

LOCATION AND DISTRIBUTION OF DIURNAL ROOSTS, ROOST SITE PARAMETERS, AND WATER QUALITY/NUTRIENT LEVELS IMPORTANT TO POPULATION HEALTH OF BOULDER COUNTY BATS (2001)

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SECTION 1. ABSTRACT

Bats are known to be important components of ecosystems worldwide. In North America they act as natural insecticides and control insect populations which when unchecked may lead to massive destruction of forest stands and agricultural crops. Despite this, little is known about bat natural history and, most importantly, what components of their natural history are in jeopardy in any given region. These data are, of course, important in synthesizing a meaningful management plan for bats. So far we have documented 18 roost sites in the Front Range. Seven bats were tagged with transmitters in 2000, and five roost sites were located for four species. Unfortunately, because of the hot dry year causing breakup of colonies as early as 15 July (approximately 2-3 weeks early), and the late date that the new transmitters arrived (17 July) we were could not pursue more radio-tracking in 2000. Fortunately, however, we have 10 transmitters in hand and therefore will not be handcuffed by lack of materials in 2001. Despite the lack of transmitters throughout this field season, it was a very productive one in terms of gaining knowledge from areas not previously censused, locating roost sites for several species, attaining data on roost site temperature profiles, and gathering home range data, especially movement patterns relative to female seeking-out and utilization calcium-rich water holes.

I propose in 2001 to continue mist netting to track species diversity and evenness at our sites, conduct netting at previously uncensused water holes, continue radio-tracking individuals to locate more maternity and bachelor colonies, conduct counts of individuals during exit flights to monitor colony sizes and health, track radio-tagged individuals at night to determine preferred water hole utilization patterns and foraging habitats and home range estimates for each of the species, and to further evaluate water quality and water hole nutrient capacity as relevant to female and juvenile bat visitation utilization.

SECTION 2. INTRODUCTION

Objectives for 2000.-- The main objectives of the proposed project are to 1) add to the current locality data base ($n = 22$) for maternity and bachelor diurnal roost sites of Boulder bats using radio telemetry, especially for two species (the fringed myotis, *Myotis thysanodes*, and Townsend's big-eared bat, *Corynorhinus townsendii*) listed as sensitive and in need of immediate conservation efforts by the Western Bat Working Group (WBWG). In 2000, we documented a maternity roost of *M. thysanodes* susceptible to human disturbance on the second Flat Iron, and a maternity colony of *C. townsendii* greatly in need of protection located in Mallory Cave. We will need to closely monitor Mallory Cave, that we anticipate will undergo a seasonal closure, over the next few years, with anticipated growth of the Townsend's colony and also with the likelihood that other bat species will once again begin using this site once human disturbance is restricted. We also had a capture of a post-lactating female *M. thysanodes* in late July at the Red Rocks site, indicating a colony of this imperiled species occurring in North Boulder. In addition,

due likely to the dryness of summer 2000, a colony of *C. townsendii* captured, but not radio tagged, in 1999 did not return to the same feeding site in 2000 located in the area of Dowdy Draw open space SE of Eldorado Mountain, despite several netting attempts .

We need to locate this maternity colony for protection, 2) one of the most important potential components for maintenance of bat biodiversity and populational stability along the Front Range appears to be water resources, both in terms of availability and nutrient loads. All water holes are not created equal, and those that have high nutrient content, especially calcium, may be a key limiting factor to bat reproduction. We have barely begun to understand and evaluate this, but data so far collected, especially in 2000, strongly support the assertion that water holes provide not only replenishment of body desiccation over the diurnal roosting period, but also are meaningful in providing some level of basic nutrients for bats in the area. Taking into account that only 33% of all captures along the Front Range have been females and young along with the fact that only a limited number of water holes provide a nutrient sink for reproductive females, suggests that reproduction may be limited by this variable, 3) with the use of temperature-sensitive data loggers, measure roost temperatures versus outside ambient temperatures throughout the summer, 4) with the use of temperature sensitive-transmitters, measure the body temperatures of bats while roosting to determine activity levels of individuals while in the day roost, 5) continue to document permanence and stability of colony sizes by conducting visual counts during evening outflights from previously discovered, and newly discovered, roost sites, 6) map roost sites and document distance between them and water hole sites of capture, 7) continue to document home-ranges and preferred foraging habitats per species

by conducting nighttime tracking of radio-tagged individuals, 8) evaluate bat species richness, diversity, and evenness at previously uncensused water hole sites.

Hypotheses.-- H_1 : Roosting colonies of Boulder County bats will be located in sites other than those documented in rock crevices; H_0 : Roosting colonies of bats will not be located at sites other than rock crevices. H_2 : Temperature parameters within roost sites will differ among species and between occupied roost sites as compared to potential but unoccupied roost sites. H_0 : There will be no differences in temperature parameters of roost sites among species or between occupied and nonoccupied roost sites. H_3 : Bats will have home ranges encompassing < 2 km in radius from their diurnal roost site; H_0 : Bats will have home ranges encompassing > 2 km in radius from their diurnal roost site. H_4 : There is a significant positive correlation between water temperature, pH, and mineral content relative to species diversity and evenness as well as the distribution of species by age and sex at waterholes. H_0 : There is not a significant positive correlation between these variables and species diversity and evenness at water holes. H_5 : Significant differences occur among bat species in preferred foraging habitats. H_0 : No significant differences occur among bat species in preference for foraging habitats.

