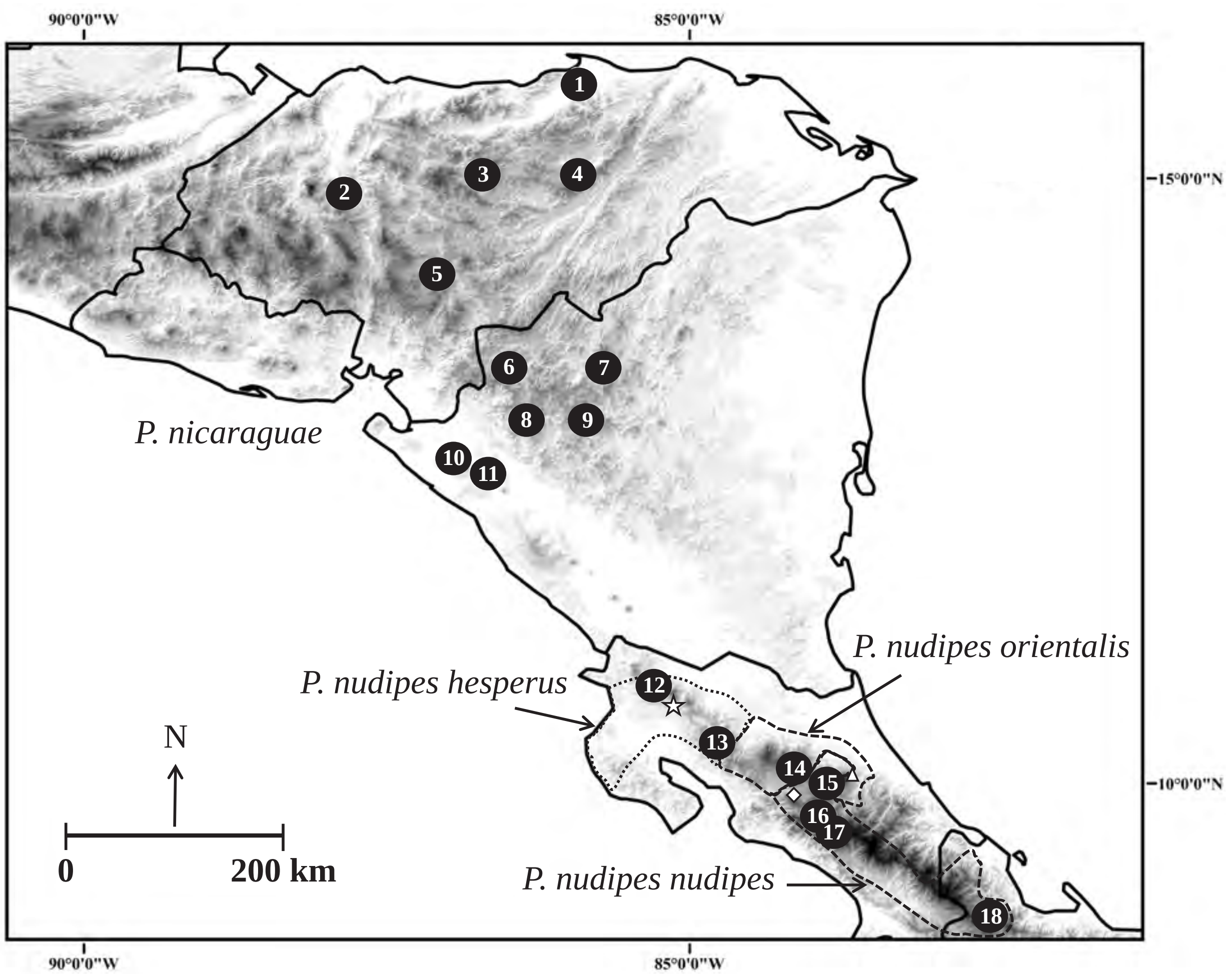

Figure 1. Distribution of selected populations and species of the *Peromyscus mexicanus* species group from Mesoamerica. Closed circles represent sampling localities and numbers refer to samples listed in the Appendix. Open diamond, star, and triangle represent the approximate location of the type localities for *P. nudipes nudipes*, *P. nudipes hesperus,* and *P. nudipes orientalis*, respectively.

(Smith and Patton 1993) and PERO3' (Tiemann-Boege et al. 2000). Thermal profiles for PCR were as follows: initial denaturation at 95°C for 2 min, followed by 35 cycles of denaturation at 95°C for 1 min, annealing at 51°C for 1 min, and extension at 72°C for 2 min, with a final extension at 72°C for 7 min. Most PCR products were purified with ExoSAP-IT (Affymetrix, Santa Clara, California). Primers used to cycle sequence the products included: WDRAT1100, 400R, 700H, and NEO700L (Peppers and Bradley 2000) and 400F, (Tiemann-Boege et al. 2000). Cycle sequencing reactions were purified using isopropanol cleanup protocols and were analyzed with an ABI 3100-Avant automated sequencer and ABI Prism Big Dye version 3.1 terminator technology (Applied Biosystems, Foster City, California). Resulting sequences (of various lengths) were aligned and proofed using Sequencher 4.0 software (Gene Codes, Ann Arbor, Michigan); chromatograms were examined to verify all base changes. *Cyt*b sequences obtained in this study were deposited in GenBank and are listed in the Appendix.

Using the phylogenetic relationships of the genus *Peromyscus* proposed by Bradley et al. (2007) and Platt et al. (2015), *Reithrodontomys fulvescens* was selected as the outgroup taxon for sequence analyses. Ten of the 11 species putatively assigned to the *P. mexicanus* species group (Bradley et al. 2007; Pérez Consuegra and Vázquez-Domínguez 2015 — *P. grandis, P. guatemalensis, P. gymnotis, P. mexicanus, P. nicaraguae, P. nudipes, P. salvadorensis, P. stirtoni, P. tropicalis,* and *P. zarhynchus*) were included in the analyses; samples were not available for *P. yucatanicus*. In addition, samples of *P. furvus, P. mayensis, P. megalops, P. melanocarpus, P. melanophrys,* and *P. perfulvous* were included based on their potential affiliations to the *P. mexicanus* species group. Further, samples of *P. boylii, P. leucopus,* and *P. ochraventer* were included as internal standards. All analyses were performed in PAUP* (Version 4.0a149; Swofford 2002).

Eighty-eight maximum likelihood models were evaluated using MODELTEST (Darriba et al. 2012) in order to determine the model of DNA evolution best fitting the data. The Akaike information criterion identified HKY+I+G as being the most appropriate model, relative to complexity of model, for this dataset. This model generated significantly better likelihood scores (-lnL = 13002.3955) than all other models and included the following parameters: base frequencies (A = 0.3525, C = 0.3080, G = 0.0838, and T = 0.2557); proportion of invariable sites (I = 0.4590); and gamma distribution (G = 0.8810).

Bayesian inference methods (MrBayes; Huelsenbeck and Ronquist 2001) were used under a maximum likelihood framework and the HKY+I+G model of evolution. Model parameters were estimated within the analysis. The analysis was run with the following options: 4 Markov-chains, 10 million generations, and sample frequency = every 1,000th generation. Following a visual inspection of likelihood scores, the 1st 1,000 trees were discarded and a consensus tree (50% majority rule) was constructed from the remaining trees. Clade probabilities values, indicative of nodal support, were estimated and only values ≥ 0.95 were considered as evidence for statistical support.

The Kimura 2-parameter model of evolution (Kimura 1980) was used to calculate genetic distances between selected taxa. These genetic distances were used: 1) as a direct comparison to values reported in Pérez Consuegra and Vázquez-Domínguez (2015) and 2) to assess levels of genetic divergence following criteria outlined in Bradley and Baker (2001) and Baker and Bradley (2006).

RESULTS

A total of 226 DNA sequences (of various lengths) representing the *P. mexicanus* species group, other closely related species groups, and the outgroup taxon were analyzed using Bayesian inference methods. In this analysis, only clade probability values (CPV) ≥ 0.95 were considered as evidence for nodal support. The resulting topology (Fig. 2) depicted a large clade (Clade A, CPV = 1.00) that included the following taxa: *P. mayensis, P. megalops, P. stirtoni, P. melanocarpus, P. melanophrys, P. perfulvous* and 9 species (Clade B, CPV = 1.00) referred, herein, as the *mexicanus* species group (*sensu stricto*). Given that the phylogenetic

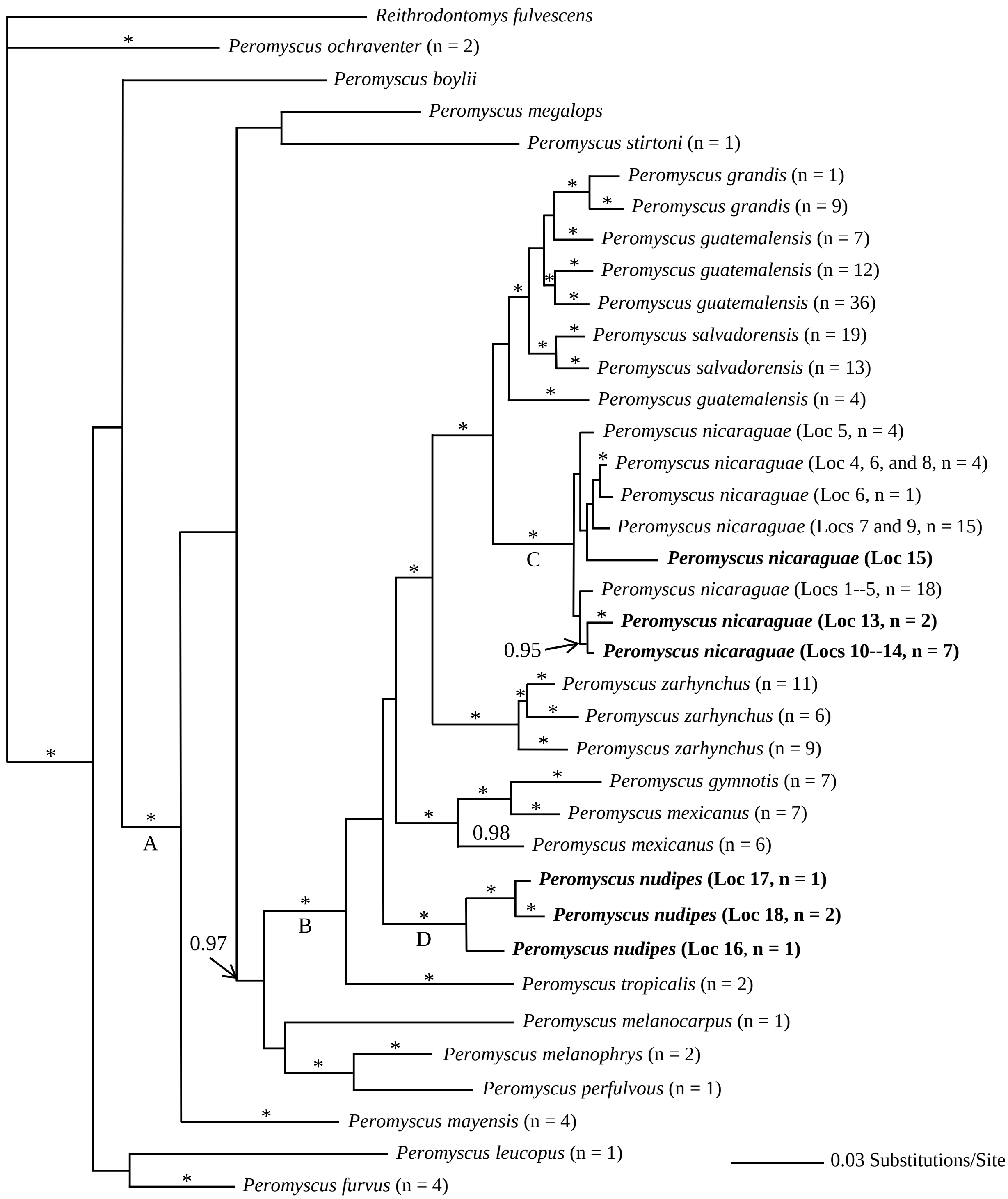

Figure 2. Phylogenetic tree generated using Bayesian methods (MrBayes; Huelsenbeck and Ronquist 2001) and the HKY+I+G model of evolution. Clade probability values are shown above branches values (values of 1.00 are indicated by an asterisk). Terminal taxa represented in bold font are indicative of samples formerly assigned to *Peromyscus nudipes nudipes*, *P. nudipes hesperus*, and *P. nudipes orientalis*. Localities (Loc) and samples sizes (n) are provided in parentheses and correspond to the specimens examined in the Appendix.

status of *P. mayensis* and *P. stirtoni* remain unclear and that *P. megalops*, *P. melanocarpus*, *P. melanophrys*, and *P. perfulvus* have been shown to be affiliated with other species groups (Musser and Carleton 2005; Bradley et al. 2007), a detailed presentation of these results will be restricted to the membership of clade B.

Within Clade B, individuals formed monophyletic clades within the boundaries of their respective, designated species except for samples of *P. guatemalensis* and *P. mexicanus*. Samples of *P. n. hesperus* (Localities 12 and 13), *P. n. orientalis* (Locality 14) and *P. n. nudipes* (Locality 15) were members of a clade containing individuals of *P. nicaraguae* (Clade C, Localities 1–11) from Honduras and Nicaragua; whereas the remaining samples of *P. n. nudipes* (Clade D, Localities 16–18) formed an independent clade near the base of Clade B.

Genetic divergence values (Table 1) were estimated for representative individuals using the Kimura 2-parameter model of evolution (Kimura 1980). In this analysis, only a single representative of each population was included in the analyses to prevent an underestimation of genetic differentiation. Further, based on the results of the Bayesian analysis, only samples from Localities 16–18 were included as representatives of *P. nudipes*; samples from localities 10–15 were treated as samples of *P. nicaraguae*. Average genetic distances among samples, representing each species ranged from 1.28% (*P. gymnotis*) to 4.17% (*P. zarhynchus*); samples of *P. tropicalis* differed by 0.09%, however, only 2 individuals were available for analysis and they were from the same population. Genetic divergence values between species ranged from 4.65% (*P. guatemalensis* and *P. salvadorensis*) to 11.13% (*P. gymnotis* and *P. nudipes*). Pairwise comparison to other species in the *P. mexicanus* group revealed that *P. nudipes* differed by values ranging from 9.20% (*P. salvadorensis*) to 11.13% (*P. gymnotis*). Overall, levels of genetic divergence between *P. nudipes* and others species in the *P. mexicanus* were similar to or exceeded values resulting from pairwise comparisons of all *P. mexicanus* groups members.

DISCUSSION

A monophyletic clade (Clade B, Fig. 2) containing members of the *P. mexicanus* group was obtained from the Bayesian Inference analysis. A *sensu stricto* interpretation of this group indicates that the *P. mexicanus* group should include the following species: *P. grandis*, *P. guatemalensis*, *P. gymnotis*, *P. mexicanus*, *P. nicaraguae*, *P. nudipes*, *P. salvadorensis*, *P. tropicalis*, and *P. zarhynchus*. Although samples of *P. yucantanicus* were not available for inclusion in this study, several lines of evidence (Huckaby 1980; Rogers et al. 1984; Smith et al. 1986; Rogers and Engstrom 1992) support its inclusion into the *P. mexicanus* species group. Phylogenetic relationships between most species were resolved, however, *P. tropicalis*, *P. nudipes*, and a clade containing samples of *P. gymnotis* and *P. mexicanus* could not be placed within the context of the remaining species. Although beyond the scope of this study, it is apparent that multiple species probably reside in what is now recognized as *P. guatemalensis* and *P. mexicanus*. Further, in agreement with Carleton (1989) and Bradley et al. (2007), it appears that the phylogenetic relationships obtained from this study indicate that *P. mayensis* and *P. melanocarpus* are probably not members of the *P. mexicanus* species group.

Based on the results of the Bayesian Inference analysis and magnitude of genetic divergence reported herein, *P. nudipes* is a valid species; however, we suggest a more restricted view of this taxon than previously described. In agreement with previous authors (Goodwin 1946; Hooper 1968; Huckaby 1980; Carleton 1989; Musser and Carleton 2005; Trujano-Alvarez and Alvarez-Castañeda 2010), samples of *P. nudipes orientalis* and *P. nudipes hesperus* are more closely related to *P. guatemalensis* or *P. mexicanus*. In the phylogenetic analysis, presented herein, samples from northern Costa Rica (Localities 12–14) formerly considered to be representative of *P. nudipes orientalis* and *P. nudipes hesperus* were included in a large clade (Clade C) containing samples from Honduras and Nicaragua (Localities 1–11). The samples from Localities 1–11 historically have been recognized as *P. m. saxatilis* (formal synonymy provided by Trujano-Alvarez and Alvarez- Castañeda 2010); portions of

Table 1. Average genetic distances estimated using the Kimura 2-parameter model of evolution (Kimura 1980) for selected comparisons of members of the *Peromyscus mexicanus* species group.

	grandis	*guatemalensis*	*gymnotis*	*mexicanus* A	*mexicanus* B	*nicaraguae*	*nudipes*	*salvadorensis*	*tropicalis*	*zarhynchus*
grandis	3.16	5.41	10.56	9.74	8.60	7.66	10.88	5.83	10.99	9.96
guatemalensis		3.18	9.98	10.38	8.82	6.97	9.79	4.65	10.38	9.55
gymnotis			1.28	6.69	7.98	10.52	11.13	10.40	11.01	10.63
mexicanus A				1.34	6.97	10.10	9.70	10.02	10.21	10.32
mexicanus B					2.24	9.46	9.26	8.90	9.63	9.04
nicaraguae						3.06	10.14	6.93	9.91	9.38
nudipes							3.75	9.20	10.80	9.80
salvadorensis								1.90	10.20	9.18
tropicalis									0.09	10.88
zarhynchus										4.17

this taxon recently were elevated to *P. nicaraguae* by Pérez Consuegra and Vázquez-Domínguez (2015). In addition, the sample from Locality 15, formerly aligned with *P. nudipes nudipes*, also was embedded within the clade containing representatives of *P. nicaraguae* and should be recognized as such. Samples from Localities 16–18 (south-central Costa Rica and Panama) formed a monophyletic clade (clade D) positioned near the base of the *P. mexicanus* group topology and distantly removed from members of clade C. The samples comprising clade C historically were considered to be examples of *P. nudipes nudipes* and should retain that name based on phylogenetic principles and levels of genetic divergence from other members of the *P. mexicanus* species group.

In resolving this conundrum, besides the genetic differentiation reported herein, it appears that elevation may be a key factor in further distinguishing samples of *P. nudipes* from those now included in *P. nicaraguae*. The type locality for *P. nudipes nudipes* (La Carpintera, Costa Rica) was reported by J. A. Allen (1891) to be approximately 1,818 m in elevation. Elevations reported for the type localities for *P. nudipes hesperus* (Hacienda Santa María, Costa Rica, about 15 mi NE of Liberia; Harris 1940) and *P. nudipes orientalis* (El Sauce Peralta, Costa Rica; Goodwin 1938) are ~ 970 m and 303 m, respectively. Elevations at the type localities for both *P. nudipes hesperus* and *P. nudipes orientalis* appear to be more similar to the low to mid elevation ranges typically associated with *P. mexicanus saxitalis* (now considered to be *P. nicaraguae*). Conversely, the samples of *P. nudipes nudipes*, examined herein, were from much higher elevations (2,500 m - Locality 16, 2,325 m - Locality 17, and 2,000 m - Locality 18). It appears that *P. nudipes* is restricted to the montane pine-oak forests of the Cordillera de Talamanca of southern Costa Rica and northwestern Panama, whereas *P. nicaraguae* (formerly *P. nudipes hesperus* and *P. nudipes orientalis*) occupies the mid to low elevation tropical forests of the Central, Tilarán, and Guanacaste Mountains in the north-central regions of Costa Rica, northward to Nicaragua and Honduras. This hypothesis needs to be tested by obtaining more samples from trapping to determine if taxa are restricted to these ecosystems.

The difference in geological age of these two ranges may have been a contributing factor to the differentiation of *P. mexicanus* and *P. nudipes*. The younger and more northern ranges (Central, Tilarán, and Guanacaste) were formed from volcanic activity during the Quaternary (Soto and Alvarado 2006; Carr et al. 2007; Gutiérrez-García and Vázquez-Domínguez 2013). Conversely, the older and more southern range (Cordillera de Talamanca) rapidly uplifted during the late Pliocene to early Pleistocene and had little volcanic activity during the Quaternary (Johnston and Thorkelson 1997). The forests of the Cordillera de Talamanca are considered the largest continuous forested area in Costa Rica (Tobler 2002) and are characterized by steep slopes and numerous small inter-montane valleys (González-Maya et al. 2009). This habitat (classified as Tropical Montane Cloud Forests, Kappelle 1996) is dominated by two species of oak (Tobler 2002) and typically ranges from 2,000 to 3,200 m. Additional sampling is needed from the high elevation areas (>2,000 m) in central and southern Costa Rica, as well as northern Panama, to resolve the elevation and habitat preferences and differences between *P. mexicanus* and *P. nudipes*. Further, special attention is needed for samples from the southern Central Range near Volcán Irazú, which Goodwin (1946) ascertained as being more closely aligned with *P. nudipes*. It may be that *P. nudipes* occurs at high elevations in this region.

The decision to resurrect the name *P. nudipes* (J. A. Allen 1891) from synonymy with *P. mexicanus* (see Trujano-Alvarez and Alvarez-Castañeda 2010) was based on the following. First, a comprehensive phylogenetic analysis that included all currently recognized members of the *P. mexicanus* group, representative of presumed closely related species, as well as, a sampling scheme that included samples from throughout the entire range of the *P. mexicanus* species group provided data that supported *P. nudipes* as a monophyletic assemblage. This monophyletic group contained samples from high elevation locations in south-central Costa Rica and Panama that resembled the initial supposition and description of *P. nudipes* by Allen (1891). Once these high elevation samples (Localities 16–18) were included with the broad geographic coverage reported in the taxonomic revision by Pérez Consuegra and Vázquez-Domínguez (2015), it became apparent that *P. nicaraguae* and *P. nudipes* represented independent evolutionary complexes.

