Table of Contents


BIOLOGY of PITVIPERS 4
CHIRICAHUA DESERT MUSEUM RODEO NEW MEXICO

Welcome to the Biology of Pitvpers 4 Conference

www.biologyofthepitvipers.com

Welcome to the beautiful "Bootheel Country" of southwestern New Mexico to participate in the Biology of Pitvipers 4 Conference (**BPV4**), July 13-16, 2022, hosted by the Chiricahua Desert Museum (CDM). Thank you for coming!

Our **Keynote Speaker** is Dr. Anita Malhotra, the **Plenary Speaker** is Dr. Juan J. Calvete, and the **Banquet Speaker** is Joseph R. Mendelson III. We have six **Invited Speakers** (Dr. Terence M. Farrell, Dr. Allyson Modra Fenwick, Dr. Christopher L. Parkinson, Dr. Darin R. Rokyta, Dr. Mark Allen Davis, and Dr. Harry W. Greene). Our **Honored Guests** are Dr. Richard C. Straight and Dr. William S. Brown. All of these individuals have made significant contributions to our understanding of pitviper biology and in other areas of science. We are indebted to all the presenters for their valuable oral and poster contributions. With this group of luminaries, we know BPV4, like those before it, will be an exceptional conference.

We urge everyone to take a moment to note our sponsors listed in this program. Please thank those who are present at the conference and support them where possible. We deeply appreciate their indispensible and gracious contributions to this meeting. We also appreciate the vendors who are participating.

The meeting will be held in the Geronimo Event Center & Apache Museum (GEC). All oral presentations will be conducted inside GEC. Posters will be up the entire meeting inside the Chiricahua Desert Museum (CDM). The formal Poster Session is Saturday from 4-6:30 pm.

Phone service in the area is supported by only Verizon and AT&T. There is free WiFi for your convenience at the museum and GEC.

The entire conference schedule is presented herein (Full Schedule and Meeting at a Glance). Oral presentations are 20 minutes in length, which includes time for questions. We have a full meeting and will be very strict about time to keep on schedule. Please be courteous to our valued speakers by refraining from talking and shuffling about the venue during presentations. Please, turn off phones or adjust to vibrate. Thank you.

You are encouraged to visit the CDM and its gift shop. There are many wonderful items for purchase including jewelry, shirts, and hats. The gift shop also boasts a large collection of natural history books, original art, maps, and a wide range of novelty items such as fossils and minerals.

If you have any questions during your stay, do not hesitate to contact any of the conference organizers (listed below) or other individuals (staff) on the BPV4 team. Please review the Important Information page in this program. Finally, please review and follow local wildlife laws for Arizona and New Mexico on the website.

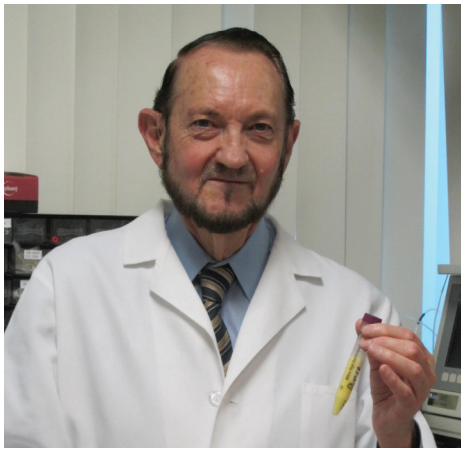
Organizing Committee
Dr. Gordon W. Schuett (520-368-7362), Dr. Chuck Smith (864-357-4757), Cristina Jones, Debra Hill, Bob Ashley (517-256-7831), Sheri Ashley, and Chelsea J. Smith (864-764-4778).

Staff
Dr. Geoffrey C. Carpenter, Michelle Simpler, Theresa Moran, Charles ("Chuck") Hathcock, Mike Hill, Sam Hill. Emory H. Schuett, Zachary ("Zach") S. Hughes, and Jason Watkins.

COVID-19 Policy
All persons attending this conference must show proof of vaccination to our local healthcare providers (full HIPAA compliance) during registration. If you are unable to be vaccinated, for any reason, you must be tested at registration. Any person testing positive for COVID-19 will not be able to attend the conference. There is no mask mandate, but masks will be made available if you choose to wear them. For further information on COVID-19 in New Mexico, go to Welcome to NewMexico.gov | The State of New Mexico E-Government Portal.

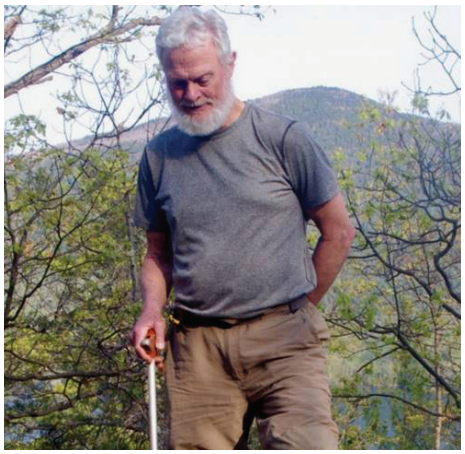
	Wednesday July 13, 2022	Thursday July 14, 2022	Friday July 15, 2022	Saturday July 16, 2022
7:30 AM		Refreshments & Continental Breakfast Provided	Refreshments & Continental breakfast provided	Refreshments & Continental breakfast provided
8:00 AM			Invited Speaker - Dr. Christopher Parkinson	Plenary Speaker - Dr. Juan Calvete
8:15 AM		Opening Remarks		
8:20 AM		Keynote - Dr. Anita Malhotra		
8:40 AM				
9:00 AM				
9:20 AM				
9:40 AM				
10:00 AM		Break (20 min); Refreshments	Break (20 min); Refreshments	Break (20 min); Refreshments
10:20 AM				Invited Speaker - Dr. Mark Allen Davis
10:40 AM				
11:00 AM				
11:20 AM				
11:40 AM				
12:00 PM				
12:20 PM		Lunch on your own	Lunch on your own	Lunch on your own
2:20 PM		Honored Guest - Dr. William S. Brown		Invited Speaker - Dr. Darin R. Rokyta
2:40 PM			Invited Speaker - Dr. Allyson Modra Fenwick	
3:00 PM				
3:20 PM			Honored Guest - Dr. Richard C. Straight	
3:40 PM		Break (20 min); Refreshments		
4:00 PM				Poster Session
4:20 PM			Break (40 min); Refreshments	
4:40 PM		Invited Speaker - Dr. Terence M. Farrell		
5:00 PM	Registration & Ice Breaker. Appetizers & Refreshments Provided by Chiricahua Desert Museum Start Poster Setup		Group Photo Meet in Front of the Geronimo Event Center	
5:20 PM		Dinner on your own		
6:00 PM			Coexisting with Pitvipers Symposium Pulled Pork BBQ Dinner at the Geronimo Event Center. Compliments of Chiricahua Desert Museum.	
6:20 PM				
6:40 PM				Banquet Dinner Silent and Live Auctions Banquet Speaker - Dr. Joseph R. Mendelson III
7:00 PM				
7:30 PM		Invited Speaker - Dr. Harry W. Greene		
8:00 PM				
8:30 PM				

Honored Guests



Dr. Richard C. Straight, Ph.D.

Dr. Richard C. Straight, Ph.D., received his doctoral degree in 1979 at the University of Utah (Salt Lake City, Utah) in photobiology and chemistry. At the Department of Veterans Affairs Medical Center (Salt Lake City), he was a Staff Scientist from 1965 to 2003, an Administrative Officer of Research and Development from 1980 to 2003, and Director and Acting Associate Chief of Staff for Research and Development from 1997 to 2003. At the University of Utah he was Research Professor in the Departments of Surgery and Medicine from 1983 to 2003, and Co-Director of the John A. Dixon Laser Institute from l984 to 1994. He was President of the Western Institute for Biomedical Research (VA) from 1990 to 2003. Currently, Dr. Straight is the Director and Manager of BTG International/BTG Specialty Pharmaceuticals-Utah Division University of Utah Research Park (615 Arapeen Drive, Suite 105, Salt Lake City, Utah 84108). Dr. Straight can be contacted by telephone: mobile (801)-913-4799 (Mobile) and work (801) 583-8077 X1, or by e-mail: richard.straight@btgsp.com.



Dr. William S. Brown, Ph.D.

Dr. William S. Brown, Ph.D., is a vertebrate zoologist and herpetologist; he holds bachelor's and master's degrees from Arizona State University (1965, 1968) and a Ph.D. degree in Biology from the University of Utah (1973). From 1974 to 1997 he was an Associate Professor of Biology (now emeritus) at Skidmore College in New York, teaching a variety of courses (Field Zoology, Comparative Anatomy, and others). Over the past twenty-one years (1997–2017), he was a part-time lecturer in the Department of Biological Sciences, State University of New York at Albany, where he taught Field Biology, Comparative Anatomy, and Histology. He is currently an Adjunct Research Biologist at Rensselaer Polytechnic Institute's Darrin Fresh Water Institute in upstate New York. In 1990, he served a one-year elected term as President of the Society for the Study of Amphibians and Reptiles (SSAR). He has served as a consultant for New York State in evaluating development projects impacting reptiles and amphibians and other wildlife. He has also provided evaluations for conservation groups and landowners concerning developments that may impact endangered or threatened species.

In 1979, Brown began a long-term study of the life history and ecology of Timber Rattlesnakes, a widely occurring North American species of the eastern deciduous forests. Brown's study—now in its 43rd year—involves capturing and marking Timber rattlesnakes in the southeastern Adirondack Mountains of northern New York. His field research is one of the longest continuous capture-recapture studies of any rattlesnake species, and his results are providing new information on longevity, reproduction, and population dynamics. Bill publishes actively on this work in periodicals (e.g., NATIONAL GEOGRAPHIC, 1987) and peer-reviewed journals. He is an author for a national group of research biologists producing a "Conservation Action Plan" for Timber Rattlesnakes throughout their North American range, and he serves on New York's Timber Rattlesnake Recovery Team of the NYS Department of Environmental Conservation. Brown was a recipient of The Nature Conservancy's (Eastern New York Chapter) annual Oak Leaf Award in 2003 citing his "many years of study and efforts toward preservation of Timber Rattlesnakes."

Organizing Committee

Dr. Gordon W. Schuett

Gordon W. Schuett, Ph.D., is an evolutionary biologist and herpetologist who has conducted extensive laboratory and field research on reptiles. His work has focused primarily on venomous snakes, but he has also published on lizards, turtles, and amphibians. His most significant contributions concern mate competition and winner-loser effects, long-term sperm storage, mating systems, seasonal steroid hormone cycles of male and female pitvipers, and facultative parthenogenesis in snakes.

He has recently finished a long-term (2001-2016) study of the ecology and social genetics of a population of western diamond-backed rattlesnakes (*Crotalus atrox*) in the Sonoran Desert of southern Arizona.

Gordon has published over 100 peer-reviewed journal articles, 20 peer-reviewed book chapters, and numerous popular magazine articles. He was the founding editor of the scholarly journal Herpetological Natural History. He co-authored a highly acclaimed zoology laboratory text (1997, 2000), and served as senior editor of the peer-reviewed book, Biology of the Vipers (Eagle Mountain Publishing, 2002). This work has been made available online via Eagle Mountain Publishing. Recently, Gordon is the senior editor of the 2-volume peer-reviewed book, *Rattlesnakes of Arizona* (ECO Publishing, 2016). He and co-authors are currently working on a chapter on snake mating systems for the prestigious Encyclopedia of Animal Behavior (Academic Press).

Gordon is an adjunct professor at Georgia State University. He serves as a Director of the Scientific Advisory Board at the Chiricahua Desert Museum.

Dr. Charles F. Smith

Charles F. Smith, Ph.D., is a behavioral ecologist and evolutionary biologist whose research interests center on the evolution of mating systems, especially the links between spatial ecology, behavior, morphology and physiology, and the fitness benefits and costs arising from each of these attributes at the population level.

His research combines field (e.g., radio-tracking, GIS analysis) and laboratory (e.g., endocrinological, histological, molecular) approaches to address hypotheses about the spatial ecology and reproductive physiology of crotaline snakes. Chuck is using these data, along with phylogenetic information, to develop an integrated framework to study the ecology and evolution of mating systems and sexual selection in pitvipers and other snakes.

Chuck is a Professor of Biology at Wofford College and is Director of The Copperhead Institute. He is an editor on the peer-reviewed 2-volume book, *Rattlesnakes of Arizona* (ECO Publishing, 2016). Chuck serves on the Scientific Advisory Board at the Chiricahua Desert Museum.

Cristina A. Jones, M.S.

Cristina's lifelong interest in reptiles was fostered through the numerous hiking and camping trips throughout Arizona where her parents taught her that wildlife is wondrous and worthy of study. It was on one such hike when she was four years old that she encountered her first Sonoran desert tortoise – and her love for turtles was ignited. As an undergraduate in Wildlife Science at the University of Arizona, she pursued this passion when hired to radio-track Sonoran desert tortoises for a study on the effects of fire on long lived species while completing her B.S. Armed with the critical necessity for Sonoran desert tortoise health studies, in 2001 she was awarded an Arizona Game and Fish Department Heritage Fund Grant to study the prevalence of *Mycoplasma agassizii* in wild and captive Sonoran desert tortoises in Arizona. This research was the focus of her Master's thesis. In 2006, she accepted the position of Turtles Project Coordinator for the Arizona Game and Fish Department. As the state lead for the eight native turtle species in Arizona, she strives to conduct and continue scientific studies that further the knowledge of turtle survival and ecology in Arizona. Through leading five inter-agency/inter-organizational working groups, she works with other scientists to identify priority research needs that could be addressed through her own research or the Department's Heritage Grant Program. In addition, she provides outreach and advocacy for turtles as a member of the Southwest Partners in Amphibian and Reptile Conservation (SWPARC) Steering Committee, a Board member for the Desert Tortoise Council, and an active member of the Turtle Survival Alliance (TSA). Her professional goal is to maintain a position in turtle conservation and management which utilizes her knowledge, leadership, organizational skills, and enthusiasm to encourage and promote innovative ideas to assure the survival of viable populations of native turtle species throughout their range.

To learn more about Cristina's work and Arizona's turtles, please visit: https://www.azgfd.com/Wildlife/speciesofgreatestconservneed/turtles/

Debra Hill, M.S.

Debra Hill grew up adjacent to the Gila National Forest in southwestern New Mexico, and can remember few weekends that she wasn't hiking, camping or riding horses. Her experiences observing nature, catching lizards and exploring the Gila Wilderness resulted in a lifetime of passion and a career. Debra received her Bachelor's degree in Zoology at Western New Mexico University. She then received her Master's degree at New Mexico State University, where she studied the Sacramento Mountain Salamander (*Aneides hardii*). In 2002, Debra took a student position with US Fish and Wildlife Service, where she was able to work in the field with most of New Mexico's reptiles and amphibians. In particular, Debra found her calling working with the Dunes Sagebrush Lizard (*Sceloporus arenicolus*) in the Mescalero Sands of southeastern New Mexico. The unique ecosystem and biological diversity is phenomenal, and has led to a career dedicated to its conservation. Debra now works with a variety of conservation tools to establish meaningful partnerships and conservation efforts in the southwest.

Bob Ashley

Bob Ashley was born and raised in Michigan and grew up in East Grand Rapids. Since he was 8-years-old, he spent his youth catching turtles and snakes in the swamps and fields of Michigan. He was an active member of the Michigan Society of Herpetologists and started the company Exotics in 1984, supplying mostly pet shops in five states with imported and captive-bred reptiles from around the globe. Bob started ECO Wear & Publishing in 1995, offering custom T-shirt designs, art, and books. Bob is the Past President of the International Herpetological Symposium (HIS) and current Vice President. In 2001, Bob started the North American Reptile Breeders Conference and Trade Shows with business partner Brian Potter. He is a co-owner and conducts these events in Arlington, Texas and Tinley Park, Illinois; they are the largest reptile trade shows in the United States, likely the world.

On April 1, 2009 Bob and his wife Sheri opened the doors to the Chiricahua Desert Museum in Rodeo, New Mexico. This facility is an educational exhibit of reptiles and amphibians from the Western Hemisphere, concentrating on taxa associated with the deserts of the Southwestern United States and Mexico. This facility highlights rattlesnakes of the Sky Islands and plateaus and mountains of Mexico. Bob has published over 50 books on the natural history and husbandry of reptiles and amphibians. He is currently working on several book projects with Gordon and Chuck, including *Amphibians of the Sky Islands – Coronado National Forest* and *Reptiles of the Sky Islands – Coronado National Forest*.

Sheri Ashley

Sheri Ashley moved to Portal, Arizona with her husband Bob in January 2009, to open the Chiricahua Desert Museum. She is the Buyer for the Gift Shop and runs marketing and order fulfillment for ECO Wear and Publishing.

Chelsea J. Smith

Chelsea J. Smith is a multi-media specialist, writer, videographer, and podcast enthusiast from Tucson, Arizona. When she's not devoting her time to visual story-telling, you can find her in the wilderness looking for rocks and critters.

Staff

Dr. Geoffrey C. Carpenter

Dr. Geoffrey C. Carpenter, Ph.D., is President, Chief of Design, Fabricator and Janitor at Herptech Metalworks in Bosque Farms, NM where he makes biologically inspired metal art. Dr. Carpenter earned his B.S. at University of Oklahoma (1982), M.S. at the University of Wyoming (1984), Ph.D. at the New Mexico State University (1991), and was a postdoc at Colorado State University (1992-1995). He has been an instructor, researcher, and consultant throughout the western U.S. Geoff attributes his passion for the world around him to his awesome parents and his fantastic upbringing. He was raised in Norman, OK, where his father Charles, a herpetologist, was a professor at the University of Oklahoma, and his mother was a biochemist at the Oklahoma Medical Research Foundation. Geoff spent his summers on Lake Texoma at the OU Biological Station, where he was exposed to lots of interesting aspects of nature, professors, students and grad students. 2019 will be the 20th consecutive year that Carp (one of Geoff's river monikers) has rafted the Grand Canyon, (which he considers his "church") chasing herps on science trips and guides training trips and taking commercial guests hiking, cooking them gourmet meals and striving to inoculate them with appreciation of Mother Nature. Geoff loves his daughter, his dogs, guitars, good music, the satisfaction of a completed metal creation, being outdoors every moment he possibly can, and savoring life!