Resource Management Needs, Anticipated Value, & Relation to Ongoing Studies.--

This project is in-line with the Resource Management needs of the City of Boulder Open Space program. It is directly related to the management of forests since bats in the area may be in need of more appropriate tree snags for roost sites, as well as older trees that provide crevice roosts. In addition, the management of water holes along streams and in the form of ponds can dramatically affect bat populations in the area and we need to

understand preferences of bats to these sites. Last, but not least, since bats apparently prefer rock-crevice roost sites, many colonies may be in danger from direct human disturbance in the form of rock climbing activities. This is consistent with other rock roosting species of concern such as the Peregrine and Prairie falcons. Anticipated value of the year 2001 effort will be the documentation and mapping of more roost sites, especially for two species of concern, *Myotis thysanodes* and *Corynorhinus townsendii*.

Understanding roost site preferences and abiotic factors preferred by bat species in the area is critical to any management plan. For example, we have yet to determine why Boulder bats are not using tree roost sites in the area, which is highly anomalous, and suggest that roosts perhaps could be limiting or perhaps that rock crevices provide a superior thermoclimate for bats. The latter, however, remains to be documented and many studies throughout the northern Rockies show that the species present in Boulder should use a variety of roosts, including tree snags. Placing temperature- and humidity-sensitive data loggers can give insight into roost parameters for these species and by placing this equipment in tree snags and unoccupied crevices we can determine what is lacking at these other sites.

Water Hole Nutrients and Bat Biodiversity: The discovery in 1999 and 2000, that the pattern of visitation to water holes by females and their young is highly correlated with calcium content of the water, is a highly significant finding. These data compel further research into the question of the importance of certain types of water holes to the long term survival and conservation of bats in the area. In other words, not all water holes are equal in value for reproductive females, that require calcium to replace what is leached

Cross observation by Collinge, Pastor - Rodriguez

from their bones during lactation (Barclay, 1996; Studier et al., 1991), and for young as required for skeletal growth. With recent literature indicating the degree of calcium deficiency incurred by reproductive female bats and the fact that diet alone cannot provide for minimum daily requirements (Barclay, 1996; Studier et al., 1992), the finding in Front Range that reproductive females and juveniles visit water holes having highest calcium loads provides new and critical data for the management of bat biodiversity in the region.

Home Range and Movement Patterns: Documenting home ranges and preferred foraging habitats for the bat species is important in understanding preferred foraging habitats and area and is also critical to formulating a management plan. In addition, tracking reproductive females in 2000 allowed for understanding how far females travel to find calcium-laden water holes. Also, changes in roost sites either daily or seasonally has been documented for some species.

distance
to Ca/H₂O

Educational Value.--Over the past four years the City of Boulder bat project has received exposure via the Daily Camera newspaper which published a front page article on their Environmental Page, complete with color photographs of bats captured during the census and more recently the Daily Camera Friday Section cover article (22 October 1999).

Three articles in the Daily Camera provided public education to the ongoing research on Front Range bats. Our work has also been featured in the *University of Colorado Alumnus* that featured a full page article on the Principal Investigator (PI) and the City of Boulder Project. In addition, the P.I.'s work in Boulder has been published recently in an article on bats in the Wisconsin State Journal, the most widely read newspaper in the state. In addition, the Colorado Bat Society has published yearly articles in *The Chiropteran*, the

Society's Newsletter, to educate our members about what CBS and the City of Boulder are doing for bat conservation and public education in the Front Range. I have also done in-the-field education programs for the public teaching them about bat ecology and conservation efforts in the City of Boulder open space. Furthermore, I have given public educational slide-talks about bats, and the efforts towards bat conservation that the City of Boulder Open Space and the Boulder Mountain Parks have undertaken. Because of these efforts, the public has become much more aware of the plight of bats and their importance in ecosystems and how the City of Boulder Open Space department is an important contributor towards bat conservation.

Research Relationships.--In relation to past and ongoing research projects in the City of Boulder Mountain Parks and Open Space, studies of bat populations are highly important as indicators of general forest health, community ecology and ecosystem stability.

Understanding critical roosting habitats, foraging habitats, and water hole requirements for bats is, therefore, instrumental in building a management plan for the Front Range Corridor for the 21st century.

Literature Review

Adams, R. A. 1988. Trends in the reproductive biology of some bats in Colorado. *Bat Research News*, 39:21-25.

Adams, R. A. 1990. Biogeography of bats in Colorado: ecological implications of species tolerances. *Bat Research News*, 31:17-21.

Adams, R. A. 1992. Developmental ecomorphology of the little brown bat, *Myotis lucifugus*. PhD Dissertation, University of Colorado-Boulder. 275 pp.

- Adams, R. A. 1995. Boulder County bats: a one year census. *City of Boulder Open Space Technical Report, Boulder.*
- Adams, R. A. 1996a. Size specific resource use between juvenile little brown bats, *Myotis lucifugus* (Chiroptera: Vespertilionidae): Is there an ontogenetic niche? *Canadian Journal of Zoology*, 74:1204-1210.
- Adams, R. A. 1996b. Patterns of water resource use and continued census of bats in Boulder County. *City of Boulder Open Space Technical Report*, 34 pp.
- Adams, R. A. 1997. Onset of volancy and foraging patterns of juvenile little brown bats, *Myotis lucifugus*. *Journal of Mammalogy*, 78:239-246.
- Adams, R. A. and K. M. Thibault. 1998. Survey of Boulder County bats: A study of roost site distribution and community ecology *City of Boulder Open Space Technical Report, Boulder*, 46 pp..
- Adams, R. A. and K. M. Thibault. 1999. Survey of Boulder County bats: A study of roost site distribution and community ecology *City of Boulder Open Space Technical Report, Boulder*, 59 pp.
- Adams, R. A. and K. M. Thibault. 1999. Records of the Brazilian free-tailed bat (Chiroptera: Molossidae), *Tadarida brasiliensis*, in Colorado. *The Southwest Naturalist*, 44:542-543..
- Armstrong, D. M. 1972. Distribution of mammals in Colorado. *Mus. of Nat. Hist., Univ. Kansas*, 3:1-415.
- Armstrong, D. M., R. A. Adams, and J. Freeman. 1994. *Distribution and ecology of bats of Colorado*. Univ. Colorado Nat. Hist. Inventory., 15:1-83.