Second, examination of the genetic distance dataset indicated that *P. nudipes* was among the most genetically divergent members of the *P. mexicanus* species group. Samples of *P. nudipes* differed from other *P. mexicanus* group members by average genetic distances ranging from 9.26% to 11.13%. As a comparison, the sister species *P. melanophrys* and *P. perfulvus* differed by 7.92% (this study). In addition, these values exceeded those estimated from other groups of closely related *Peromyscus* species (Durish et al. 2004; Bradley et al. 2004, 2014) indicating either a more rapid rate of molecular divergence or a longer elapsed time period since sharing a most recent common ancestor. Interpretation of the phylogenetic and genetic distance data under the auspices of the Genetic Species Concept (see Bradley and Baker 2001 and Baker and Bradley 2006) argues that *P. nudipes* represents a genetic species within the *P. mexicanus* species group.

In conclusion, it is suggested that 1) *P. nudipes*, restricted to samples from south-central Costa Rica and northern Panama, be reinstated as a species, 2) samples of *P. nudipes hesperus* and *P. nudipes orientalis* should be subsumed into *P. nicaraguae*, and 3) further sampling be conducted in the montane regions of central Costa Rica to better diagnose the distribution and habitat differences associated with *P. nudipes* and *P. nicaraguae*.

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APPENDIX

Specimens examined in the DNA sequencing portion of this study. Taxonomic designations following and the results of Bradley et al. (2007), Pérez Consuegra and Vázquez-Domínguez (2015), and those presented herein. For each specimen reported herein the collection locality, museum catalogue number (to left of slash) and GenBank accession number (to right of slash) are provided in parentheses. Abbreviations for museum acronyms follow Hafner et al. 1997). For most sequences obtained from GenBank only the accession number is provided. Abbreviations are as follows: Museum of Natural History (KU), Museum of Southwestern Biology (MSB), Museum of Texas Tech University (TTU), United States National Museum of Natural History (USNM), and Zadock Thompson Natural History Collection, University of Vermont (ZTNHC). If museum catalog numbers were unavailable, specimens were referenced with the corresponding TK number (special number of the Museum of Texas Tech University). Localities corresponding to Figure 1 are provided in parentheses.

***Peromyscus mexicanus* species group:**

Peromyscus grandis.—GUATEMALA: Alta Verapaz; Chelemhá Yalijux Mountain (USNM569843/KX998940, USNM569910/KX998941). Sequences from GenBank: GQ461919, GQ461920, GQ461921, GQ461922, GQ461923, GQ461924, GQ461925, KP284306.

Peromyscus guatemalensis.—GUATEMALA: Huehuetenango; 9 km NNE Cuilco, El Retiro (USNM570208/KX998915, USNM570213/KX998916, USNM570220/KX998917),10 Km. NNE Cuilco, El Retiro (USNM570233/KX998918, USNM570234/ KX998919, USNM570235/ KX998920, USNM570236/KX998921, USNM570237/KX998922, USNM570239/KX998923, USNM570240/KX998924, USNM570241/KX998925, USNM570242/KX998926, USNM570243/KX998927). Sequences from GenBank: EF281171, EF281172, GQ461926, GQ461927, GQ461928, GQ461929, GQ461930, GQ461931, GQ461932, GQ461933, GQ461934, GQ461935, KP284351, KP284352, KP284353, KP284354, KP284355, KP284356, KP284357, KP284358, KP284359, KP284360, KP284361, KP284362, KP284363, KP284364, KP284365, KP284366, KP284367, KP284368, KP284369, KP284370, KP284371, KP284372, KP284373, KP284374, KP284375, KP284376, KP284377, KP284377, KP284378, KP284379, KP284380, KP284381, KP284382, KP284383, KP284384.

Peromyscus gymnotis.—Sequences from GenBank: EF028169, EF028170, KP284385, KP284386, KP284387, KP284388, KP284389.

Peromyscus mexicanus.—EL SALVADOR: Santa Ana; Parque Nacional Montecristo (TTU61014/KX998944. GUATEMALA: Chiquimula, 8 Km SW Esquipulas, Plan de la Arada, (TTU125805/KX998942, TTU125806/KX998943). MEXICO: Chiapas, 25 km S, 3 km N Ocozocoautla (TTU104622/KX998938); Veracruz; 6.7 km NE, 13.5 km SE Perote (TTU105005/KX998945). Sequences from GenBank: EF028174, HQ269736, KP284422, KP284423, KP284424, KJ526415, AY376425, JX910118.

Peromyscus nicaraguae.—COSTA RICA: Cartago; Capellades; (Loc 15, EF989991); Guanacaste; Volcán Santa María (Loc 13, EF989993); Heredia: 2 km NE Getzemani (Loc 14, AY041200); Puntarenas; Monte Verde Biological Station (Loc 13, KU142102/KX998930, KU143321/KX998931, EF989994). HONDURAS: Colón: Trujillo; Parque Nacional Capiro y Calentura (Loc 1, TTU104186/KX998935); Comayagua; Parque Nacional Cerro Azul Meámbar (Loc 2, TTU104357/KX998934); Francisco Morazán; Parque Nacional La Tigra (Loc 5, TTU83698/KX998948, TTU83731/KX998932, TTU83708/KX998963, KP284309, KP284310, KP284311, KP284312,); Olancho; Parque Nacional La Muralla (Loc 3, KP284314, KP284315, KP284316, KP284317, KP284318, KP284319, KP284320); Parque Nacional Sierra de Agalta, Babilionia Mountain (Loc 4, KP284321, KP284322, KP284323, KP284324, KP284325, KP284326, KP284327). NICARAGUA: Chinandega; Chichigalpa, Bella Vista (Loc 10,

TTU105099/KX998959, TTU105096/KX998962); San Cristóbal (Loc 11, TTU105108/KX998960, TTU105111/KX998961); Madriz; San Lucas, Los Mangos (Loc 6, TTU9672/FJ214687); Jinotega; El Cuá, Galope (Loc 7, TTU119600/KX998936, TTU119601/KX998937); Matagalpa; Selva Negra (Loc 9, TTU88195/KX998951, TTU93013/KX998954, TTU97009/KX998953, TTU97020/KX998947, TTU96980/KX998964, TTU105180/KX998939, TTU105193/KX998955, TTU105190/KX998956, TTU105164/KX998958, TTU101386/KX998957, TTU101406/KX998933, TTU101409/KX998949, TTU101421/KX998950, TTU101441/KX998952), Posada Tisev (Loc 8, KP284313).

Peromyscus nudipes.—COSTA RICA: Cartago; Cerro de la Muerte, San Gerardo del Dota (Loc 17, EF989992); San José; 2.2 km E (by road) La Trinidad de Dota (Loc 16, KP284425). PANAMA: Chiriqui; Bugaba, La Amistad International Park, Las Nubes Ranger Station (Loc 18, MSB262229/KX998928, MSM262207/KX998929).

Peromyscus salvadorensis.—Sequences from GenBank: KP284390, KP284391, KP284392, KP284393, KP284394, KP284395, KP284396, KP284397, KP284398, KP284399, KP284400, KP284401, KP284402, KP284403, KP284404, KP284405, KP284406, KP284407, KP284408, KP284409, KP284410, KP284411, KP284412, KP284413, KP284414, KP284415, KP284416, KP284417, KP284418, KP284419, KP284420, KP284421.

Peromyscus stirtoni.—DQ973108.

Peromyscus tropicalis.—Sequences from GenBank: KP284307, KP284308.

Peromyscus zarhynchus.—GUATEMALA: Huehuetenango; Nenton 1 km NE (by road) of Yalmbojoch (USNM570460/KX998946). MEXICO: Chiapas; Yalentay UTM 15-524171-1852486 (TK93297/AY195800). Sequences from GenBank: EF028167, KP284328, KP284329, KP284330, KP284331, KP284332, KP284333, KP284334, KP284335, KP284336, KP284337, KP284338, KP284339, KP284340, KP284341, KP284342, KP284343, KP284344, KP284345, KP284346, KP284347, KP284348, KP284349, KP284350.

Peromyscus mayensis.—Sequences from GenBank: DQ836300, DQ836301, EF989987, EF989988.

Peromyscus melanocarpus.—Sequences from GenBank: EF028173.

Outgroup and internal reference specimens:

Peromyscus furvus.—AF270993, AF270995, AF271006, AF271026.

Peromyscus megalops.—DQ000475.

Peromyscus melanophrys.—AY322510, AY376424.

Peromyscus perfulvus.—DQ000474.

Peromyscus boylii.—DQ000478.

Peromyscus leucopus.—DQ000483.

Peromyscus ochraventer.—FJ214689, JX910119.

Reithrodontomys fulvescens.—AF176257.

An Inventory of Bats in Arch Canyon, San Juan County, Utah

Tony R. Mollhagen and Michael A. Bogan

Abstract

Arch Canyon is located in southeastern San Juan County, Utah, southwest of Blanding, and west of Comb Ridge. During the summer of 2007, we conducted an inventory for bats in the canyon at the request of the Bureau of Land Management, which oversees management of the area. We were especially interested in the status of state species of concern, which include Fringed Myotis, *Myotis thysanodes*; Allens Big-eared Bat, *Idionycteris phyllotis*; Townsends Big-eared bat, *Corynorhinus townsendii*; Spotted Bat, *Euderma maculatum*; and Big Free-tailed Bat, *Nyctinomops macrotis*. We netted at 10 sites in the canyon and captured a total of 295 individual bats of 15 species. The eight most common species of bats were Western Pipistrelle, *Parastrellus hesperus* (32.9% of total captures), Big Free-tailed Bat (23.4%), Brazilian Free-tailed Bat, *Tadarida brasiliensis* (12.5%), Big Brown Bat, *Eptesicus fuscus* (7.1%), Pallid Bat, *Antrozous pallidus* (5.4%), Yuma Myotis, *Myotis yumanensis* (4.7%), Spotted Bat, *Euderma maculatum* (3.7%), and California Myotis, *Myotis californicus* (3.4%). We captured 11 individual *Euderma maculatum*, a number that seems remarkable given the level of effort. The capture of 69 individual Big Free-tailed Bats, representing over 23 percent of the total sample of Arch Canyon, is unusually high in comparison with other surveys in nearby areas.

Key words: Arch Canyon, bats, Chiroptera, inventory, Utah

Introduction

The Colorado Plateau has attracted the attention of many scientists since J. W. Powell explored and mapped the canyon country of the Colorado River in 1869 (Powell [reprinted] 1961). C. H. Merriam, V. Bailey, M. Cary, W. H. Osgood, and other employees of the Bureau of Biological Survey conducted biological explorations of the area in the late 1800's. More recent studies of mammals found on the Colorado Plateau have included those by Durrant (1952) for Utah, Armstrong (1972) and Fitzgerald et al. (1994), Armstrong et al. (2011) for Colorado, Findley et al. (1975) for New Mexico, and Hoffmeister (1986) for Arizona. All of the aforementioned researchers and their work have contributed to our understanding of the fauna of the Colorado Plateau.

Nonetheless, details of distribution and abundance for many species of plants and animals of the southeastern Utah canyon country are poorly known, and future management plans for such areas are dependent upon the availability of current information on the status of these species. It was in this context that the Monticello office of the Bureau of Land Management (BLM) requested specific information for selected species of small mammals occurring in canyons in southeastern Utah. BLM was specifically interested in acquiring information concerning bats in Arch Canyon.

Arch Canyon is located in southeastern San Juan County, southwest of Blanding, and west of Comb Ridge. It is accessed from US Hwy 95, initially through tribal lands. There is an 8.9 mi (19.5 km), primitive, two-track trail from the canyon entrance to the National Forest Boundary. Motorized traffic entering the canyon must exit by the same route. Under normal circumstances, several of the stream crossings are impassable for any except high-clearance, four-wheel-drive (4WD) vehicles. However, the canyon periodically is subject to flash flooding, thus rendering much of it inaccessible except by hiking.

Arch Canyon appeals to a variety of interests. There are the eponymous arches in the upper canyon. There are a number of sites suitable for primitive camping. Hiking is not difficult if walkers remain on the trail. Similarly, experienced drivers utilizing all-terrain (ATVs) or larger 4WD vehicles will find the trail sometimes challenging, but usually not dangerous. There are the remains of at least three Anasazi dwellings along the canyon walls. Also, a resident fish species of concern, the Flannelmouth Sucker (*Catostomus latipinnis*) can be found in pools of the lower canyon. It is these last two attractions, plus the at least seasonally-resident chiropteran species, that raise concerns related to unlimited human access to the canyon.

The bat species of concern include the Fringed Myotis, *Myotis thysanodes;* Allen's Big-eared Bat, *Idionycteris phyllotis;* Townsend's Big-eared Bat, *Corynorhinus townsendii;* Spotted Bat, *Euderma maculatum*; and Big Free-tailed Bat, *Nyctinomops macrotis*. All of these species occur on, but not necessarily throughout, the Colorado Plateau (e.g., Mollhagen and Bogan 1997, Bogan et al. 2006, O'Shea et al. 2011), and there is a high probability that these bat species are found in Arch Canyon. The possible impact of foot and vehicle traffic in association with recreational activities on these species is unknown.

Durrant's *Mammals of Utah* (1952), the first comprehensive report on mammals of Utah, provided statewide records for 17 species (1 erroneously) of bats. However, Durrant had little information on bats found in southeastern Utah. Armstrong (1974, 1982) reported ten species of bats from Canyonlands National Park, including *Myotis californicus*, *M. evotis*, *M. thysanodes*, *M. yumanensis*, *Lasiurus cinereus*, *Parastrellus hesperus*, *Eptesicus fuscus*, *Corynorhinus townsendii*, *Idionycteris phyllotis*, and *Antrozous pallidus*.

Schafer (1991) reported the occurrence of six species of bats from the Abajo Mountains (*Myotis evotis*, *M. ciliolabrum*, *M. volans*, *Lasionycteris noctivagans*, *Eptesicus fuscus*, and *Lasiurus cinereus*). Mollhagen and Bogan (1997) documented 15 species of bats from the Henry Mountains and surrounding areas in southeastern Utah, including those reported by Schafer (1991) plus *Euderma maculatum* and *Tadarida brasiliensis*; and Mollhagen and Bogan noted the nearby capture of *Nyctinomops macrotis*. Bogan et al. (2006), working in Canyonlands National Park, reported 16 species, excluding *Myotis lucifugus*, records of which are problematic in the region.

Although long-lived (5–20 yrs), bats as a group are of concern because they have low reproductive output (usually 1 young/female/yr) and may roost in large groups (hundreds to thousands) where they are susceptible to human disturbance (O'Shea and Bogan 2004). Furthermore, much of the existing data on chiropteran population trends is of limited use; because of methodological issues with collecting the data, limited time periods of data collection, or inadequate sample sizes for statistical analysis (O'Shea and Bogan 2004).

Our objectives were to: (1) conduct an inventory of all bat species in Arch Canyon; and (2) to identify differences in occurrences of bats, if any, between upper and lower reaches of the canyon.

METHODS

The study area of the bat survey was the portion of Arch Canyon between the 4,977 ft (1,517 m) and 5,621 (1,713) elevations. The coordinates are N37.545079 x W109.666013 and 37.60657 x 109.761735, respectively. The lower boundary is marked by a cattleguard, a fence and a visitor registration station. The upper boundary lacks a fence but, at the time of our work, there were Forest Service markers delineating the boundary line. One of the two state sections of a 16-section township extends across the study area. The state section divides the canyon into nearly equal upper and lower portions. There are no obvious markers, but this reach of the canyon lies approximately between the coordinates of N37.563017 x W109.719205 and

37.566902 x 109.730099. No work was undertaken on the state section.

We were defeated by extreme flooding on our initial visit to Arch Canyon in September 2006. We could not pass the second crossing and mist nets yielded no captures. In June, 2007, there was again considerable water, but we were able to identify 19 sites with pools over which we might capture bats. We mist netted on six consecutive nights in the period 12–17 June. We netted again on six consecutive nights 11–16 July. Another flash flood had occurred in the canyon a few days prior to our arrival on 6 August 2007. We hiked to our previously-utilized netting sites on 7 and 8 August. After some trail repair on 9 August, we were able to drive approximately 1.5 mi (2.4 km) up the canyon. Stream flow was nearly equivalent with the previous September. We did not continue the netting effort in the upper canyon because of poor netting success, the abundance of muddy water in the canyon, the onset of the monsoon rain season, and the poor state of the trail.

We recorded GPS coordinates and elevations for each netting site using Garmin GPS units set to record coordinates in decimal degrees (WGS84 datum; Table 1). Elevations were reconciled with USGS quad maps and, when there was a discrepancy between sources, interpolated values were used. The distance from the entrance to each netting location was also documented. We made daily journal entries while in the field, and recorded all data onto pre-printed datasheets. The data were later entered into an Excel spreadsheet for analysis.

We believe that quiet, permanent pools with fetches of at least 25 ft (8 m) best serve the continuum

Table 1. Locations in Arch Canyon, Utah. Locations listed are the USFS boundary at the upper part of the study area (USFS), the five sampling locations in the upper canyon (U5 to U1), the upper boundary of the state section (State), the lower boundary of the state section (Section), the five sampling locations in the lower canyon (L5 to L1), and the entrance to the canyon (Entrance). In the right-most column are the trail miles to each of the landmark locations. Data presented are coordinates as decimal degrees (WGS84 datum) and elevation in both feet and meters.

	Northing	Westing	Elevation (ft)	Elevation (m)	Trail Miles
USFS	37.606570	109.761735			8.9
U5	37.605416	109.760757	5598	1707	8.8
U4	37.604525	109.759209	5596	1707	8.7
U3	37.578576	109.737058	5396	1646	6.1
U2	37.576471	109.734863	5374	1639	5.7
U1	37.568405	109.730730	5312	1620	5.1
State	37.566902	109.730099			5.0
Section	37.563017	109.719205			4.2
L5	37.561455	109.718088	5270	1607	4.1
L4	37.550217	109.683029	5045	1539	1.5
L3	37.549276	109.679446	5038	1537	1.3
L2	37.547641	109.676701	5024	1532	1.1
L1	37.546128	109.670412	4833	1474	0.7
Entrance	37.545079	109.666013			0.0

between the small, slow, agile bat species and the large, swift, direct-flying species. We were seeking locations that exhibited some evidence of permanence so we might return to these sites later in the season. This evidence included an apparent spring discharge, water depth of a foot or more, fishes larger than fry in the pools, and the occurrence of obligate wetlands vegetation. Many of these sites occur at trail crossings, but it was not clear if the pools were created by vehicle traffic, or if the pool margins simply provided gentle slopes for the passage of vehicles.

Our main objective was to compare faunas above and below the state section of Arch Canyon. Pools L1–L5 (Table 1) are in the reach below the state section, whereas U1-U5 are above the state section. L1 is the lower-most pool whereas U5 is the upper-most site. We found many more possible netting locations on our first reconnaissance, but the aforementioned localities were the only 10 that met our requirements for the duration of the project.

We initially prepared a list of bats for Arch Canyon that included all species that might occur in the region. Primary references for this list were Durrant (1952), Hall (1981), Armstrong (1982), Mollhagen and Bogan (1997), Haymond et al. (2003), Bogan et al. (2006) and a series of unpublished reports by Bogan and cooperators who have inventoried mammals occurring in southern Utah national parks. This original list included 16 species, not including *M. lucifugus*.

Mist nets were deployed across and around bodies of water to capture bats flying in to drink or foraging on insects over the water. Mist netting especially is effective when sources of water in the landscape are limited, as this causes bats to be concentrated in a relatively small area where they are more susceptible to capture.

The lengths of nets ranged from 9 to 60 ft (3–20 m) and the numbers of nets deployed on any single evening varied from one to five, depending upon the pool surface area and shape. Mist nets were set up shortly before sunset and tended for several hours until activity declined; in some cases nets were observed throughout the night. The nets were never left untended.

Bats were immediately removed from nets following capture. The time of capture, species, sex, reproductive condition, and any miscellaneous comments were recorded on standardized data sheets. The unharmed bats were released within minutes after capture in the net. All participants in this work were experienced and knowledgeable in capturing, handling, and identifying bats. Personnel handling bats previously had taken the standard pre-exposure rabies immunization and had demonstrated titers indicating rabies antibody activity.

Common and scientific names of mammals follow those of Bradley et al. (2014). All capture and handling of animals was performed in accordance with the written protocols approved by the American Society of Mammalogists. Some individuals of previously undocumented species from the study area were retained and prepared as voucher specimens (skins and skeletons) and deposited in the USGS Biological Surveys Collection in the Museum of Southwestern Biology at the University of New Mexico. No specimens of species of concern were prepared.

RESULTS

We netted at five sites both above and below the state section (Table 1). We captured a total of 295 individual bats of 15 species at the 10 collecting sites (Table 2). The total number of 15 species obtained in this study is consistent with the results of surveys in the Henry Mountains by Mollhagen and Bogan (1997) and in Canyonlands National Park (Bogan et al. 2006).

The eight most common species of bats were *Parastrellus hesperus* (32.9% of total captures), *Nyctinomops macrotis* (23.4%), *Tadarida brasiliensis* (12.5%), *Eptesicus fuscus* (7.1%), *Antrozous pallidus* (5.4%), *Myotis yumanensis* (4.7%), *Euderma maculatum* (3.7%), and *M. californicus* (3.4%). We captured 1–6 individuals (less than 3% of total captures) for

Table 2. Bat capture summary for the BLM portions of Arch Canyon, Utah, 2007. A total of 295 bats of 15 species were taken at ten separate localities. Captures sites are arranged from highest to lowest elevation, then from the earliest to latest sampling date. The coordinates and elevations of the capture localities are in Table 1. The acronyms for the bat species in the table are as follows: Myca, *Myotis californicus*; Myev, *M. evotis*; Myth, *M. thysanodes*; Myvo, *M. volans*; Myyu, *M. yumanensis*; Laci, *Lasiurus cinereus*; Lano, *Lasionycteris noctivagans*; Pahe, *Parastrellus hesperus*; Epfu, *Eptesicus fuscus*; Euma, *Euderma maculatum*; Coto, *Corynorhinus townsendii*; Idph, *Idionycteris phyllotis*; Anpa, *Antrozous pallidus*; Tabr, *Tadarida brasiliensis*; and Nyma, *Nyctinomops macrotis*. At the bottom of the table are the grand total captures and percent of total captures for each species.