Charles (Chuck) Hathcock

Charles (Chuck) Hathcock, M.S., grew up in the Sonoran Desert in Arizona where he learned to appreciate the natural world. He graduated with a B.S. in Conservation Biology from Arizona State University and a M.S. in Biology from New Mexico Highlands University. He is an ecologist with 23 years of experience as a federal action agency biologist and biological consultant. Recently retired from Los Alamos National Laboratory, Chuck managed the Biological Resources Program for his last 12 years there. In 2019 he was awarded the Dorothy Hoard Stewardship Award by the Friends of Bandelier for his years of support and contributions to Bandelier National Monument. He has published or co-authored several papers and natural history notes. Now semi-retired and living in Rodeo, NM, Chuck plans to explore his research interests in avian demographics and herpetological conservation. One of the most important things we can do as scientists of the natural world is to communicate and try to mentor the next generation of biologists.

Michelle Simpler

Michelle Simpler grew up in the Portal, Rodeo area. She moved back east for college, but could not stay away from her desert home. She's back to stay! She and her teenage daughter reside near the museum. Michelle has worked for the Chiricahua Desert Museum since 2010. She loves learning about the desert and all its wildlife. She loves passing information on to all our visitors at the museum.

Theresa Moran

Theresa Moran graduated from Michigan State University with a B.S. in Wildlife Management. She founded (or re-founded) the Michigan Society of Herpetologists and was an active board member for almost 30 years. Theresa was a reptile keeper and curator at Potter Park Zoo for 21 years. Theresa has published numerous articles on the care of captive reptiles and amphibians and has been active in several herpetological organizations. Currently, she is the coordinator for the scholarship program for the Midwest Herpetological Symposium. Theresa has assisted us in other technical conferences.

Important Information

Time

IMPORTANT: The Biology of Pitvipers 4 Conference will be operating on New Mexico Time (Mountain Time)

Locations

Registration is Wednesday (July 13) at the Geronimo Event Center (Apache Museum). Cash or credit cards accepted. Other days go to CDM check-out counter.

The Ice Breaker will begin at 1800 (6:00 pm) New Mexico time on Wednesday (July 13). There will be appetizers and refreshments.

The Museum is not able to sell alcohol. Bring Your Own Booze (B.Y.O.B.) or purchase it locally. See back of program book for list of local stores that sell beer, wine, and other spirits.

All Oral Presentations will be inside the Geronimo Event Center. Posters will be presented for the entire conference, but the formal Poster Session will be held Saturday from 4:00-6:30 pm, inside the Chiricahua Desert Museum. Snacks and beverages will be served compliments of CDM.

Information for Oral Presentations

NOTE: ALL Oral presentations must be uploaded the evening before your talk or no later than 7:00 am of the day of your talk. Contact Chuck Smith (864-357-4757) or Chelsea Smith (864-764-4778)

Silent Auction Information

The Biology of Pitvipers 4 (BoPV4) Silent Auction is an opportunity to support a worthy cause – a research grant that is established by the BoPV4 Scientific Advisory Committee to support research on reptiles and amphibians of the Southwest. http://www.chiricahuadesertmuseum.com/research-grants. Please note that items made from amphibians, reptiles, or parts thereof, should NOT be donated. If you are interested in donating to the silent auction to support research, please contact Bob Ashley (bobashleycdm@hotmail.com) or Dr. Gordon W. Schuett for more information.

Coexisting with Pitvipers Symposium at Biology of Pitvipers 4

Rodeo, New Mexico, USA

Start: Friday, July 15, 2022 • 6:00 PM
End: Friday, July 15, 2022 • 8:30 PM

Effective Outreach Brainstorm
After a brief welcome and introduction, we'll start our evening with a brainstorming session where participants contribute to a list of effective outreach practices. We encourage everyone to bring a local-to-you libation of choice (e.g., beer, wine, spirits, kombucha) for a beverage exchange – please also bring your own cup. We'll share beverages while we learn together how to be the most effective pitviper advocates.

Panel Discussion
Dr. Emily Taylor will moderate a discussion with people who have extensive experience with various forms of outreach about pitvipers. Confirmed panelists include:

- Melissa Amarello, Executive Director, ASP
- Erika Nowak, Ph.D.
- Bryan Hughes
- Maria Elena Barragán-Paladines
- William S. Brown, Ph.D.

Improving Perceptions of Rattlesnakes with Conservation Message Framing
A presentation by Erin Allison on a recent study testing the efficacy of different types of messaging on changing attitudes toward rattlesnakes.

The Guide to Coexisting With Pitvipers
At the end of the symposium, we will form a working group of participants interested in contributing to a guide on best practices for pitviper education and outreach to be published in an academic journal. This symposium is only the beginning of a collaboration to improve coexistence between people and pitvipers — we hope you'll join us!

Registration
There is no additional charge to attend this symposium.

Keynote Speaker

Dr. Anita Malhotra

Dr. Anita Malhotra, Ph.D., was born and brought up in India. She moved to the UK in her mid-teens. After getting a B.A. in Zoology from Oxford University and a Ph.D. in Evolutionary Biology (population evolution and adaptation in Lesser Antillean anole lizards) at the University of Aberdeen, Dr. Malhotra began her specialist research focusing on a revision of the systematics of Asian pitvipers. This work, based in the Molecular Ecology and Evolution group at Bangor University, involved integration of field collection, multivariate morphometrics and DNA phylogenetics, and led to substantial revisions in the systematic arrangement of the group at both the species and generic levels. As a result of the extensive fieldwork underpinning this research, Anita developed a large network of collaborators in many Asian countries, which has been further enhanced by being the regional co-coordinator for the IUCN Viper Specialist Group. In more recent years, her focus has shifted to addressing the human suffering and death toll that these snakes can bring, particularly in India, and is a member of the WHO expert roster for snakebite.

Plenary Speaker

Dr. Juan J. Calvete

Born in Valencia, Spain (1957), Dr. Juan J. Calvete, Ph.D. is Professor of the Spanish National Research Council and PI and Director of the Evolutionary and Translational Venomics Laboratory at the Biomedicine Institute of Valencia (Spain). His research group has developed proteomic platforms to study the composition and evolution of snake venoms ("venomics") and the effectiveness of antivenoms ("antivenomics"), with the aim of contributing to alleviate the neglected pathology of snakebite envenoming. Published papers (ORCID 0000-0001-5026-3122) accumulate more than 27000 citations, with an H index of 90 (linked here). Dr. Calvete was founding member and served as first President (2004-2009) of the Spanish Proteomics Society, and from 2011-2019 was President of the European Section of the International Society on Toxinology. Currently he is Editorial Board Member of Toxicon and Toxicon:X, Journal of Venom Research, Toxin Reviews, Biochemie, PLoS Neglected Tropical Diseases, and Editor-in-Chief of the Journal of Proteomics. Dr. Calvete belongs to the Board of Directors of the Global Snakebite Initiative (http://www.snakebiteinitiative.org), an internationally-active non-profit organisation, registered in Australia, led by snakebite experts who are dedicated to improving access to good quality, robustly tested, safe, and effective antivenoms in the world's poorest communities. Dr. Juan Calvete is also a member of the Roster of Experts that assists WHO in the implementation of its Strategic Plan for Control and Prevention of Snakebite Envenoming, and of the Technical and Scientific Advisory Group on the Development of Target Product Profiles (TPPs) for Snake Antivenom Products. Dr. Calvete has received several awards, including the 1989 Young Scientist Award of International Society on Thrombosis and Haemostasis, the 2008 Premio La Luna Sale a Tiempo de Ciencia y Tecnología, the Vital Brazil Medal of the Brazilian Instituto Vital Brazil, Niteròi, RJ (September 2013), and more recently the 2019 Redi Award, the highest award granted by the International Society on Toxinology on the occasion of its biennial World Congress, for "*The development of an entirely new experimental venomics and antivenomics platforms for revealing the true complexity (and evolutionary wonder) of venoms*".

Banquet Speaker

Dr. Joseph R. Mendelson III

Dr. Joseph R. Mendelson III, Ph.D., has been studying herpetology for more than 30 years, concentrating mostly on taxa from Mexico, Central America, and the southwestern U.S. Most of his work has involved evolutionary studies and taxonomy-including the description of more than 40 new species. He received a B.S. from the University of California at Santa Barbara, a M.S. from the University of Texas at Arlington, and a Ph.D. from the University of Kansas. In addition to field-based work, he also pursues lab projects at the Zoo and on campus involving behavior, biomechanics, and traditional descriptive morphology. Significant recent efforts have included a series of papers studying snake locomotion in the context of both functional anatomy and the physics of granular media (e.g., sand) focused on such iconic sand-specialist species as the sidewinder and the shovel-nosed snake. Joe also is very active in basic research and development conservation programs and policies related to global amphibian extinctions. Joe is Director of Research at Zoo Atlanta and Adjunct Professor of Biology at Georgia Tech University, where he teaches regularly. He also is Past-President of the Society for the Study of Amphibians and Reptiles. Joe has published more than 125 technical papers in peer-reviewed journals such as *Science*, *Nature*, *Biology Letters*, *Proceedings of the National Academy of Sciences*, and *Journal of Herpetology*.

Invited Speakers

Dr. Terence M. Farrell

Dr. Terence Farrell, Ph.D., was born in Morristown, New Jersey and began catching ring-necked snakes and red-backed salamanders in his backyard four years later. He received a bachelor's degree in Biology from Bucknell University and a Ph.D. in Zoology from Oregon State University, studying the ecology of algae and invertebrates on rocky shores. He then did postdoctoral research at Stanford University for two years. Since 1989, he has been a faculty member at Stetson University in DeLand, Florida where he typically teaches Ecology, Biostatistics, and Invertebrate Zoology. He is the recipient of the McEniry Award, Stetson's highest award for outstanding teaching, and currently holds the endowed Hyatt and Cici Brown Chair in Biology.

For three decades, Terry has studied the biology of pygmy rattlesnakes in the lab and in the field with a series of talented collaborators and dedicated groups of Stetson students. Their published research includes papers on foraging behavior, parental behavior, defensive behavior, demography, venom effects on prey, and the endocrinology of pygmy rattlesnakes. Much of his recent research focuses on two important conservation issues, snake fungal disease and invasive pentastome parasites.

Dr. Allyson Modra Fenwick

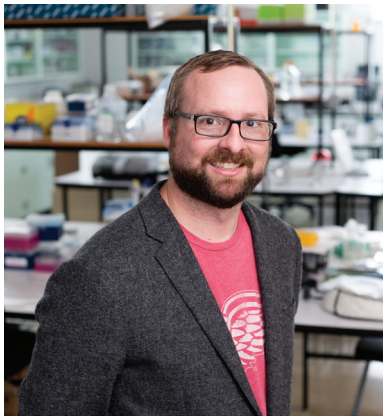
Dr. Allyson Fenwick, Ph.D., spent her childhood in Milwaukee, Wisconsin learning to love wild animals through the local zoo, which also sparked her interest in herpetology. She earned a B.S. in Zoology (Zoo and Aquarium Science) and a B.A. in Theatre from Michigan State University. She became involved in pitvipers through her M.S. in Biology from the University of Texas at Tyler, studying morphological phylogenetics of South American species. She studied all of Crotalidae and some of Viperidae in the Parkinson lab at the University of Central Oklahoma, combining morphological and DNA evidence in phylogeny and investigating interesting evolutionary patterns like egg-laying versus live-bearing. She did postdoctoral research at Stetson University in DeLand, Florida and has been a faculty member at the University of Central Oklahoma in Edmond, Oklahoma since 2013. Her current work with students often focuses on Mediterranean gecko genetics and ecology including overwintering behavior. She is currently a member of the Board of Directors of the Society for the Study of Amphibians and Reptiles and is on multiple committees.

Dr. Christopher L. Parkinson

Dr. Christopher Parkinson, Ph.D., grew up in Ohio where he started catching lizards and snakes as a child. He attended Ohio University for his undergraduate education and where Dr. Scott Moody nurtured and guided his passion for snakes. He then went on to earn his Ph.D. from the University of Louisville and carried out postdoctoral work at Indiana University and the Carnegie Museum of Natural History. Christopher is currently a Professor in the Departments of Biological Sciences and Forestry and Environmental Conservation at Clemson University where he and his team utilize genomic approaches to investigate the evolution, conservation, and systematics of vertebrates. Dr. Parkinson is interested in understanding the evolutionary processes of speciation and utilizes New World venomous snakes as a model system. Over the last 25 years, Christopher has worked extensively with the biogeography, systematics and taxonomy of pitvipers, and has recently started using whole genome sequencing and transcriptomics to investigate the evolution of venom and venom variation. Dr. Parkinson has carried out fieldwork in over 20 countries and has built numerous, multidimensional collaborations with researchers across the globe and welcomes many more.

Dr. Darin R. Rokyta

Dr. Darin R. Rokyta, Ph.D., received a B.S. in Zoology from the University of Texas at Austin in 1999 and a Ph.D. in Bioinformatics and Computational Biology from the University of Idaho in 2006. After two additional years of postdoctoral research at the University of Idaho, Dr. Rokyta joined the faculty in the Department of Biological Science at Florida State University, where he remains. Dr. Rokyta is a broadly trained molecular and evolutionary biologist with expertise in computational biology and protein evolution. His graduate and postdoctoral training focused on mathematics and statistics, emphasizing probability theory and stochastic processes and their applications in evolutionary theory. His primary field of study is the genetics of adaptation, and he has used venoms, viruses, and theory in his pursuit of establishing general rules for adaptive evolution. Much of Dr. Rokyta's current work focuses on venom evolution and how the genetic encoding of venom systems biases their evolutionary patterns.



Dr. Mark Allen Davis

Dr. Mark Allen Davis, Ph.D., is a Conservation Biologist and the Director of the Collaborative Conservation Genetics Laboratory at the Illinois Natural History Survey. He earned B.S. and M.S. degrees from the Department of Biological Sciences at North Dakota State University, a M.S. in the Graduate Degree Program in Ecology from Colorado State University, and a Ph.D. from the department of Natural Resources and Environmental Sciences at the University of Illinois Urbana-Champaign. Mark's current research is broad, interdisciplinary, and collaborative, with a general interest in measuring, monitoring, and promoting biodiversity, with the goal of extending species' evolutionary trajectories well into the future. Though his research is taxonomically diverse (from springtails to gar, from stoneflies to alligator snapping turtles), he has a deep affinity for and is inspired by those maligned creatures like bats and pitvipers. While often societally reviled in western cultures, these organisms yield tremendous value in terms of the critical ecosystem services they provide. Therefore, the development of effective strategies to ensure their persistence is conservation imperative. Necessarily, his work uses modern methodologies and diverse datasets to assess the endangerment process and identify ecological factors and life history characteristics that may predispose species to extinction in the Anthropocene. Leveraging the information gleaned from these approaches, Mark works with partners to collectively develop impactful approaches and conservation initiatives designed to promote population growth and long-term persistence of imperiled species.

Dr. Harry W. Greene

Dr. Harry W. Greene, Ph.D., is emeritus professor of ecology and evolutionary biology at Cornell University and adjunct professor of integrative biology at University of Texas at Austin. He graduated from Texas Wesleyan in 1968, served three years as an army medic, then earned an M.A. from University of Texas at Arlington and a Ph.D. from University of Tennessee. Before moving to Cornell, he was professor and curator in the University of California, Berkeley's Museum of Vertebrate Zoology. Harry has taught behavior, vertebrate natural history, herpetology, introductory biology, evolution, and field ecology, all the while studying animals in more than a dozen countries. His honors include Berkeley's Distinguished Teaching Award, Edward O. Wilson Naturalist Award, Henry S. Fitch Award for Excellence in Herpetology, and Cornell's highest teaching prize, a Stephen H. Weiss Presidential Fellowship. In 2013 Business Insider named him one of Cornell's "Top Ten Professors" and in 2014 he was elected to the American Academy of Arts and Sciences. Now back in Texas, he divides time between Austin and a ranch in the Hill Country, where he pampers Longhorns with names like Pancho and Lefty while writing a book about wildness. Harry's *Snakes: The Evolution of Mystery in Nature*, earned a PEN Literary Award, Commonwealth Club of California's Silver Medal, and a place on the New York Times 100 Most Notable Books list. His more recent *Tracks and Shadows: Field Biology as Art*, was highly praised in Publishers Weekly, Booklist, Science, Nature, Current Biology, The Sciences, Natural History, and Times Higher Education.