- Armstrong, D. M., R. A. Adams, K. Navo, J. Freeman, and S. Bissell. 1995. *Bats of Colorado: Shadows in the night*. Colo. Div. Wildlife Publ., Denver.
- Barclay, R. M. R. 1995. Does energy or calcium availability constrain reproduction in bats? In *Ecology, Evolution and Behaviour of Bats*, eds. P.A. Racey and S.M. Swift, pp 245-258. Oxford: Clarendon Press
- Findley, J. S. 1993. *Bats: a community perspective*. Cambridge Univ. Press, 167 pp.
- Fitzgerald, J. P., C. A. Meaney, and D. M. Armstrong. 1994. *Mammals of Colorado*. Denver Mus. Nat. Hist., Denver, and Univ. Colorado Press, Niwot.
- Hall, J. 1995. Results of the Colorado Bat Society's Bat Trend Survey. *The Chiropteran*, 4:3.
- Kunz, T.H. 1982. *Ecology of bats*. Plenum Press, New York.
- Kunz, T. H. 1988. *Ecological and behavioral methods in the study of bats*. Smithsonian Press, Washington.
- Kurta, A., K. J. Williams, and R. Mies, 1996. Ecological, behavioural, and thermal observations of a peripheral population of Indiana bats (*Myotis sodalis*) in *Bats and Forests* (R. M. R. Barclay and R. M. Brigham, eds.). Research Branch Ministry of Forests, Victoria, British Columbia, Canada.
- McNab, B. K. 1982. Evolutionary alternatives in the philological ecology of bats. Pp 151-200 in *Ecology of bats* (T. H. Kunz, ed.) Plenum Press, New York.
- Norberg, U. M. 1995. Wing form and flight mode in bats. Pp. 43-56 in *Recent advances in the study of bats* (M. B. Fenton, P. Racey, and J. M. V. Rayner, eds.). Cambridge University Press, Cambridge.

- Ormsbee, P. C. 1996. Characteristics, use and distribution of day roosts selected by female *Myotis volans* (long-legged myotis) in forested habitat of the central Oregon Cascades. Pp.124-131 in *Bats and Forests Symposium*, (R. M. R. Barclay and R. M. Brigham, eds.) Ministry of Forestry Program, British Columbia.
- Perkins, J. M. 1996. Does competition for roosts influence bat distribution in managed forests? Pp. 164-174 in *Bats and Forests Symposium* (R. M. R. Barclay and R. M. Brigham, eds). Ministry of Forestry Program, British Columbia.
- Studier, E. H., D. P. Viele, and S. H. Sevick. 1991. Nutritional implications for nitrogen and mineral budgets from analysis of guano of the big brown bat *Eptesicus fuscus* (Chiroptera: Vespertilionidae). *Comparative Biochemistry and Physiology*, 100A: 1035-1039.
- Thibault, K. M., and R. A. Adams. 1996. Patterns of water usage by a Coloradan bat assemblage. *Bat Research News*, 37:153.
- Thibault, K. M. and R. A. Adams. 1998. Use of rock crevices as day roosts by the bat of Boulder. *Bat Research News*, In Press.
- Tuttle, M. D. 1988. *America's neighborhood bats*. Univ. Texas Press, Austin.
- Webb, P. I. 1995. The comparative ecophysiology of water balance in microchiropteran bats. Pp. 203-218 in *Ecology, Evolution and Behaviour of Bats*, P. A. Racey and S. M. Swift, eds. Oxford Press, Oxford.
- Wilkinson, G. S., and J. W. Bradbury. 1988. Pp 105-124 in *Ecological and behavioral methods in the study of bats* (T. H. Kunz, ed). Smithsonian Press, Washington D.C.

SECTION 3: METHODS

Survey Methods.—Methods for 2001 will be consistent with previous field seasons to allow for data comparison across years. Bats will be captured using Japanese mist nets that typically are stretched over a pond or other water source. Nets will be erected approximated 20-30 minutes before dark. Number of nets erected per site will vary depending upon P.I.'s strategy and size of water hole. Percentage of net coverage at water holes will be kept consistent. Captured individuals will be distinguished to species, weighed, sexed, and checked for reproductive condition. To allow for analysis of movement patterns, all captured individuals will be marked with a plastic, split-ring, numbered forearm band for identification in the case of recapture (Adams, 1992; Kunz, 1988). Some ($n = 10$) captured individuals of each species at different sites will be outfitted with LB-2 temperature-sensitive radio transmitters produced by Holohil Systems, Ltd. These transmitters are the smallest and lightest (0.47 grams) currently available commercially. Each transmitter, having a life-span of 10-14 days, will be attached to the fur using surgical glue. Two Wildlife Materials (Carbondale, IL) 48-Channel Receiver outfitted with a Yagi antenna will be used to track radio-tagged individuals to their roost sites and, by using triangulation techniques, we will follow tagged individuals nightly to document movement and foraging patterns.

Onset temperature-sensitive and humidity-sensitive data loggers will be placed in occupied and unoccupied, but potential, roost sites to compare and contrast these parameters. These data will allow to better understand how particular species of bats chose the roost sites that they prefer. In addition, temperature-sensitive transmitters will

give us data on the body temperatures of bats in their roost sites. It will also allow us to monitor behavior such as periodic arousals from torpor and how activity differs between males and females of a species in the roost sites because the pulse rate of the transmitter changes as the body temperature of the bat increases or decreases.