Locality	Date	Myca	Myev	Myth	Myvo	Myyu	Laci	Lano	Pahe	Epfu	Euma	Coto	Idph	Anpa	Tabr	Tyma	Total bats	Total species
U5	14-Jun	0	0	0	0	4	1	3	4	7	2	0	2	3	2	1	29	10
U5	14-Jul	2	1	0	1	0	0	0	14	2	2	1	1	4	0	2	30	10
U4	13-Jul	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	2	2
U3	15-Jun	0	0	0	0	2	1	0	1	3	4	0	0	1	2	0	14	7
U2	15-Jul	3	1	0	0	1	0	0	27	1	3	0	0	2	7	29	74	9
U1	16-Jun	0	0	0	0	0	0	1	6	1	0	0	0	2	0	0	10	4
Upper Total		5	2	1	1	7	2	4	52	14	11	1	3	13	11	32	159	15
L5	16-Jul	3	0	0	1	0	0	0	11	3	0	0	0	2	4	1	25	7
L4	9-Aug	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
L3	13-Jun	1	0	0	0	1	0	0	5	0	0	0	0	0	1	3	11	5
L3	12-Jul	0	0	0	0	1	0	0	2	0	0	0	0	0	6	27	36	4
L3	8-Aug	0	0	0	0	1	0	0	3	0	0	0	0	0	0	1	5	3
L2	17-Jun	0	0	0	0	2	0	1	3	1	0	0	1	0	13	3	24	7
L2	11-Jul	1	0	0	0	1	0	0	17	0	0	1	0	1	1	2	24	7
L2	7-Aug	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0	5	2
L1	12-Jun	0	0	0	0	0	1	1	0	2	0	0	0	0	1	0	5	4
Lower Total		5	0	0	1	7	1	2	45	7	0	1	1	3	26	37	136	12
Grand Total		10	2	1	2	14	3	6	97	21	11	2	4	16	37	69	295	15
% Total		3.4	0.7	0.3	0.7	4.7	1.0	2.0	32.9	7.1	3.7	0.7	1.4	5.4	12.5	23.4		

each the seven other species. By month, we captured 93 individuals and 10 species in June, 191 individuals and 10 species in July, and 11 individuals and 3 species in a storm-shortened August trip. We saw very few bats flying in the canyon in August.

Above the state section we captured a total of 159 individuals and 15 species (Table 2); below the state section, we took 136 of 11 species. Those species captured only above the state section were *M. evotis, M. thysanodes*, *M volans,* and *E. maculatum*. Most species were caught in roughly equal numbers above and below the state section, although slightly more *P. hesperus* (52 above, 34 below) and significantly more *A. pallidus* were captured above the state section (13:1). More Free-tailed Bats (*T. brasiliensis* and *N. macrotis*) were captured in the lower reach of the canyon (58) than in the upper (43).

Given the relatively short study period we are reluctant to emphasize these differences too much. However, our impressions of habitat preferences of these bats gained from this (and previous) study are that those four species caught only in the upper canyon may prefer somewhat higher elevations; especially *M. evotis* and *M. volans*. *Euderma maculatum* is known from a variety of habitats but the species may be somewhat more common at upper elevations. However, the slightly increased capture rates of two arid-adapted species, *A. pallidus* and *P. hesperus,* at the upper sites suggests that upper Arch Canyon may possess some subtle advantage for some species. We are reluctant to emphasize this because there seemed to be a greater number of larger pools, in the lower canyon, particularly in the lower reaches. The greater availability of water at the lower elevation netting sites may have rendered netting efforts less effective than in the upper canyon.

DISCUSSION

We suspect that most of the species we captured have roosts in the canyon and many probably hibernate nearby. The two species of tree-roosting bats (*L. cinereus* and *L. noctivagans*) occur seasonally and presumably migrate to the south prior to winter. Most individuals of these two species in the area are males. Females occur farther east, where they give birth (Cryan 2003). *Tadarida brasiliensis* and *N. macrotis* are likewise believed to be migratory, spending the winter to the south. We are aware of one small and one large maternity colony for *N. macrotis* along nearby Comb Wash.

Armstrong (1982) postulated two additional species to occur in the general area of Arch Canyon, the Little Brown Myotis (*M. lucifugus*) and the Eastern Red Bat (*Lasiurus borealis*). The former is represented by a specimen captured at French Spring in Glen Canyon National Recreation Area (GCNRA). We have examined the specimen (University of Colorado Museum no. 15207) and it is instead a *M. volans*. However, *M. lucifugus* does occur in southern Utah. We have examined specimens from the Fremont River in the vicinity of Bicknell and Donkey Lake on Boulder Mountain, Wayne County, Utah (specimens in Utah Museum of Natural History). Hasenyager (1980) listed two occurrences of *M. lucifugus* from Bluff City, San Juan County but we have found no specimens to document these records during our travels to Utah museums. As Oliver (2000) noted, recent studies of bats across southern Utah have failed to document the occurrence of *M. lucifugus*, and it seems parsimonious to assume the species is absent from much of this area. Should a short-eared, large-footed, medium-sized myotis be captured that is not *M. yumanensis*, it should be examined carefully as it may actually be *Myotis occultus*.

Armstrong (1982) also listed the possible occurrence of *Lasiurus borealis* in the area. He referred to the records of Hardy (1941) from Carbon County (presumably Kenilworth Mine, Price) and from Washington County (La Verkin Cave; St. George). We searched for the origins of these records and located only a specimen from the Kenilworth Mine at the museum at California State University, Long Beach. Our supposition is that the specimens were in Hardy's personal collection and were taken to Long Beach when Hardy left employment at what was then Dixie Junior College. We have not examined this specimen as of this writing and are uncertain whether the Kenilworth specimen represents the Eastern Red Bat (*L. borealis*) or Western Red Bat (*L. blossevillii*) as now recognized

(Oliver 2000). Although the Carbon County record could have been *L. borealis*, the absence of any records of this species since 1937 from anywhere in eastern Utah suggests this species should not be considered as part of the regional bat fauna. The nearest records are in northeastern Colorado. Conversely, there continue to be reports of *L. blossevillii* from southwestern Utah and a young-of-the-year male from Springville, Utah County (Mollhagen and Bogan 1997; Oliver 2000). Nonetheless, we have engaged in considerable field work where *L. blossevillii* might seasonally inhabit (Kane, Garfield, Wayne and San Juan counties) and none have been captured. Thus, we regard this species as of unlikely occurrence in the Arch Canyon area.

We did not catch *Myotis ciliolabrum* in Arch Canyon, although we are confident the species occurs in the area, at least seasonally. This species likely is restricted to higher elevation areas of southeastern Utah for most of the year. They have been captured in the Henry Mountains (Mollhagen and Bogan 1997). The species was not captured in the Canyonlands National Park (CANY) survey (Bogan et al. 2006), but it was recorded acoustically.

The Utah bat species of concern are *M. thysanodes, I. phyllotis, C. townsendii, E. maculatum* and, *N. macrotis*. A comparison of the occurrence of these species in Arch Canyon with other bat inventories on the Colorado Plateau is warranted. There are six such inventories. The Henry Mountains and Canyonlands National Park inventories presented in Table 3 are within 100 miles of Arch Canyon. The other four inventory sites are greater distances away in New Mexico, Arizona, Colorado and Utah.

Mollhagen and Bogan (1997) captured bats from 22 separate localities in the Henry Mountains (Table 3). The Henrys are approximately 80 miles west and differ from Arch Canyon in occupying a much larger geographic area, having a greater elevational relief and, consequently, much greater habitat variation. Bogan et al. (2006) conducted a two-year study of bats in Canyonlands National Park (CANY), approximately 50 miles to the north. Bats were captured at 32 localities over a wider area and a greater elevational range than occur in Arch Canyon. Both of these studies had many more total captures (Table 3), nearly double in the Henry Mountains and over five times the number in CANY.

Table 3. Comparison of the abundance of Utah bat species of concern among six inventories for bats on the Colorado Plateau. The studies are as follows: Arch Canyon, UT, this report; Henry Mountains, UT, Mollhagen and Bogan (1997); Jemez Mountains, NM, Bogan et al. (1998); Coconino Plateau, AZ, Rabe et el. (1998); Morell et al. (1999); Canyonlands National Park, UT, Bogan et al. (2006); Dinosaur National Monument, Bogan and Mollhagen (2010); and Mesa Verde National Park, O'Shea et al. (2011). Data shown are the total number of captures for each study and the respective percentage of the total fauna of each species of concern. The acronyms for the bat species are as follows: Myth, *Myotis thysanodes*; Idph, *Idionycteris phyllotis*; Coto, *Corynorhinus townsendii*; Euma, *Euderma maculatum*; and Nyma, *Nyctinomops macrotis*.

	State(s), region, and total bat captures for each study						
Species	UT, Henry Mountains, 572	UT, Canyonlands NP, 1,717	CO, Mesa Verde NP, 1,996	UT, CO, Dinosaur NM, 909	AZ, Coconino Plateau, 1,532	NM, Jemez Mountains, 1,532	UT, Arch Canyon, 295
Myth	34 (5.9%)	64 (3.7%)	41 (<0.1%)	7 (1.5%)	122 (7.2%)	69 (4.5%)	1 (0.3%)
Idph	9 (1.6%)	36 (2.1%)	0	0	26 (1.5%)	0	4 (1.4%)
Coto	16 (2.8%)	23 (1.3%)	13 (<0.1%)	14 (3.0%)	2 (< 0.1%)	7 (0.5%)	2 (0.7%)
Euma	1 (0.2%)	0	10 (<0.1%)	5 (1.1%)	0	12 (0.8%)	11 (3.7%)
Nyma	0	3 (0.2%)	0	0	0	15 (1.0%)	69 (23.3%)

Even though the other four other bat inventories (Table 3) are hundreds of miles away, their respective faunas each have at least three of the five Utah bat species of concern. In northern New Mexico, Bogan et al. (1998) captured 1,532 bats in the Jemez Mountains, at Bandelier National Monument and the Los Alamos National Laboratory. There are two reports on the same bat fauna (1,684 captures) on the Coconino Plateau in northern Arizona, Rabe et al. (1998) and Morrell et al. (1999). Bogan and Mollhagen (2010) reported on a reinventory of the bats in Dinosaur National Monument. They captured 909 bats at localities in northwestern Colorado and northeastern Utah. O'Shea et al. (2011) detailed an inventory of 1,996 bats captured in southwestern Colorado, in Mesa Verde National Park.

In a direct comparison among the faunas, *M. thysanodes* seems underrepresented in Arch Canyon and Mesa Verde NP (Table 3); we captured only one individual in Arch Canyon. Only four individuals of *I. phyllotis* were captured in Arch Canyon, but there is no material difference in the percent representation among the four faunas where *Idionycteris* is represented. Based on the brevity of this study and small sample size, *C. townsendii* may also be underrepresented in Arch Canyon.

However, 11 captures of *E. maculatum* seem remarkable (Table 3). To put this into perspective, fieldwork in the Henry Mountains continued well beyond the published study period, until 2003. This extension of sampling time more than doubled the total bat captures (unpublished data), but no additional *Euderma* were captured. This would reduce the percent of Spotted Bat captures to approximately 0.1. Although no *Euderma* were captured in Canyonlands, the vocalizations of two individuals were heard over the course of that study. Including these records in the calculation of the percent of fauna at Canyonlands also yields a value of approximately 0.1. The percents of *Euderma* captures are similar among the other three studies.

The capture of *Nyctinomops* is not surprising to us because there are two known maternity colonies in nearby Comb Ridge, and we had captured *Nyctinomops* in Arch Canyon some years ago (also see Zimmerman 1970). However, the capture of 69 individuals, representing over 23 percent of the total sample of Arch Canyon, is unusually high in comparison with the Henry Mountains, Canyonlands, and Jemez Mountains bat faunas (Table 3). No *N. macrotis* had been taken in the Henry Mountains at the time of the Mollhagen and Bogan (1997) report. Subsequent field work, more than doubling the total bats captured, has produced only a single individual of this species (unpublished data). Thus *Nyctinomops*' contribution to the total fauna is approximately 0.1 percent. The respective value in Canyonlands is 0.2 percent. Clearly, *Euderma* and *Nyctinomops* were common at the time of our study, perhaps because Arch Canyon and vicinity provided abundant roosting sites, foraging sites, and water.

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Comparison of Pasturelands Containing Texas Kangaroo Rat (*Dipodomys elator*) Burrows to Adjacent Roadsides in Wichita County, Texas, with Comments on Road Usage by *D. elator*

Jim R. Goetze, Allan D. Nelson, and Larry L. Choate

Abstract

The Texas Kangaroo Rat (*Dipodomys elator*) is a threatened species in Texas. This heteromyid has been nominated for federal protection under the Endangered Species Act. The United States Fish and Wildlife Service completed a 90-day finding on the petition and stated that the use and effects of roads on the Texas Kangaroo Rat was unclear. We surveyed pasturelands and adjacent roadsides for *D. elator* in Wichita County, Texas, and examined differences in vegetation composition between pasturelands and roadsides. Over 1,000 trapnights were conducted in each habitat. Only three percent of *D. elator* captures occurred along roadsides. Roadside vegetation was taller, had less bare ground, more introduced grass species, and higher species richness than adjacent pasturelands. Forb coverage was similar between the pasturelands and roadsides. In Wichita County, *D. elator* uses pastureland more frequently than adjacent roadsides. This is likely due to differences in vegetation between the two habitats.

Key words: *Dipodomys elator*, habitats, pastureland, roadside, Texas, Texas Kangaroo Rat, vegetation, Wichita County

Introduction

The Texas Kangaroo Rat, *Dipodomys elator*, is unusual because the habitat in which it is found is not typical for kangaroo rats. It seems to prefer soils with high clay content which support overgrazed or short grasses (Dalquest and Collier 1964; Roberts and Packard 1973; Dalquest and Horner 1984; Stangl et al. 1992; Schmidly 2004; Goetze et al. 2007; Nelson et al. 2009; Stasey et al. 2010) and has rarely been recorded in locations with dense vegetation.

As a result of overgrazing and control of wildfires, mesquite (*Prosopis glandulosa*) and other disturbance-related shrubs, grasses and forbs have increased in abundance across much of Wichita County, Texas, and habitat modification, such as conversion of pastureland to monoculture, has resulted in extensive fragmentation of Texas Kangaroo Rat habitat (Diamond and Shaw 1990). From 1996 to 2000, Martin (2002) surveyed the historic range of *D. elator* and found the range of *D. elator* reduced from 10 to five counties in north Texas. He did not find *D. elator* in Oklahoma (Martin 2002). This concurs with other researchers who have been unable to locate any populations of *D. elator* in Oklahoma (Jones et al. 1988; Moss and Mehlhop-Cifelli 1990).

Federally, *D. elator* was listed as a Category 2 candidate species under the Endangered Species Act of 1973 (Martin 2002). Category 2 candidates were formerly considered species of concern for the United States Fish and Wildlife Service (USFWS), and endangered or threatened status was possibly warranted. However, insufficient data existed to justify an elevated listing (USFWS 1996).

In Texas, *D. elator* is listed as a threatened species by the Texas Parks and Wildlife Department (TPWD)

(Martin 2002; Schmidly 2004). Reasons for *D. elator* being listed as a threatened species by the TPWD are based on scarcity of this species and the small geographic range from which it is known (Stangl and Schafer 1990).

Most recently, WildEarth Guardians petitioned USFWS to federally list the Texas Kangaroo Rat (WildEarth Guardians 2010). In the petition to USFWS, WildEarth Guardians stated that many factors had contributed to the decline of *D. elator* across its historic range. Among the factors WildEarth Guardians listed were: 1) loss of native habitat to cropland; 2) loss of historic ecological processes involving bison, prairie dogs and fire; 3) domestic livestock grazing; 4) development and roads; 5) brush control; 6) overharvesting for scientific purposes; 7) parasites and predation; 8) little regulatory protection; and 9) climate change. The USFWS responded with a 90-day finding that concluded the petition presents substantial scientific information indicating that listing the Texas Kangaroo Rat throughout its entire range may be warranted (USFWS 2011). This finding was based on the present or threatened destruction, modification, or reduction of the Texas Kangaroo Rat's habitat or range, and the inadequacy of existing regulatory mechanisms (USFWS 2011). Specifically, the USFWS found that the loss of burrowing habitat and genetic isolation of populations due to the conversion of native rangeland to agricultural cropland, and the inadequacy of existing regulatory mechanisms to protect against such land conversion, may pose a threat to the Texas Kangaroo Rat throughout all or a significant portion of its range (USFWS 2011). We agree with the assessment of the USFWS, and within this paper expand upon vegetation associated with roads and adjacent pasturelands in Wichita County and presence of *D. elator*.

Much of Martin's research methodology involved roadside surveys and trapping along roadsides (Martin 2002). Other researchers have studied the effects of roads as potential corridors or barriers to distribution and movement of small mammals, including species of kangaroo rats (Roberts and Packard 1973; Brock and Kelt 2004). Stephen's Kangaroo Rat (*D. stephensi*) is known to colonize dirt roadsides (O'Farrell 1990), and Brock and Kelt (2004) noted that *D. stephensi* may occur in small, linear populations along roadsides even when adjacent habitats are unsuitable.

Although a relatively large number of studies have examined aspects of their ecology (Dalquest and Collier 1964; Roberts and Packard 1973; Jones et al. 1988; Moss and Mehlhop-Cifelli 1990; Stangl and Schafer 1990; Stangl et al. 1992; Martin 2002; Stasey 2005; Goetze et al. 2007; Goetze et al. 2008; Nelson et al. 2009; Stasey et al. 2010) and systematics (Merriam 1894; Johnson and Selander 1971; Hamilton et al. 1987; Dalquest et al. 1992; Mantooth et al. 2000), few investigators have closely examined vegetation associated with *D. elator* burrows (Martin and Matocha 1991; Martin 2002; Nelson et al. 2009). No researchers have specifically examined roadside vegetation adjacent to pasturelands containing known populations of the Texas Kangaroo Rat.

Because previous researchers have utilized road surveys to verify the presence of *D. elator* within its current range, the primary goals of this investigation were to quantify vegetative characteristics within pasturelands that contained burrows where the Texas Kangaroo Rat was obtained and to gather preliminary information concerning suitability of roadsides as habitat for *D. elator* within Wichita County, Texas.

METHODS

Twenty-one active *D. elator* burrows were identified from Wichita County from four different localities (Fig. 1). Trapping to test for burrow occupancy was conducted by placing three 7.5 x 8.8 x 30 cm Sherman Live Traps within 0.10 to 0.50 m of each burrow entrance, with the open end of each trap facing the entrance (Cross and Waser 2000). Traps were baited with dry oatmeal each evening and checked each morning.

If *D. elator* were captured, vegetation was sampled during May using a 1 m^2 quadrat placed directly over burrows where *D. elator* were captured. Burrow parameters were taken in May to avoid seasonal influences. Within each quadrat, vegetative richness was recorded as total number of species present. Percentage coverage of grass, forbs, and bare ground within each quadrat was recorded, as was average herbaceous

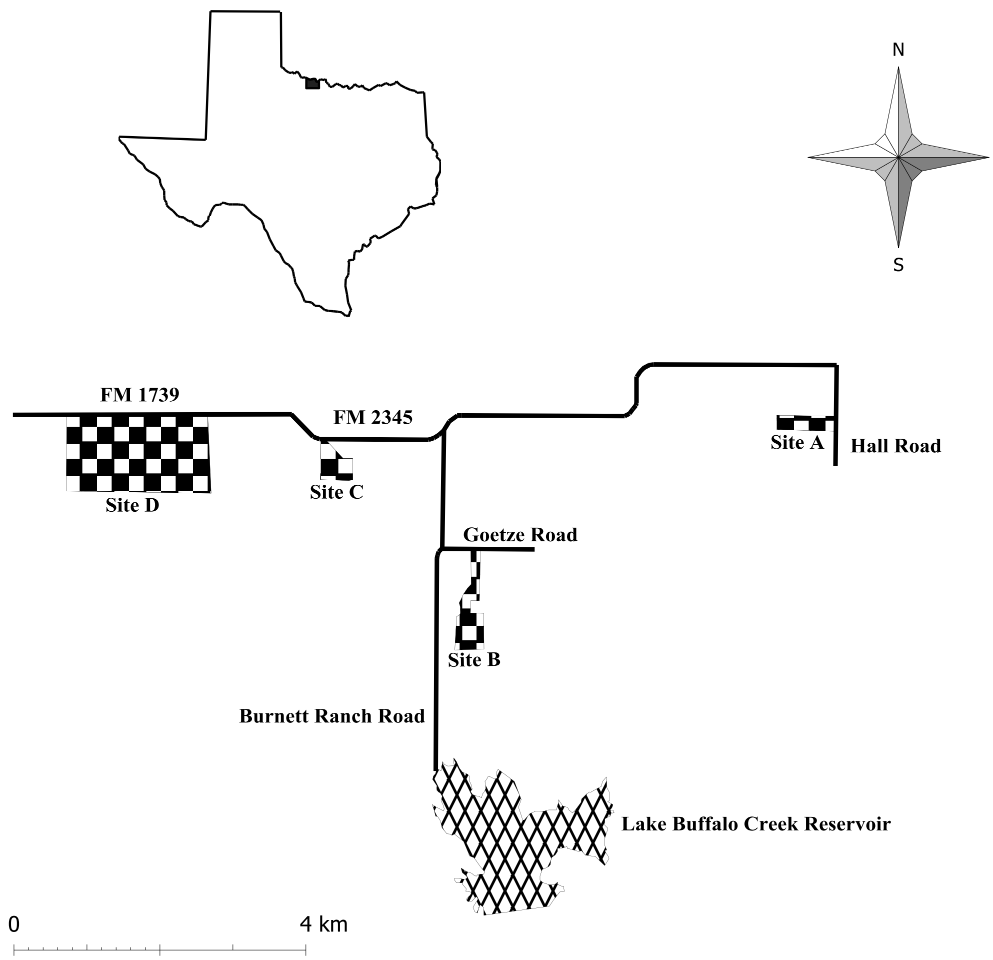

Figure 1. Map showing the four sampling locations in Wichita County with associated roads where study samples and data were taken. Geographic coordinates to the entrance gates of the four localities are Site A (34.05756N, 98.69716W), Site B (34.06497N, 98.70709W), Site C (35.05446N, 98.78699W), and Site D (34.05423N, 98.781721W).

vegetation height (obtained by averaging the height of the herbaceous vegetation 15 cm interior to each corner of the quadrat). Specimens of the dominant herbaceous plants were collected, identified with appropriate keys (Diggs et al. 1999), and made into vegetation vouchers subsequently deposited in the herbarium of Tarleton State University.