		Wednesday July 13, 2022
5:00 PM		**Registration & Ice Breaker. Appetizers & Refreshments Provided by ChiricahuaDesert Museum**
		Start Poster Setup
		Thursday July 14, 2022 ***Moderator morning session: Dr. Wolfgang Wüster***
7:30 AM		**Refreshments & Continental Breakfast Provided at Geronimo Event Center**
8:15 AM		**Opening Remarks**
8:20 AM	1	**Keynote Address** - Dr. Anita Malhotra. Title: Patterns of diversity in Asian pitvipers
9:20 AM	2	**Dr. Stephen P. Mackessy.** Title: Venom expression in rattlesnakes – mechanisms of regulation of activity and control of venom synthesis
9:40 AM	3	**Dr. Drew R. Schield.** Title: The roles of balancing selection and recombination in shaping rattlesnake venom evolution
10:00 AM		**Break (20 minutes). Refreshments Provided at the Geronimo Event Center**
10:20 AM	4	**Jessica Hill.** Title: Determining the potential for geographic range expansion of pitvipers at northern latitudes in the context of climate change

10:40 AM	5	**Dr. Edward A. Myers.** Title: Gonna need more genomes: genomic implications of introgression in rattlesnakes
11:00 AM	6	**Dylan Maag.** Title: Rattlesnake hunting behavior: a case study across a hybrid zone
11:20 AM	7	**Jade Mellor.** Title: Give and take: testing for exchange of crotoxin in rock rattlesnakes (*Crotalus lepidus*) within and between species
11:40 AM	8	**Dr. Emily N. Taylor.** Title: Introducing Project RattleCam, a community science project on denning rattlesnakes
12:00 PM	9	**Dr. Scott Boback.** Title: Project RattleCam: what have we learned so far by spying on rattlesnakes?
12:20 PM		**Lunch on Your Own. See List of Restaurants in Back of Program** ***Moderator afternoon session: Dr. Christopher L. Parkinson***
2:20 PM	10	**Honored Guest** **Dr. William S. Brown.** Title: Timber Rattlesnakes: after 40 years, what have we learned?
3:20 PM	11	**Dr. Sasha Tetzlaff.** Title: Fission-fusion dynamics in the social networks of a North American pitviper
3:40 PM		**Break (20 minutes). Refreshments Provided at the Geronimo Event Center**
4:00 PM	12	**Andrew C. B. Jesper.** Title: Overwintering phenology and refugia use of the Timber Rattlesnake (*Crotalus horridus*) in Illinois
4:20 PM	13	**Joe Aguglario.** Title: Factors impacting metabolic rate and water loss in pitvipers

4:40 PM	14	**Invited Speaker** **Dr. Terence M. Farrell.** Title: Technology aided natural history: Insights on snake behavior from field videos
5:20 PM		**Dinner On Your Own**
7:30 PM	15	**Invited Speaker** **Dr. Harry W. Greene.** Title: Rewilding the Earth, rewilding our lives
		Friday July 15, 2022 ***Moderator morning session: Dr. Rulon W. Clark***
7:30 AM		**Refreshments & Continental Breakfast Provided at the Geronimo Event Center**
8:00 AM	16	**Invited Speaker** **Dr. Christopher Parkinson.** Title: The genomic landscape and the evolution of New World pitvipers
8:40 AM	17	**Rhett M. Rautsaw.** Title: Never underestimate the power of phylogenetics: Macroevolution of New World pitviper venom
9:00 AM	18	**Ramses Rosales-Garcia.** Title: Up the mountain: Venom evolution in montane pitvipers (*Cerrophidion*)
9:20 AM	19	**Chelsea Martin.** Title: Social security? Evidence of stress reduction through social buffering in rattlesnakes
9:40 AM	20	**Dr. Craig M. Lind.** Title: Understanding the sublethal consequences of ophidiomycosis: lessons from pygmy rattlesnakes
10:00 AM		**Break (20 minutes). Refreshments Provided at the Geronimo Event Center.**

10:20 AM	21	**Jenna Palmisano.** Title: The potential impact of an invasive pentastome parasite (*Raillietiella orientalis*) on North American pitvipers
10:40 AM	22	**Dr. Karl W. Larsen.** Title: Complicated conservation for a far-northern rattlesnake: ecological diversity over a small peripheral range
11:00 AM	23	**Chloe R. Howarth.** Title: Understanding inter- and intra-population variation in Western Rattlesnake migratory tactics in British Columbia
11:20 AM	24	**Jade Spruyt.** Title: Effectiveness of road mortality mitigation for Western Rattlesnakes (*Crotalus oreganus*) in Canada
11:40 AM	25	**Matt MacPherson.** Title: Anthropogenic activity as an evolutionary driver of phenotypic variation in western rattlesnake behaviour
12:00 PM	26	**Dr. Harry Ridgway.** Title: Synthesis and in-silico modeling of novel bisphenyltetrazole drugs for inactivation of rattlesnake venom components
12:20 PM		**Lunch on your own. See List of Restaurants in Back of Program**
2:20 PM	27	**Kaleb Hill.** Title: Auto-resistance toward snake venom metalloproteases in North American pitvipers
2:40 PM	28	**Invited Speaker** **Dr. Allyson Modra Fenwick.** Title: Changes in pitviper taxonomy and systematics since Biology of Pitvipers 2
3:20 PM	29	**Honored Guest.** **Dr. Richard C. Straight.** Title: North American pitviper antivenom: selected venom proteins, fab and affinity pure: past, present, future (1973-2003), and (2003-2023)
4:20 PM		**Break (40 minutes). Refreshments Provided at the Geronimo Event Center.**

5:00 PM		**Group Photo. Meet Outside in Front of the Geronimo Event Center & Apache Museum**
6:00 PM		**Coexisting with Pitvipers Symposium (6:00 PM - 8:30 PM)** **Pulled Pork BBQ Dinner at the Geronimo Event Center. Compliments of Chiricahua Desert Museum.**
		Saturday July 16, 2022 ***Moderator for morning session: Dr. Warren Booth***
7:30 AM		**Refreshments & Continental Breakfast Provided at the Geronimo Event Center**
8:00 AM	30	**Plenary Speaker** **Dr. Juan Calvete.** Title: Quo vadis venomics?
8:40 AM	31	**Dominic L. DeSantis.** Title: Integrating radio telemetry and accelerometry to monitor the spatial and temporal movement patterns of snakes
9:00 AM	32	**Cara F. Smith.** Title: Patterns and drivers of venom variation in the Western Rattlesnake complex (*Crotalus viridis/oreganus*)
9:20 AM	33	**Anthony Pawlicki.** Title: Long-term comparison of diets in three syntopic rattlesnake species
9:40 AM	34	**Henderson C. Gull. Title:** Evidence of non-strike induced chemosensory searching by eastern copperheads (*Agkistrodon contortrix*) during cicada predation
10:00 AM		**Break (20 minutes). Refreshments Provided at the Geronimo Event Center**
10:20 AM	35	**Invited Speaker** **Dr. Mark Allen Davis.** Title: Old wine in new bottles: Viewing modern pitviper conservation through the lens of legacy data

11:00 AM	36	**Dr. Michael J. Dreslik.** Title: Demographic forecasting of *Sistrurus* rattlesnakes using Integral Projection Modeling
11:20 AM	37	**María Elena Barragán-Paladines.** Title: Notes on reproductive behavior and birth of captive Two-Striped Forest Vipers (*Bothrops bilineatus*) from Ecuador
11:40 AM	38	**Dr. Matt Goode.** Title: Tiger Rattlesnake population demography based on 20 years of capture-recapture data
12:00 PM	39	**Ryan Hanscom.** Title: Rattlesnake feeding ecology: using high frequency accelerometry to capture feeding events across *Crotalus*
12:20 PM		**Lunch on Your Own. See List of Restaurants in Back of Program** ***Moderator for afternoon session: Dr. Stephen P. Mackessy***
2:20 PM	40	**Invited Speaker.** **Dr. Darin R. Rokyta.** Title: The genomics of venom ontogeny in rattlesnakes
3:00 PM	41	**Dr. William K. Hayes.** Title: It's complicated! Ontogenetic variation in venom composition of rattlesnakes
3:20 PM	42	**Michael P. Hogan.** Title: The genetics of sensory perception in the Eastern Diamondback Rattlesnake
3:40 PM	43	**Dr. Rulon W. Clark.** Title: Lessons learned from 20 years of rattlesnake field studies: a perspective on why studying animals in nature is critical for understanding biological systems
4:00 PM		**FORMAL POSTER SESSION. CHIRICAHUA DESERT MUSEUM** **Refreshments Provided at the Chiricahua Desert Museum**
6:30 PM	44	**Banquet Dinner. Silent and Live Auctions** **Banquet Speaker.** **Dr. Joseph R. Mendelson III.** Title: Sidewinders vs. robots: how a herpetologist learned to love physics

Oral Abstracts

1. An integrative taxonomic approach to determining species boundaries in Asian pitvipers.

Malhotra, Anita
School of Natural Sciences
Bangor University, Bangor, Gwynedd, U.K.

While substantial advances have been made in recent years in elucidating the phylogeny and systematics of pitvipers, phylogenies of the Asian representatives are still predominantly based on mitochondrial loci, and many species have been described on the basis of a very limited geographic sampling and an emphasis on colour pattern differences. This not only leaves their validity open to question but also fails to meet the needs of medical and conservation practitioners for whom the distribution of species is vital information. In this talk I will describe the combined analysis of a geographically comprehensive morphological and molecular data collected over a 30-year period in one of the most wide-ranging and iconic pitviper groups, the white-lipped pitviper (*Trimeresurus albolabris*) complex, showing how a combination of these data is far more valuable than one data type alone. However, whether to treat resulting units as full species or subspecies is still a matter of interpretation and I will use this talk as an opportunity to seek the views of the attendees.

2. Venom expression in rattlesnakes – mechanisms of regulation of activity and control of venom synthesis

Mackessy, Stephen P.
stephen.mackessy@unco.edu

School of Biological Sciences
University of Northern Colorado
Greeley, Colorado USA

Castoe, Todd A.
Perry, Blair W.
Schield, Drew R.
Department of Biology
University of Texas
Arlington, Texas USA

The evolution of a chemical means of dispatching prey has provided numerous advantages to venomous snakes, but it has also presented them with a conundrum: how are venoms stored for long periods of time, instantly available for dispatching prey or warding off predators, but not undergoing degradation or intoxicating the snake? Rattlesnake venoms are rich in enzymatic components, and metalloproteinases (SVMPs) are particularly abundant in type I venoms. In general, expressed venoms are stable and show relatively little degradation even when stored in liquid form under less-than-ideal conditions. However, when purified, numerous components are much more labile, and metalloproteinases in particular are subject to autolytic degradation. We sought to investigate how venoms can be expressed into the ductules and basal lumen of the gland and stored for long periods of time, often years in captive snakes, without a loss in potency or endangering the snake. We used a variety of techniques, including protein chemistry, electron microscopy, histochemical and immunochemical staining of glands, and time course gene expression analyses to address mechanisms of regulation of venom secretion and storage. Several redundant mechanisms exist that protect the snake from venom toxins and maintain venom patency, including the presence of high concentration/low abundance tripeptide SVMP inhibitors and maintenance of the venom at an acidic (pH = 5.4) pH. Localized upregulation of vacuolar H+-ATPases (but not H-K ATPases) was demonstrated via Western blots and immunological staining, strongly supporting our earlier hypothesis that mitochondria-rich cells are responsible for venom bolus acidification. Together, these mechanisms allow for safe storage of a labile, toxic protein solution (venom) for long periods of time, inactive while in the gland but immediately activated upon deployment (prey tissues are ~2 log steps higher pH), again demonstrating that venomous snakes can serve as informative model systems for the investigation of novel regulatory mechanisms.

3. The roles of balancing selection and recombination in the evolution of rattlesnake venom

Schield, Drew R.
drew.schield@colorado.edu

Department of Ecology and Evolutionary Biology
University of Colorado
Boulder, Colorado USA

The origin of snake venom involved the duplication of non-venom genes and the recruitment of these duplicates into venom systems. For decades, studies have predicted that directional positive selection has governed this process. Venom composition varies substantially across snake species, and venom phenotypes are thought to be locally adapted to prey, leading to coevolutionary interactions between predator and prey. Here, prey may evolve mechanisms to resist snake venom, and in turn snakes may evolve novel venom components to kill prey more effectively. Distinct from venom origins, contemporary patterns of snake venom evolution may therefore be driven by fundamentally different selection regimes, yet population-level patterns of selection have been only rarely investigated. Here we use whole-genome data from 68 rattlesnakes to test hypotheses about selection and the drivers of genomic diversity and differentiation in major venom gene regions. Our results indicate that selection has resulted in long-term maintenance of genetic diversity within and between species in multiple venom gene families. Our findings are inconsistent with a dominant role of directional positive selection, and instead support a role of long-term balancing selection in shaping venom evolution. We also detect rapid decay of linkage disequilibrium due to high recombination rates in venom regions, suggesting that venom genes have reduced selective interference with nearby loci, including other venom paralogs. Our results characterize a new example of long-term balancing selection that drives trans-species polymorphism – for which there are few examples—and help explain major evolutionary forces underlying a widely studied adaptation.

4. Determining the potential for geographic range expansion of pitvipers at northern latitudes in the context of climate change

Hill, Jessica L.
jhill7021@sdsu.edu

Department of Biology
San Diego State University
San Diego, California USA

Grisnik, Matt
Tennessee State University
Department of Agricultural and Environmental Sciences
Nashville, Tennessee USA

Hanscom, Ryan
Department of Biology
San Diego State University
San Diego, California USA

Sukumaran, Jeet
Department of Biology
San Diego State University
San Diego, California USA

Higham, Tim
Department of Evolution, Ecology and Organismal Biology
University of California, Riverside
Riverside, California USA

Clark, Rulon W.
Department of Biology
San Diego State University
San Diego, California USA

Ecological niche modeling (ENM) is being increasingly used on a variety of taxa to predict both the current and future range of species under climate change conditions. Ecological niche modeling is a framework that predicts where viable habitat will be located using a combination of geographical presence points, environmental variables, and absence or background points. The ENMs we are currently working on are of Prairie Rattlesnakes (*Crotalus viridis*) and Ord's Kangaroo Rat (*Dipodomys ordii*). These two species represent a predator-prey system, and they are co-distributed across the great plains of North America. This system is of particular interest in the face of climate change because rattlesnakes are ectothermic whereas kangaroo rats are endothermic. This mismatch leads to the prediction that changing temperatures will have a greater impact on the performance of ectothermic Prairie Rattlesnakes than endothermic kangaroo rats. Due to this asymmetry in the biotic interaction, we anticipate differences in the environmental predictor variables that best model their niches and in whether their geographic distribution expands or contracts. The models we will show in this talk represent a preliminary model of the niche of prairie rattlesnakes as well as a possible demonstration of how their range may shift in the face of different climate change scenarios. Additionally, these models are contextualized by being part of a broader study of this system using data collected in the field across a natural thermal cline. Data collected at our sites will allow us to compare the home ranges and activity patterns of these two species at different temperatures. By pairing these natural data with the predictive ecological niche models, we aim to create a clearer picture of how climate change may impact the predator-prey relationship and overall dynamics of prairie ecosystems.

5. Gonna need more genomes: genomic implications of introgression in rattlesnakes

Myers, Ed
eamyers@clemson.edu

Rautsaw, Rhett
Parkinson, Chris
Department of Biological Sciences
Clemson University
Clemson, South Carolina USA

The evolutionary history of rattlesnakes has been notoriously difficult to estimate, with different datasets and methods of phylogeny reconstruction resulting in different topologies. Recent population genomic and small-scale phylogenetic studies have suggested that divergence with gene flow is common within this group. Whether gene flow and introgression among species has influenced past interpretations of phylogenetic relationships is not known. Here, we generate transcriptomic data for nearly all named species of rattlesnake (genera *Crotalus* and *Sistrurus*), generate a fossil calibrated phylogeny, and conduct genomic tests for introgression across this radiation. Introgression between species has led to a high degree of gene-tree discordance; this is likely the cause of disagreement between previously published phylogenies in the placement of several taxa (e.g., *C. horridus* and *C. willardi*). We discuss these results in the context of the consequences of hybridization and introgression in rattlesnakes and across the tree of life.

6. Rattlesnake hunting behavior: a case study across a hybrid zone

Maag, Dylan W.
dmaag3229@sdsu.edu

Shaw, Noelle
Soni, Ashana
Department of Biology
San Diego State University
San Diego, California USA

Nikolakis, Zachary L.
Ivey, Kathleen
Department of Biology
University of Texas at Arlington
Arlington, Texas USA

Schuett, Gordon W.
Department of Biology
Georgia State University
Atlanta, Georgia USA

Chiricahua Desert Museum
Rodeo, New Mexico USA

Castoe, Todd A.
Department of Biology
University of Texas at Arlington
Arlington, Texas USA

Clark, Rulon W.
Department of Biology
San Diego State University
San Diego, California USA

The last several decades of work have demonstrated that hybridization between diverged species is relatively common occurrence. Studying hybrid zones can provide unique insight into the factors that contribute to both pre- and postzygotic isolation and yield critical insights into the processes of introgression and speciation. There is a rich literature characterizing morphology, rates of gene flow, and relative reproductive success at the population level across hybrid zones involving species with strong prezygotic isolating mechanisms. Here, we focus on a system that lacks apparent strong prezygotic mechanisms, which provides the opportunity to examine how postzygotic mechanisms related to the behavior and ecology of individuals may impact hybrids. In this study we focus on a narrow hybrid zone between two rattlesnake species, *Crotalus scutulatus* and *Crotalus viridis*, in southwestern New Mexico, and analyze their relationships between ecologically relevant behaviors and the ancestry of individuals. We used a combination of radiotelemetry and field videography to analyze individual snake hunting behaviors across habitat gradients across this hybrid zone. Individuals from all lineages (parentals and hybrids) exhibited similar rates of encounters and successful attacks toward prey (mainly nocturnal mammals). However, in contrast to hybrids and *C. viridis*, adult *C. scutulatus* hunted almost exclusively during the night, and they never encountered or struck at potential lizard prey. These findings indicate that *C. scutulatus* may be more of a small mammal specialist than the other lineages we studied. We discuss the potential implications of these findings in the context of hybrid zone dynamics and postzygotic isolation.

7. Give and take: testing for exchange of crotoxin in rock rattlesnakes (*Crotalus lepidus*) within and between species

Mellor, N. Jade
Njmello@g.clemson.edu
Parkinson, Chris
Department of Biological Sciences
Clemson University
Clemson, South Carolina USA

Snake venoms display a range of hemorrhagic (Type I) to neurotoxic (Type II) venoms. Type I venoms are characterized by the expression of snake venom metalloproteinases and low toxicity while Type II venoms are characterized by low snake venom metalloproteinases and high toxicity. Although many rattlesnake species have been classified as either Type I or Type II, population-level variation in venom phenotype has been documented in several species. Much of the variation in venom phenotype is driven by the presence or absence of Crotoxin (or its homologs, hereafter all referred to as CTx). CTx is a highly toxic heterodi-

meric beta-neurotoxin, and the main component of Type II venoms in many species. The phenomenon of population-level variation has been most widely studied in large-bodied lowland rattlesnakes (*Crotalus scutulatus*, *C. helleri*, and *C. horridus*). While it has been suspected in C. lepidus, CTx presence has not been genetically confirmed in the small-bodied montane clade. We used genomics and transcriptomics to test for the presence, distribution, and evolution of CTx in the Rock Rattlesnake (*C. lepidus*). Out of 104 individuals from across the species' range, 17 were genetically confirmed to have CTx. Interestingly, CTx presence was not significantly associated with longitude, latitude, subspecies, or elevation. However, we did identify several climatic variables associated with CTx presence, including one which has been identified in previous studies on CTx expression variation. These findings expand our understanding of CTx evolution in rattlesnakes by providing insights on the phylogenetic distribution of CTx across rattlesnakes, the variation in crotoxin expression, and highlighting environments to which CTx may be locally adapted. Our results likely support previous hypotheses of an ancestral origin for crotoxin followed by independent sorting in lineages; therefore, future studies should focus on testing for the presence of CTx in other species of montane rattlesnakes.