Water samples will be collected from the surface of the water at as many water holes as afforded. In order to determine relative mineral and nutrient content of our six sites of highest bat activity, we will collect two samples, each 250 ml, of water from each site. One sample from each site will be immediately acidified to a pH level below 2 with nitric acid, while the other sample from each site will be immediately treated with phenylmercuric acetate (PMA). Samples will be transported to a chemical laboratory (yet to be determined). The samples treated with nitric acid will be utilized to determine the concentrations of minerals, Na, K, Ca, Mg, and Fe, with the atomic absorption spectrophotometric method. The samples treated with PMA will be analyzed for concentrations of the nutrients, Cl, PO₄, SO₄, and NO₃, using ion chromatography. All concentrations will be measured in micrograms.

Statistical Analyses.—One-way ANOVA will be used to discern significant differences among species visitation times at water holes. Spearman Rank Correlation analysis will be used to discern relationships between physical parameters of water holes (i.e. water temperature/water pH) and measures of species diversity and evenness. Principle Component Analysis will be used as a multivariate comparison among water holes in terms of mineral content values. Kruskal Wallace nonparamteric one-way will be used to discern the relationship between nutrient value of water holes and availability of water holes to

bats of different body sizes, both intraspecific differences between sexes and interspecifically among species. Once sample sizes allow, Chi Square analysis for general (GO) and specific overlap (SO) will be used to test for significant differences in habitat utilization among bat species (Ludwig and Reynolds, 1988).

Project Schedule.—Data will gathered from 20 May to 25 August 2000. Data collection will involve nighttime mist netting at each of the water holes on a rotational basis of no less than 10 days to avoid disturbance at the sites. Daytime search for previously unnetted (new) sites will occur. Daytime reconnaissance of roost site locations based upon nighttime tagging of individuals will also be performed. Evening counts of individuals leaving roosts will allow for colony size estimations. Radio-tracking will take place at night, and placing of data recorders will take place during the day. Because field work on bats is driven primarily by weather conditions, it is impossible to determine a day-specific trapping schedule. However, we head into the field on most weather-permitting nights and days.

Project Requirements.—Colorado Division of Wildlife Research/Collection and City of Boulder Open Space Research Permits. Overnight Parking Permit for City of Boulder Trailhead parking lots. We will need to coordinate with Ranger Burton Stoner who has graciously volunteered to help in the placing of data loggers in roost requiring technical climbing experience.

Potential Impacts.—Whenever manipulations of animal populations are considered, so must be the risk of impacting those populations due to investigative techniques. The use of radio telemetry and light tags have been used by bat biologists for more than 20 years

to study foraging behavior in bats. It is also the method of choice for locating maternity and hibernation sites because it is the safest, most effective, and least disruptive way to gather such data (Buchler, 1976; Kunz, 1988; Wilkinson and Bradbury, 1988). The skin-bond (Smith & Nephew Inc., Largo, FL) used to attach radio transmitters disintegrates within two weeks of application. In addition, because bats groom themselves and each other when roosting, they usually inadvertently remove devices from themselves and colony members. Since the primary effort in this project is to locate roost sites, a transmitter removed and dropped in the roost is a welcomed event. There is no anticipated long-term impact to marked individuals during the study, and the knowledge gained will go a long way in helping to maintain healthy bat populations for the future in Boulder County. Split-ring forearm bands have been used on bats for the last 10 years and have proven to be a safe method for marking with little or no impact to individuals if they are applied correctly (Kunz, 1988). We have used this method over the past four years on the Boulder bat populations ($n = 1272$) without incident.

The impact on roost sites in terms of data logger placement will be minimized by placing the loggers preferably before bats arrive in large numbers at the known roost sites, and as least disruptively as possible into newly found roost sites. When possible, data loggers will be placed in occupied sites after the bats have left to forage for the evening.

SECTION 4. BUDGET

P.I. costs.....\$4000.00

Research Assistant.....\$2000.00

TOTAL \$6000.00

CURRICULUM VITAE

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DEGREES

Ph.D. 1992 Department of Environmental, Population, and Organismic
Biology, University of Colorado at Boulder.
M.A. 1989 Department of EPO Biology, University of Colorado, Boulder
B.A. 1985 Department of EPO Biology, University of Colorado, Boulder

PROFESSIONAL EXPERIENCE

TEACHING

Associate Professor, Department of Biological Sciences, University of Wisconsin, Whitewater. *General Zoology, Biological Foundations* (nonmajors), *Comparative Vertebrate Anatomy, Vertebrate Field Biology, Mammalogy*. 1993-Present, Tenured 1999.

Curator of Mammal Collections, Department of Biological Sciences, University of Wisconsin, Whitewater. 1993-Present.

Visiting Professor, University of Colorado Mountain Research Center. *Living on the Edge: Biodiversity of Rocky Mountain Mammals*. Summer 1996.

Visiting Professor, Department of Biological Sciences, California State University, Stanislaus. *Mammalogy, Environmental Biology*, 1993.

Instructor. Cloud Ridge Naturalists. *Pinon Juniper Woodlands: A Workshop in Forest Ecology*. 1994.

Instructor, Cloud Ridge Naturalists. *The Natural History of Bats at Colorado National Monument*, 1993.

Instructor, Institute of Arctic and Alpine Research and the University of Colorado Mountain Research Station. *Animal Ecology*, 1992-1994.

Instructor, Aspen Center for Environmental Studies. *Montane and Alpine Mammal Ecology*, 1988 - 1989.