During the course of our study, no Texas Kangaroo Rat burrows were tentatively identified along roadsides. Therefore, a 100 m tape was placed along roadside traplines and random numbers were selected as sites for quadrat sampling as described above. A total of 20 quadrats were sampled along roadsides adjacent to the aforementioned pastureland localities (Fig. 1). To survey for the presence of the Texas Kangaroo Rat in the absence of burrow evidence, Sherman live traps were placed approximately 10 m apart in a transect along roadside fences, baited, and checked as described above.

Averages and ranges for vegetative data as well as comparisons between sites were calculated in Microsoft Excel. Comparisons between pasturelands and adjacent roadsides were made using *SigmaPlot 12* software (Systat 2016) to calculate a Mann-Whitney

Rank Sum Test. Manifold 8.0 GIS software program (Manifold Software Limited 2013) and a digital, 1 m resolution, orthographic quadrangle (DOQ) map of Wichita County from the Natural Resources Conservation Service (NRCS) were utilized to generate the base map for Figure one.

RESULTS

In May of 2011, 2012, and 2015 we characterized the vegetation associated with 21 Texas kangaroo Rat burrows from four locations in Wichita County as well as 20 quadrats along roadsides adjacent to the four localities. During this period of time, trapping efforts consisted of a total of 1,031 trap nights within pasturelands and 1,045 trap nights along adjacent roadsides.

The most common plant dominants in the pasturelands were Little Barley (*Hordeum puscillum*) and Virginia Pepper-grass (*Lepidium virginica*) (Table 1). Next in vegetation dominance were Whorled Dropseed (*Sporobolus pyramidatus*) and Silverleaf Nightshade (*Solanum eleagnifolium*). The most common dominants along the roadsides were Johnsongrass (*Sorghum halepense*) and an unknown forb (Table 1). During sampling time, the unknown forb consisted of only a short stem with a few leaves and was unidentifiable. Next in vegetation dominance were two introduced bromes (*Bromus catharticus* and *B. japonica*) and two native species, Needlegrass (*Nasella leuchotricha*) and Western Ragweed (*Ambrosia psilostachys*). Average herbaceous height, percent bare ground, percent grasses, and species richness were significantly different between pasturelands and adjacent roadsides (Table 1). Average percent forbs was not significantly different ($p = 0.07$). Averages for all of the vegetation parameters were greater in the roadsides except for percent bare ground, which was greater in the pasturelands (Table 1).

Along with *D. elator*, five species of mammals were captured in the pastureland sites, whereas three species were obtained along the adjacent roadsides (Table 2). The Texas Kangaroo Rat was the most commonly obtained species within pasturelands and the White-footed Deermouse (*Peromyscus leucopus*) was the most commonly captured mammal along roadsides. Within the pastureland sites, both *P. leucopus* and the North American Deermouse (*P. maniculatus*) were obtained, but no *P. maniculatus* was captured along roadsides during the study. The Hispid Cotton Rat (*Sigmodon hispidus*) and Hispid Pocket Mouse (*Chaetodipus hispidus*) were obtained in both pasturelands and roadsides, whereas the Southern Plains Woodrat (*Neotoma leucodon*) was captured only in pasturelands (Table 2).

Table 1. Dominant vegetation and average herbaceous height, percent coverage of bare ground, forbs, grasses, and species richness in the pastureland and adjacent roadsides. Ranges are enclosed in parentheses following means. An asterisk indicates significant differences between means at the < 0.001–0.01 levels.

	Pastureland (n = 21)	Roadside (n = 20)
Dominant forb	Virginia Pepperweed	Unknown
Dominant grass	Little Barley	Johnsongrass
*Average herbaceous height (cm)	13.2 (0.0–59.0)	69.7 (6.9–129.3)
*Average % bare ground	51.7 (20.0–94.0)	11.2 (0.0–20.0)
Average % forbs	11.9 (0.0–50.0)	19.8 (1.0–65.0)
*Average % grasses	25.0 (1.0–45.0)	69.0 (10.0–98.0)
*Average richness	5.0 (1.0–12.0)	6.6 (4.0–10.0)

Table 2. Mammalian species and numbers obtained from live traps in pasturelands and adjacent roadsides.

Species	Pastureland	Roadside
Dipodomys elator	36	1
Peromyscus maniculatus	17	0
Peromyscus leucopus	14	29
Sigmodon hispidus	2	3
Neotoma leucodon	2	0
Chaetodipus hispidus	4	2

DISCUSSION

WildEarth Guardians (2010) suggested that all roads within the range of *D. elator* increased the risks of predation and mortality from vehicle collisions. USFWS (2011) indicated that Texas Kangaroo Rats (Roberts and Packard 1973; Stangl and Schafer 1990; Stangl et al. 1992), and other species of kangaroo rats (Brock and Kelt 2004), may preferentially use dirt roads as migration corridors. Although there are reports of specimens killed by vehicular traffic (Dalquest and Collier 1964; Jones et al. 1988), USFWS suggested that roads were not having a negative impact on Texas Kangaroo Rat mortality. During the course of our study, only a single *D. elator* was salvaged from a paved roadside adjacent to Locality A (Fig. 1).

USFWS (2011) also mentioned that it is well established that nighttime road surveys are an easy and effective way to determine the presence of the Texas Kangaroo Rat, suggesting the Texas Kangaroo Rat does not entirely avoid these areas. During our study, we captured only one of 37 *D. elator* from a roadside location (site D; Fig. 1). When released at the roadside, this individual entered a burrow within the adjacent pastureland. All *D. elator* burrows were found within pasturelands. Our results differ from those of Stapp and Lindquist (2007) who worked with *D. ordii*. In a study of Ord's Kangaroo Rat in Colorado, Stapp and Lindquist (2007) reported greater numbers of *D. ordii* captured from roadsides as opposed to adjacent pasturelands. However, the vegetation in the Colorado pasturelands was similar to the cover and height of our Wichita County roadside vegetation. Brock and Kelt (2004) reported usage patterns similar to *D. elator* for Stephen's Kangaroo Rat in California.

Based on the results of our study, vegetation and numbers of Texas Kangaroo Rats found in pasturelands and along adjacent roadsides often significantly differ (Tables 1 and 2). Brock and Kelt (2004) and Stapp and Lindquist (2007) reported significant use of roadsides by *D. stephensi* and *D. ordii* for burrowing and foraging sites. In our study, 37 *D. elator* were captured within pasturelands and only one Texas Kangaroo Rat was captured along a roadside. However, four of the 21 burrows within pasturelands were along unimproved (dirt) roads. This supports the findings of Brock and Kelt (2004) regarding Stephen's Kangaroo Rat and Stapp and Lindquist (2007) regarding Ord's Kangaroo Rat. The Wichita County roads sampled adjacent to the pasturelands were improved roads (gravel or asphalt). Although Roberts and Packard (1973) stated that *D. elator* used roads as burrow locations, we did not find that to be the case in our study.

Dominant vegetation found at burrows within the pasturelands was mostly native. Little Barley was the most dominant native grass with Whorled Dropseed being the second most common native grass. Introduced grasses dominated in roadsides and included Johnsongrass, Japanese Brome, and Rescue Grass. As we surveyed for trapping locations, we often encountered dense concentrations of introduced grasses such as Japanese Brome. Similarly, introduced plant numbers were higher along roadsides than in grasslands in the *D. ordii* study in Colorado (Stapp and Lindquist 2007). Increases of these introduced grasses likely will negatively affect the Texas Kangaroo Rat and are probably why many sites, especially along roadsides, no longer have Texas Kangaroo Rats. Dense vegetation likely impedes burrow construction and prevents Texas Kangaroo Rats from locating potential predators. In addition, dense vegetation reduces bare patches needed for dust bathing (Goetze et al. 2008). In Wichita County, *D. elator* uses pastureland more frequently than adjacent roadsides. This is likely due to differences in vegetation between the two habitats.

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Don Wilson (p. 49)

Clyde Jones was a people person. He had a knack for making everyone feel comfortable and important. I followed him in graduate school at the University of New Mexico, but did not meet him in person until the Texas A&M mammal meetings in 1970, when I had just finished at UNM. He was warm and welcoming and made me feel a part of his group immediately. I didn't see him again until he hired me to come to the National Museum over a year later, while I was on a post-doc in Costa Rica. He welcomed my family into his house while we looked for housing, and he car-pooled into work with me for years, again bringing me into his world and making me feel welcome in all circles. I witnessed this behavior with everyone who came to work for Clyde in those early years of the 1970s.

Clyde was ambitious and hard-working, and worked his way up the ladder in the Fish and Wildlife Service, but he always remembered those who worked for him and with him. He loved field work and tried hard to involve everyone who wanted to participate in field activities. He was a good observer, a keen trapper, and an excellent preparator, so field work with Clyde was always productive and fun. Also, thirst was rarely a problem if Clyde was in charge. I think he was singularly responsible for the Jos. Schlitz Brewing Co. lasting as long as it did.

Clyde had a favorite watering hole called the Crown Bar & Grill, on E Street, just a couple of blocks from the Museum. He came to work early every morning, and put in long days, but he then extended them by heading up to the Crown after work. He recruited whoever was around for these excursions, from staff to visitors. We had to learn to pace ourselves early on, as keeping up with the Jones in this case was a difficult proposition. Good conversation and beer went hand-in-hand for Clyde, and he had an enormous capacity for both. Our workforce was diverse in those days, and international visitors from every part of the world were with us regularly. Clyde treated everyone equally, and made sure everyone was involved in whatever was going on.

Although hindsight undoubtedly filters memories of 40 years ago, those halcyon days of yore were heady ones for all of us who came into contact with Clyde, and I believe we were all made better for it. He was the best boss I ever had and just had that knack for making all of us feel like what we were doing was important and worthwhile. He built a terrific team during his tenure in Washington, and his presence was missed immediately on his departure. Nevertheless, he was very good at keeping up with all of us over the years. Someone, somewhere in the world, is skinning a mouse with a cold beer in reach, and thinking of Clyde and what he meant to all of us.

Richard Manning (p. 67)

It may not be possible for me to articulate how important Clyde Jones (CJ) was in my development as a mammologist, and it's also difficult to talk about Clyde without mentioning J Knox Jones, Jr. (JKJ). There never is a day, even now, that I don't think back to my training at Texas Tech and the influence CJ and JKJ had on my career.

Clyde Jones and Knox Jones were co-chairs on my PhD committee. I was at the NSRL in Knox's office, during the summer of 1985, when I first met CJ. Clyde was more the field-guy, while Knox was the museum-guy or office-museum-administrator guy. Clyde had been gone most of the summer months traveling throughout north-central Texas gathering data on

Texas Kangaroo Rat (*Dipodomys elator*) distribution for Texas Parks and Wildlife Department.

My first impression of Clyde was that he was a friendly, outgoing man with a great sense of humor. I remembered Knox later cautioning me "… don't mistake his casual or informal manner as a lack of interest in your work and academic progress." True, he and Knox, were serious about academics. Both were strict concerning field research. It was "drummed into me," early and often, that I needed to take detailed field notes, accurately record my observations in the field, and most importantly prepare museum-quality mammal specimens. I had good instruction. There always was a good amount of friendly banter, and advice, while preparing specimens. After each field trip, with or without them, all specimens were meticulously examined and critiqued, often with a few friendly jibes. Both gave suggestions and usually some comment like "Is that all you caught?" or "Where are the rest of them?" -- usually in good humor! I often heard another old adage from them: "…when there are a lot rats, get as many as you can, and when there are not very many, get them all."

As a graduate student these goals were expected: (1) to perform at a high academic level in the classroom; (2) to show up and work in the mammal collection at the Museum (NSRL); and (3) during my "copious and significant free time" conduct field work and publish the results of that effort. Both Clyde and Knox were supportive in my efforts and always available for discussions and consultation. Their personal libraries always were available for my use.

I took a couple of courses from Clyde (I believe a Museum Science class and a couple of seminars and a field methods course) and over the years got to know him quite well. Only rarely could I get both Clyde and Knox out into the field with me at the same time. Those trips were some of the most memorable experiences of my PhD training. Those trips were filled with continuous stories about their earlier careers; their colleagues and friends; their memories of former colleagues; and various escapades they had enjoyed with each other.

Did I mention both Clyde and Knox enjoyed a "cold beer" now and then? The more 'relaxed' they got, the more interesting the stories got. What oral history lessons! I wish I had taken a portable tape recorder on some of those trips in order to record those conversations.

After I graduated I stayed in contact with Clyde and did field work with him, usually in far West Texas. He had an intrinsic interest in mammals and was enthusiastic about sharing his thoughts.

He always had ideas about potential mammal research projects to discuss. More than once he said something like "…we need to look into that a little more seriously" or "…let's try to get a few more of those (rats/bats) so we can try and figure out what's going on with them."

I knew Clyde as an "academic" father and mentor; as an "uncle-like" figure, and finally as a close friend. One more thing I'll always remember him saying -- "be sure to have fun!"

Mike Bogan (p. 97 and p. 215)

When I reflect on my time spent with Clyde, it seems almost impossible that we were together as much as we were and how the times all seem so good. Although I'd known about Clyde since 1964, when my graduate career in mammalogy started under Gene Fleharty at Fort Hays State, I didn't meet him until 1971 when I was enrolled at the University of New Mexico (UNM). My first field trip with him was in 1974, my second summer of working for him and Don Wilson at the National Museum of Natural History (USNM). My last field outing (but no real work!) was in mid-June of 2013 with several friends and colleagues. This marked over 40 years during which I spent some time with Clyde. And I think that much of what I am, and have, today is a direct consequence of having worked for and with him. Clyde, his research philosophy, the opportunities he helped provide, and the organization he built were very influential in my life. It was at the request of Clyde and Don Wilson that I applied for a position with the Fish and Wildlife Service. And later, after Clyde moved to Denver, I took advantage of an offer from him and moved to Colorado as well. After he moved to Texas we stayed in touch, often attending meetings together or working together in the field.

Clyde made many contributions to our understanding of southwestern mammals, especially bats, while he was a graduate student at UNM. These contributions were a great help to those of us that followed him and who were able to use the specimens, field notes, as well as publications that he left for us. The rigor of his work is shown by the fact that today's younger scientists still commonly cite many of these studies.

I've always been impressed with his work in Rio Muni, Africa, on primates and other mammals. The work was funded by grants and lasted about three years, but it resulted in several of his favorite publications and demonstrates Clyde's abilities and willingness to work, as we say now, "outside the box." Rather than "playing it safe" as a beginning Assistant Professor in a university in the U.S., I think he saw this as an opportunity to conduct research on a new group of mammals in a foreign setting and with the opportunity to interact with several experts, such as Louis Leakey. This work predates my time with him, but I've always been impressed that he did it. It's tangible evidence of his interest in other mammals, his interest in working overseas, and his ability to work constructively with others.

His experience in Rio Muni was valuable to him when he went to work for FWS in 1970. His ability to interact successfully with a wide array of people and agencies in seeking support for FWS research, especially on endangered species and marine mammals, was impressive. He also was very successful as a research administrator for FWS. That is, up until the FWS changed his job and tried to return him to DC and he quit. When he quit FWS, many of us were very disheartened, probably partly because we knew we would have to work harder because Clyde wouldn't be there to do it for us!

Not surprisingly, as we say, Clyde landed on his feet and probably ended up where he always belonged: in academia, at Texas Tech University. He started as the Director of The Museum, later Chair of the Department of Museum Science, and then Professor in the Department of Biological Sciences for over 20 years. He's had over 20 graduate students, many of whom I know and have spent time with in the field. Clyde has acknowledged that without his graduate students he would feel that he would have failed at Tech.

And, the story is incomplete without reflecting on the time I spent with him in the field; and now I realize that our time together, in many ways, was a gift. We were happy to spend the day, skinning trays in our laps, preparing specimens that we referred to as "things of beauty and joys forever." I think we envisioned the specimens residing in their trays in museums for decades if not centuries--and being of great use to other scientists. I don't know how many hours I've spent in camp with him doing this. Thousands of hours I am sure. And at sites in New Mexico like Willow Creek in the Gila National Forest or Cloverdale in the bootheel, or Tiburon Island, or Baja California Sur, as well as federal lands in Nebraska, Colorado, Utah, Arizona, and elsewhere.

Our last fieldwork together was in the Chinati Mountains in far southwestern Texas. We made several trips to different sites there and had really magical times. It was a nice mix of older and younger scientists, all committed to reaching a better understanding of the mammals of the Chinatis. And there was the occasional sip of "top-shelf" bourbon or rye that we brought along for after-hours relaxation.

In the summer of 2013, several of us that had worked with Clyde in one capacity or another, got together with him and Mary Ann at Big Bend Ranch State Park for a few days. Mark Lockwood put this trip together, although I don't think he had anything to do with the golf-ball sized hail that did thousands of dollars of damage to our trucks! I had recently gotten a knee replacement and was trying to do a little hiking to strengthen it. Clyde wasn't hiking at that time but twice he came out in his truck after I'd been gone awhile to check on me and offer a ride back to camp. That was typical of CJ and I appreciated it.

"Adios CJ--we had a good one."

David Schmidly (p. 127)

I first met Clyde Jones in 1969 while attending the annual meeting of the American Society of Mammalogists. Over the next 46 years I had the great pleasure to get to know him as a friend, companion on field trips, and as a faculty and administrative colleague.

Clyde's life story is fascinating and we are fortunate that it was recorded in his own words. In a paper entitled "You Have to Catch Them First," published in the book "Going Afield"(Carleton Phillips and Clyde Jones eds., 2005, Museum of Texas Tech University, 289 pp), he chronicled his life from growing up as a boy on a small cattle farm in Nebraska, where he was raised by his mother and aunts and uncles; to graduate work in mammalogy at the University of New Mexico; to an adventure studying African mammals; to an accomplished career as a government scientist and administrator; and finally as a successful academic scientist and administrator. As Clyde put it himself, "my personal life in general and my professional career in particular have been quite rewarding to me."

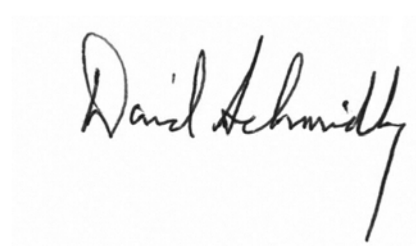
There are many words I could use to describe Clyde—honest, decent, fair-dealing, commonsensical, great sense of humor and optimism—but I will always remember him for his basic kindness. My wife, Janet, and I vividly recall the time he met Janet's mother, when she was an elderly woman in her 90s. He went out of his way to talk with her and to make her feel special. Afterwards, Mrs. Knox commented to us—what a kind and decent man!! And, that is the way Clyde was—a gentle person who was kind and helpful.

At the same time, Clyde lived life on his terms. Perhaps it was his growing up on a farm and being close to the land. He lived life to the fullest and did it his way never compromising his fundamental values. So, when James Watt took over as Secretary of the Interior and tried to change the philosophy of managing the nation's natural resources, Clyde wouldn't have it. He walked away from his government career rather than compromise his values and scientific underpinning.

Clyde was of the old guard of naturalists—those that believed that field work and collecting was essential to natural history. We are losing a generation of these field biologists and they are not likely to be replaced. Clyde will be missed but remembered for his many accomplishments and for living life his way.

Waldo McAtee, who spent five decades working for the U. S. Biological Survey, said this about the death of valued colleagues, "Merely to recall all of these departed comrades is enough to break one's heart, and no cry of woe, however deep, can assuage the feeling of their loss." I can think of no better way to express my feelings about my friend and colleague, Dr. Clyde Jones.

Finally, I along with my co-authors, John Karges and Robert Dean, feel a need to apologize to Clyde for having published a paper in his honor in which we did not collect any specimens!!



Frank Yancey (p. 147)

In 1994, Clyde Jones presented to me an autographed copy of *Handbook of the Mammals of the South-Central States*, a recently released book of which Clyde was a co-author. The inscription that precedes his signature reads "TO FRANKLIN DELANO YANCEY, II, STUDENT-COLLEAGUE-FRIEND." From that point until his death, I was very fortunate to know Clyde on all three levels.

With his reputation and high stature as one of the world's premier mammalogists, clearly Clyde could have chosen someone much smarter than me as his student. But for reasons I don't quite gather, Clyde agreed to serve as my PhD advisor. As one might guess, Clyde was very effective in distributing his knowledge of mammals. But what made Clyde such an exceptional mentor was his brilliant knowledge of the history of mammalogy and his close association with so many renowned field biologists. Moreover, his willingness to share this knowledge and introduce his students to so many of these "legends" was what made Clyde truly unique as an advisor.

Field trips, of course, were a focal point in the curriculum of a Clyde Jones student. I recall my very first field trip with Clyde to Big Bend National Park, at which time I was introduced to the Clyde Jones philosophy of problem solving. I had just captured a woodrat, and as I was removing it from the trap, it clamped down on my hand in the soft tissue area between the thumb and index finger, almost penetrating entirely through with its large incisors. I scurried over to Clyde and asked him to help me pry this thing off my hand. Clyde responded with a "no problem," and then grasped the rat firmly and, with a sudden and direct jerk, ripped the animal from my hand, apparently forgetting the "pry" part of my plea for help. He then calmly stated "problem solved…nothing that a little duct tape won't fix." That was the first of many memorable field trips with Clyde, each with its own set of unique and humorous stories.

It wasn't until after I read the dedication on the book that I gave the term colleague much thought. But that really is how Clyde treated his students. Students were included in all of Clyde's professional activities. We were not only included in Clyde's research publications, but, upon Clyde's insistence, were always listed first on the author line (whether deserved or not). Clyde's rationale for this policy was that he was "…not the one trying to build a résumé." For nearly 20 years after completing my degree under his guidance, I had the privilege to continue working on various research projects with Clyde, completing a final jointly-authored manuscript three days prior to his death.