8. Introducing Project RattleCam, a community science project on denning rattlesnakes

Taylor, Emily N.
etaylor@calpoly.edu

Department of Biological Sciences
California Polytechnic State University
San Luis Obispo, California USA

Boback, Scott M.
Department of Biology
Dickinson College
Carlisle, Pennsylvania USA

Documenting animal behavior can be expensive, arduous, and labor intensive. This is especially true for secretive animals inhabiting hard to reach areas. To overcome these obstacles, ecologists are increasingly relying on remotely deployed devices to detect and document populations. Digital camera traps have massively impacted wildlife monitoring and hold tremendous opportunities for the behavioral ecologist. We have been deploying time-lapse cameras to monitor Prairie rattlesnake (*Crotalus viridis*) behavior near hibernacula and rookeries at a site in northwestern Colorado. These cameras amass tens of thousands of images within an active season, that require new approaches for processing. In summer of 2021 we developed a community science project, Project RattleCam, using the Zooniverse web platform (Zooniverse.org). Community scientists answer questions about each photo to create a database that we can analyze to study snake behaviors, while simultaneously involving the public in data collection. In addition, we deployed the first ever live-streaming camera on a rookery of Southern Pacific rattlesnakes in California in summer 2021, where people watched rattlesnakes interact live on YouTube. Camera projects like Project RattleCam have the potential to reach many people and impact their perceptions of rattlesnakes in a positive way, while also assisting scientists with data collection.

9. Project RattleCam: what have we learned so far by spying on rattlesnakes?

Boback, Scott M.
bobacks@dickinson.edu

Department of Biology
Dickinson College
Carlisle, Pennsylvania USA

Tu, Eddie
Department of Mathematics and Computer Science
Dickinson College
Carlisle, Pennsylvania USA

Taylor, Emily N.
Department of Biological Sciences
California Polytechnic State University
San Luis Obispo, California USA

Project RattleCam is a community science project where participants answer questions about images taken by time lapse cameras at a Prairie rattlesnake (*Crotalus viridis*) hibernaculum and rookery in Colorado. In less than 9 months, more than 6,200 community members made 397,801 classifications from 60,360 images and completed the first segment of the project. In this talk I will discuss what we have learned thus far about snake behavior at rookeries and the value of community science in addressing camera trap data. Project RattleCam has revealed activity patterns and unique behaviors such as rain harvesting in adults and newborn snakes. One example of a new discovery is that neonate rattlesnakes appear to be born "thirsty" and can be observed rain-harvesting mere days after birth. Additional observations including the presence of potential snake predators will be discussed.

10. Timber Rattlesnakes: after 40 years, what have we learned?

Brown, William S.
wbrown@skidmore.edu

Department of Biology (emeritus)
Skidmore College
Saratoga Springs, NY USA

A four-decade career studying *Crotalus horridus* in the field at a single locality in northeastern New York allows me to cautiously suggest some successes in quantifying this species' life history. In recent years, researchers and field biologists who work on this species (a "quirky subculture") have met in annual gatherings to exchange experiences, thus knitting together a social network of those with an enduring interest in the snake's welfare. Importantly, since 1983 the State of New York lists the species as "threatened" allowing a spread of public knowledge of Timber Rattlesnakes' legal protection. This status permits field biologists to proceed with a degree of confidence that their work will not be grossly disturbed by factors such as bounty hunting or commercial collecting, activities that were formerly widespread. Described as potentially "charismatic" when viewed undisturbed in nature but "problematic" phylogenetically, I will summarize prominent aspects of the snake's local distribution and natural history, focusing on the following topics: (1) the regional setting and dens; (2) shelter-rock structural requirements; (3) methods employed in measuring and marking individuals; (4) examples of bad things (and some good things) that have happened to Timber Rattlesnakes; (5) aspects of behavior, e.g., warnings by rattling or occasional inflationary hissing; silently gliding under shelter when discovered; gregarious tendencies of newborns and gravid females; and the so-called "spook factor" wherein the snakes become intimidated and respond later by making themselves scarce; (6) observations of falling prey to predators; and (7) life history attributes such as extended longevity, low-frequency reproduction, and high adult survival. Additional topics may include shedding and aging, intraspecific reproductive comparisons, and feeding and energetics. Finally, in "Rays of Hope" I will provide several optimistic examples of conservation including reversals of negative attitudes concerning this species, and efforts to save its remaining populations.

11. Fission-Fusion dynamics in the social networks of a North American pitviper

Tetzlaff, Sasha J.
Sasha.J.Tetzlaff@usace.army.mil

Ecological Processes Branch
US Army Construction Engineering Research Laboratory
Champaign, Illinois USA

Illinois Natural History Survey, Prairie Research Institute
University of Illinois Urbana-Champaign
Champaign, Illinois USA

Vizentin-Bugoni, Jeferson
Programa de Pós-Graduação em Biologia Animal,
Instituto de Biologia, Universidade Federal de Pelotas, RS, Brazil

Sperry, Jinelle H.
U.S. Army Corps of Engineers
Engineer Research Development Center
Champaign, Illinois USA

Department of Natural Resources and Environmental Sciences
University of Illinois at Urbana-Champaign
Urbana, Illinois USA

Davis, Mark A.
Illinois Natural History Survey, Prairie Research Institute
University of Illinois Urbana-Champaign
Champaign, Illinois USA

Clark, Rulon W.
Department of Biology, San Diego State University
San Diego, California USA

Chiricahua Desert Museum
Rodeo, New Mexico USA

Repp, Roger A.
National Optical Astronomy Observatory (NOAO)
Tucson, Arizona USA

Schuett, Gordon W.
Department of Biology - Neuroscience Institute
Georgia State University
Atlanta, Georgia USA

Chiricahua Desert Museum
Rodeo, New Mexico USA

Social network ecology is a powerful conceptual and analytical framework for identifying group-level interaction patterns of and contributions by individuals. We examined the structure of social networks for adult western diamond-backed rattlesnakes (*Crotalus atrox*) in Arizona, USA using long-term (>10 years) data to determine if group-level patterns emerged in network structures for three types of social interactions: denning, pairing, and parentage. We also investigated whether body length, sex, and home range size were predictive of individuals' centrality (i.e., individual importance for group connectivity) in each of the three networks. Of 191 genotyped adults, a subset of 50 snakes (28 females, 22 males) were radio-tracked from 2001–2010. We found the three networks were structurally modular (i.e., formed distinct clusters of individuals interacting). Sex was the only significant predictor of centrality in the parentage network, with females slightly more connected than males, likely due to high levels of multiple mating, long-term sperm storage, and resultant multiple paternity. Interacting telemetered snakes were unlikely to be related in any of the three networks. Despite ample opportunities to interact with numerous conspecifics that had highly overlapping spring-summer home ranges, individuals tended to interact with limited partners, which also differed from individuals they associated with at communal dens during winter. Thus, our results show strong seasonal fission-fusion dynamics exist in this *C. atrox* population. Furthermore, although both sexes show high annual fidelity to both home ranges and communal dens, females occasionally alter den sites and overwinter privately in mammal nests or burrows, indicative of active manipulation of their social environment. We illustrate that comprehensive and long-term datasets incorporating social network analysis with spatial and genetic information provide robust and unique insights to understanding social structure of understudied secretive taxa such as pitvipers.

12. Determining the phenology and predictors of spring emergence for the Timber Rattlesnake (*Crotalus horridus*) in Illinois using in-field cameras

Jesper, Andrew C.
ajesper2@illinois.edu

Dreslik, Michael J.
Illinois Natural History Survey
University of Illinois Urbana-Champaign
Champaign, Illinois USA

Eckert, Scott A.
Department of Biology and Natural Resources
Principia College
Elsah, Illinois USA

Ballard, Scott R.
Illinois Department of Natural Resources
Carterville, Illinois USA

Bielema, Brian J.
21491 Lake Rd
Morrison, Illinois USA

Many ectotherms are particularly vulnerable during spring egress when thermoregulating individuals congregate near communal refugia for several weeks. Consequently, entire congregations are susceptible to potential threats such as management activities (e.g., prescribed burning, logging), poaching, and wanton killing. The Timber Rattlesnake (*C. horridus*) is a species of conservation concern which relies on subterranean refugia to survive temperate winters. As a slow maturing and long-lived reptile, *C. horridus* lacks the demographic plasticity to recover from population declines rapidly, and even limited mortality events can be detrimental to population viability. Thus, information regarding the timing and predictors of spring emergence in *C. horridus* is required to inform conservation and land management. Here, we describe the phenology of spring emergence for two populations of *C. horridus* in Illinois and build a predictive model of phenology across the latitudinal gradient of Illinois using in-field cameras. Our results suggest *C. horridus* have substantial variability in the timing of emergence across the latitudinal gradient, which should be considered when conducting conservation and management activities near the species' refugia.

13. Factors influencing resting metabolic rate and evaporative water loss rate in Pygmy Rattlesnakes *(Sistrurus miliarius)*

Agugliaro, Joseph
jaguglia@fdu.edu

Department of Biological Sciences
Fairleigh Dickinson University
Madison, New Jersey USA

Lind, Craig M.
Department of Natural Sciences and Mathematics
Stockton University
Galloway, New Jersey USA

Farrell, Terence M.
Department of Biology
Stetson University
DeLand, Florida USA

A central goal in physiological ecology is to understand the intrinsic and extrinsic factors that influence the allocation of available resources (such as energy and water) to competing physiological functions, and how the allocation "decisions" of individuals may in turn influence fitness and population persistence. Pygmy Rattlesnakes (*Sistrurus miliarius*) in central Florida are locally abundant and surface active year-round, making them well-suited for physiological sampling of field-acclimatized individuals in this context. Since winter 2017-2018, we have measured resting metabolic rate (RMR, as CO2 production rate) and total evaporative water loss rate (EWL) of over 200 *S. miliarius* via flow-through respirometry. Our work began by investigating the energetic and hydric consequences of an endemic mycotic disease (snake fungal disease or ophidiomycosis) naturally afflicting snakes in our study population. Ongoing sampling of RMR and EWL continues to shed light on a number of factors influencing the energy and water budgets of *S. miliarius*. We additionally report on progress made assessing the following: thermal sensitivity and allometric scaling of RMR; season variation in RMR and EWL; effects of reproductive and disease status on the cost of mounting an immune response to a bacterial antigen; the metabolic cost of pregnancy; and the repeatability of RMR. Our work demonstrates how measurements of the energy and water relations of pitvipers provide valuable information that may inform conservation efforts.

14. Technology aided natural history: insights on snake behavior from field videos

Farrell, Terence M.
tfarrell@stetson.edu

Department of Biology
Stetson University
DeLand, Florida USA

Technology often provides tools for gaining natural history knowledge. The use of inexpensive video recorders (camcorders) offers an accessible path to increase understanding of snake behavioral ecology. I will show a series of videos recorded in central Florida focused on pygmy rattlesnakes, cottonmouths, and natricine snakes. These videos indicate that snakes are often multitaskers and are not restricted to focusing on a single or goal activity at any one time. The latter is a common assumption of snake behavior, especially in the context of reproduction. I argue that snakes engage in a wide variety of social behaviors in addition to those associated with mating, such as intraspecific and interspecific kleptoparasitism. There are many benefits to using unattended video cameras including lessening the impact of an observer on the behavior of snakes and their predators and prey. The videos also preserve brief interactions and behaviors that may be misinterpreted if viewed only once. For the general public, viewing videos of snakes engaging in a diversity of non-defensive behaviors (including drinking, ecdysis, courtship, and interacting with offspring and siblings) reduces antipathy toward snakes. Most importantly, the curiosity-driven video observations provide highly memorable material that provides a great path for hypothesis generation and for future investigations of behaviors in more controlled environments.

15. Rewilding the Earth, rewilding our lives

Greene, Harry W.
harry.greene@austin.utexas.edu

Department of Ecology and Evolutionary Ecology
Cornell University
Ithaca, New York USA

Department of Integrative Biology
University of Texas at Austin
Austin, Texas USA

My talk will set us up for the next evening's symposium on coexistence with pitvipers by first clarifying instrumental vs intrinsic values, land sparing vs land sharing, the contested meanings of wildness and wilderness, and the indigenous concept of eco-kin-centricity. I'll use pitvipers and giant herbivores with horns to illustrate these issues, and how their mutualistic resolution might lead to maximizing biodiversity in a world ever-more dominated by humans.

16. The genomic landscape and the evolution of New World pitvipers

Parkinson, Chris
viper@clemson.edu

Department of Biological Sciences
Clemson University
Clemson, South Carolina USA

The family Viperidae consists of three subfamilies, Viperinae, Azemiopinae, and Crotalinae, with the highest species diversity being in the Crotalinae. We have sequenced and assembled the genomes of representative species from all three subfamilies, including *Echis carinatus*, *Azemiops feae*, and multiple New World pitviper species. With these data, we are investigating the evolutionary history and biogeography of this family with a specific focus on New World pitvipers. Combining our newly sequenced genomes with previously published genomes, we aim to improve our understanding of chromosomal and venom gene family evolution. With these data, we find that most of the venom genes are found on microchromosomes, in contrast with Elapidae, and that substantial structural evolution has occurred across relatively short timescales. To further address evolutionary and biogeographic questions, we use a multi-omic approach combining multiple data types to infer one of the first phylogenomic inferences of this family. Using this phylogeny, we infer diversification rates and test models of biogeographic history. We reveal several novel, well-supported relationships within vipers which helps clarify taxonomy as well as a rapid speciation rate upon invasion of the New World. Together, we demonstrate the utility of the next-generation sequencing era in improving our understanding of genome biology, phylogenetics, systematics, and venom evolution within Viperidae.

17. Never underestimate the power of phylogenetics: macroevolution of New World pitviper venom

Rautsaw, Rhett
rrautsa@g.clemson.edu

Parkinson, Chris
Department of Biological Sciences
Clemson University
Clemson, South Carolina USA

Competition is a critical selective force for diversification; however, empirical studies on its role in promoting differentiation of adaptive phenotypes have largely been limited to small spatial and taxonomic scales. Here, we test the effect of competition on the evolution of pitviper venoms – a cross-continental radiation of venomous snakes each with tens to hundreds of individual toxins varying in expression, composition, and overall complexity among species. Using our novel phylogenomic reconstruction and >500 venom gland transcriptomes, we reveal that venom phenotypes diverge when multiple species coexist in a given area through time. Furthermore, we find that pitviper communities have evolved to maximize functional diversity despite comparatively low phylogenetic diversity, suggesting an evolutionary response of venom rather than communities accumulating phylogenetically diverse species. Together, these findings support competition as a likely selective pressure driving venom diversification in pitvipers.

18. Up to the mountain: venom evolution in montane pitvipers (*Cerrophidion*)

Rosales Garcia, Ramses A.
ramsesr@g.clemson.edu

Parkinson, Chris
Department of Biological Sciences
Clemson University
Clemson, South Carolina USA

Snake venom is an adaptive trait shaped by selection. However, genetic drift might be more important in determining venom phenotypic variation than previously thought. Drift is particularly important in species with isolated, small populations, such as pitvipers inhabiting high elevation mountains. The montane pitvi-

pers of the genus *Cerrophidion* inhabit the mountainous regions of Middle America. Here, we use this group as a model to explore the roles of selection and drift in venom evolution. Montane pitviper venom is mainly known from studies of the Costa Rican endemic *C. sasai*, yet the venom composition of the other species has not been studied. Therefore, we describe the venom gland transcriptome of *C. petlalcalensis*, *C. tzotzilorum*, and *C. godmani* from Mexico, and a *C. sasai* from Costa Rica. Additionally, for *C. godmani*, we test for a signal of selection on toxin genes. We found that *Cerrophidion* venom transcriptomes are mainly composed of SVMPs, PLA2s, and SVSPs; however, the expression of these toxin families and individual toxins varies considerably among and within species. Toxins within *C. godmani* are not under strong selection pressures and are instead evolving via mutation-drift equilibrium. Additionally, we determined the PLA2s composition of each species and found variation in paralog composition among taxa and compositional variation within *C. godmani*. Our results indicate that *C. godmani* has a phenotypically diverse venom that varies among populations.

19. Social security: can rattlesnakes reduce stress through social buffering?

Martin, Chelsea
cemartin@students.llu.edu

Gerad, Fox
Department of Earth and Biological Sciences
Loma Linda University
Loma Linda, California USA

Putman, Breanna
Department of Biology
California State University at San Bernardino
San Bernardino, California USA

Hayes, William K.
Department of Earth and Biological Sciences
Loma Linda University
Loma Linda, California USA

Social buffering comprises the reduction of stress an organism experiences when in the presence of a companion and has been well documented in highly social animals such as birds and mammals; however, it has not been reported in reptiles. Furthermore, most previous work has been conducted on laboratory-bred animals, so we lack knowledge on attributes of social buffering in nature. Rattlesnakes are cryptically social, exhibiting kin recognition and forming subtle social networks in certain contexts. We tested the presence of social buffering against acute stress in 25 wild-caught adult southern Pacific rattlesnakes (*Crotalus helleri*) by measuring heart rate increase during a standardized disturbance when alone, in the presence of a rope (inanimate object control), and in the presence of a same-sex companion. Results indicated that the presence of a companion significantly reduced emotional tachycardia after disturbance compared to the other treatments. Reduction in rattling also approached significance. Further study is underway to examine social buffering in the context of companion familiarity and chronic stress. These novel studies can fill the gap in our understanding of social buffering, including its evolution, adaptive roles, and practical applications.