Instructor, Keystone Science School. *Mammalian Ecology*, 1989.

Graduate Teaching Assistant. *Mammalogy, Human Anatomy, Biology for nonMajors, General Biology*, 1985-1992.

Graduate Curatorial Assistant: CU Museum, Mammal Range. 1989-1991.

Instructor, Science from CU, Outreach Program, 1988-1991.

ADMINISTRATIVE

Chairman: SubCommittee on Research and Monitoring. North American Bat Conservation Partnership (Mexico, Canada, United States). **2000-Present.**

Steering Committee. Western Bat Working Group –Colorado Representative. **2000-Present.**

Founder and President. The Colorado Bat Society: a Federally exempt nonprofit corporation dedicated to fostering educational information and the conservation of bat species in Colorado. **1990-Present.**

MENTORING/ADVISING

Summer 2000. *Research Assistant.* Water use patterns of Coloradan bats. *Student:* Jenna Jadin, UW-Madison.

Summer 1999. *Independent Study,* Paid Field Assistant. Thermophysiology of roost sites of Boulder County Bats. *Student:* Brad Petru

Summer 1998. *Independent Study Project:* Distribution of fruit bats on Montserrat. *Student:* Samuel Daane

Fall 1997. *Independent Research Project:* Comparative roosting ecology between eastern gray and eastern fox squirrels. *Student:* Jacob Schleuter.

Fall 1996. Honors Mentor. *Honors Project:* Speciation as a consequence of genetic drift. *Student:* International Exchange Student (Tanzania): Joana Nqwilizi

Fall 1996. *Independent Research Project:* Pedagogy in Biology. *Student:* Amy Kylmanen.

Fall 1996. *Undergraduate Teaching in Biology,* Laboratory Assist. for General Zoology. *Student:* Amy Kylmanen

Summer 1996. *Project:* Water use patterns of a Coloradan bat assemblage. *Research Assistant:* Katherine Thibault, Boston College

Fall 1995 and Spring 1996. *Independent Research Project:* Comparative skeletogenesis of Old and New World bats. *Student:* Aaron Briggs

Spring 1995. *Independent Research Project:* Nest site selection by Gray (*Sciurus carolinensis*) and Fox squirrels (*Sciurus niger*) living in sympatric populations. *Student:* Shelly Hammer

Fall 1994 and Spring 1995. *Independent Research Project:* Development of the handwing in *Myotis lucifugus*. *Student:* Meg Sorensen.

Fall 1994. *Independent Research Project:* Development of the hind foot and calcar in *Myotis lucifugus*. *Student:* Kay Olsen.

Spring 1994. *Independent Research Project:* Use of human trails by Cottontail Rabbits. *Student:* Shala Werner.

Spring 1994. *Independent Research Project:* Development of the hind limb in *Myotis lucifugus*. *Student:* Beth McDonough.

1993-Present. *Student Advising:* Incoming Freshmen and 30 Continuing Majors

RESEARCH AND CONSULTING

Co-Principal Investigator: Comparisons of biodiversity of bats on Montserrat & Antigua, BWI: the effects of the Soufrier Hills Volcano. **1998-Present.**

Principal Investigator: Water use patterns and continued census of Boulder County bats. Summers. **1995-Present.**

President of Organizing Committee: Four Corners Regional Bat Conference, Durango, Colorado. January **1996.** 2 days/153 attendees.

Principal Investigator. Distribution and ecology of bats of Boulder County. City of Boulder Open Space, Boulder County Open Space, Boulder Mountain Parks, Boulder, CO. **1995.**

Research Associate: A Survey of Preble's Jumping Mouse, National Institute of Standards and Technology Site, Boulder, CO. The S. M. Stoller Corporation, Boulder, CO. **1994.**

Research Associate: Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO. **1994-Present.**

Principal Investigator. Bat/Inactive Mine Project, CDOW, **1992.**

Research Associate. University of Colorado Museum, **1992-Present.**

Consultant. Bat Relocation Project, Fort Laramie National Historical Site, **1992-1994.**

Principal Investigator. Bat species distribution and abundance at Colorado National Monument, **1989-1994.**

Principal Investigator. Status of Brazilian Free-tailed bats in the San Luis Valley of Colorado, **1988.**

Consultant and Trapper. David Attenborough's Living Planet Series, **1987.**

Graduate Curatorial Assistant. Mammal Section, University of Colorado Museum, **1987-1992.**

Graduate Research Assistant. Small Mammal Project, Institute of Arctic and Alpine Research, University of Colorado, Boulder, **1985-1988.**

Graduate Research Assistant. Mammal Survey, Rocky Mtn Natl. Park, **1987.**

Graduate Research Assistant. Vertebrate Survey of Devil's Tower National Monument, Wyoming, **1986.**

RECOGNITION AWARDS

2000 Recipient of the College of Letters and Sciences Excellence in Research Award for 1999-2000.

2000 Nominated for University of Wisconsin-Whitewater Award for Outstanding Scholarship.

1996 Nominated for University Excellence in Research Award

1996 Chosen for Inclusion in Who's Who Among American Teachers

1995 Excellence in Teaching Award, University of Wisconsin Whitewater

1995 Chosen for Inclusion in Marquis Who's Who in the World, 12th Edition

1994 Chosen for Inclusion in Marquis Who's Who in the West, 25th Edition

1993 Chosen for Inclusion in Marquis Who's Who in the West, 24th Edition

1990 Student Honor. Award: Best Student Paper, NA Symposium on Bat Research
 1987 Nominated Member of Sigma Xi Scientific Society

PUBLICATIONS

BOOKS

- Adams, R.A., and S.C. Pedersen, eds. 2000. *Ontogeny, Functional Ecology, and Evolution of Bats*. 2000. Cambridge University Press, Cambridge, 410 pp.
 Adams, R.A. In Prep. *Natural History and Conservation of Rocky Mountain Bats Ranging from Mexico to Canada*.