Being a student and colleague of Clyde was an honor and a privilege, but being a close friend of Clyde is what I cherish most. Getting to know Clyde on a personal level made for the time of my life. His kindness and generosity were beyond what I have ever experienced in a friend. The countless field trips, skinning sessions, dinner outings, and friendly gatherings with an "occasional beer" will live on in lore. "Saving rats on the pinning board," Natural Light, 20 minute naps, Yucatecas, navy windbreakers, Birkenstocks, Conference Café, Whiskey Club, etc. bring back the best of memories. Clyde: You, as you often referred to a well-prepared specimen, are a thing of beauty and a veritable joy forever. Thank you for being the best possible mentor-colleague-friend.

Art Harris (p. 157)

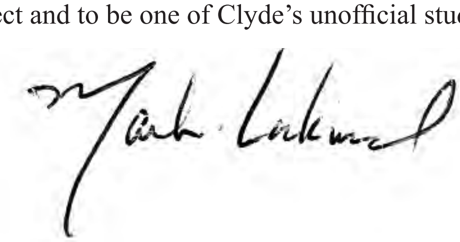
As part of the research for *The Mammals of New Mexico*, Clyde and I toured western U.S. mammal collections to document their holdings of New Mexican specimens. Clyde was the designated driver, and he also acted as gopher in the collections as I, right wrist in a cast, spoke into a wire recorder.

Both of us were in awe of the collections and the reigning mammal curators, but it was not all business. Clyde had relatives (in-laws, as I recall) in California which we were to visit, and one of my clearest memories is of the elaborate preparation he insisted we make before ringing the doorbell. It took careful coaching by Clyde and several tries before he concluded we were suitably positioned to announce our presence and be greeted by his relative—each of us with hand extended, carefully sculptured to the exact fit of an expected can of brew. Although a serious researcher, he also knew how to party.

Mark Lockwood (p. 177)

I first met Dr. Clyde Jones in 1994 when he, along with Frank Yancey and Mary Ann, came to the Texas Parks and Wildlife Department headquarters to meet with David Riskind. Frank was conducting his dissertation research at Big Bend Ranch State Park and the meeting concentrated on incorporating GIS into the work. I was familiar with Clyde because he has served on a thesis defense committee for a fellow graduate student at Sul Ross State University. At the time I was investigating the small mammal remains from Barn Owl pellets from a grain storage bin on my family's farm in Crosby County but was not confident in my ability to correctly identify the skulls. I approached Clyde to ask if he would be interested in the project and before I could even finish asking him he simply stated "Yes." My next question was how many pellets would make for an adequate sample and he responded "I want all of them." Over the next three years I would deliver at least one gallon-sized ziplock bag full of pellets, until one day in 1998 I realized that "all of them" actually had a limit!

In 2003 Clyde started a baseline survey of the small mammals of Chinati Mountains State Natural Area in Presidio County. By that time I was working in the Texas State Parks regional office in Fort Davis and was involved in coordinating such projects in Trans-Pecos parks. I accompanied Clyde, Mike Bogen, Tony Mollhagan, and a couple of students into the property in the spring to start the project. Clyde was very pleased to finally have the opportunity to work in the range, and I provided the needed information about access to the various areas in the SNA and departed. I made a second trip down with Clyde in the summer of 2004 to discuss how the project was progressing and was involved for the first time in trapping small mammals. I knew very little about rodents and Clyde noted my curiosity and suggested that it would be important to the project that I have a larger role and thus began my education. I had the great privilege of working with Clyde through the completion of the project and sharing many days at camp with him, Mike, Tony, Frank, Steve Kasper, Rick Manning, and Sam Braudt among others. In the latter portions of the project among the many rituals surrounding putting up specimens was added the reasons why I was close to being a mammologist, but not quite there. Clyde would recite that I "trapped mammals, pinned specimens, kept a mammal as a pet (a *Perognathus flavus*), and all that was left was for me to skin and stuff a specimen." I am still lacking that last part. It was my great pleasure to contribute to that project and to be one of Clyde's unofficial students.



Ken Geluso (p. 183)

Unlike most contributors to this volume, I never had the pleasure of being in the field with Clyde; however, at meetings and on other occasions, I enjoyed Clyde's friendship and our conversations about bats, rats, and other things. And, I always appreciated the sound advice and encouragement that he gave me through the years. It was Clyde's study of bats in southwestern New Mexico (1966, The American Midland Naturalist 76:522–528) that inspired me to initiate a 34-year study of bats in the San Mateo Mountains of New Mexico. For many years, Clyde's greeting to me would be, "So Ken, how's that Bear Trap study going?" I thanked Clyde once again soon after the study was published in 2012 (Journal of Mammalogy 93:161–169).

Robert Bradley (p. 201)

I first met Dr. Clyde Jones in February 1984. I was a young MS student from Texas A&M University and was attending the annual meetings of the Texas Society of Mammalogists at the Texas Tech University Campus in Junction, Texas. Paisely Cato, a PhD student at A&M, was being co-chaired by Dr. Jones and she introduced the two of us. As I remember, Clyde and I were part of a group of graduate students and faculty who spent the first night of the meetings socializing on the bank of the South Llano River, which flows through the TTU campus. I was anxious to meet the man I heard so much about and became enamored by his stories of field-work and of his association with the icons in mammalogy. About every 30 minutes, Clyde tried to convince me that the South Llano River was fairly shallow and one could probably successfully drive the A&M van across it, if one achieved the appropriate speed. A few beers later, I countered that it probably could be done, but I needed his local expertise for calculating slope of the riverbank, trajectory of proposed entry, necessary speed of vehicle across the floodplain, and other factors that only a TTU professor, such as he, would know. Eventually, Clyde agreed to be my co-pilot in this endeavor and a plan was formulated. Fortunately, Paisley retrieved a couple of more Natty Lites and confiscated the keys. It is debatable whether the plan would ever have been implemented, but I did gain a life-long friend that night!

In 1994, I returned to TTU as a brand new Assistant Professor. Clyde was now an "old fart" (his words) in the Department of Biological Sciences and Curator of Mammals at the Natural Science Research Laboratory. His advice and wisdom on how to survive as a young faculty member and handle departmental politics was generously given and heeded. I learned to value our conversations on departmental and university happenings. He always knew what was coming down the pike and provided the necessary "heads up" when needed. He was a valued resource to the Department of Biological Sciences and he acted as the go-to resource relative to institutional memory.

Over time, I co-authored 17 papers with Clyde. Most pertained to the *Revised Checklist of North American Mammals North of Mexico* series or were distributional records and natural history manuscripts from our work in the Trans-Pecos region. My favorite manuscript was "Molecular Systematics of *Dipodomys elator* (Rodentia: Heteromyidae)", in which I drug Clyde kicking and screaming into the world of molecular systematics. Often he would good-naturally comment to his contemporaries that I had ruined his reputation!

I have many fond memories of working with Clyde in the Davis Mountains (see Photos 12 and 13 in the "Photographs" section of this volume). From his license plate (last three digits - 007) that gave him a self-proclaimed announcement—"Name is Jones, Clyde Jones, and I have a license to kill - it says so right there on my license plate"—to his vast knowledge of the Trans-Pecos mammal fauna, I learned a lot and had many laughs. My students adored Clyde and cherished the times they spent with him, whether it was in the field or through his weekly excursions to my research laboratory. How he could ever prepare a *Perognathus flavus* specimen with those catcher's-mitt hands is still a mystery! He "salvaged" many of my specimen-preps and turned all of our specimens into THOBs!

Clyde, I miss you. I hope your traps and nets are always full and may you never run low on cotton and wire.

Tony Mollhagen (p. 215 and p. 97)

Clyde Jones and Gene Fleharty were undergraduates and friends at both Hastings College and later at the University of New Mexico. After leaving New Mexico, Fleharty took a position at Fort Hays State, where I was enrolled. He was my supervisor, first as a work study undergraduate student, then eventually as his Assistant Curator in the mammal collection. He was also the advisor for my master's thesis. I had heard many, many stories about Clyde Jones long before I ever met him.

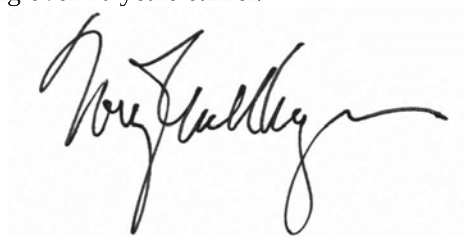
In 1965, Fleharty took me, Elmer Birney, and John Farney on a collecting trip to New Mexico. One of our camps was at a then famous *Euderma* locality, Willow Creek, in the Mogollon Mountains. It was there I met Clyde. He drove from Albuquerque and arrived in camp after dark. After introductions, he took drink orders. In the trunk of his car was a homemade, built-in primitive bar with a wooden rack for bottles, a cutting board, and a cooler with ice and condiments. He and Fleharty just had Black Label Jack; I don't remember what the rest of us took. They told stories and we laughed. Clyde spent only the one evening with us.

In 1967, I came to Texas Tech as a PhD student of Bob Packard. By then Clyde had taken a job at Tulane. Before my first class at Tech I was in a conversation with a new faculty member in the mailroom, Francis Rose. Rose had come from Tulane, so I asked if he knew Clyde. He most certainly did and we exchanged several stories. Shortly, I learned my TA assignment had been changed from freshman Zoology lab to a premium assignment, Rose's Anatomy and Physiology lab. Presumably simply knowing Clyde Jones was an endorsement.

For years after our meeting at Willow Creek, I had only minimal contact with Clyde. This was true even after he came to Tech in 1982. The encounters were chiefly at meetings or in the company of a visiting friend, Mike Bogan, who had worked with Clyde for many years. While my own career had substantially deviated from my earlier training, Clyde generously asked my opinions as though I was current in all things mammalogical and I could possibly contribute to a discussion.

Nevertheless, it was during this period (1989) I shared my first author line with Clyde, a result of a capture of a range extension of a Harvest Mouse some time earlier. A person has to be a certain age, and have a certain academic heritage, to appreciate having one's name associated with that of even one of the Jones boys (Clyde and J Knox), much less both. Never mind that it was a minor pub and my name was an afterthought in a string of authors. I had published more significant work in other disciplines, but I admit to being a little puffed-up over that one.

My next and last shared authorship with Clyde resulted from the only period I actually worked in the field with him. This was his Chinati Mountains project, published in 2011. I was retired from the faculty in Civil Engineering, but still had some skills at collecting mammals and prepping specimens, thanks to a long association with Bogan. Most commonly the trips to the Chinatis consisted of small to large crews of current or former colleagues and current or former students, but sometimes it was just me and Clyde. Whatever the case, whenever the serious work was done, the evenings usually concluded with Clyde holding court. There was laughing, story-telling, and beverages over ice; Knob Creek was favored at the time, among other distillates. The circumstances were not unlike our first meeting over 40 years earlier.



Jim Goetze (p. 225)

My family has a fairly long association with Dr. Clyde Jones. This association was initiated when Dr. Jones first began sampling small mammals, and in particular the Texas Kangaroo Rat (*Dipodomys elator*), on some Goetze family properties in Wichita County, Texas. This occurred when Clyde was a faculty member at Tulane University. As Dr. Jones told me later, "I first met you when you were about knee-high."

My next brief encounter with Dr. Jones was when I traveled to Lubbock around 1985 to research a Master's Degree in Museum Science from Texas Tech University. At that time, Clyde was the Director of the Museum of Texas Tech University and intimately involved in the Museum Science Program. At this time, circumstances intervened and I ended up not pursuing that particular pathway.

I didn't meet Clyde again until the summer of 1989, when, once more, I traveled to Texas Tech University to interview for a spot in the Doctoral program of the Department of Biological Sciences. My purpose was to interview with Clyde and J. Knox Jones concerning their program and my particular research interests. I don't remember too many specific questions from that interview, but one, duel question is still crystal clear in my mind; and it was this, "Why, in particular, do you wish to pursue a PhD with us, and what do you intend to do with it, **IF** you earn one?" Now, I don't remember my exact answers to those two distinguished scientists, but recall telling them that I had developed my current interest in biological sciences while attending Midwestern State University and, initially, taking courses for a teaching certification. As a result, I had become very interested in the discipline (particularly in field work, museum specimen preparation and care, and curatorial activities in a natural history collection) and had decided to obtain a Master's Degree in Biology from MSU and perhaps pursue a doctorate degree, if accepted. In fact, my paleontological-based, reworked master's thesis had recently been published in the Texas Journal of Science, of which both Clyde and Knox were involved in peer-review, editing, and the publication process of that journal. I told Clyde and Knox that I really enjoyed the field research and publication aspects of biological sciences.

What sticks in my mind about this is that they both smiled and allowed that I had given them a 'good answer' because, if I had said "I want the degree to teach at a college or university" then I would not have been accepted into their program. Clyde and Knox demanded that their graduate students conduct independent research, and that this research had to be "publication grade." In addition to their graduate students' own thesis or dissertation research, Clyde and Knox also expected their students to participate in other, numerous projects that they (Clyde and Knox) initiated.

I was subsequently accepted into their program, and thus began a longer and closer association with Clyde. As stated before, with Clyde most of your own graduate research was expected to be independent and, despite wracking my brain for memories, I can't think of an instance where Clyde was involved in my dissertation fieldwork on the Edwards Plateau of Texas.

HOWEVER, I was associated with Clyde on several other field-based, research projects including the mammal and herpetological survey work on the Harte Ranch addition of Big Bend National Park, the Lake Meredith National Recreation Area mammal research project, the Lake Allan Henry environmental impact study for the City of Lubbock, and the non-field-based publication of two *Mammalian Species* accounts and a species account for the *Smithsonian Book of North American Mammals*.

The first thing that I can say is that I thoroughly enjoyed working with Clyde on all of these projects (field-based or not). It seemed to me that Clyde was always happiest when conducting fieldwork and, as everyone who knew Clyde Jones can attest, he was a consummate, professional field biologist and a "specimen preparator" par excellence!

Also, it was a great deal of fun to be in the field with Clyde; where he never seemed to lose his sense of humor (rain, shine, hail, cold, or come-what-may) and always performed more than his share of the tasks. Clyde was almost always the first one up in the mornings, and was usually cooking everyone breakfast (with the coffee pot on—although Clyde often was drinking some 'liquid cereal' because we all knew that, "One beer is worth 20 minutes of sleep.") with the usual small smile on his face and a cheerful greeting. We would be "out the door" to take down mist nets at the break of dawn and "down the road" for the Sherman traps or Museum Specials, depending upon the season of the year.

I especially enjoyed Clyde's system of "assembly line" preparation of the day's catch. Each field party member had a job or part in the overall specimen preparation that the individual was at least pretty good at, and, using this system on a daily basis, large numbers of specimens could be prepared, pinned, and stored for drying in a most time-efficient manner. Clyde often ended up as one of the people with the final task of pinning out the voucher specimens for drying. This was the time of the famous lines from Clyde that all of us remember!

One: "Well…maybe I can save this one on the pinning board…" and Two: "It's a thing of beauty and a joy forever!"

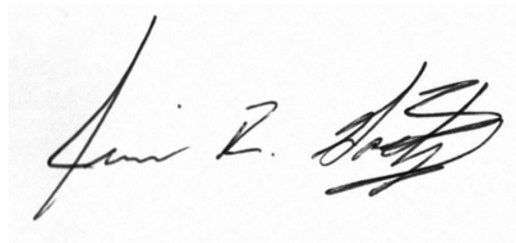
One collecting trip memory that I can recount (as common in fieldwork, others are perhaps best left unwritten) occurred during the Harte Ranch survey. I was on this particular collecting trip with Clyde and Rick Manning. We drove the old, Dodge, university van out from our base camp in the early evening looking for a likely place to set some Shermans where we had not previously trapped. This is the Chihuahuan Desert, so all was dry. Therefore, we drove off of the travelled road and some distance through a creosote flats area until we reached a small arroyo. Upon inspection of the area, we all agreed that this was the "sweet spot" and we laid down the traps. I don't remember exactly how many traps, but I would guess a minimum of 300 because there were three of us. At the time, 100 traps per mammalogist seemed to be the standard minimum number for each set or transect. However, we probably set more traps because we were in a 'new locality.'

Well, we went back to base camp at Mountain Lodge and roosted for the evening after a stint of night-driving road surveys for nocturnal mammals and any herpetological specimens we could find. During the night, an intense thunderstorm rolled through the area and soaked everything down really well.

The next morning, we then attempted to reach our traps in the old, non-four-wheel-drive van and soon discovered that we had better give up on that endeavor and start walking to the trap lines. Needless to say, the traps were some distance away from where we abandoned the university van. Now I can't speak for Clyde or Rick Manning's footwear, but by the time we reached the trap lines, my boots had grown about three sizes larger and were somewhat heavier than when we began our trek. We picked up all of the Sherman traps (empties in the wooden trap boxes and 'full ones' in canvas trap bags) and started slogging out toward the van. About half-way back, my boots are now six sizes bigger with the mud and muck on them and much, much heavier. At this point, I made what I felt to be a relevant comment regarding my condition and Clyde smiled and laughed. However, the Boss—as we called Clyde—never forgot it, and would occasionally remind me of it when times got tough! I just told CJ that, "Hey, I can hear my heart pounding in both of my ears now!"

We made it back and all was well. Clyde would always make sure of that with his watchful eye and concern for his students, and I hope, if he is watching now, I have made him just a bit proud of his "more deliberate" graduate student.

So long, Boss, and I hope that where you are at, your trap lines and mist nets are as-full-as you want them, your shotgun never misses its mark, and you are still making "things of beauty and joy forever!"



Allan Nelson (p. 225)

I met Clyde Jones for the first time at the Texas Society of Mammologist meetings at Junction, Texas. We ended up sitting at the same table after the banquet tables had been moved to the periphery to make room for dancing. We introduced ourselves and he pulled out a bottle of bourbon and offered it to add to the cola I was sipping. I thanked him, added a slug and settled in to watch the dancing. He sat for a few minutes and then said, "I really liked your paper in the Museum Occasional Papers series, where you compared the flora of the Texas barrier islands."

First this struck me as incredibly nice and secondly, I was amazed he remembered a rather obscure botany paper. Next he began to talk with me about the paper recounting details and discussing his own thoughts regarding the biogeography of plants and mammals in Texas. I remember this because it made me feel that others, even people outside my field, were looking at something that I did. I guess you could say it sort of gave me a mid-career boost regarding my research.

As the night continued, Clyde did this same sort of thing with numerous individuals that visited the table to talk or get bourbon. There is no doubt in my mind that few field biologists that work in Texas today have the breadth and depth of knowledge that Clyde displayed that night.

Larry Choate (p. 225)

Writing an encomium for Clyde Jones is especially difficult because the very act of putting words on paper acknowledges that he is gone—difficult to believe because, in many ways, Clyde had a larger-than-life persona. A scientist of international reputation whose published works encompassed the breadth of mammalogy, he also was involved in and published in a variety of other disciplines. For example, before I became his graduate student, he auditioned me by having me accompany him for a week on a month-plus-long trip with Royal Suttkis and three graduate students who were engaged in sampling fishes in the Red River drainage in Oklahoma and Texas. What an eye-opener: endless seining in daylight and dark, lots of heat and sand, and even more cold beer—sometimes not so cold.

Clyde was unique in so many ways. His professional career, as a researcher in equatorial West Africa, with the U.S. Fish and Wildlife Service, and in academia was inundated with big personalities with even larger egos. Clyde Jones had an excellent sense of propriety. I never heard him 'blow his own horn;' he did not have to because only the most dim-of-bulbs were unaware of his status and accomplishments. Still, it was never his style to brag. Many times I was with him in the presence of others holding forth their theses, opinions, or learned postulations while he remained stoic. If directly questioned, Clyde would either agree or diplomatically provide an alternative explanation or solution. Rarely would he take someone to task, and never without substantial thought and justification. He did, however, enjoy recounting amusing anecdotes, primarily regarding field exercises that did not go exactly as planned. To refer to Clyde as "Old School" was truer than most realized. He knew and had interacted with many of the first modern mammalogists, and with many senior scientists from other disciplines. Clyde had been in "the field" with many of these folks.

Clyde had an exceptional talent for leadership: getting others to WANT to do what he wished them to do. And, his outstanding interpersonal communication ability spanned the human spectrum. Whether he was speaking in Spanish to a construction crew, working a cocktail party fundraiser, or interacting with peers at a scientific meeting, Clyde got things done and, usually, everyone left happy. Although he was adept at these exercises in leadership, Clyde seemed not to enjoy many of these people-interactions as well as his solitude. Many of Clyde's value systems were rooted in the past, from his Nebraska ranching heritage.

But, his range of interests was more varied than most would imagine and always included a forward-thinking element. While in his company, I often was somewhat taken aback when he received an "old friend" acknowledgement from people outside of academia in everyday life. People such as ranchers at the end of a rutted road, florists, painters and sculptors, poets, gardeners, hardware store clerks, band members at a country music concert or dance, and many others seemed to genuinely enjoy recognizing Clyde's friendship. Even his knowledge in his chosen discipline of mammalogy was extremely varied; for example, among many taxa, Clyde was an expert on Primates and marine mammals, especially Cetaceans. He loved flowing water and was a river boatman of some experience and skill.

Clyde always had a strong interest in the arts, and thought this would be a much better world if our public education system did a better job of introducing everyone to the arts. In many ways, Clyde Jones was a Renaissance man; however, he did have more than a few quirks. He used to keep an ornate box turtle as a free-range, backyard pet, and he went through a period of not answering a telephone. Pavlov notwithstanding, it is disconcerting to attempt to carry on a conversation while ignoring a ringing telephone. For a few years, he also would only drink Schlitz Beer. Schlitz! (and then he changed to Miller Lite. Lite!) If Clyde thought you needed to sort an answer out for yourself, he would not directly answer a question; rather, he would assign you an oblique task which (in his mind at least) was supposed to lead you to the correct answer.

I miss him.

Lou Densmore

What can I say about Clyde Jones? He was a friend, a colleague, a confidant, a mentor and an advisor. Not being a mammologist, I do not have stories about skinning 'rats' or traveling to Africa with Clyde that so many folks do. To be truthful, I really did not get to know him well until about 15 years ago. Everyone knew Clyde by reputation, as he was one of the truly iconic mammalogists of the last half of the 20th century (and Texas Tech had three of them, Clyde, Knox Jones and Robert Baker). However, until about 2000, our relationship was friendly but a bit distant.