20. Understanding the sublethal consequences of ophidiomycosis: lessons from pygmy rattlesnakes

Lind, Craig M.
Craig.lind@stockton.edu

Department of Natural Sciences and Mathematics
Stockton University
Galloway, New Jersey USA

Agugliaro, Joe
Department of Biological Sciences
Fairleigh Dickinson University
Madison, New Jersey USA

Farrell, Terence M.
Department of Biology
Stetson University
DeLand, Florida USA

It has been over a decade since the causative agent of ophidiomycosis (or snake fungal disease), *Ophidiomyces ophiodiicola* (Oo), was identified as a potential threat to pitviper populations in North America. Researchers have since employed a variety of strategies to better understand the causes and consequences of ophidiomycosis in snake populations, and much has been learned. However, an understanding of how host coping mechanisms interact with environment to drive disease outcomes remains a work in progress, rendering our understanding of the threat that Oo poses to snakes incomplete. Recent work has demonstrated that the fungus has been present in North American snake populations since at least the mid-20th century, but the spread of Oo in North America and the negative impacts observed in host populations may be emerging phenomena. We have tracked fungal disease since the 1990's, and, in the last seven years, intensively studied the ecological and physiological correlates of ophidiomycosis in a population of pygmy rattlesnakes, *Sistrurus miliarius*, in Central Florida. Here we incorporate seasonal correlates of natural Oo infection into a framework to better understand the intrinsic and extrinsic drivers of ophidiomycosis in free-living pygmy rattlesnakes. Specifically, we highlight seasonal variation in disease prevalence and severity and describe endocrine, energetic, and thermal correlates of infection. Collectively, our results indicate that ophidiomycosis is associated with seasonal physiological responses that reduce host fitness. We also highlight current gaps in knowledge and avenues for future research that would improve on our current efforts to understand the population-level consequences of ophidiomycosis.

21. The potential impact of an invasive pentastome parasite (*Raillietiella orientalis*) on North American pitvipers

Palmisano, Jenna N.
jpalmisano@stetson.edu

Farrell, Terence M.
Department of Biology
Stetson University
DeLand, Florida USA

Lind, Craig M.
Department of Natural Sciences and Mathematics
Stockton University
Galloway, New Jersey USA

Agugliaro, Joe
Department of Biological & Allied Health Sciences
Fairleigh Dickinson University
Madison, New Jersey USA

An emerging parasite from Southeast Asia, *Raillietiella orientalis*, has exploited at least 14 snake species native to Florida as hosts. All three pitviper genera (*Agkistrodon*, *Crotalus*, and *Sistrurus*) in Florida have been infected with this invasive pentastome parasite. Mature *R. orientalis* are hematophagous and reside in the lungs of snakes. Native snake species have higher infection intensities and larger adult pentastomes compared to snake species that share a native range with *R. orientalis*. Snakes with a co-evolutionary history with pentastomes may experience reduced pathogenic effects compared to naïve species. *Sistrurus miliarius* appears highly susceptible to infection and lacks a history with any pentastomid, including New World species. Approximately 70% of the *Crotalus*, *Sistrurus*, and *Agkistrodon* species in the USA also appear naïve to pentastome infection. The known intermediate hosts of *R. orientalis* in Florida include members of several genera of geographically widespread lizards and anurans, which help indicate the pitvipers at high risk of pentastome infection. We document several sites in Florida where pygmy rattlesnakes have undergone severe population declines after the arrival of *R. orientalis*. We will present the results of a simulation model designed to predict the effects of pentastome infection on female reproduction. As this pathogen spreads beyond peninsular Florida, it could present a threat to many pitviper species in the USA. Highly abundant synanthropic intermediate hosts, includ-

ing cockroaches, treefrogs, and anoles, could assist the rapid range expansion of *R. orientalis*. Further efforts should be made to better characterize the threats posed by *R. orientalis* spread and infection in pitvipers.

22. Complicated conservation for a far-northern rattlesnake: ecological diversity over a small peripheral range

Larsen, Karl W.
klarsen@tru.ca

Department of Natural Resource Sciences
Thompson Rivers University
Kamloops, British Columbia Canada

All Canadian snake species reach the northern limits of their distribution within the country, and many have limited ranges that invoke the 'peripheral population' concept. While the biological value of these populations long has been used as an argument for their conservation (and peripheral populations in general), the limited ranges often seen within Canada prompt fairly uniform assessments and management strategies, and a 'one size fits all' approach. However, in conducting detailed ecological study of the threatened Western Rattlesnake (*Crotalus oreganus*) over 25+ years, our research program has revealed a striking diversity of life-history traits and behaviors within the very limited Canadian range of the animal, including some that may have developed relatively recently. This variation includes migratory tactics, size at first reproduction, behavioral over short distances, and significantly different habitat use even within the same subpopulations. I will provide a synthesis of this variation, the research behind it, and the possible contributing factors (anthropogenic and natural) that may be at work. I also will outline the further complications in conservation caused by multiple layers legislation. All told, the striking differences witnessed over a 'pocket range' of the species are not altogether unexpected given our understanding of peripheral populations, and they suggest a blanket approach to management may be an oversimplification of a more complex problem.

23. Understanding inter- and intra-population variation in Western Rattlesnake migratory tactics in British Columbia

Howarth, Chloe R.
howarthc17@mytru.ca

Larsen, Karl W.
Department of Natural Resource Sciences
Thompson Rivers University
Kamloops, British Columbia Canada

Bishop, Christine A.
Wildlife Research Division
Environment and Climate Change
Delta, British Columbia Canada

Migration is a phenomenon central to many animals' ecology, allowing individuals to respond to changes in resource availability and exploit habitats favourable for critical life-history processes. Yet, migratory behaviour is not always ubiquitous within populations: multiple tactics can exist, often related to age class, sex, or reproductive condition. For Western Rattlesnakes (*Crotalus oreganus*) at the northernmost extent of their range (British Columbia - BC), seasonal migrations between hibernacula and summer ranges provide access to essential food resources and mates. Multiple studies by our group has revealed immense variation in migratory behaviour and habitat use within and between populations, although the reasons for this variation remain unclear. I will be providing an overview of the current state of knowledge in the field of Western Rattlesnake movement ecology in BC, and I will highlight how our ongoing research aims to address gaps in current understanding. Specifically, using radio-telemetry data from multiple sites collected over 15 years, we are quantifying clear and unique migratory tactics and considering whether these tactics appear linked to site, landscape characteristics, and coarse-scale habitat features across BC. Further, we are considering whether ontogenic shifts in migratory strategies (seen in many other species) occur in our study populations. While several studies have investigated the movements of adult rattlesnakes and a handful has

explored neonatal den location behaviour, little information exists regarding the ontogeny of rattlesnake migration behaviour; in general, juveniles are a grossly understudied rattlesnake demographic. We used radio-telemetry to assess juvenile movement and collected habitat data along their movement pathways. Our preliminary results indicate that the variation seen in adult rattlesnake migration also is present in juveniles, and that these younger animals select habitat with high rock and woody-debris cover at multiple spatial scales. This work is providing vital information for developing conservation strategies that recognize varying types of migratory behaviour in a threatened species.

24. Effectiveness of road mortality mitigation for Western Rattlesnakes (Crotalus oreganus) in Canada

Spruyt, Jade A.
jade.spruyt@outlook.com

Matson, Michelle
Larsen, Karl W.
Department of Natural Resource Sciences
Thompson Rivers University
Kamloops, British Columbia Canada

Bishop, Christine A.
Wildlife Research Division
Environment and Climate Change
Delta, British Columbia Canada

Reptiles, and especially species with life histories characterized by low reproductive rates and low adult mortality - like rattlesnakes - are extremely vulnerable to demographic consequences of road mortality. To combat road mortality and aid in habitat connectivity for vulnerable reptile species, mitigation measures are becoming increasingly common. However, in-depth analyses of their effectiveness on reptile species remain rare, both at the level of direct roadkill and the population persistence level. This study assesses the immediate impact of recently installed ecopassages and directional fencing on a Western Rattlesnake (*Crotalus oreganus*) population in British Columbia, Canada. Using road survey, traffic monitoring, and mark-recapture methods, we analyze trends in the roadkill rates and population size throughout the periods before, during, and after the mitigation was installed. Wildlife cameras in ecopassages allow us to quantify use by Western Rattlesnakes, and compare detection frequencies to other at-risk snake species in the area. Rattlesnake roadkill rates have decreased after mitigation installation, despite there being an increase in traffic. However, rattlesnakes were less likely to use ecopassages than colubrids in the same community, and population estimates do not indicate a clear trajectory of recovery. This study highlights the short-term effects of road mortality mitigation on this federally and provincially threatened species, and improves our understanding of how these animals adjust to the change in their environment. It also emphasizes that long-term monitoring is necessary in order to detect changes in ecopassage use and population size past the initial implementation phase.

25. Anthropogenic activity as an evolutionary driver of phenotypic variation in western rattlesnake behaviour

Macpherson, Matthew R.
mmacph02@mail.ubc.ca

Department of Biology University of British Columbia Okanagan
Kelowna, British Columbia Canada

Ford, Adam T.
Department of Biology, BRAES Institute
University of British Columbia Okanagan
Kelowna, British Columbia Canada

Larsen, Karl W.
Department of Natural Resource Sciences

Thompson Rivers University
Kamloops, British Columbia Canada

Environmental pressures have long been known to drive natural selection of species by influencing either evolutionary change or extinction within species. The initial response of populations to selective pressure is often behavioural, which can have long term effects on the viability and evolution of populations. While behavioural responses can be beneficial, they can also be maladaptive. Maladaptive responses most often occur when populations are subject to conditions that they have not previously encountered during their evolutionary history, such as anthropogenic-induced changes that continue to develop at an unprecedented scale and rate. Among the vertebrate taxa most at risk from human activity are snakes, with several studies already noting the effects of human activity on snake behaviour. However, most studies have only looked at single parameters for snake behavior and human activity, and there are discrepancies in their results. My study is taking a multi-variate approach to investigate which human activities are affecting snake behavior, and which of these behaviors are being significantly affected. To quantify snake behavior, I'm using a combination of radiotelemetry and anti-predator behavior experiments using the Western rattlesnake, a species-at-risk in British Columbia. Human activities such as land use, presence, and persecution are also being measured. I am also comparing behaviors between parents and offspring to determine if these behavioral trends are plastic or genetic. Preliminary results will be presented. By determining which snake behaviors are being negatively affected, to which degree, and by which activities, I'm hoping to inform land-use decisions to better conserve this species.

26. Synthesis and in-silico modeling of novel bisphenyltetrazole drugs for inactivation of rattlesnake venom components

Ridgway, Harry
ridgway@vtc.net

Institute for Sustainable Industries and Liveable Cities
Victoria University, Melbourne, Australia
AquaMem Consulting, Rodeo, New Mexico USA

Matsoukas, John
NewDrug PC, Patras Science Park, Greece Department of Physiology and Pharmacology, Cumming School of Medicine, University of Calgary, Alberta, Canada Institute for Health and Sport, Victoria University, Melbourne, Australia

Kelaidonis, Konstantinos
Moore, Graham
NewDrug PC, Patras Science Park, Greece

Snake venoms comprise a pharmacologically-complex cocktail of peptides, phospholipases, metalloproteases, serine proteases and other lesser characterized components. Venom biochemistry is optimized to act synergistically to swiftly immobilize both predator and prey animals. Venom phospholipases and metalloproteases in particular are cytotoxic across a broad range of prey species where they exhibit acute myotoxic, neurotoxic and inflammatory host responses. The secreted phospholipase A2 (sPLA2) family includes 12 members with highly conserved sequences and catalytic motifs, including low molecular weight (13–17 kDa), presence of Ca2+ cofactors for catalytic activity, and histidine/aspartic acid dyads in the catalytic site. Elevated sPLA2 levels in humans are associated with serious clinical conditions, e.g., systemic viral and bacterial infections (including Covid-19), adult respiratory disease syndrome, atherosclerosis, cancer, and multiple organ trauma. Here we report the facile synthesis and in-silico modeling of a novel class of antihypertensive bisphenyltetrazoles known as "Bisartans." Bisartans are members of the "Sartan" family of drugs currently in wide use around the globe for controlling hypertension and related vascular disorders in cardiac patients. Bisartans are distinguished from all other "monotetrazole" Sartan drugs (e.g., Losartan) by harboring dual anionic bisphenyltetrazole groups connected by a central cationic imidazole ring. Because of their uniquely branched molecular structures, and a net negative charge at physiological pH, Bisartans efficiently coordinate with metal cation cofactors required for catalytic activity of venom metalloproteases and PLA2 neurotoxins. Our computational modeling indicates various Bisartan homologs are promising candidates for inactivation of key rattlesnake venom components, including PLA2 and

various metalloproteinases, such as Atrolysin-C from *Crotalus atrox*. Based on molecular docking studies and molecular dynamics (MD) simulations, we predict stable binding of selected Bisartans in the catalytic domains of rattlesnake venom PLA2, Atrolysin-C and related metalloproteinases.

27. Auto-resistance toward snake venom metalloproteases in North American pitvipers

Hill, Kaleb
kaleb.hill@unco.edu

Mackessy, Stephen P.
School of Biological Sciences
University of Northern Colorado
Greeley, Colorado USA

Analysis of natural snake venom inhibitors in snake blood began in the 18th century with the pioneering work of Fontana on European vipers. Serum resistance to conspecific and heterospecific venoms has subsequently been identified in many snakes, but results vary. Many of these snakes demonstrating resistance are either allopatric or distantly related, making the ecological explanation of this resistance unclear. Auto-resistance to one's own venom for protection against self-envenomation has been suggested to be provided by endogenous antibodies to the venom components or by other serum-based protective molecules. Toxin resistance could develop in venomous organisms resulting from the physiological production of their own venom, but this connection remains unclear, and it is uncertain if mechanisms may be broadly protective against other species' venoms. North America has many species of pitvipers; these snakes are commonly social animals, often communally hibernating and providing maternal care to young, and they are not known cannibalize other snakes. Therefore, predator avoidance does not seem to be a driving factor favoring resistance. In general, North American pitviper venoms contain high levels of snake venom metalloproteases. Using microassays containing venom and serum from 44 individuals representing 3 genera and 17 species of pitvipers, I measured serum ability to inhibit SVMP activity. Serum reduced SVMP activity by 40% or higher when assayed with the snake's own venom. Resistance levels can vary between snakes, and individuals from the same population demonstrated varying levels of resistance to conspecific venoms. Several species displayed broad resistance against multiple species' venoms, while other species had high resistance to only a few venoms. Auto-resistance in pitvipers thus may provide protection against biochemically similar toxins that other snake species produce, and this system can serve as a model for testing auto-resistance in other venomous organisms.

28. Changes in pitviper taxonomy and systematics since Biology of Pitvipers 2

Fenwick, Allyson
afenwick@uco.edu

Department of Biology
University of Central Oklahoma
Edmond, Oklahoma USA

Interest in and work on pitviper evolutionary relationships has been steady since before the first Biology of the Pitvipers conference in 1989. Since Biology of the Pitvipers 2 in 2014, genomic techniques have brought new insight to some persistent questions about group relationships. Progress has been especially marked in New World groups. However, variability in sampling has left some questions unanswered. The most dramatic changes to pitviper taxonomy and systematics have been at the species level: new species have been discovered and clades that were formerly described as single species have been split into species complexes. Discussion continues about the importance of sampling across the entire ranges of proposed species versus relying on detailed genetic data from fewer individuals. This talk celebrates evolutionary work that has been done since Biology of the Pitvipers 2 and looks forward to new directions to better understand this charismatic group of snakes.

29. North American pitviper antivenom: selected venom proteins, fab and affinity pure: past, present, future (1973-2003), and (2003-2023)

Straight, Richard C.
straight.richard@btgsp.com

BTG International Inc.
Salt Lake City, Utah USA

1. Bridging the gaps from "genomics/venomics/proteomics/toxinomics/antivenomics" to medical envenomation therapy(s) and outcomes.

2. Antivenom type: The path to an optimally safe and effective antivenom drug for envenomation therapy is long, multistep and challenging. Consider:

a) Is the proposed antivenom (antibody or non-antibody) rational?
b) Can effectiveness be demonstrated in laboratory studies?
c) Can safety and effectiveness be demonstrated in well-designed clinical studies?
d) Is the proposed antivenom drug commercially viable?
e) Can the drug after well designed Clinical Trials receive regulatory approval?
f) Be prepared to spend 5-20 years from concept to approved commercial product.

3. Envenomations and therapies are complex, often uncontrollable multi-factor processes. Consider:

a) Snake: species/venom proteins/geographic/habitat/ecology/climate/behavior/circumstances.
b) Patient: age and health status.
c) Envenomation: bite site/dose of venom/ time-to-treatment (premedical & medical)/major venom protein toxins/ protein toxin biochemistry and direct and induced pathology(s)/antibody drug-purified (IgG-Fab2-Fab), and non-antibody drug used (dose and dose schedule).
d) Treatment(s) outcomes.

4. Historical example: North American pitviper antivenom: selected venom proteins, fab and affinity pure: past, present, future (1973-2003), and (2003-2023).

Richard Straight, Ph.D.
Director/Site Manager
BTG Specialty Pharmaceuticals
615 Arapeen Drive, Suite #105
Salt Lake City, UT, 84108 USA

D: +1 801 583 8077 x1 | C: +1 801 913 4799 | F: +1 801 583 8076

30. Quo vadis venomics?

Calvete, Juan J.
jcalvete@ibv.csic.es

Evolutionary and Translational Venomics Lab
Instituto de Biomedicina de Valencia, CSIC
Valencia, Spain

The primary function of venom in snake ecology is prey subjugation, with defensive deployment of venom typically considered a secondary function. Defensive bites occur as the result of an interaction between a human and a snake that feels threatened. This ecological problem claims over 100,000 human lives annually worldwide, and a much higher incidence of permanent physical and mental co-morbidities that affect not only the victims but often their entire families. Conceptual frameworks from ecology and evolutionary biology can enter into a mutually enlightening relationship with clinical toxinology, providing the knowledge gathered from -omics technologies, such as "venomics" and "antivenomics" is combined with evolutionary evidence to deliver ecological explanations free of anthropocentric bias. On the other hand, deep knowl-

edge of the identity and taxonomic distribution of the relevant toxins in the context of prey capture and human envenoming, are both key for improving our understanding of both the underlying pharmacology and how to generate effective antidotes with broad neutralisation paraspecificity. The thesis advocated in this talk is that integration and contextualisation of complementary evolutionary, ecological, molecular and clinical toxinological information represents a powerful holistic approach to learn from Nature how to refurbish current-generation antivenoms to tackle the pressing need for effective antidotes.