ARTICLES

- Adams, R.A. 2000. Wing ontogeny, shifting niche dimensions, and adaptive landscapes. Pp 275-316 in *Ontogeny, Functional Ecology and Evolution of Bats* (Adams and Pedersen, eds.). Cambridge University Press, 410 pp.
 Adams, R.A., and S.C. Pedersen. 2000. Integrating ontogeny into ecological and evolutionary investigations. Pp1-8 in *Ontogeny, Functional Ecology and Evolution of Bats* (Adams and Pedersen, eds.) Cambridge University Press.
 Adams, R.A. and K.M. Thibault. 2000. Ontogeny and evolution of the bat hindlimb and the calcar: assessing phylogenetic trends. Pp 333- 361 in *Ontogeny, Functional Ecology and Evolution of Bats* (Adams and Pedersen, eds.) Cambridge University Press, 410 pp.
 Adams, R.A. and K.M. Thibault. 1999. Growth, development, and histology of the calcar in the little brown bat, *Myotis lucifugus*. *Acta Chiropterologica*, 1:215-221.
 Adams, R.A. and K.M. Thibault. 1999. Records of the Brazilian free-tailed bat, *Tadarida brasiliensis* (Chiroptera: Molossidae) in Colorado. *The Southwestern Naturalist*, 44:542-543.
 Adams, R. A. 1998. Evolutionary implications of developmental and functional integration in bat wings. *Journal of Zoology, London*, 246:165-174.
 Adams, R. A. 1997. Onset of juvenile volancy and foraging patterns of little brown bats, *Myotis lucifugus*. *Journal of Mammalogy*, 78:239-246.
 Adams, R. A. 1996. Size-specific resource partitioning among juvenile little brown bats (*Myotis lucifugus*): Is there an ontogenetic shift? *Canadian Journal of Zoology*, 74:1204-1210.
 Armstrong, D. M., R. A. Adams, K. Navo, J. Freeman, and S. J. Bissell. 1995. *Bats of Colorado: shadows in the night*. Colorado Division of Wildlife Publication, Denver, 30 pp. (*not peer-reviewed*)
 Armstrong, D. M., R. A. Adams, and J. Freeman. 1994. Distribution and ecology of bats of Colorado. *Natural History Inventory*, University of Colorado Museum, Boulder, 15:1-83.
 Adams, R. A., and S. C. Pedersen. 1994. Wings on their fingers: despite 50 million years of evolution, bats don't become expert fliers overnight. *Natural History*, 103:48-55.

- Adams, R. A. 1993. Consumption of water boatmen (Hemiptera: Corixidae) by little brown bats, *Myotis lucifugus*. *Bat Research News*, 34:66-67.
- Adams, R. A. 1992. Comparative growth and development of the forearm between the little brown bat (*Myotis lucifugus*) and the Norway rat (*Rattus norvegicus*). *Journal of Morphology*, 214:251-260.
- Adams, R. A. 1992. Stages of development and sequence of bone formation in the little brown bat, *Myotis lucifugus*. *Journal of Mammalogy*, 73:160-167.
- Adams, R. A. 1990. Biogeography of bats in Colorado: ecological implication of species tolerances. *Bat Research News*, 31:17-21.
- Adams, R. A. 1988. Trends in the reproductive biology of some bats in Colorado. *Bat Research News*, 29:21-25.
- Adams, R. A., B. J. Lengas, and M. Bekoff. 1987. Variations in the avoidance responses of black-tailed prairie dogs (*Cynomys ludovicianus*). *Journal of Mammalogy*, 68:696-689.
- Adams, R. A. 1982. The endothermic properties of Dinosaurs. *Journal of the Northern Ohio Association of Herpetologists*, 8:2-13.

PROCEEDINGS (* = undergraduate student)

- Sorensen, M.*, and R. A. Adams. 1996. Comparative development of the forelimb between the little brown bat (*Myotis lucifugus*) and the Norway rat (*Rattus norvegicus*). Pp 1438-1440 in *Proceedings of the 10th Natl. Conference on Undergraduate Research*, Ashville.

ARTICLES IN PREPARATION

- Adams, R. A. *In Prep.* Bat Species Coexistence: Resource partitioning among bat species utilizing water holes in a xeric environment. *American Naturalist*.
- Pedersen, S. C., and R. A. Adams. *In Prep.* The effects of natural disasters on Caribbean bat populations. *Proceeding of the National Academy of Sciences*.

ABSTRACTS (* = undergraduate student)

- Adams, R. A.. 2000. More on the complexities of water resource use by a Coloradan bat Assemblage. 30th North American Symposium on Bat Research, Miami. *Bat Research News*, In Press.
- Daane, S.*, and R. A. Adams. 2000. Bat diversity and decline on the Caribbean island of Montserrat. *National Conference on Undergraduate Research (NCUR)*, Missoula.
- Adams, R. A., K. M. Thibault, and B. Petru*. 1999. Are all waterholes created equal? 29th North American Symposium on Bat Research, Madison, *Bat Research News*.
- Adams, R.A. and K.M. Thibault*. 1998. Timing of visitation at waterholes of a Coloradan bat assemblage: Is there pattern? 28th North American Symposium on Bat Research, Hot Springs. *Bat Research News*, 39: 156.
- Pedersen, S.C. and R.A. Adams. 1998. A comparison of 20 years of data with historical accidents in the Belham River Valley of Montserrat, BWI. 28th North American Symp. on Bat Research, Hot Springs. *Bat Research News*, 39:182.