Maybe that is because I had several interactions with Clyde early on, some of which were not that cordial. One of our first 'encounters' was in the early 90's. My then fiancé (and now wife of 21 years), Erika, had driven my vehicle over to the University for some long forgotten reason. We had assigned parking spaces in Biological Sciences in those days and someone had taken my space. Erika was only going to be there for about 15 minutes, so she just parked in the space next to mine, which happened to be Clyde's. Dr. Jones showed up about 5 minutes later, and needless to say, he was not very happy about it. The next time he saw me in the hall (which just happened to be in front of the faculty mailboxes outside the main office), I got 'dressed down' for about 10 minutes. When Clyde was upset he rarely minced words…..and true to form, he did not on that morning. Needless to say, neither Erika nor I ever parked in Clyde's parking place again. In later years, we all laughed about it, as Clyde and Mary Ann came to be some of our closest friends.

Clyde had an incredibly keen sense of humor, sometimes caustic, but at the same time very dry. There were times when he would say something to you and after the conversation was over and you were walking away, the realization hit that you had just been verbally eviscerated and were now 'tripping over your own entrails' --- and at the same time you were laughing about it. I remember several instances when his short quips, stated totally off the cuff and at the perfect time, would just about bring me (and others if they heard them) to tears. One example occurred during a faculty meeting that dealt with bringing into our department an entire center of researchers recruited to Texas Tech from another university. As per usual, we had considerable discussion about the matter, with both pro and con opinions being voiced. After one person's rather negative and frankly ludicrous comment, Clyde (who was sitting next to me) leaned over and stated something to the effect: "isn't it terrible what chlorine bleach can do to the human brain" (let's just say the person was not a true blonde and leave it at that). I literally had to "chew" on my arm to keep from laughing out loud. I knew at that moment we would be friends forever.

After Clyde retired, I took over his position as Associate Chair. He was still a regular visitor to the department and that is when I truly started to benefit from his counsel and advice. His impact on me was even greater when I became Chair in 2009. Clyde had truly just about 'seen it all' in his various roles with the federal government, in museum administration, and in the department. He had the remarkable ability to recognize and ferret out the difference between administrative BS and legitimate (and important) issues. To a new chairman sometimes struggling to know where to devote his time and energy, Clyde's advice on such matters was critical.

Probably my favorite moments spent with Clyde were during his last years when he and Mary Ann would invite Erika and me to come to the Frazier Alumni Pavilion on football Saturdays to sit at their table in a cordoned off area, consume adult beverages (it was Clyde that first introduced me to Knob Creek bourbon), and watch the Texas Tech and other football games. Clyde has his own "uniform" and everybody who knew him can relate to it. He preferred to wear a cream colored to tan TravelSmith "Great Escape" style short-sleeved shirt (see Photo 26 in "Photographs" section of this book) that was *never* tucked in. His pants were normally blue jeans (or sometimes shorts for August or early September games), but his *pièce de résistance* was that pair of Birkenstock sandals that were worn (obviously with no socks) whether it was 95 degrees or 35 degrees outside. I do not think that anyone knew the actual age of those shoes, but they were definitely 'broken in'. If it got bitterly cold, one would see him in the same outfit, but also wearing what Mary Ann describes as 'very well worn' blue or black windbreaker.

Clyde and Mary Ann were clearly adored by the Frazier staff and typically allowed to come in a bit early and sit at their centrally located table. And it was obvious that those feelings were reciprocated. They knew everyone by first name, from the janitors, to the police officers, bartenders and administrators, and there was genuine affection displayed by these people for 'Dr. and Mrs. Jones'. During the most recent (2015) football season, after his passing, people regularly came up to talk to Mary Ann, often tearfully conveying their sincere condolences and relating their own 'Clyde stories.'

Clyde Jones was a man that could be deadly serious in one breath and hilariously funny in the next. Honest to a fault, the better you knew him the more you began to understand and appreciate his perspective and approach. It is perfectly clear to me why he was so beloved and is so greatly missed by so many people.

Gene Fleharty

It was in August 1953 that I first met Clyde. We were both on the Hastings College football team—Clyde, a freshman, and I, a sophomore. Clyde never became first string but subbed a great deal and did an excellent job at guard. In 1954 we were both on the undefeated team that played in the Mineral Water Bowl.

I graduated in 1956 and became a student of Dr. J. S. Findley at the University of New Mexico. The next year I tried in vain to get Clyde to apply to UNM. He had accepted an assistantship in the physical therapy program at Southern Illinois, as I recall. I called Clyde and begged for him to send in an application to UNM.

I didn't think he would apply, but in a week or so Dr. Findley called me into his office and asked if I knew a Clyde Jones. I assured him I did and gave him my best recommendation. Findley wanted to know what the statement "academic suspension" meant on his transcript. I told him that Clyde was found drinking beer on campus which was a definite "no no" at the Presbyterian school. Findley sort of overlooked that and eventually Clyde came to UNM.

In August of 1957 he immediately went with me to collect chipmunks in the Guadalupe Mountains in southeastern New Mexico. I had to tell him what a chipmunk was, and Clyde collected his first specimen. Over the next few years we spent much time together taking numerous trips to mountain ranges in New Mexico as Dr. Findley hired us as field assistants on a NSF grant to study the mammals therein.

Many happy hours were spent with Clyde. We both had experiences that are probably best told after a few drinks.

Steve Kasper

My experiences with Clyde Jones are bimodal, first as an educational advisor and teacher to a student and, years later, as a friend and confidant. I first met Clyde Jones while I was a graduate student at Midwestern State University (MWSU). He and several of his students were examining mammal specimens in the MWSU collection, then under the supervision of Dr. Walter W. Dalquest. My first impression was that Clyde's students were devoted to him. Years later, after I arrived at Texas Tech University (TTU) in the fall of 1991, Clyde spoke to incoming graduate students at the beginning of the semester. His witty and insightful comments were comforting, but I was impressed by his quiet confidence.

My first fieldwork experiences with Clyde were during a summer field mammalogy course being team-taught by Drs. J. Knox Jones and Clyde Jones; we had several field trips during this course, including the upper panhandle of Texas, the City of Lubbock's reservoir mitigation lands east of Justiceburg, Texas (which, ironically, is where I presently work), and the Harte Ranch mammalian survey project for Big Bend National Park. Clyde was always quietly in charge because everyone wanted to make sure that he was pleased. For me that sentiment never stopped. During the years at TTU, I was privileged to have been his teaching assistant for the labs of two courses he taught (Vertebrate Structure and Development and Natural History of the Vertebrates).

We lost touch after I left TTU and went into the private sector in Lubbock. Then, around 2005, Clyde showed up at my place of business regarding a gift for his lovely wife Mary Ann. After some remembrances of field work, he stated "Why don't you come visit me?" Over the following years, I went to Clyde and Mary Ann's home countless times to sip some refreshments and just discuss life, politics, TTU and Nebraska football, and of course biology. Clyde subsequently invited me to accompany him on field projects to the Chinati Mountains State Natural Area and Big Bend Ranch State Park. His legacy persists to this day with the continuing research on both of these projects.

Clyde's breadth of overall knowledge and the mammalian literature was remarkable and never left him. I was always impressed with this facet of Dr. Jones during our mammalian discussions. Our friendly debates at his home were always entertaining, often educational, and therapeutic for the both of us. Clyde was a kind, thoughtful man who would have found his way in anything he decided to undertake. We are all fortunate that he chose the course that he did.

David Riskind

All my professional life, starting in the mid-60s, I had heard of Dr. Jones, the eminent mammalogist. Through him, I educated myself of the mammalian diversity and distribution of mammals in Texas. Dr. Jones helped me greatly with some publication difficulties I was having with the Texas Journal of Science. I regularly used the Checklist of North American Mammals North of Mexico, and the regular revisions, published through the Occasional Papers of the Museum at Texas Tech University. In about 1970-ish, I snapped to the fact that there were two of them (Dr. Clyde Jones and Dr. J Knox Jones)! And, it was my good fortune (and the good fortune of the Natural Resources Program, Texas State Parks) to finally work directly with Clyde Jones. I met him at a 'Small Mammal Workshop' I had organized with Dave Schmidly at the newly acquired 300,000 acre Big Bend Ranch State Park (BBRSP).

Clyde, his students, and his colleagues were the core of the field and lab crew running us through the paces of field collection methods and the specimen preparation techniques for documenting small mammal diversity and distribution for the newly acquired, and largest, state park. The workshop formed the basis for a relationship with El Professor, and the Natural Science Research Laboratory (NSRL) of the Museum, Texas Tech University. Clyde became the nexus for a long-term project to establish and conduct baseline small mammal investigation on Texas State Parklands. The core of the effort would be a series of studies leading to MS and PhD degrees. The Natural Resources Program provided the funding base; TTU, Dr. Jones, the Biology Department, and the NSRL provided the graduate students, curation, and academic spine. It didn't hurt our effort that Dr. Schmidly became Vice President for Research, and then President of TTU, about this time.

In addition to Dr. Jones and his cadre of faithful, enthusiastic, and talented students, we also got Clyde's long-term colleagues, former students, and friends—among them Richard Manning, Mike Bogan, Tony Mollhagen, Jim Goetze, Larry Choate, Sam Braudt, and of course Clyde's wife, Mary Ann.

Fast forward and we have as a result long-term plots established at Big Bend Ranch State Park, Chinati Mountains State Natural Area, Davis Mountains State Park and TNC's Davis Mountains Preserve, Caprock Canyons State Park, Lost Maples State Natural Area, among others. Franklin D. Yancey, II, currently is engaged in revisiting his dissertation research and, as an honor to Clyde, continuing our investigations of small terrestrial and volant mammals of the Chinati Mountains SNA and Big Bend Ranch.

Along the way we had some absolutely terrific field days (and nights) and some memorable moments that will be fodder for legend and lore. The 4X4 adventure trip to conduct field investigations along Terneros Creek, BBRSP, Presidio County, stands out. Sitting around the campfire enjoying friends and the evening sky, Joel Brant hops up, grabs his shotgun, and "ON THE FLY" collects a new record! Clyde dutifully demonstrates to Jana Higginbotham the fine art of specimen preparation.

San Antonio Cabin at Chinati Mountains SNA was a favorite of Clyde's. It provided an outstanding field lab/camp and came with its own population of Pallid Bats. The composition and seasonality of that night roost became the subject of detailed analysis.

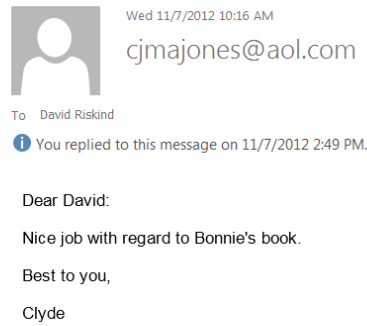
I had for more than four decades studied the flora and vegetation of northeastern Mexico and especially the Sierra Del Carmen just south of the Chisos Mountains. Clyde had always wanted to go and, finally, in 2007 was hosted by our good friends Bonnie and Billy Pat McKinney. I guided him and Mary Ann there.

The trip wasn't especially long but because the terrain was unfamiliar, Clyde was anxious to arrive. A blown and ruined tire, along the way, didn't help. We arrived at Pilares, and were greeted by Bonnie. I recall that about 2.5 minutes after we arrived Clyde said "Where are the specimens?" Recall the only small mammal records in the literature were Rollin Baker's study published in 1956. Clyde was especially interested in the Coahuila Mole and Miller's Shrew. Bonnie had recent specimens of both, and Clyde wasted 'NO' time in examining them. He was giddy, and then Bonnie pulled out the *Leptonycteris*!

My conversations with Clyde, even in the evenings were brief, as I recall. He communicated frequently by expression. I especially enjoyed his eye-rolls (these told you exactly what he thought). As a born and reared Plainsman, he usually was guarded in his opinions—but the eye-rolls told the story. For actual news I relied on Mary Ann; and, of course, she told all.

I never could get much out of Clyde via e-mail. A greeting, one sentence, and closing were about it.

I attach one of his lengthy "missives":


Wed 11/7/2012 10:16 AM
cjmajones@aol.com
To David Riskind
You replied to this message on 11/7/2012 2:49 PM.

Dear David:

Nice job with regard to Bonnie's book.

Best to you,

Clyde

I miss them, short as they were!

I am hopeful that decades from now, someone will revisit the work spearheaded by Clyde and his colleagues and gauge how our parkscapes have fared – for better, or worse. They will be able to do so because of his efforts.

Fred Stangl

I was a second-year graduate student at Texas Tech under Robert Baker, and life couldn't have been better for a young rat-stuffer. In addition to my major advisor and the students who shared the lab with me, the Biology Department and Museum were staffed with the likes of mammalogists J. Knox Jones, Jr., Dilford Carter, Mike Willig, and even a young Ron Chesser. How could things get better?

Then, Clyde Jones came into town to interview for the directorship of The Museum. His presentation on mammals of the Grand Canyon's Colorado River was promising. Even more promising was what I saw shortly after he assumed the job: feeling the need to take off for a weekend, this museum administrator headed off into the northern Panhandle and came back with pinning trays full of mammals.

Among all those rats and mice, I remember stuffed examples of a coyote and striped skunk. This kindred spirit came along a little too late to serve on my graduate committee, but he was a good friend and valued mentor throughout my career and continuing on until after my own retirement.

Richard Stevens

I met Clyde in the Fall of 1990. I took Mammalogy from him and it changed my life. The next semester I took Vertebrate Structure and Development from him. Perhaps halfway through the semester he pulled me aside after class and said that he had a graduate student conducting a biodiversity survey of a new extension to Big Bend National Park (Harte Ranch) and asked if I would go on the next trip and help him out. The first night we placed a mist net over a metal overflow tank right outside the house at Harte Ranch and caught among other things, a Townsend's long-eared bat (*Corynorhinus townsendii*). That moment too changed my life for I have worked on bats ever since. Clyde and J. Knox Jones Jr. (Los Cojones) nominated me to the American Society of Mammalogists back in the day when such a formality was necessary. This remains my "home society" and has had a huge place in my life for the last 25 years. Clyde was responsible for much of the mammologist I am today. He taught me the nuances of trapping and preparing, though you would not know it by comparing my specimens to his. He also taught me how to drink Natural Light…for breakfast, that when you are really tired and hot in the field a beer is equal to a 15 minute nap, and perhaps most importantly, not to try to keep up with him. Clyde was one of a kind. He was also one of a cadre of traditional mammalogists from another time; the golden age of Mammalogy. My experiences with Clyde were some of the most important to the development of my career. Through those interactions, the stories, and the pedagogy on how to study mammals, I was connected with this golden age. My time spent with Clyde Jones was a true honor though not sufficiently appreciated at the time. It's not that I was unappreciative. It is that I did not have the capacity to fully appreciate the giant I was amongst and how truly fortunate I was.

Ernie Valdez

It was the early 1990s and I was just a neophyte to mammalogy when I went on my first major field expedition to the Sandhills of Valentine, Nebraska, to trap small mammals. That is where I met some "giants" in the field of mammalogy, with one of them being Clyde Jones, but I didn't really know much about them or their greatness at the time. Being young and impressionable, I was like a sponge in absorbing knowledge from Clyde and others while in the field. It also helped that Clyde could see my desire for mammalogy and willingness to learn as much as I could and he was happy to pass on his knowledge.

We would spend mornings picking up traps that were set the night before and return to camp to prepare them as museum specimens. During our morning prep of rodents that included *Peromyscus, Dipodomys, Onychomys, Microtus,* and more, we would set up our assembly line and prepare specimens together. Willie and Family Live would be playing in the background, then you'd hear the crack of a beer, and fur would be flying, so to speak. During this time is when I would hear the first of many sayings by Clyde such as, "skinning mice gives me gas" after a low burp. Other sayings included comments about rodents that I had never seen before in my life, such as seeing *Onychomys* for the first time. In particular, we would skin them out and then collect reproductive data from them. As many of you know, male *Onychomys* can have large testes when they are in breeding condition, and during our prepping Clyde would make the sympathetic comment towards them by saying, "Did ya see the size of nuts on that guy? Oh my God," as he would cup his hands out as if holding two grapefruits. These sayings would make me laugh and engrave a long-lasting, great memory into my mind, but also helped me remember the genus *Onychomys* by association.

Clyde also had a major impression on me when it came to prepping rodents. Although he was skilled at skinning small mammals, he was the grand master of stuffing and pinning rodents. I could see that he would take pride using pins to hold back the smallest hair that was out of place and was keen on giving the rodents square butts, while telling folks that he could save our specimens on the board. He set the bar high for me when it came to the quality of preparing a museum specimen; a dying art that has since taken second or even last ranking to preparing fluid/alcohol specimens, taking only fur clips and biopsies, or collecting genetic material first while letting the skins dry out or become greasy from melting fat. Fortunately, he instilled the importance of having a quality voucher specimen that can be used in perpetuity and did so by being frank about his critiques related to my museum preparation of specimens.

One of my fondest memories of his frankness was when he had given me my first *Neotoma* to skin and stuff. This was a large adult and should have been easy to prepare but after spending more time on it than I should, I finally had a rodent that was stuffed and wired. In my proud but humble moment, I asked Clyde what he thought of my work before I sewed it closed. His response was, "Jesus Christ! This looks like shit! I give you a piece of cake; all I wanted was a little cherry on top. Go ahead and do it again, ok?" I smiled at him and he back at me, knowing that this was honest but tough love. Since then, I have worked over the decades perfecting my prepping skills, as well as my impersonation of his voice and this saying. I often share this story with young students learning how to prepare museum specimens. As I go through my routine, I tell them that it is ok to get honest opinions instead of saying that something looks fantastic, when it truly looks like it came out of the south end of a northbound coyote.

As time went by, my admiration for Clyde grew with my own personal growth in knowledge and where I am today as a mammologist. In fact, Clyde's work on bats in New Mexico helped strike a passion in me to work on *Myotis occultus*. I used this passion to help resolve a taxonomic question that he had been working on with Jim Findley in 1967. Without this inspiration to work on *M. occultus,* I think my MS and PhD degrees would have been influenced by another mammal.

In closing, I must say that in some ways I am thankful that I didn't know who Clyde was when I first met him, because I have an unbiased opinion of how truly great he was to me and to the field of mammalogy. This became more evident to me as I learned more about Clyde through interactions at meetings, social gatherings, working together in the field, or from the papers he had written. As with many, I think of Clyde often and miss him greatly. However, in some ways I like to think that he still lives on. I can see this when I examine voucher specimens by Clyde that are housed at the Museum of Southwestern Biology, but even more so when I delve into my fond memories of him and give my impersonation of Clyde saying "Valdez, are you gonna skin it or make love to it, huh?" as I prepare to skin something in front of me.

Cheri Jones

Memories of my Dad

My brother, Craig, and I were born shortly after Dad began his work as a graduate student at the University of New Mexico. When we were very small, Dad was gone a lot. He was busy with his courses, research, and jobs required to support his young family (I seem to remember that one of his summer jobs was picking watermelons). We were excited and happy when he came home. Mom was the main disciplinarian in those days, but Dad mastered the common family strategy known as The Look, which I imagine was equally effective with errant students later in his career. As he advanced after completing his PhD, we moved to New Orleans and Mandeville, Louisiana, Bata, Río Muni (Equatorial Guinea), and Vienna, Virginia. We learned to adapt to new neighborhoods and new schools fairly quickly.

Dad kept Walker's *Mammals of the World* and the *Life* series of science books at home. However, I didn't immediately gravitate toward biology in public school because most of my science classes were less than inspirational. One exception was a summer class I took in junior high school. That class involved activities, such as a field trip to a herbarium, and I chose to identify and press leaves as my final project. Dad gave me my first Peterson field guide, one that addressed the wildflowers of the eastern United States. By that time, I also was more aware of what fun (and work) was involved in biology because of a greater understanding of my father's work.

Dad and I enjoyed learning and practicing Spanish, traveling overseas, and discussing new discoveries in zoology. Two special memories involved work as field mammalogists. When I started collecting mammals, I discovered that my hands were small enough to reach into Sherman traps. Dad's big hands wouldn't fit inside a live trap, but with those big hands, he prepared voucher specimens more quickly and consistently than anyone else I've ever seen. The second memory I'll recount was when he accompanied me on one of my field trips in southern Colorado. After years of hearing about his field trips (and going with him on a few), I was so excited to have him with me. He really enjoyed himself, too; he mentioned that an elk herd we saw was the largest he'd ever seen, and he had had little or no experience capturing water shrews and jumping mice. I really miss Dad, not only as a father, but also because I miss sharing so many things with him.

Norm Scott

Clyde was one of the most important people in my life. He took a callow youth who had just lost tenure at the University of Connecticut and molded him into someone who could contribute meaningfully to the scientific community. Early on, he recognized that I enjoyed the fieldwork too much and I didn't follow through with the dreary publication process in a timely manner; he mentioned it once—and once was enough. Clyde also reveled in the fieldwork, and he managed to shoehorn it into his heavy administrative and scientific schedules whenever he could, and his success at this balance provided a model that we all could follow.

Clyde was a man of bedrock principals, honed early in the Sandhills of rural Nebraska. I could always depend on him to have my back in the often political climate of the Fish and Wildlife Service bureaucracy. When one of his team made a mistake that drew the attention of the Service, he never even mentioned it to us. He took the heat and shielded us, figuring that we had already learned a lesson and didn't need any extra pressure. I can't imagine a better boss, and, when he left the Service after a conflict of principles, our tight-knit lab unraveled some and was never quite the same again.

What follows are some of my most valued remembrances of Clyde, and what he did with and for me. They are in chronological order.

Barro Colorado Island

The Howler Monkeys (*Alouatta palliata*) at the Smithsonian Research Station on Barro Colorado Island (BCI) in Gatún Lake, Panamá, were one of the most studied monkey populations in the world (Carpenter 1965). In 1973, Richard Thorington, a mammalogist at the Smithsonian Museum of Natural History, Washington D.C., had asked Clyde, then the director of the U.S. Fish and Wildlife Service's National Fish and Wildlife Laboratory (NFWL) located in the Museum, to recruit a team of biologists to tag Howler Monkeys on the island.