31. Integrating radio telemetry and accelerometry to monitor the spatial and temporal movement patterns of snakes

DeSantis, Dominic L.
dominic.desantis@gcsu.edu

Tipton, Anna F.
Thompson, Morgan
Department of Biological and Environmental Sciences
Georgia College and State University
Milledgeville, Georgia USA

Clark, Rulon W.
Hanscom, Ryan
Department of Biology
San Diego State University
San Diego, California USA

Mata-Silva, Vicente
Johnson, Jerry D.
Wagler, Amy
Department of Biological Sciences
University of Texas at El Paso
El Paso, Texas USA

Diosdado, Jorge
School of Veterinary Medicine and Science
University of Nottingham, Sutton Bonington Campus
Leicestershire, United Kingdom

Hand-held radio telemetry has historically represented the best available tool for quantifying the movement behavior of relatively small and secretive taxa, such as snakes. However, labor intensive protocols often limit spatial estimates of movement to relatively coarse temporal resolutions. These constraints hinder inspection of fine-scale patterns over long time periods, precluding the detection of shifts in the duration and timing of movement that might occur without changes in spatial metrics. Integrating radio telemetry (RT) and accelerometry (ACT) circumvents these limitations, providing protocols for simultaneous monitoring of spatial and finescale temporal movement patterns in snakes for up to 10 months. Rechargeable batteries also allow repeated use of ACTs, enhancing cost-effectiveness. Here, we report on the recent validation of this technique with Western Diamond-backed Rattlesnakes (*Crotalus atrox*) in west Texas along with ongoing extensions with Timber Rattlesnakes (*Crotalus horridus*) in middle Georgia. Using this integrative approach, researchers can evaluate patterns associated with broader spatial and finer temporal patterns of movement and, as a result, more confidently evaluate the causes and consequences of variation in snake movement behavior. Moving forward, we aim to refine accelerometry protocols in snakes so that additional cryptic behaviors are identifiable beyond general movement and immobility, including foraging and reproductive behaviors.

32. Patterns and drivers of venom variation in the Western Rattlesnake (*Crotalus viridis viridis*)

Smith, Cara
smithcf385@gmail.com

Department of Biochemistry & Molecular Genetics
University of Colorado School of Medicine
Aurora, Colorado USA

Nikolakis, Zachary L.
Ivey, Kathleen
Perry, Blair W.
Castoe, Todd A.
Department of Biology
University of Texas at Arlington
Arlington, Texas USA

Saviola, Anthony J.
Hansen, Kirk C.
Department of Biochemistry & Molecular Genetics
University of Colorado School of Medicine
Aurora, Colorado USA

Schield, Drew R.
Department of Ecology & Evolutionary Biology
University of Colorado
Boulder, Colorado USA

Balchan, Neil
Mackessy, Stephen P.
School of Biological Sciences
University of Northern Colorado
Greeley, Colorado USA

Parker, Joshua
Fresno City College
Fresno, California USA

Snake venoms are trophic adaptations that represent an ideal model to examine the evolutionary factors that shape polymorphic traits under strong natural selection. Venom compositional variation is substantial within and among venomous snake species. However, the forces shaping this phenotypic complexity, as well as the potential integrated roles of biotic and abiotic factors, have received little attention. Here, we investigate geographic variation in venom composition in a wide-ranging rattlesnake (*Crotalus viridis viridis*) and contextualize this variation by investigating dietary, phylogenetic, and environmental variables that covary with venom. Using shotgun proteomics, venom profiling, and lethality assays, we identify 2 distinct divergent phenotypes that characterize major axes of venom variation in this species: a myotoxin-rich phenotype and an SVMP-rich phenotype. We find that while phylogenetic relationships do not explain the geographic distribution of venom variation, dietary availability, and temperature-related abiotic factors are correlated with geographic trends in venom composition. Our findings highlight the potential for snake venoms to vary extensively within species, for this variation to be driven by biotic and abiotic factors, and for the importance of integrating biotic and abiotic variation for understanding complex trait evolution.

33. Long-term comparison of diets in three syntopic rattlesnake species

Pawlicki, Anthony
pawlicki@arizona.edu

Goode, Matt
Saban, Kristen
Wildlife Conservation and Management
School of Natural Resources and Environment
University of Arizona
Tucson, Arizona USA

Fundamental aspects of a species' ecology, behavior, physiology, life history, and evolution can be learned from information on diet; however, research on diet is often considered as less important, because it is thought of as too descriptive or lacking in scientific rigor. The fact that diet is an important aspect of a species' natural history is precisely why we take the time to study it, placing an emphasis on organismal biology with an eye towards the ethological dictum, "know thy animal," put forth by pioneering behavioral ecologists, such as Konrad Lorenz and Nico Tinbergen. Understanding diet leads to a treasure trove of information about animals, ranging from foraging strategies (e.g., sit-and-wait vs. active foraging), to physiological ecology (e.g., energetics), to fitness consequences related to body condition and reproductive frequency. And from an evolutionary perspective, correlates of diet, such as life history strategies, consequences of body size, and functional morphology (head size and gape limitations) can only be examined if diet is well understood. We present data on diet gleaned from fecal analyses of three syntopic rattlesnakes living in rocky foothills of the Sonoran Desert near Tucson, Arizona. The three species, Tiger Rattlesnake (*Crotalus tigris*), Black-tailed Rattlesnake (*C. molossus*) and Western Diamond-backed Rattlesnake (*C. atrox*) vary in several important ways, including habitat preferences, feeding strategies, venom composition, body size, fecundity, defensive behavior, abundance, and phylogeny. Understanding their diets can shed light on why these differences have evolved and whether competitive interactions among the species may be an organizing force in snake assemblages. We obtained fecal samples from all three species over a 20-year period, allowing for examination of changes in diet related to variation in climatic variables, population of origin, sex, body size, and age-class. We discuss our results in the context of ecological differences among the species, and in response to anthropogenic change due to urbanization. Examining diet of syntopic congeners provides insight into species-specific responses to environmental change that would otherwise be difficult to discern.

34. Evidence of non-strike induced chemosensory searching by eastern copperheads (*Agkistrodon contortrix*) during cicada predation

Gull, Henderson Cyrenius
henderson_gull@mymail.eku.edu

Richter, Stephen
Department of Biology
Eastern Kentucky University
Richmond, Kentucky USA

New evidence of active foraging by eastern copperheads (*Agkistrodon contortrix*) contradicts its description as an envenomation-reliant ambush predator. Recent studies on foraging excursions by *A. contortrix* in the Red River Gorge (Kentucky) showed potential use of non-strike induced chemoreception to track cicada nymphs during seasonal emergences. Lab evidence of this behavior was previously found in a congener, the cottonmouth (*A. piscivorus*), but could not be replicated with *A. contortrix*. I hypothesized that *A. contortrix* does actively forage for cicadas using chemoreception without envenomation, and that tongue flick rates would be higher for foraging behaviors than for non-foraging behaviors. Behavior of 12 *A. contortrix* was filmed at a campsite in Kentucky during foraging excursions in the summer of 2020. Recordings were analyzed for tongue flick rates and presence or absence of seven behavioral activities. Each minute of recording was assigned to a behavioral category (ground movement, climbing, post-consumption movement, pausing, periscoping, eating, and fighting) based off behaviors within the minute and ecological context of the recording. I found statistically significant differences between tongue flick rates of foraging and non-foraging related behaviors, differences among distinct foraging categories, and no differences in tongue flick rate between non-foraging categories. I also compared predatory movement tongue flick rates between successful events of tracking cicadas to unsuccessful attempts and found a significant difference in tongue flick rates. My results support the hypothesis that elevated tongue flick rates in movement categories appear to be evidence of active chemoreceptive searching without reliance on envenomation cues. Previous studies evaluating this behavior in *A. contortrix* did not find evidence supporting its use, and this behavior has not been previously documented in a wild population. Documentation of this behavior provides ecological context for how this behavior is used during predation, and provides knowledge useful in supporting future laboratory replication of the behavior.

35. Old wine in new bottles: viewing modern pitviper conservation through the lens of legacy data

Davis, Mark A
davis63@illinois.edu

Illinois Natural History Survey, Prairie Research Institute
University of Illinois Urbana-Champaign,
Champaign, Illinois USA

Department of Natural Resources and Environmental Sciences
University of Illinois at Urbana-Champaign
Urbana, Illinois USA

Pitvipers are among the most imperiled vertebrate groups in the world, and causes for their declines range from loss of habitat to human persecution. Not only is their venom a natural biological resource for basic research and therapeutic agents, but their role as key predators and ecosystem engineers is unequivocal. Conservation of these incredible organisms is critical, yet effective conservation is often hindered in numerous ways. First, pitvipers are often long-lived with overlapping generations, which may obscure population trends. Second, modern funding and research generally follows 3-5 year cycles, often rendering it difficult to acquire data on a scale synchronous with the species' life history. Finally, stochastic events can profoundly impact populations and yet fully and accurately assessing their impacts require data from before, during, and after the event. These factors underscore the tremendous value long-term datasets and argue for decadal-scale data acquisition. Several legacy datasets exist for pitvipers, and here we will explore the inferences gleaned, the advances gained, and the opportunities that have arisen to understand the impacts of stochastic events on natural populations. Here I will explore several of these legacy datasets, detailing the novel insights derived from them, future applications of these data, and how they can inform pitviper conservation.

36. Demographic forecasting of Sistrurus rattlesnakes using Integral Projection Modeling

Dreslik, Michael J.
dreslik@illinois.edu

Kessler, Ethan J.
LaGrange, Seth M.
Illinois Natural History Survey
University of Illinois Urbana-Champaign
Champaign, Illinois USA

Farrell, Terence M.
Department of Biology
Stetson University
DeLand, Florida USA

Baker, Sarah J.
Department of Biology
McNeese State University
Lake Charles, Louisiana USA

Understanding an organisms' biology necessitates deep knowledge of its life history patterns and how those traits interact. Although we have a rapidly growing body of knowledge on the life history of pit-vipers, many species remain data deficient in one or more parameters or are represented by single estimates. Full demographies are known for few species, likely because of the relatively reclusive nature of snakes. Thus, obtaining sufficient sample sizes is difficult, and approaches to studying pit-viper demographics necessitate long-term commitments. In addition, traditional demographic analyses focus on stage- or age-based vital rate estimates, neither of which best represents maturity in reptiles. Newer methods such as Integral Projection Modeling (IPM) use continuous, size-based estimates of vital rates and are likely more appropriate for ectotherms. We compare the demography of two *Sistrurus* species, *S. catenatus* and *S. miliarius*, from long-term data sets using Bayesian survival and regression methods within an IPM framework. Although sister taxa, both species have

different range extents, across vastly different habitats, and likely have adaptational differences in survival, fecundity, and maturity. Our data will also provide insight into the diversity and plasticity of pitviper life history strategies.

37. Notes on reproductive behavior and birth of captive Two-Striped Forest Vipers (*Bothrops bilineatus*) from Ecuador

Barragán-Paladines, María Elena
mbarraganp@vivarium.org.ec

Executive Director, Ecuadorian NGO
Fundación Herpetológica Gustavo Orcés-Vivarium de Quito
Quito, Ecuador South America
www.vivarium.org.ec

In this talk I will describe reproductive behavior observed on two occasions in captivity of the Two-Striped Forest Viper (*Bothrops bilineatus*). This information is based on two copulations and two litters of this species born in the Quito Vivarium. As a complement, a review of data on dead specimens from the organization's reference collection will be included. In the year 2021, an extensive copulation period of at least 6 hours was observed, reported in the afternoon and after causing a gentle artificial rain of warm water. The copulation in 1996 reported male activity in days prior to copulation. Mating periods in the different years were recorded (May 1995 and September 2021). Although males and females were kept together in the same exhibit, this behavior had not been previously reported. After approximately 8 months of gestation, in both cases, the female descended to a branch located about 20 cm from the floor of the exhibit to give birth. In both cases, we do not know the exact time of delivery, although the babies in both cases were found in the morning, a few centimeters from the female, on branches located 20-30 cm from the exhibit floor. Once babies were found, they were separated from the mother and kept in individual cages. The male (from mating in 2021) was kept in the same exhibit, while the mother remained on the same branch until the next day when she climbed to the highest branches of the exhibit. No parental care behavior was noted toward the young.

38. Tiger Rattlesnake (*Crotalus tigris*) population demography based on 20 years of capture-recapture data

Goode, Matt
mgoode@arizona.edu

Pawlicki, Anthony
Wildlife Conservation and Management
School of Natural Resources and Environment
University of Arizona
Tucson, Arizona USA

Hanscom, Ryan
Department of Biology
San Diego State University
San Diego, California USA

Accurate estimation of demographic parameters is critical to our understanding of population dynamics, ecology, evolution of life history strategies, and effective conservation and management of wildlife populations. Reliable demographic parameter estimates rely on long-term monitoring data, typically consisting of marked individuals that are captured and recaptured over time. Although wildlife demography has focused primarily on game species, primarily to establish harvest limits, the need for robust monitoring and demographic analyses of non-game species has become increasingly common, especially for at-risk species. Among wildlife species, there remains an obvious lack of information regarding population demography of snakes. This lack of information is likely due to a combination of taxonomic chauvinism and the secretive nature of snakes, leading to low detection probabilities (i.e., low recapture rates) that produce parameter estimates with large error terms. Although considered rare, Tiger Rattlesnakes (*Crotalus tigris*) can be locally abundant, especially in rocky foothill environments in the Sonoran Desert. At our long-term study site near Tucson, where we have

been studying the effects of urbanization on snakes and lizards since 2002, Tiger Rattlesnakes are the most common of 21 total snake species observed. From 2002-2021, we captured 877 Tiger Rattlesnakes, which we recaptured a total of 372 times (range 1-9). We produced annual estimates of population size/density, survival, and realized population growth using Program Mark and RMark. In addition, we examined the association of body size and growth with survival. We interpret results in the context of increasing urbanization and discuss insights into Tiger Rattlesnake ecology gleaned from demographic analyses.

39. Rattlesnake feeding ecology: using high frequency accelerometry to capture feeding events across *Crotalus*

Hanscom, Ryan J.
rhanscom6545@sdsu.edu

Hill, Jessica
Clark, Rulon W.
Sukumaran, Jeet
Marbach, Tyler
Department of Biology
San Diego State University
San Diego, California USA

DeSantis, Dominic L.
Tipton, Anna F.
Thompson, Morgan
Department of Biological and Environmental Sciences
Georgia College and State University
Milledgeville, Georgia USA

Higham, Tim
Department of Ecology, Evolution, and Organismal Biology
University of California, Riverside
Riverside, California USA

Rattlesnakes are cryptic animals that are rarely encountered and difficult to directly observe because they spend large portions of their lifetime hidden and are sensitive to the nearby presence of humans. Some methodological approaches (e.g., field-based surveillance while a rattlesnake remains in ambush) have been developed to assemble large datasets of different aspects involved in the feeding ecology of rattlesnakes (e.g., encounter rates, strike success rates, prey species encountered, etc.). However these methods are limited and labor intensive. Over the past decade, animal-borne accelerometers have been used by a variety of ecologists to quantify activity and moment-to-moment behavior of free ranging animals. Accelerometry can provide new insight into the cryptic lives of rattlesnakes, and here, we propose a new method to quantify feeding events, and in turn the foraging rates, of rattlesnakes. Accelerometers were externally attached to individual rattlesnakes (3 species; *C. horridus*, *C. oreganus*, and *C. viridis*) and logged acceleration data at rates of 25 Hz. We used direct observations in the lab to validate our classification model to detect the feeding event of a rattlesnake via acceleration patterns. The following behavioral states during a rattlesnake feeding event were classified: strike, strike-induced chemosensory searching, carcass investigation, carcass dragging, ingesting, and swallowing. By validating this method and training supervised machine learning models to automate classification of a feeding event in rattlesnakes by using this lab observation approach, we believe we will be able to accurately determine the foraging rate of free ranging rattlesnakes.

40. The genomics of venom ontogeny in rattlesnakes

Rokyta, Darin R.
drokyta@bio.fsu.edu

Florida State University
Department of Biological Science
Tallahassee, Florida USA

The major axis of venom variation in many pitviper species is related to animal age; adults and juveniles often show divergent expression patterns that result in compositionally and functional different venoms. We will first explore general patterns of venom variation in pitvipers native to the eastern United States and see that, although variation is the norm, the presence and extent of ontogenetic variation is highly variable among species. *Crotalus adamanteus* and *Crotalus horridus*, in particular, show striking patterns of venom ontogeny that include both gradual and abrupt changes in expression patterns with age. To determine the mechanisms underlying venom ontogeny in *C. adamanteus*, we applied cutting-edge genomic and epigenomic techniques to identify the regulatory control of venom expression in both adults and juveniles, then used comparative-genomic analyses to reveal how genes move into and out of the ontogenetic regulatory network.