- Thibault, K.M*, and R.A. Adams. 1998. Roosting behavior of bats in the Front Range of Colorado. 28th NA Symposium Bat Res., Hot Springs. BRN, 39: 190.
- Adams, R.A. 1997. Growth of the wing in *Myotis lucifugus*: the dynamics of size over shape. 27th North American Symposium on Bat Research, Tucson.
- Adams, R.A., and S.C. Pedersen. 1997. The functional matrix and evolutionary innovations in bats. Society for the Study of Evolution Meetings, Boulder.
- Adams, R. A, and A. Briggs*. 1996. Development and growth of the calcar in the little brown bat, *Myotis lucifugus*. Bat Research News, 37:20. Presented Paper. North American Symposium on Bat Research (NASBR), Bloomington.
- Thibault, K. M.*, and R. A. Adams. 1996. Timing of visitation to ponds by a Coloradan bat assemblage. Bat Research News. Poster. NASBR, Bloomington.
- Sorensen, M.*, and R. A. Adams. 1996. Comparative development of the forelimb between the little brown bat (*Myotis lucifugus*) and the Norway rat (*Rattus norvegicus*). Proceedings of the 10th NCUR, Ashville.
- Adams, R. A. 1996. Troubles in Camelot?: Boulder County bats show skewed sex ratios. Four Corners Regional Conference, Durango. Presented Paper.
- Adams, R. A., and S. C. Pedersen. 1995. Cruising for a bruising: volant juveniles face a steep learning curve. International Bat Research Conference, Boston. Bat Research News, 36:42.
- Adams, R. A. 1994. Compensatory growth of the wing in *Myotis lucifugus*. Bat Research News. Poster. NASBR, Ixtapa, Mexico.
- Adams, R. A. 1992. Density dependent effects and the ontogenetic niche in *Myotis lucifugus*. Bat Research News, 33:38. Presented Paper, (NASBR). Lincoln,
- Adams, R. A. 1992. Developmental ecomorphology of the little brown bat (*Myotis lucifugus*). Presented Paper, American Society of Mammal., Salt Lake City
- Adams, R. A. 1991. Growth of the wing and developmental convergence in niche space in the little brown bat (*Myotis lucifugus*). Bat Research News, 32:63. Presented Paper, NASBR. Quebec, Canada.
- Adams, R. A. 1990. Resource partitioning between juvenile and adult *Myotis lucifugus* in a mosaic habitat setting. Bat Res. News, 31:69. Paper, NASBR.
- Adams, R. A., and S. C. Pedersen. 1990. Comparative development of the forelimbs of three bats: *Myotis lucifugus*, *Eptesicus fuscus*, and *Artibeus jamaicensis*. American Zoologist, 29:181. Poster, Amer. Soc. Zool. Meetings, Boston.
- Adams, R. A. 1989. Growth and development of flight morphology in the little brown bat, *Myotis lucifugus*. BRN, 30:59. Pres. Paper, NASBR, Knoxville.
- Adams, R. A. 1987. Aspects of forelimb development in bats of the family Vespertilionidae. Bat Research News, 28:31. Presented Paper, NASBR.
- Adams, R. A., B. J. Lengas, and M. Bekoff. 1985. Variations in the threshold response in black-tailed prairie dogs (*Cynomys ludovicianus*). American Zoologist, 24:120. Presented Paper, ASZ Meetings, Denver.
- Adams, R. A., and J. Freeman. 1984. Synopsis of reproductive information on the bats of Colorado. Journal of the Colorado/Wyoming Academy of Science, 16:31. Presented Paper, Gunnison, CO.

TECHNICAL REPORTS

- Adams, R. A., and K. M. Thibault. 1999. Roosting and foraging ecology of Boulder County Bats. City of Boulder Open Space Department, Boulder. 59 pp
- Adams, R.A. 1998. Survey of Boulder County Bats: A study in Roost Site Distribution and Community Ecology. City of Boulder Open Space Depart., Boulder. 41 pp
- Adams, R. A. 1997. Survey of Boulder County Bats: A Study in Biodiversity and Community Ecology. City of Boulder Open Space Department, Boulder. 42 pp.
- Adams, R. A. 1996. Patterns of water use by Boulder Bats, 33 pp. City of Boulder Open Space Department, Boulder.
- Adams, R. A. 1995. Boulder County bats: a one-year census, 15 pp. City of Boulder Open Space Department, Boulder.
- Adams, R. A. 1994. Report: 1994. Continued census of the bat fauna at Colorado National Monument, 5 pp.
- Adams, R. A., and J. Freeman. 1993. Status of Townsend's big-eared bats at historic cave sites in Colorado. Colorado Division of Wildlife. 20 pp.
- Freeman, J., and R. A. Adams. 1992. Bat species occurrence, abundance, and distribution in inactive mines in Colorado. Colorado Division of Wildlife. 20 pp.
- Adams, R. A. 1990. Bat species abundance and distribution in Colorado National Monument. National Park Service, Supplements 1992 and 1993, 19 pp.
- Adams, R. A. 1989. Population status of Brazilian free-tailed bats at the Orient Mine. Colorado Division of Wildlife. 15 pp.
- Armstrong, D. M., and R. A. Adams. 1988. The vertebrates at Fort Laramie National Historical Site: an historical and ecological perspective. 73 pp.