I had been working with a team of graduate students at the University of Connecticut, and we had developed techniques for capturing and marking Howler Monkeys (Scott et al. 1976). We had tagged over 100 monkeys in Costa Rica, and Clyde asked me to come to BCI to be a part of his team, which included Al Gardner and Don Wilson, both NFWL mammalogists.

Don and I arrived at BCI on the shuttle boat (Fig. 1), climbed the 350 stairs from Gatún Lake up to the station (Fig. 2), and went into the dining room where I met Clyde for the first time. He immediately provided us all with beer.

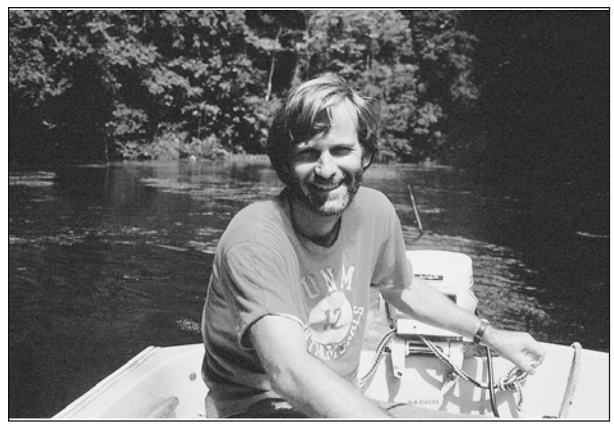


Figure 1. Don Wilson taking boat from Gamboa, Panamá, to Barro Colorado Island, 1973.

Figure 2. Smithsonian Tropical Research Institute laboratory and dock at Barro Colorado Island on Gatún Lake, Panamá.

We spent the next month tromping over the entire island, catching Howler Monkeys with anesthetic darts and tagging them for future studies (Fig. 3). If the anesthetic took hold immediately, the monkeys fell within 5 or 10 minutes, and we were able to catch them in a canvas cloth held up by two people (Fig. 4). Sometimes, however, the monkey wouldn't come down immediately. They would crawl into the fork of the tree, wrap their tail around the branch, and go to sleep. Usually, when they began to awaken, they would fall out of the fork, but even then they often didn't lose their tail grip, and they would hang head down for up to an hour more. Then, when the drug started to finally wear off, the monkey would relax its tail and fall. It was dangerous for us to stand for more than an hour under a 12 kg monkey that could come crashing down at any moment, so we piled branches on the ground to break the fall and sat down and waited. We weighed and measured the drugged monkeys and returned them to their home habitat (Fig. 5).

Figure 3. Clyde and Norman taking aim at a Howler Monkey.

Figure 4. Clyde and Norman examining the drugged monkey.

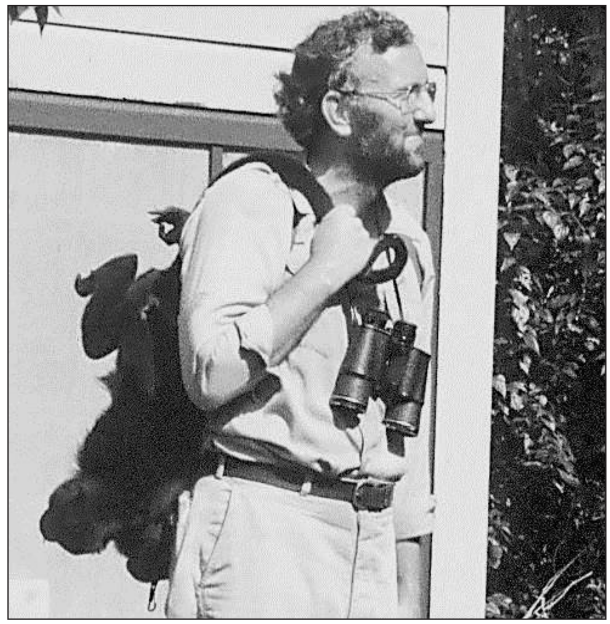


Figure 5. Clyde ready to return the monkey to its habitat and go get another one.

Old Scar was the dominant male in the troop that had its territory around the station. He had been named by Carpenter, and was still the lead male when we got there. On one of our last days on the island, just about lunch time, Clyde and I got a tranquilizer dart into Scar's butt and he hung by his tail. One of my most pleasant memories of Clyde was when he and I were sitting next to the trail, reminiscing about monkeys and waiting for Scar to fall. The crash, when it finally came, was a satisfying climax to an unforgettable month (Fig. 6).

It wasn't all monkeys on BCI. To take a break on some days, Clyde, with Don and me and Robin Andrews, a herpetologist, would cruise the forest, looking for *Norops frenatus*, a medium-sized lizard that perched on tree trunks and searched for invertebrate prey in the leaf litter. We developed a theory as to why larger lizards perched higher on tree trunks and used larger diameter perches (Scott et al. 1976).

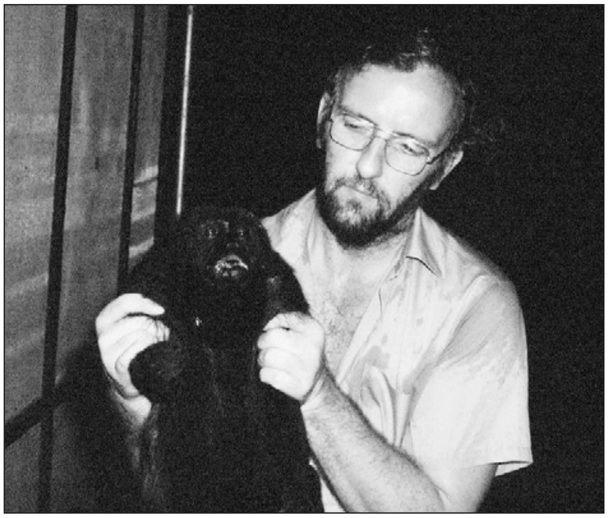


Figure 6. Clyde showing old Scar, the lead male in the laboratory troop.

Clyde's Stryders was a name coined on BCI by Thorington (Fig. 7). On Sundays, Clyde's howler monkey team competed with teams of other scientists to see who could most rapidly race over the muddy forest trails and ascend the 350+ steps that lead from Gatún Lake up to the research station. Clyde's Stryders usually took the honors (I remember that Don Wilson was the quickest; Fig. 8).

Figure 7. Clyde and two of his Stryders, Don and Norman.

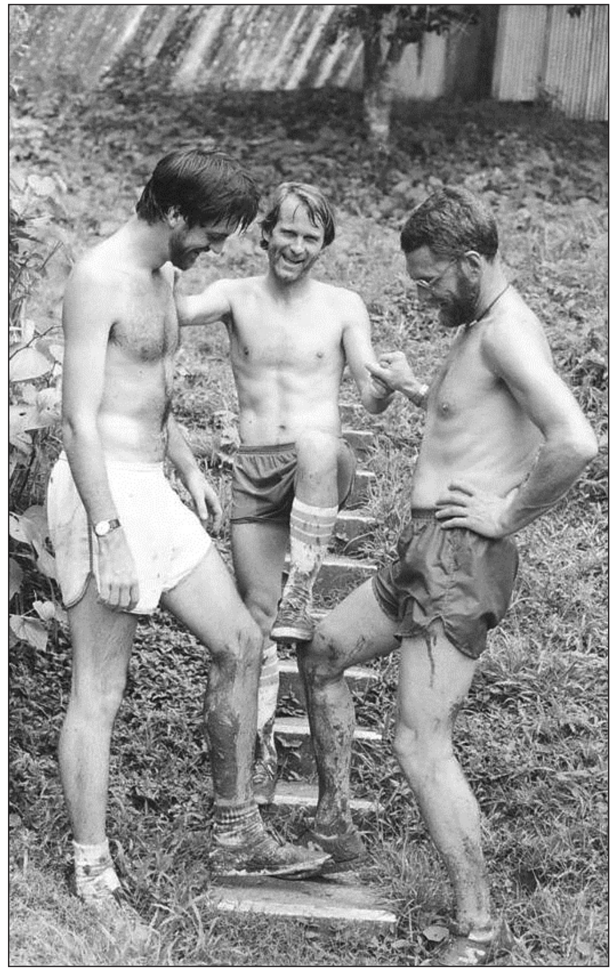


Figure 8. Two Stryders, Don and Norman, after the trail/stair run with a respected opponent from another team.

University of New Mexico

After BCI, Clyde hired me to head up a new NFWL field station at his alma mater, the University of New Mexico. In the first years, I studied (and captured) monkeys in Colombia (Scott et al. 1976), Costa Rica (Heltne et al. 1976) and Cameroon.

Clyde's grant money for monkey research ran out in 1976, and I was basically a herpetologist, not a primatologist, so, while in Cameroon chasing Black Colobus (*Colobus satanas*) and Gray-cheeked Mangabey (*Lophocebus albigena*, Fig. 9) monkeys, I returned to my roots and extended to Africa previous studies that I had done in Costa Rica on the forest leaf litter herpetofauna (Fig. 10; Scott 1982).

Figure 9. Gray-cheeked Mangabey (*Lophocebus albigena*), Lombe, Cameroon, 1975.

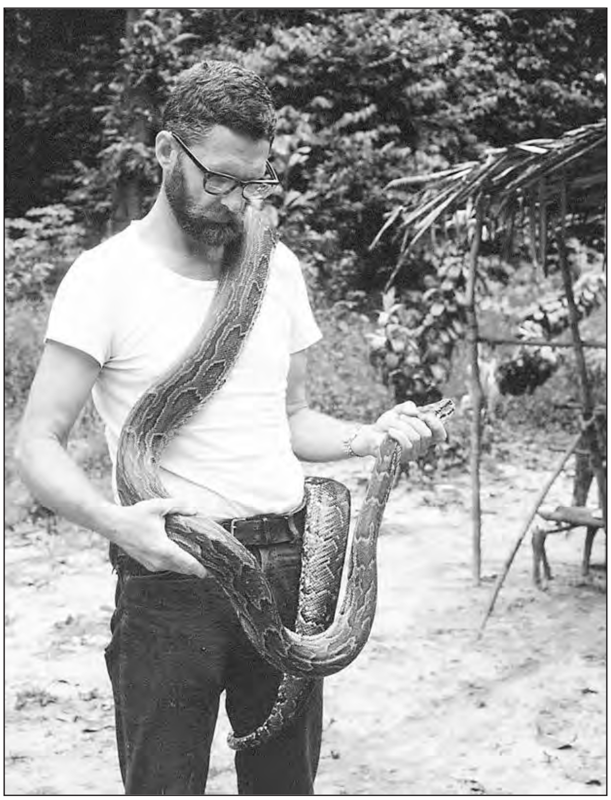


Figure 10. Norman with *Python regius*, Lombe, Cameroon.

Over the next 28 years, the New Mexico NFWL team studied vegetation, frogs, toads, turtles, lizards, snakes, kangaroo rats, bird faunas, Mexican ducks (*Anas platyrhynchos diazi*) and ants in Texas, Arizona, and New Mexico, and in Aguascalientes, Baja California, Sinaloa and Sonora, México.

In 1987, we resurrected the Stryder team and made t-shirts for a 10 km run on the campus of the University of New Mexico. Cindy Ramotnik was the leading standard-bearer for this event (Fig. 11).

Figure 11. T-shirt made for the last Stryder run at the University of New Mexico, 1987.

Isla Tiburón

Clyde developed a cooperative agreement between the NFWL lab and Fauna Silvestre, the Mexican equivalent of the U. S. Fish and Wildlife Service. Under this agreement, Roy McDiarmid and I gave a frog workshop on the shores of Lago Chapala, but the main activities were field collecting trips with Mexican biologists to Arizona and Baja California.

On these trips, mammalogists, herpetologists, and even sometimes ornithologists, would observe and collect specimens of the local faunas, thereby greatly extending our knowledge of the abundances and distributions of the animals of these biologically unexplored regions. Herpetologists were especially important on these trips, because the mammalogists insisted that we remove all of the rattlesnakes before they put out their traplines.

There are many great memories of these trips, but one stands out. In 1976, Clyde, Don Wilson, Mike Bogan, and I were on Isla Tiburón in the Sea of Cortés (Fig. 12). From our base camp at Caracol (Fig. 13), we were trapping kangaroo rats (*Dipodomys*) and other small mammals. Above our camp loomed the island's highest point: Cerro Kunkaak (Fig. 14).

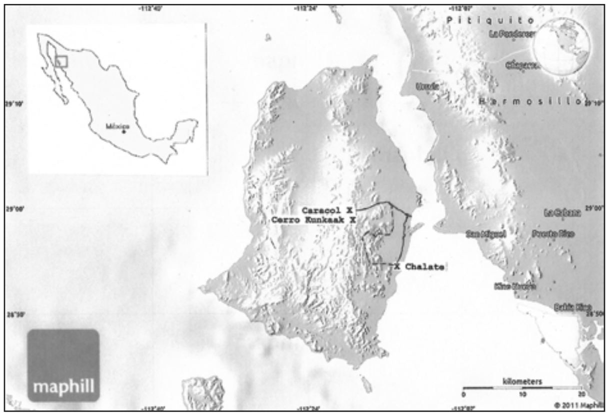


Figure 12. Isla Tiburón, Sonora, México. Solid lines are roads, dashed line is the hike that Clyde and I took.

Figure 13. Clyde in camp at Caracol, Isla Tiburón, México, 1976.

Figure 14. Cerro Kunkaak at dawn, Isla Tiburón, México.

After an overnight trapping session at a spring in Arroyo Chalate on the island's east coast, Mike and Don left in the truck, and Clyde and I started to hike back to our camp at Caracól. We knew what direction the camp was, so we headed across the island on foot. However, we made the mistake of heading straight for Caracól instead of going around the mountain range in between. The terrain was rough and steep, and we followed canyons and ridge lines, going ever higher. We ended up spending the afternoon napping in a cave near Cerro Kunkaak. In the cave, Clyde found the skull of a ring-tailed cat (*Bassariscus astutus*) which is now in the National Museum (USNM 514028). This, and another skull (USNM 514027) from the same trip, may be the only records for the species from the island. We had only brought a liter of water with us, and, by this time, we were getting pretty dry.

After our nap, thirsty and blocked by the vertical, colorful red and green lichen-covered walls of Cerro Kunkaak (Fig. 15), we headed down the nearest canyon. Lo and behold, we were saved when we came upon a large *tinaja*, a 3m x 18m pool of water in the eroded igneous rocks of the canyon floor (Fig. 16).

Figure 15. Summit of Cerro Kunkaak, Isla Tiburón, México.

Figure 16. Life-saving tinaja (waterhole) with fig tree, Isla Tiburón, México.

By this time it was getting late, and we hiked down the canyon to the bajada at the base of the mountain at night, and there we slept until dawn. In the morning, we started walking around the base of the mountain to the road to Caracol, where we met a search party that was looking for us (Fig. 17).

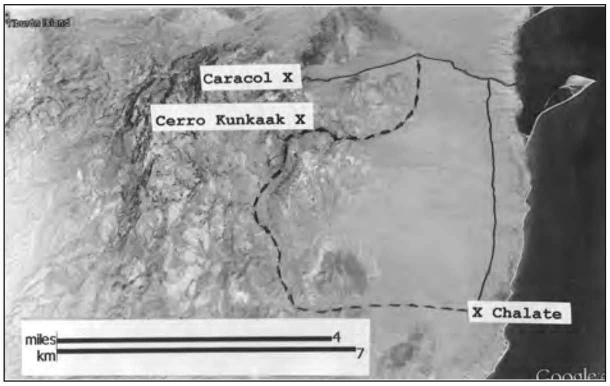


Figure 17. Central Isla Tiburón, Sonora, México. Solid lines are roads, dashed line is the hike that Clyde and I took. Map courtesy of Google, Terrametrics, Digital Globe and INEGI; data from SIU, NOAA, U.S Navy, NGA and GEBCO.

Colorado River

I think that Clyde's favorite professional activity was the raft trips that he organized on the Colorado River through the Grand Canyon. In 1969, he left Tulane University, and in 1970, he went to Washington D.C. to be the Chief of the U.S. Department of the Interior's Bird and Mammal Laboratories located in the National Museum. Clyde developed a project with the National Park Service to survey and collect the small vertebrates present along and in the Colorado River through the Grand Canyon. From 1970 through 1981, he went on at least 16 river trips, many of them covering the entire 290 miles from Lee's Ferry to Lake Mead (Fig. 18). The trips included up to 17 people, mostly scientists, but also some "significant others" that went along for support. They took habitat photographs in canyons surrounded by towering cliffs (Fig. 19), and they ran river rapids (Fig. 20). During afternoons and nights ashore, they made collections of plants, fish, small mammals, reptiles and amphibians. The 14 trips from 1970 to 1976 resulted in a report to the Park Service (Suttkus et al. 1976).

Figure 18. Start of Colorado River trip, Lee's Ferry, Arizona, 1980.

Figure 19. Colorado River, Fern Glen Canyon.

Figure 20. Colorado River, Hermit Rapids.

For fish studies, he recruited two ichthyologists, former colleagues from Tulane University, Royal Suttkus (Sut) and his student, Glenn Clemmer (then at Mississippi State University). They were the core team that was surveying (Fig. 21) for any remnant populations of six native fish species that had been largely eliminated from the main Colorado River by coldwater releases from the bottom of the lake behind Glen Canyon Dam. Small populations of the Federally Endangered Humpback Chub (*Gila cypha*, Fig. 22), the Flannelmouth Sucker (*Catostomus latipinnis*), the Bluehead Sucker (*Catostomus discobolus*), and the Speckled Dace (*Rhinichthys osculus*) persisted in the warmer waters at the mouths of the larger tributaries to the river; however, two other native species, the endangered Colorado Squawfish (*Ptychocheilus lucius*) and the endangered Razorback Sucker (*Xyrauchen texanus*) were not found and are believed to have been extirpated from the river in the Grand Canyon. The team made several recommendations for the management of the critically endangered Humpback Chub (Suttkus et al. 1976; Valdez and Clemmer 1982).

Figure 21. Clyde, Glenn, and Sut seining at the mouth of the Little Colorado River.

Figure 22. Humpback Chub (*Gila cypha*) in net, Little Colorado River.

Between the fish sampling sites, Clyde and various mammalogists and herpetologists set out traplines and hunted for specimens. By the time the trips ended in 1981, the project had recorded 19 species of fish, four amphibians, 16 reptiles, and 28 mammals from the river and the canyon floor (Suttkus et al. 1976, 1978).

Joan and I participated in the last Colorado River trip. The boat ran out of gas when we reached the upper reaches of Lake Mead, and we spent the eve of our 25th wedding anniversary floating at the whim of the gentle breezes. By this time on the trip, alcohol was getting scarce, but Pat Mehlhop had brought a bottle of Lejon Cold Duck champagne just for the occasion, and we had saved a bottle of Kahlua. I spent the evening in the warm waters of Lake Mead with a bottle, going around the raft filling everyone's cups as I went, all except for Clyde, who was still drinking beer. It was a unique celebration to say the least.

For Clyde, those trips were more than collecting expeditions—they were a spiritual experience, facilitated by the absence of ringing phones and bureaucratic meetings, and surrounded by friends, all working towards the same goal, all the time overshadowed by the towering cliffs and hanging gardens of the canyon (Fig. 23). One of my fondest memories of Clyde is of him standing in the bow of the raft, gazing up at the looming walls, and hearing him say that these trips were the closest that he had ever felt to having a religious experience.

Postlude.—Clyde was a wonderful boss, colleague and friend, and I miss him greatly.

Figure 23. Colorado River; Clyde and colleagues at the mouth of Havasu Creek.

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Photographs

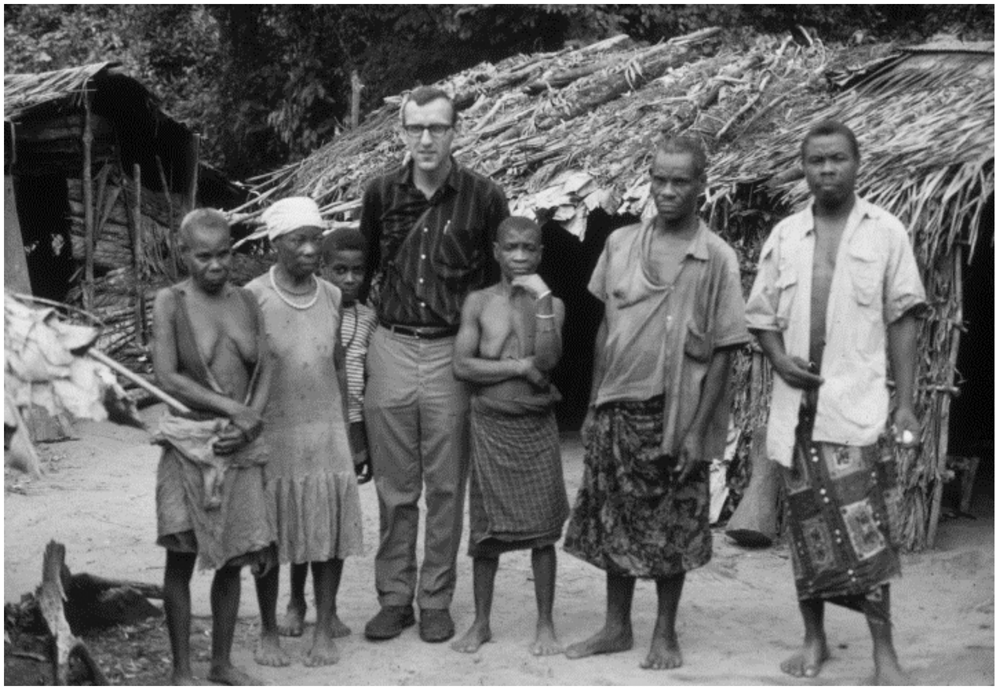

Photo 1. Clyde with pygmoid forest dwellers, Rio Muni, West Africa. Photo submitted by David Marshall.

Photo 2. Foot bridge. West African rain forest, Rio Muni, 1967. Photo submitted by Mary Ann Jones.