41. It's complicated! Ontogenetic variation in venom composition of rattlesnakes

Hayes, William K.
whayes@llu.edu

Fox, Gerad A.
Kelln, Wayne
Department of Earth and Biological Sciences
Loma Linda University
Loma Linda, California USA

Gren, Eric C. K.
University of Montana, Bitterroot College Campus
Bitterroot Community Science Center
Hamilton, Montana USA

Cochran, Chip
Travis, Zachary D.
Department of Earth and Biological Sciences
Loma Linda University
Loma Linda, California USA

Dugan, Eric A.
Dugan Biological Services, LLC
Upland, California USA

Lee, Kyung H.
Neurology Residency
Dartmouth Hitchcock Medical Center
Lebanon, New Hampshire USA
Cardwell, Michael D.
Biology Department
San Diego State University
San Diego, California USA

Goode, Matthew J.
School of Natural Resources
University of Arizona
Tucson, Arizona USA

Morris, Cale
Heritage Academy
Mesa, Arizona USA

When young, the small size of rattlesnakes severely constrains the prey they can capture and consume. As the snakes grow their larger size and greater venom supply expands their range of prey intake, often from smaller ectothermic prey to larger, endothermic prey. Smaller snakes are also subject to a greater range of

predators. We examined ontogenetic changes in venom composition and complexity of seven southwestern North American rattlesnake species to test four hypotheses: that (1) change is greater in species or populations possessing largely proteolytic (type I or type B) rather than largely neurotoxic (type II or type A) venom; (2) change is greater in species that transition from reptile to mammal prey than those which specialize on mammals throughout their life; (3) change occurs continuously as an individual grows, even after attaining reproductive size; and (4) venom complexity is moderate in small individuals, greatest during the period of ontogenetic shift in toxins, and least in adults. We separated venom components of individual venoms using reverse-phase high-pressure liquid chromatography (RP-HPLC), and quantified protein content of individual chromatogram peaks. We identified specific toxins using mass spectrometry. To associate ontogenetic changes in venom with diet, we dissected prey material from the stomachs and/or guts of snakes. Results indicated that ontogenetic change in venom composition exists in all seven species. Moreover, we found support for all but one hypothesis. Hypothesis 2 proved wrong, as the most profound ontogenetic change occurs in *C. ruber*, which feeds largely on mammals throughout its life. Collectively, our findings demonstrate the remarkably varied patterns of venom ontogeny that exist within a closely related group of vipers, and even within a single species, leading to few, if any, general patterns. They also underscore the likely adaptive importance of venom composition changes coincident with dietary shifts.

42. The genetics of sensory perception in the Eastern Diamondback Rattlesnake

Hogan, Michael
mhogan@bio.fsu.edu

Rokyta, Darin
Department of Biological Sciences
Florida State University
Tallahassee, Florida USA

Venom and other traits involved in subduing and digesting prey are only relevant following the detection of prey, since the act of predation initiates when the predator perceives the presence of a potential prey item. Prey-based selective pressures should therefore drive the evolution of genes responsible for prey detection, resulting in signals of adaptive evolution in sensory genes comparable to venom genes. Pitviper sensory systems are among the most biologically impressive and phenotypically unique in the animal kingdom, consisting of four primary senses: trichromatic color vision; bi-focal thermal or infrared perception via two specialized facial pits; mechanoperception enabling the detection of low-frequency vibrations; and chemoperception implementing both a functional olfactory bulb and forked-tongue vomeronasal system. Of these senses, chemoperception represents the biggest gap in our genetic understanding of pitviper sensory perception. Using a systematic homology and RNA-seq guided approach, we annotated all putative sensory genes present in the genome of the eastern diamondback rattlesnake (*Crotalus adamanteus*), highlighting an extreme diversity of chemoreceptor genes (~1000+ putatively functional genes) compared to the other senses. Both chemosensory and venom genes are organized into tandem-repeat-arrays in the genome, which very likely enabled snakes to rapidly diversify and expand these predatory genes. Chemoreceptor gene phylogenies were generated from coding sequences to test for signals of gene expansion and positive selection corresponding with predicted protein structure, identifying biologically relevant and key chemoreceptor genes for this species. Chemoreceptor gene expression variation relating to sex and age revealed biases relating to development and mate detection. This represents the most thorough genetic characterization of snake chemoperception to date and provides a foundation for multispecies gene comparisons within a bioinformatic framework.

43. Lessons learned from 20 years of rattlesnake field studies: a perspective on why studying animals in nature is critical for understanding biological systems

Clark, Rulon W.
rclark@sdsu.edu

Department of Biology
San Diego State University
San Diego, California USA

As several prominent herpetologists have argued previously, the field of natural history (i.e., observational or basic research on the behavior or ecology of organisms in nature) is in trouble. It is increasingly difficult to find funding or institutional support for non-applied research, especially at the organismal level. This problem stems in part from an underappreciation for the value of natural history research. Controlled experimental studies are useful only when scientists have developed a deep enough understanding of a natural system to be able to formulate relevant and testable hypotheses. The understanding of natural systems itself comes from observational natural history research (which can be quantitative or qualitative), but studies of this type do not often get disseminated in the scientific literature. In this talk, I hope to illustrate with examples that natural history often provides the raw material that is refined into empirical research, and discuss ideas for increasing the quantity and quality of natural history research.

44. Sidewinders vs. robots: how a herpetologist learned to love physics

Mendelson III, Joseph R.
jmendelson@zooatlanta.org

Zoo Atlanta
Atlanta, Georgia USA

Georgia Institute of Technology
Atlanta, Georgia USA

Our collaborative team based at Zoo Atlanta and Georgia Tech, working with a number of additional institutions, has produced a series of about 10 papers involving the interface of snakes and sand substrates, focusing heavily on sidewinders (*Crotalus cerastes*). The team included biologists, physicists, and a variety of types of engineers. One of our most novel approaches was to develop a robotics model to test alternate gaits, for example, in a non-biological sidewinder. I will review the highlights of this series of papers and discuss the sometimes bumpy, sometimes hilarious, and often illuminating experiences of working with such a diverse group of specialists—an intellectual Dream Team if there ever was one.

Poster Abstracts

1. Human-snake conflict mitigation: policies for relocating nuisance snakes in the U.S.

Bedard, Robin
rbedard@calpoly.edu

Goode, Alex
Martin, Maddy
McIntyre, Tess
Rottenborg, Megan
Taylor, Emily N.
Biological Sciences Department
California Polytechnic State University-San Luis Obispo
San Luis Obispo, California USA

In recent years, relocation of nuisance snakes has become a widespread practice in the United States, aided by social media pages connecting people to volunteer and for-profit snake relocators. However, this has led to a growing disconnect between the individuals performing the relocations and the state wildlife agencies responsible for the policies, permitting, and training regarding nuisance snake management. Misinformation about permitting or training required for snake relocation abounds, and most relocators are unsure about requirements and often struggle to find relevant information and resources from the wildlife agencies responsible for policies. Additionally, many relocators use procedures that intentionally or unintentionally disregard the health and survival of the snakes and are instead intended only to mitigate human-wildlife conflict. To bridge this disconnect, we conducted a study to obtain data on policies, permitting, and training from the sole wildlife official responsible for nuisance snake relocations in each U.S. continental state. We compared the policies gathered from these officials with data on actual procedures being performed by snake relocators that we uncovered with another survey, including the relocators' understanding of required permits, training, and best practices (e.g., how far to relocate snakes and other items). The final product of this study will be a database connecting relocators with policies and best practice information to assist them in conducting relocations legally, safely, and in the best interest of the snakes. This project will mitigate human-wildlife conflict by benefitting everyone involved, including the wildlife agencies, snake relocators, and the snakes being relocated.

2. Development of an in vitro profiling platform for the mechanistic assessment of cytotoxic activities of (crotalid) snake venoms

Bittenbinder, Matyas A.
m.a.bittenbinder@vu.nl

Division of BioAnalytical Chemistry, Department of Chemistry and Pharmaceutical Sciences, Amsterdam Institute of Molecular and Life Sciences (AIMMS), Faculty of Sciences, Vrije Universiteit Amsterdam, The Netherlands

Centre for Analytical Sciences Amsterdam (CASA), Amsterdam, The Netherlands
Naturalis Biodiversity Center, 2333 CR Leiden, The Netherlands

van der Wel, Nicole N.
Department Cell Biology and Histology, Amsterdam University Medical Centers, University of Amsterdam, Amsterdam, The Netherlands

Department Electron Microscopy Center Amsterdam, Amsterdam University Medical Centers, University of Amsterdam, Amsterdam, The Netherlands

Jennings, Paul
Division of Molecular Toxicology, AIMMS, Faculty of Sciences, Vrije Universiteit Amsterdam, The Netherlands

Kool, Jeroen
Centre for Analytical Sciences Amsterdam (CASA), Amsterdam, The Netherlands
Naturalis Biodiversity Center, Leiden, The Netherlands

Vonk, Freek J.
Division of BioAnalytical Chemistry, Department of Chemistry and Pharmaceutical Sciences, Amsterdam Institute of Molecular and Life Sciences (AIMMS), Faculty of Sciences, Vrije Universiteit Amsterdam, The Netherlands

Centre for Analytical Sciences Amsterdam (CASA), 1098 XH Amsterdam, The Netherlands

Naturalis Biodiversity Center, 2333 CR Leiden, The Netherlands

Snakebite is a global tropical disease that has long had huge implications for human health and well-being, with annual mortality ranging from 81,000 to 138,000. Although most life-threatening pathologies in snakebite victims result from hemotoxins and neurotoxins, cytotoxins are the main cause of life-long disabilities such as blindness and amputations. In order to better understand cytotoxic effects that venoms potentially can have on bite victims it is important to study the composition and biological function, both of crude venoms and their individual venom components. This research focuses on investigating methods to study mechanistic (molecular) mechanisms behind cytotoxicity including crotalid venoms. Varying activity patterns were observed for the panel of species used in this study. Additionally, MS data of the active components will be discussed in relation to the Viperidae and Elapidae. This research focused on investigating methods to study mechanistic (molecular) mechanisms behind cytotoxicity using 10 different medically relevant snake species. Combined, the integrated dataset provides us with an in vitro profiling platform that allows for the mechanistic assessment of cytotoxic activities of snake venoms.

3. Evolution of phospholipase A-2 venom proteins across Rattlesnakes (genera *Crotalus* and *Sistrurus*)

Broussard, Emilie M.
ebroussard@bio.fsu.edu

Hogan, Michael P.
Rokyta, Darin R.
Department of Biological Sciences
Florida State University
Tallahassee, Florida USA

Phospholipase A-2 (PLA2) proteins belong to a gene family of enzymes that are found across the animal kingdom and have been recruited as a toxin in many animal venoms. Rattlesnake (genera *Crotalus* and *Sistrurus*) venom consists of a cocktail of proteins and toxins that include a repertoire of PLA2s. These PLA2s contribute to the split in venom type observed in rattlesnakes between Type I and Type II venom, which have different pharmacological effects. To better understand the evolutionary history of this ecologically important gene family in rattlesnakes, we searched the transcriptomes of 198 individuals from 35 subspecies of *Crotalus* and *Sistrurus* for PLA2 sequences. Recovered sequences were used to construct a phylogeny, which identified clades for the acidic and basic subunits of the PLA2 proteins, as well as a clade of the neurotoxic Mojave Toxin sequences which characterize the Type 2 venom. Domains and functional sites of the recovered sequences were identified and Fixed Effects Likelihood (FEL) and Mixed Effects Model of Evolution (MEME) tests were performed to identify sites under purifying and positive selection.

4. You can't see me: background matching in the Western Diamond-backed Rattlesnake

Da Cunha, Oceane
odacunha@miners.utep.edu

Fournier, Corentin
Horne, L. Miles
Mata-Silva, Vicente
Johnson, Jerry D.

Department of Biological Sciences
University of Texas at El Paso
El Paso, Texas USA

In ectotherms, coloration is under heavy selection as it is linked to two essential functions for survival: thermoregulation and crypsis. As an ectothermic species and an ambush predator, rattlesnakes rely on their coloration for crypsis making them excellent models to study background matching crypsis. The Western Diamond-backed Rattlesnake (*Crotalus atrox*) possesses the photoreceptors necessary to see colors, UV, in addition to be able to perceive infrared. Presuming this species could perceive colors, it would be advantageous for *C. atrox* to select backgrounds that match their own coloration to enhance crypsis. To investigate this hypothesis, pictures of 14 radio-tracked *C. atrox* and their backgrounds were taken at each relocation site when visible with a modified camera with visible and UV filters. For each picture taken, a picture of a random background within the snake home range was also taken for comparison. Pictures were converted to the relative photon catches of a human (*Homo sapiens*) and a Blue Tit (*Cyanistes caeruleus*). Achromatic and chromatic just noticeable differences (JND) were then calculated to compare snakes and their backgrounds, and snakes and a randomly chosen background. On average, chromatic JNDs were higher between snakes and a randomly chosen background than their selected backgrounds for both human and avian photon catches. However, these differences were not statistically significant. On the other hand, achromatic JNDs were significantly different between selected backgrounds and random backgrounds showing that rattlesnakes might choose to limit contrast differences between themselves and their backgrounds. Rattlesnakes appear to always be chromatically indiscriminable for human eyes in their natural habitat but appear to be distinguishable for avian eyes under photopic conditions. These preliminary results suggest that *C. atrox* and other rattlesnakes might select their habitat to enhance their crypsis as shown in other taxa.

5. Conservation planning for Illinois' pitvipers through expert solicitation

Dreslik, Michael
dreslik@illinois.edu

Kuhns, Andrew R.
Illinois Natural History Survey
1816 South Oak Street
Champaign, Illinois USA

Crawford, John A.
National Great Rivers Research and Education Center
One Confluence Way
East Alton, Illinois USA

With global biodiversity declining at an alarming rate, numerous species are listed as conservation-dependent. In addition to habitat loss, fragmentation, disease, and global climate change, Pitvipers often face additional threats from continued human persecution and a general malaise of directing public resources toward their conservation. Within the United States, two native species are protected under the Endangered Species Act of 1973. In 2000, Congress created the State Wildlife Initiative Grant program, requiring each state to maintain a Wildlife Action Plan, which identifies sensitive species needing conservation action. Unfortunately, conservation action has been haphazard and limited due to the number of species listed across taxa, available funds, and logistical feasibility. Therefore a need for hierarchical priorities providing a unified course of conservation action is necessary. We ascertained the current knowledge base, perceived threats, data gaps, actionable items, and conservation synergies for the Eastern Massasauga and Timber Rattlesnake in Illinois through expert solicitation (in a structured decision-making framework). Our results will help guide conservation actions toward species recovery or stabilization of current declines.

6. Creating and implementing a functional body condition index (BCI) for montane rattlesnakes (*Crotalus*): an investigation of how habitat dynamics, diet, and wildfire affect snake health

Drukker, Saunders
ssd50@txstate.edu

Forstner, Michael R.J.
Department of Biology
Texas State University
San Marcos, Texas USA

Holycross, Andrew T.
Life Science
Mesa Community College
Mesa, Arizona USA

In several areas of ecological research, body condition indices (BCI) have been used as a method for assessing the health of individual organisms and inferring the health of populations as a whole. Currently, little work has been done towards creating any sort of BCI for snakes of the genus *Crotalus*. This project uses data from several research seasons in the Peloncillo, Animas, and Sierra San Luis mountain ranges of the US and Mexico, to create a working BCI for several species in this genus. Using this data and data collected regarding habitat conditions, stable isotope values, and more, a functional BCI may be used to determine which factors negatively or positively influence snake health. Such a metric becomes increasingly important given the effects of climate change, and volatile fire regimes. In July of 2019, the Miller Fire burned ~5,761 acres of forest and grassland in the Peloncillo Mountains of New Mexico, giving us a unique opportunity to study what influence it may have had on snake body condition.

7. Movement, home range size, and habitat use of Eastern Black-tailed Rattlesnakes (*Crotalus ornatus*) in the northern Chihuahuan Desert

Emerson, James D.
jamesdavidemerson@gmail.com

DeSantis, Dominic
Biological and Environmental Sciences
Georgia College & State University
Milledgeville, Georgia USA

Johnson, Jerry
Department of Biology
University of Texas at El Paso
El Paso, Texas USA

Despite its wide distribution throughout the northern Chihuahuan Desert, extraordinarily little is known about the ecology or behavior of Eastern Black-tailed Rattlesnakes (*Crotalus ornatus*). The primary literature for black-tailed rattlesnakes was largely based on research conducted on the former conspecific (*C. molossus*), thus the re-validation of *C. ornatus* widened the void in our understanding of the species. The aim of this study was to elucidate movement patterns, home range size, and habitat use by *C. ornatus* in the northern Chihuahuan Desert of Far West Texas. Radio-telemetry was used to monitor individual snakes for at least one active season (March–October) from May 2015 through August 2018. Mean (±1 SE) home range size for all individuals was 22.84 ± 4.49 ha and mean daily distance moved was 9.28 ± 0.93 m/day. Male snakes had larger home range sizes, larger core use areas, and higher daily distance moved than female snakes. On a monthly basis, male movement peaked in August and female movement was statistically similar throughout the active season. Multinomial logit models were used to analyze habitat use patterns of *C. ornatus*, while controlling for snake, habitat availability, and season. Despite low availability within snake home ranges, most observations of snakes occurred in arroyos or on rocky slopes. Microhabitat was also used non-randomly, with snakes seeking cover in rocky refugia or under dense vegetation, rather than areas containing high proportions of gravel or plant litter. This study presents the first detailed information about habitat and microhabitat use, along with patterns of movement and home range size for the recently re-validated *C. ornatus*.

8. Feeling rattled? Resident attitudes, urban habitat features, and patterns of snake removals in the Phoenix Metropolitan Area

Enloe, Annika
amenloe@asu.edu

College of Integrative Science and Arts
Arizona State University
Mesa, Arizona USA

Brown, J.
Julie Ann Wrigley Global Institute of Sustainability
Arizona State University
Tempe, Arizona USA

Larson, K. L.
Julie Ann Wrigley Global Institute of Sustainability
Arizona State University
Tempe, Arizona USA

School of Geographical Sciences and Urban Planning
Arizona State University
Tempe, Arizona USA

Bateman, H. L.
College of Integrative Science and Arts
Arizona State University
Mesa, Arizona USA

Understanding how wildlife is adapting to urban environments is critical as urbanization contributes to habitat change and fragmentation globally. Patterns of human-wildlife interactions can be informative when trying to ascertain information about urban wildlife and possible conflicts with humans. In Phoenix, Arizona, these conflicts commonly involve reptiles, especially venomous and nonvenomous snakes. Researchers have partnered with a local business, Rattlesnake Solutions, LLC, which removes and relocates snakes from residential yards and businesses in the greater Phoenix area. This partnership has provided records of snake removals to pair with social and ecological datasets. During 2021, we measured habitat along 100m front yard transects in residential areas with snake removals and from randomly paired residential areas. Analyses have shown a positive relationship between snake removals and habitat variables relating to available cover, vegetation, and tidiness of the yard. Further analyses are underway to assess these relationships among snake taxa. Along with habitat features, social data was collected on perceptions of snakes. Clients of Rattlesnake Solutions, LLC, were asked to answer a short survey regarding attitudes towards snakes that mirrors questions asked in the 2021 Phoenix Area Social Survey (PASS). From the social surveys, we found that both clients of the snake removal service and PASS respondents felt snakes were important part of the desert ecosystem. Although PASS respondents were split on if it's okay to kill snakes, a majority of clients of the removal service responded it was not okay to kill snakes, perhaps suggesting that clients are using the snake removal service as a wildlife stewardship action.