INVITED TALKS

2000. Bat diversity and decline due to natural disasters on the Caribbean island of Montserrat. Boulder Chapter of the Conservation Society, Boulder.
2000. Bat species coexistence: abiotic factors of waterholes affecting assemblage structure. University of Colorado-Boulder, Dept. EPO Biology Invited Colloquium Series
- 1996-99. How to teach children about flight development and the echolocation ability of bats. Denver Regional Teachers Conf., Denver Museum of Natural History.
1997. Wing ontogeny, foraging ecology and population dynamics of little brown bats, *Myotis lucifugus*. Dept. Biol. Colloq., Carleton College, Northfield.
1996. Wonderful World of Bats: Audubon Society, Williams Bay, WI
1995. Embryos, wings, and evolution. Dept. Bio. Sci. Colloq. UWW.
1995. Development and ecology of bats. Denver Museum of Natural History.
1994. The ontogenetic niche in the little brown bat, *Myotis lucifugus*. Department of Biology Colloquium Series, University of Windsor, Ontario.
1994. "Bats I've known and loved." UWW Colloquium Series.
1994. Bats: Myths and Realities. UWW Biology Days for High School Teachers
1994. The Natural History of Bats. Front Range Chapter of the Audubon Society.

MANUSCRIPT REVIEWS (1998-2000)

Ten articles for *Journal of Mammalogy*, One article for *Behavioral Ecology*, One article for *EcoScience*, One article for *Acta Chiropterologica*, Two articles for *Great Basin Naturalist*, One article for *Condor*

RESEARCH GRANT AWARDS

- 2000 Location and distribution of diurnal roosts and the use of water resources by Boulder County bats. City of Boulder (\$12,000)
- 1999 Location and distribution of diurnal roosts and the use of water resources by Boulder County bats. City of Boulder (\$9,389)
- 1998 Loss of biodiversity of bats on the Caribbean island of Montserrat. UWW-Research Grant (\$3,000)
- 1998 Continued research on bat roost locations. City of Boulder Grant (\$7,585)
- 1997 Location of bat roost sites using radio telemetry. City of Boulder Open Space Competitive Grant Program (\$6,600)
- 1996 Location and distribution of Boulder County bats. City of Boulder Open Space Competitive Grant Program (\$3,300)
- 1995 University of Wisconsin-Whitewater Research Grant (\$4,900)
- 1994 University of Wisconsin-Whitewater, Research Grant (\$4,000)
- 1994 Sponsor: University of Wisconsin Undergraduate Research Grants (2) (\$500 each)
- 1991 Research Fellowship, Department of EPO Biology, UC Boulder (\$1,000)
Dean Small Grant Award (\$250), William H. Burt Award (\$1000.00)
- 1990 William H. Burt Award (\$1,200)
- 1988 William H. Burt Award (\$1,600)
- 1987 Grant-in-Aid of Research, Sigma Xi (\$800), Kathy Lichty Memorial Fund (\$600), Colorado Mountain Foundation (\$500)
- 1986 Lichty/Alexander Memorial (\$800), Colorado Mtn. Foundation (\$ 700)
- 1985 Grant-in-Aid of Research, Sigma Xi (\$800)

GRANTS PENDING

- * 2000 *NSF-RUI* (\$267,000). Adams, R.A. Water holes and the structure of insectivorous bat communities: an experimental field approach. Asked to resubmit for 2000-2001 cycle.
- 2000 *National Geographic Society* (\$23,000). Adams, R.A. & S.C. Pedersen. Recovery of Montserrat: Importance of Fruit Bats in Primary and Secondary Succession on a Volcanically Inundated Island.
- 2000 *NSF-CCLI*. (approx. \$500,000) Adams, R.A, S. Ghosh, & J. McKinnon. Integrative Freshman Biology: A Modular Approach.

SERVICE

- 1999/2000 Invited Seat: Provost's Research Strategy ThinkTank Group.
 1999/2000 Chair: Search and Screen Committee. Evolutionary Ecologists
 1999/2000 College of L&S Computer Program Committee
 1998-Present UWW-University Graduate Council Committee
 1998-Present College of Letters and Sciences Honors Committee
 1998 College of Letters and Sciences Salary Committee
 1998 College of Letters and Sciences Audit & Review Committee
 1997 UWW-University Graduate Council Committee
 1997 College of Letters and Sciences Award for Excel. in Res. Committee
 1997 University Audit and Review Committee
 1997 Dept. Bio. Sci.-Merit Review Committee
 1997 Dept. Bio. Sci.-Merit Form Revision Committee
 1997 Scout Night: Biology Education for Boy Scouts-Upham Hall
 1996 College of Letters and Sciences Award for Excel. in Res. Committee
 1996 College of Letters and Sciences Audit and Review Committee
 1996 Biological Sciences Search and Screen Committee
 1996 Judge: Oral Presentations for Wisconsin Colleges Undergrad. Res. Day
 1996 Scout Night: Biology Education for Boy Scouts (Lakeview Elementary)
 1995 College of Letters and Sciences Award for Excel. in Res. Committee
 1995 Wisconsin Bat Advisory Committee, Dept. Nat. Res.
 1994 Chair, Search and Screen Committee. Vertebrate Evol. Ecologist
 1993-97 Biological Sciences Curriculum Committee, UWW
 1993 College of Letters and Science Curriculum Committee, UWW
 1993 Biological Sciences Search and Screen Committee, UWW

PROFESSIONAL MEMBERSHIPS

Sigma Xi Scientific Foundation, American Society of Mammalogists, American Society of Naturalists, Society for the Study of Mammalian Evolution, Colorado/Wyoming Acad. Sci.

REFERENCES

- Dr. David M. Armstrong**, Professor, Department of Environmental, Population, and Organismic Biology, UC-Boulder, 303-492-7965, david.armstrong@colorado.edu
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