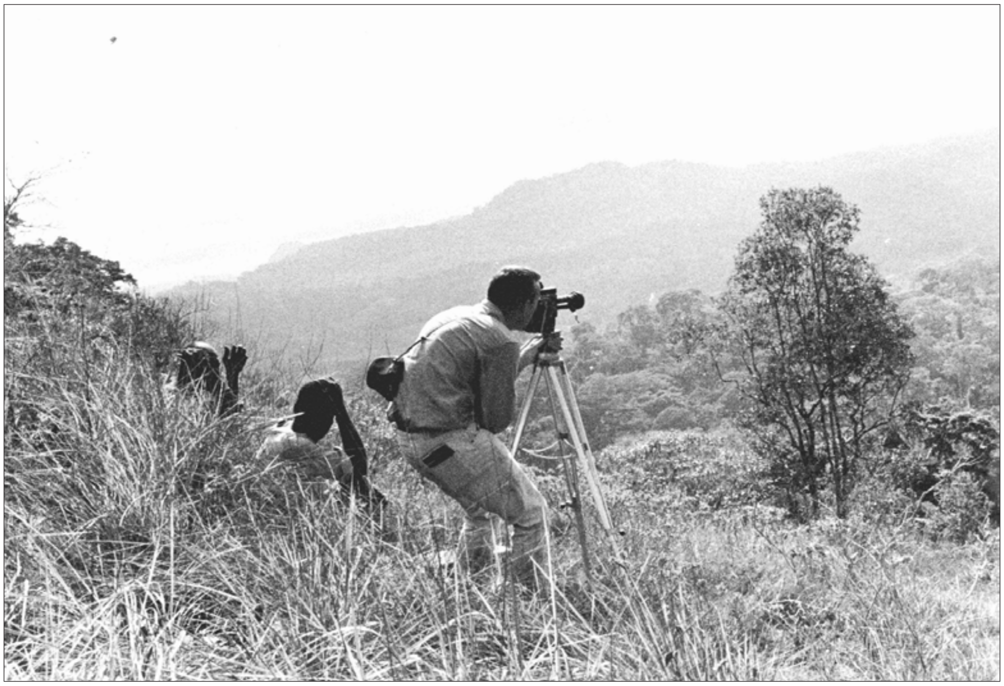

Photo 3. Habitat shot, Rio Muni, 1968. Photo submitted by Mary Ann Jones.

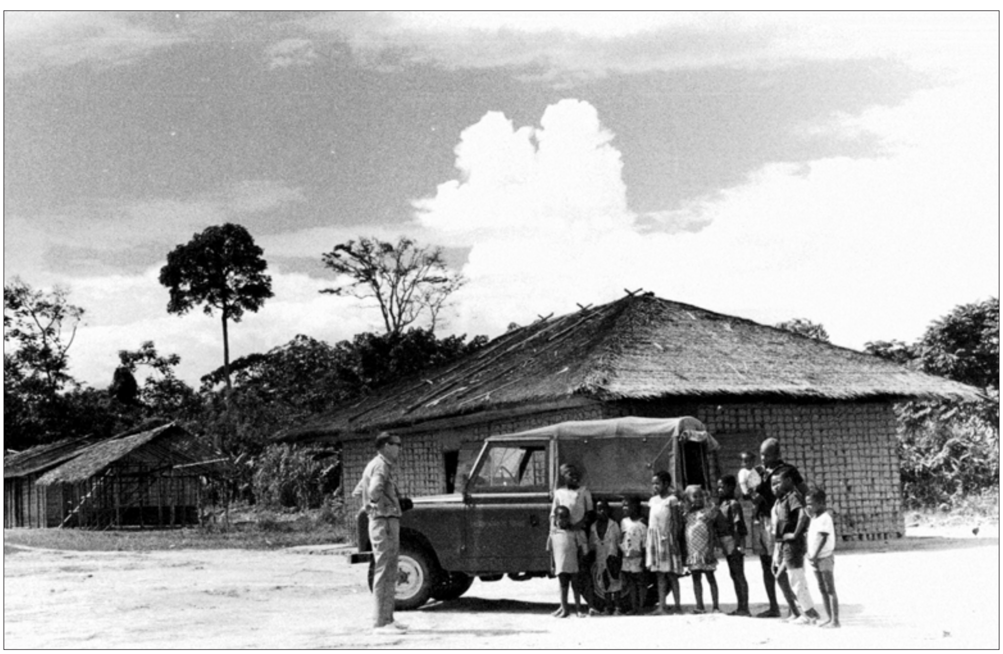

Photo 4. Making arrangements for lodging and a tracker. Evinayong, Rio Muni, 1968. Photo submitted by Mary Ann Jones.

Photo 5. Receiving an Antarctic medal, 1971. Photo submitted by Mary Ann Jones.

Photo 6. Clyde (back row, right), Royal Suttkus (front row, fourth from left) and the rest of the 'River Rats', Colorado River, ca. 1970s. Photo submitted by Mary Ann Jones.

Photo 7. "All in a Day's Work." Depicted (left to right) are: Rick Manning, Clyde Jones, J. Knox Jones, Jr., and Larry Choate. Mammals were taken in Andrews and Winkler counties, Texas (ca. Spring, 1989). Photo taken at the NSRL, mammal prep room. Photo submitted by Rick Manning.

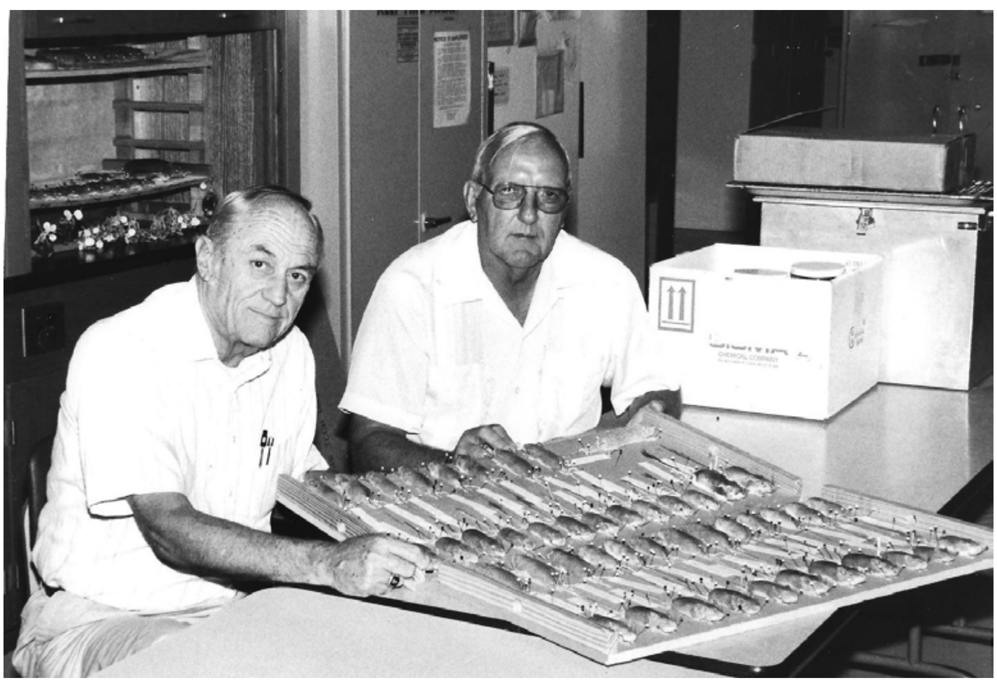

Photo 8. "Inspecting the rats." J Knox Jones, Jr. and Clyde Jones with mammals taken at Harte Ranch, Brewster County, Texas (ca. October 1991) by Rick Manning and Jim Goetze. Photo taken at the NSRL, mammal prep room. Photo submitted by Rick Manning.

Photo 9. Seining for fish, Limpia Creek, Fort Davis, 1998. Photo submitted by Mary Ann Jones.

Photo 10. Collecting fish from a seine, Limpia Creek, Fort Davis, 1998. Photo submitted by Mary Ann Jones.

Photo 11. Clyde at Big Bend Ranch State Park, 1998. Photo submitted by Mary Ann Jones.

Photo 12. Ron Van Den Bussche, Robert Bradley, Meredith Hamilton, and Clyde preparing beer-batter pancakes in the Davis Mountains, 1998. Photo submitted by Robert D. Bradley.

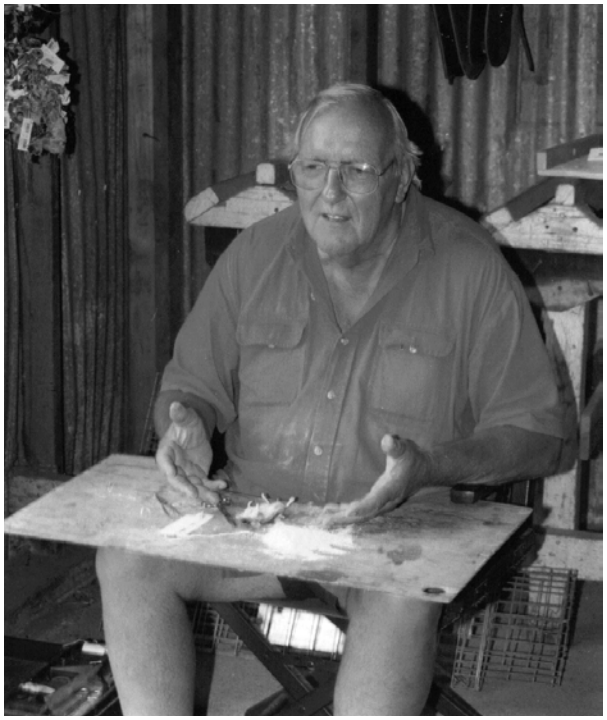

Photo 13. Clyde preparing a specimen in the Davis Mountains, 1999. Photo submitted by Robert D. Bradley.

Photo 14. Sowell Expedition, Ecuador, 2004. Photo submitted by Lisa Bradley.

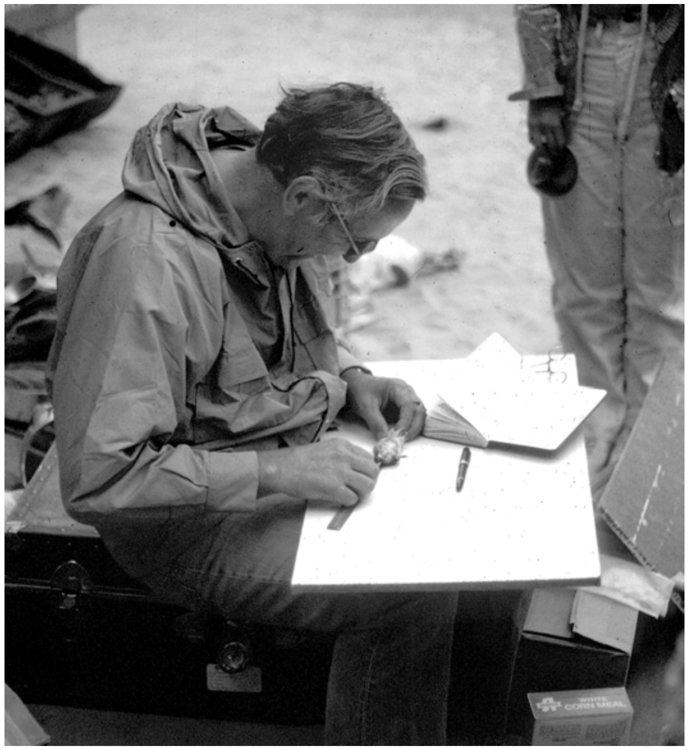

Photo 15. Clyde measuring a mouse. Photo submitted by David Riskind.

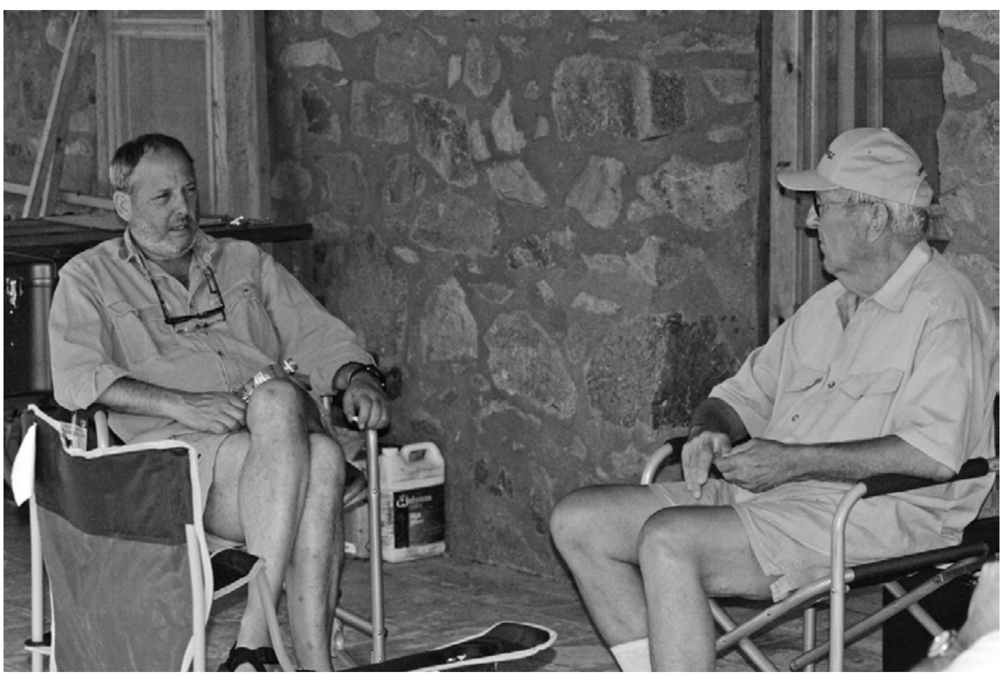

Photo 16. David Riskind and Clyde, San Antonio Cabin, Chinati Mountains State Natural Area, 2005. Photo submitted by David Riskind.

Photo 17. Mark Lockwood and Clyde at a field camp in Teneros Creek, Big Bend Ranch State Park, 2002. Photo submitted by David Riskind.

Photo 18. Clyde landing on top of Sierra Parda, Chinati Mountains State Natural Area, 2005. Photo submitted by Frank Yancey.

Photo 19. Mike Bogan, Cindy Ramotnik, Clyde, and Frank Yancey on a collecting trip to the Chinati Mountains, 2005. Photo submitted by Frank Yancey.

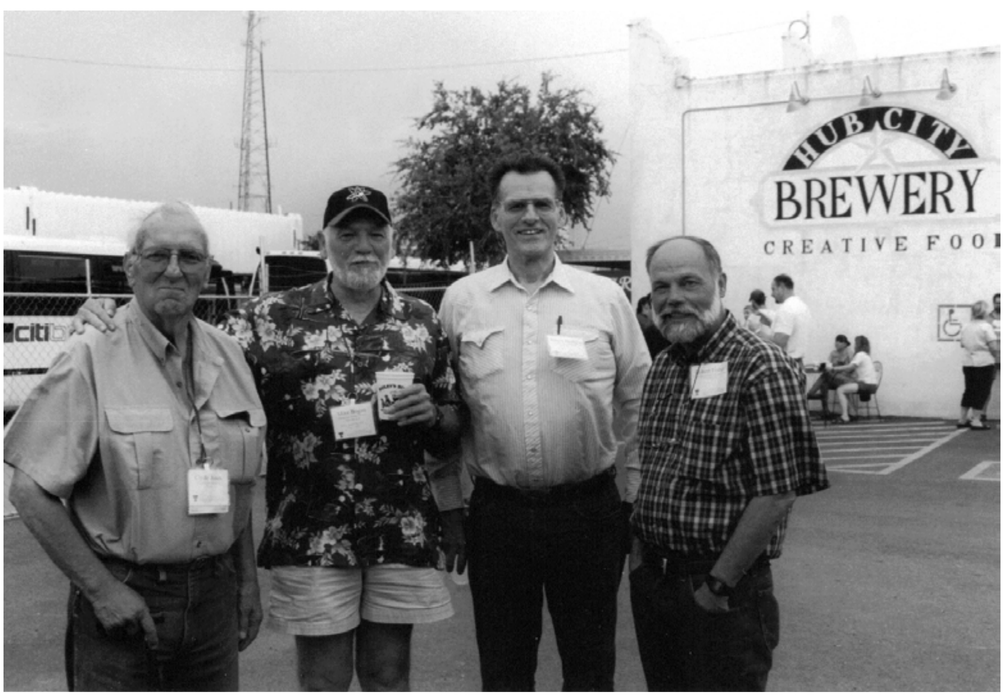

Photo 20. Clyde, Mike Bogan, Al Gardner, and Robert Fisher. 83rd Annual Meeting of the American Society of Mammalogists, hosted by Texas Tech University, 2003. Photo submitted by Mary Ann Jones.

Photo 21. A moment of reflection after preparing several bat specimens - each one a "thing of beauty and joy forever". San Antonio Cabin, Chinati Mountains, 2007. Photo submitted by Mary Ann Jones.

Photo 22. Clyde with colleagues, friends, and former students. Standing, left to right: Steve Kasper, Joel Brant, Rick Manning, and Larry Choate. Seated, left to right: Jim Goetze, Frank Yancey, Clyde Jones, and Fred Stangl. Texas Society of Mammalogists, Junction, Texas, 2013. Photo submitted by Lisa Bradley.

Photo 23. Sherman trap damaged by hail. Big Bend Ranch State Park, June 2013. Photo submitted by Mary Ann Jones.

Photo 24. Clyde with former students (and the editors of this volume) Rick Manning, Frank Yancey, and Jim Goetze. Big Bend Ranch State Park, June 2013. Photo submitted by Mary Ann Jones.

Photo 25. Clyde with part of the Big Bend Ranch State Park field crew, June 2013. Photo submitted by Mary Ann Jones.

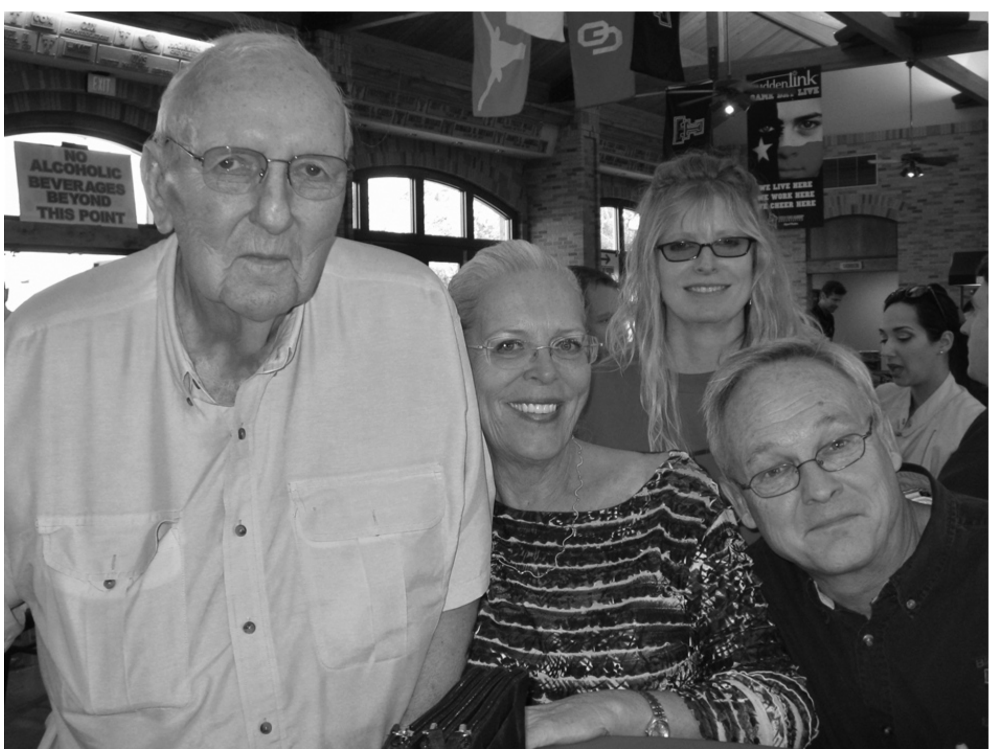

Photo 26. Clyde, Mary Ann, Erica, and Lou at the Texas Tech Frazier Alumni Pavilion, 2013. Photo submitted by Lou Densmore.

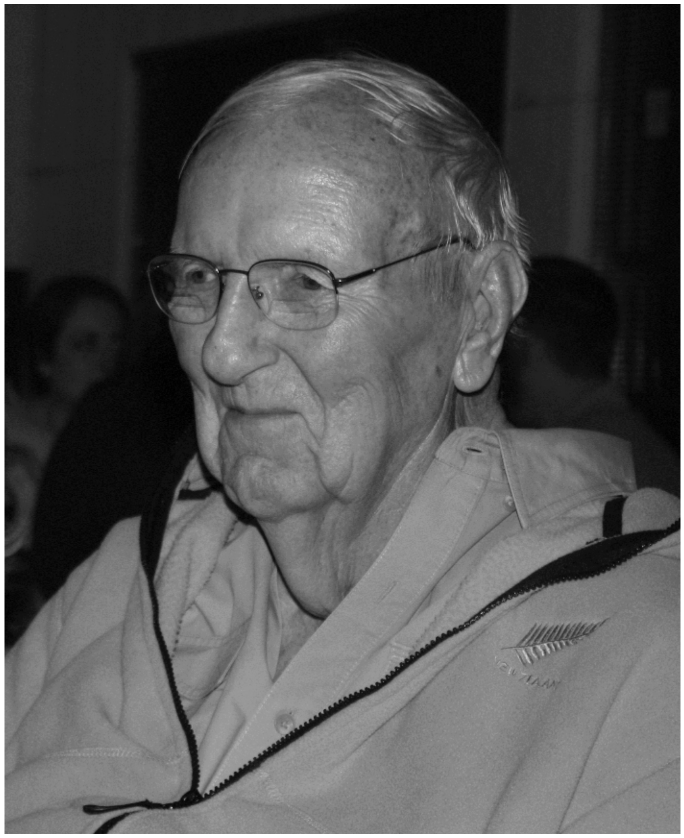

Photo 27. Clyde at TSM meeting, 2014. Photo submitted by Lisa Bradley.

Photo 28. Rick Manning, Clyde, and Frank Yancey, Junction, Texas (post-TSM meeting), February 2015. Photo submitted by Frank Yancey.

IN MEMORY