9. Investigating personality in venomous vipers: individual rattlesnakes exhibit consistent behavioral responses in defensive and exploratory contexts

Gibert, Ricardo G.
rggibert@sdsu.edu

Maag, Dylan W.
Sanders, Lea N.
Clark, Rulon W.
Department of Biology
San Diego State University
San Diego, California USA

A burgeoning literature in animal behavior has demonstrated that most animals exhibit consistent individual variation in core behavioral traits, or personality. However, the taxonomic spread of animal personality studies is uneven, with some ecologically important and diverse taxa still unstudied. Some of these understudied groups, such as venomous snakes, are also frequent targets of mitigation due to human/wildlife conflict, and conservation researchers have been increasingly focused on developing a general understanding of how individual personality, or temperament, mediates wildlife responses to management or mitigation actions. In this study, we used 20 captive Western Rattlesnakes (*Crotalus oreganus*) in standardized assays to test for repeatable behaviors (i.e., personalities) between individuals and examine possible relationships in personality traits across contexts (i.e., behavioral syndromes). Repeatability of behaviors was assessed over five repeated trials consisting of a handling assay, an open field test, and a threat assay. We found several behaviors related to exploration/avoidance, activity level, and boldness/shyness showed significant repeatability. However, we found no evidence for behavioral syndromes across contexts. Our analysis shows that, similar to many other species and taxonomic groups, viperid snakes also display individual personality traits when tested under standardized conditions, and we discuss the implications of this finding for mitigation, conservation, and comparative analyses across broadly similar species groups.

10. Extrinsic factors affecting the survival of *Sistrurus catenatus*

Hiner, Blaine
bahiner@illinois.edu

Dreslik, Michael J.
LaGrange, Seth
Illinois Natural History Survey
University of Illinois at Urbana-Champaign
Champaign, Illinois USA

Baker, Sarah
Science Department
McNeese State University
Lake Charles, Louisiana USA

Combatting declines often requires data targeted at specific threats whether intrinsic or extrinsic. Unfortunately, such data are difficult to obtain for most snake species due to their cryptic nature. Although the Eastern Massasauga exhibits great plasticity in habitat preference range-wide, they have suffered from habitat loss and fragmentation. Survival estimates are critical for understanding population dynamics at individual sites. Extrinsic factors affecting survival could include the time between management burns, flooding events, aberrant seasonal climate, and differences in growing seasons. Using a long-term capture-mark-recapture dataset (1999 - present), we will determine if extrinsic management and climate factors affect survival rates in the Eastern Massasauga. Analyzing environmental factors could prioritize resources toward more site-specific habitat management to mitigate environmental factors negatively impacting survival. Potential habitat management recommendations could include increased riparian buffers near Eastern Massasauga sites to decrease intense flood frequency or alterations in burn intervals.

11. Size and fidelity of annual home ranges for the Timber Rattlesnake (*Crotalus horridus*) in west-central Illinois

Jesper, Andrew
ajesper2@illinois.edu

Illinois Natural History Survey University of Illinois Urbana-Champaign
Champaign, Illinois USA

Armesy, Ian
Eckert, Scott
Department of Biology and Natural Resources
Principia College
Elsah, Illinois USA

Quantifying the home range and space-use of animals is fundamental in understanding their life history and ecology and implementing effective conservation and management strategies. The threatened Timber Rattlesnake (*Crotalus horridus*) has one the largest geographic ranges of any North American snake, persisting across much of the eastern U.S and occupying a diversity of habitat types. While numerous studies focus on the home range and movements of *C. horridus*, particularly in the northern/eastern portions of their range, little information exists for populations in the upper Midwest which occupy predominantly old-growth deciduous forests. Furthermore, there is a general lack of information describing the fidelity *C. horridus* has to its annual home ranges. To fill the knowledge gap, we report the size of, and fidelity to, annual home ranges for 31 *C. horridus* (13 female, 16 male) radio-tracked daily for one or more active seasons from 2015 to 2019 in west-central Illinois.

12. Factors influencing failure strikes to terrestrial and aquatic prey animals in *Gloydius* spp. in the field

Kodama, Tomonori
asukamasuku@gmail.com

Mori, Akira
Department of Zoology
Graduate School of Science
Kyoto University
Sakyo, Kyoto, Japan

Water and air have different physical properties. Accordingly, behaviors of animals within each medium largely differ. Therefore, researchers have attempted to clarify how different the feeding behavior and performance of species feeding in both media are. However, no study has examined differences of factors influencing the outcome of snake-prey interactions under natural conditions in different media or at the boundary between them. Recent field studies on rattlesnake-mammalian prey interactions have demonstrated that predation success is determined not only by performance of strikes (acceleration or velocity) but also by strike accuracy (whether strike reaches the place where the prey is positioned) and reactions of prey (latency to start to dodging). In this study, we focused on predatory strikes of two species of *Gloydius* in Japan, *G. blomhoffii* and *G. tsushimaensis*, feeding on various vertebrates from fish to mammals. Our goal is to clarify any difference of strike kinematics, strike success rate, and factors influencing the outcome between terrestrial strikes to frogs and mammals (TS) and aquatic strikes to fish (AS) under natural conditions. We used combined methods of radiotelemetry and fixed-videography to record predatory strikes. TS and AS were kinematically different from each other. Some of AS were lateral strikes and included successive strikes, whereas all TS were performed as a single frontal strike. Strike success rate was lower in AS than in TS. In failure strikes, the rate of accurate strikes was lower in AS than in TS. In these accurate strikes, reaction time of prey was shorter in AS than in TS. These findings indicate that the factors influencing strike outcome are different between TS and AS. Pitvipers may have difficulties especially in recognizing aquatic prey animals accurately and thus adopt different striking tactics in aquatic strikes. We discuss implications of the differences between TS and AS.

13. Winter behavior of rattlesnakes at Indio Mountains Research Station, Hudspeth County, Texas

Mata-Silva, Vicente
vmata@utep.edu

Department of Biological Sciences
University of Texas at El Paso
El Paso, Texas USA

Da Cunha, Oceane
Rocha, Arturo
DeSantis, Dominic L.
Department of Biological and Environmental Sciences
Georgia College and State University
Milledgeville, Georgia USA

Rattlesnakes spend a considerable amount of time below the surface during the winter period (the inactive period) at both high elevations and high latitudes. Therefore, our goal for this study is to determine the characteristics of their overwintering sites, which are critical for their survival in the Chihuahuan Desert of the Trans-Pecos region. Herein, we present overwintering data from individuals of Western Diamond-backed Rattlesnakes (*Crotalus atrox*), Rock Rattlesnakes (*C. lepidus*), and Eastern Black-tailed Rattlesnakes (*C. molossus*) from Indio Mountains Research Station (IMRS), located in far west Texas. These individuals were monitored during different winters since 2007 to present with radio telemetry. Until now, our data showed that snakes overwinter singly and their winter shelters are located inside their home ranges. Most snakes of *C. atrox* and *C. ornatus* selected west facing slopes, and most individuals of *C. lepidus* selected southeast facing slopes. A PCA analysis showed that the winter shelters of *C. lepidus* and *C. ornatus* are more similar when compared to those selected by *C. atrox*. In general, all three species spent five months (November-March) overwintering at IMRS, and on average, *C. lepidus* lost 8.5%, *C. ornatus* 15.9%, and *C. atrox* 26.9% of their body mass. The ongoing gathering of data will allow us for a more in-depth analysis and identify possible patterns regarding their overwintering behavior with respect to sex, age classes, body temperature, and underground activity on this region of the Chihuahuan Desert, which experiences relatively mild winters.

14. Rain harvesting behavior in free-ranging Prairie Rattlesnakes (*Crotalus viridis*)

McIntyre, Madison
madimcintyre00@gmail.com

Boback, Scott
Department of Biology
Dickinson College
Carlisle, Pennsylvania USA

Organisms inhabiting xeric environments face many challenges to obtain dietary water. Numerous species have evolved unique adaptations to collect, harvest, and condense water from infrequent and unpredictable rainfall. Several snake species have been documented collecting and drinking precipitation from their skin, referred to as rain harvesting behavior. In some areas of their range, Prairie Rattlesnakes (*Crotalus viridis*) inhabit environments with soil that has poor water retention properties, and therefore may have evolved and adapted to obtain dietary water through harvesting rain. We designed an experiment to elicit and observe rain harvesting behavior (RHB) in Prairie rattlesnakes in their natural environments. Using a hand-held pump sprayer, we sprayed snakes with short bursts of water to simulate rainfall and recorded their behavior using a Canon EOS 80D Digital SLR camera with a 28-300 mm zoom lens. In a two week period between 25 May and 5 June 2021, we obtained 72 videos of 94 snakes (70 free-ranging snakes). Using these videos, we described rain harvesting behavior using a six-phase illustrated ethogram. Various postures and movements (e.g. tongue flicking rates, head angles, drinking surfaces, body positions, etc.) were quantified using Tracker, ImageJ, and R. Our results show that Prairie Rattlesnakes harvest rain from themselves, neighboring snakes, and non-snake surfaces. Snakes coiled in concentric, overlapping coils and dorsoventrally flattened (despite uneven substrates) when drinking from themselves. Prairie Rattlesnakes exhibited various head angles dependent on drinking surface, presumably to maximize water intake. Snakes were also noted to drink with their heads elevated and no labial contact to a specific surface; suggestive of drinking water run-off from the head. This observation supports previous descriptions of interscalar channels exhibiting capillary action directing water more efficiently to the mouth in *Phrynosoma cornutum* and *Moloch horridus*. This research serves as a baseline for further understanding rain harvesting in desert-inhabiting species. Furthermore, we introduce several hypotheses to explain dorsoventral flattening variation, drinking from non-snake surfaces, drinking with the head elevated and no labial contact to a surface, and drinking from neighboring snakes.

15. Cracking the conundrum of communal denning through an assessment of hibernacula features and availability

McKelvey, Veronica
vmckelvey@tru.ca

Isaac, Leigh Anne
Department of Natural Resource Science
Thompson Rivers University
Kamloops, British Columbia Canada

BC Provincial Government
Kimberly, British Columbia Canada

Larsen, Karl W.
Department of Natural Resource Science
Thompson Rivers University
Kamloops, British Columbia Canada

Due to the harsh weather that winter brings in temperate regions, snakes must locate and use dens that meet their requirements for survival. Within higher latitudes, snakes increasingly den communally (i.e., congregate to overwinter). Why communal denning occurs is still unclear: One leading theory proposes that this phenomenon results from decreased availability of adequate overwintering habitat. However, other potential explanations could include specific life history characteristics, physical constraints, migration pathways that may not overlap with other available dens, and environmental requirements of different species. The overall goal of this proposed research is to investigate the communal overwintering behaviour of the Western Rattlesnake (*Crotalus oreganus*) and the apparent mix of communal and solitary behaviour of the sympatric Great Basin Gophersnake (*Pituophis catenifer deserticola*) and Western Yellow-bellied Racer (*Coluber constrictor mormon*) in south-central British Columbia. To do so, the variation in environmental characteristics and availability of atypical and typical hibernacula used for communal and solitary denning species or conspecifics is being quantified. For this research, we are defining 'typical dens' as those found within rocky outcrops at the base of a rockface, while 'atypical dens' include a range of other features. Another potential explanation for communal denning is being investigated by measuring the physical attributes of the snakes to determine if there are constraints (i.e., head size, mid-body size) that limit the accessibility of typical versus atypical den sites. A minimum of 24 dens (14 believed to be typical and 10 atypical) have been discovered and are currently being assessed. This research will further our understanding of the communal overwintering behaviour in northern snakes and uncover important habitat features that characterize dens and their availability on the landscape.

16. Hot bodies, cool data: insights from body temperature in the Western Diamond-backed Rattlesnake

Mead, Joshua J.
jjmead@miners.utep.edu

Vicente Mata-Silva
Jerry D. Johnson
Department of Biological Sciences
The University of Texas at El Paso
El Paso, Texas USA

Snakes are able to alter their body temperature behaviorally by selecting locations on the landscape that correspond with preferred temperatures. Use of areas such as basking sites or burrows allow for adjustments from the ambient temperature. Small temperature data loggers, such as the WeePit Temperature Data Logger from Alpha Mach can be internally implanted within the coelomic cavity to record frequent internal temperature readings of individual snakes. We considered temperature data from six free ranging Western Diamond-backed Rattlesnakes (*Crotalus atrox*) in Hudspeth County, Texas. Internal body temperatures were recorded every thirty minutes over a year-long period. This is compared with bi-weekly temperature readings from Holohil SI-2T VHF transmitters. Data from this technology allows for valuable insights into the natural history of these secretive ectotherms.

17. Relatedness within and between aggregations of Prairie Rattlesnakes (*Crotalus viridis*) in northern Colorado

Muller, Zoe
zoemuller@live.com

Department of Quantitative Biology
University of Texas at Arlington
Arlington, Texas USA

Boback, Scott
Somers, Dana
Department of Biology
Dickinson College
Carlisle, Pennsylvania USA

Cryptically social animals can give us greater insight into how sociality evolved as they present social behavior in ways that have been previously unexplored. Most reptiles are solitary for much of their lives and are traditionally viewed as non-social, aggregating mainly for reproductive needs (e.g., courtship and mating). However, some temperate snakes, rattlesnakes in particular, are well known for their massive denning aggregations during winter, yet very few studies have investigated the possibility of "cryptic" (i.e., chemically mediated) social interactions at these communal dens. This study aims to gain insight into the details of Prairie Rattlesnake (*Crotalus viridis*) population structure in the wild. We strive to understand whether this species aggregates in a non-random fashion. This work was focused on aggregations of pregnant snakes at collective birthing sites called rookeries. We examined rattlesnakes from five rookery sites and compared these with individuals from the general population on Rattlesnake Butte in Steamboat Springs, Colorado. By genotyping microsatellite loci, we determined patterns of relatedness by calculating FST and genetic differentiation with GenePop R package. Our results showed 4 examples of high to moderate FST values across the gravid female group comparison, which was supported by significant p-values in the gravid female genetic differentiation analysis. Based on our current data, we see patterns of relatedness in gravid female aggregations, supporting the possibility for the aggregations being kin neighborhoods. Further studies need to be conducted to definitively identify the groupings as kin. These data have allowed us to further investigate population structure in cryptically social species to explore the evolution of sociality in broader contexts than have previously been documented.

18. A behavioral analysis of male-male combat in free-ranging Eastern Massasauga rattlesnakes (*Sistrurus catenatus*)

Perelman, Zander E.
zanderp2@illinois.edu

Department of Biological Sciences
Sam Houston State University
Huntsville, Texas USA

Illinois Natural History Survey
University of Illinois Urbana-Champaign
Champaign, Illinois USA

Lutterschmidt, William I.
Department of Biological Sciences
Sam Houston State University
Huntsville, Texas USA

Reinert, Howard K.
Department of Biology
The College of New Jersey
Ewing, New Jersey USA

Although male-male combat has been documented for numerous snake species, combat events and behaviors are not often quantified or analyzed beyond simple descriptions. Combat events between snakes within the genus *Sistrurus* are rarely observed, and only one previous report has offered detailed descriptions and analyses of behaviors. Observation of snake combat behavior is an opportunistic event, and consequently, detailed behavioral descriptions and analyses as performed here are particularly rare under natural field conditions. We discuss a combat event between two free-ranging male Eastern Massasauga (*Sistrurus catenatus*) in western Pennsylvania. A video recording of the event was used to describe and quantify the behaviors. Observations of male-male combat were possible because of the close monitoring of a radio-tracked female Eastern Massasauga (MS-01). While tracking MS-01, we first encountered male

MS-04 close to her (0.5 m) on 30 July 2021. Male MS-04 accompanied MS-01 until he engaged in combat with another male (MS-05) on 1 August 2021. On 2 August, MS-05 ousted MS-04 and successfully copulated with MS-01. Observing the full progression of behaviors allowed us to describe the combat event accurately and subsequently analyze and compare the combat behaviors displayed by MS-04 and MS-05 with respect to the outcome of the combat; MS-05 winning and copulating with MS-01. Such social behaviors have clear implications for reproductive success at individual and species levels. Detailed analyses of combat behavior may prove useful in an evolutionary context by allowing for potential phylogenetic comparisons regarding reproductive success and fitness.

19. The impact of development on copperheads in Connecticut: a preliminary study

Powers, Andrew
powers077@wcsu.edu

Pinou, T.
Department of Biology
Western Connecticut State University
Danbury, Connecticut USA

The eastern copperhead (*Agkistrodon contortrix*) is a medium-sized viper native to the east coast of the United States of America. However, within New England, the copperhead has experienced declines within this range and is considered a sensitive species in Connecticut. The main cause of this decline is thought to be a combination of human persecution and habitat loss. Within the last three decades there has been an increase in urbanization and land-use change in central Connecticut. The effect of land-use change on snakes is not fully studied. Previous research has found that southern copperheads in urban sites are significantly smaller than those in rural sites (Carrasco-Harris et al. 2020). Our preliminary study examines the effects of habitat fragmentation on copperhead body size by comparing snout-vent length of snakes sampled at two fragmented sites and a larger unfragmented site. By understanding how development is impacting copperheads in their central Connecticut stronghold, this sensitive species can better be preserved at the northeastern edge of their range.

20. Does rattlesnake rattling resemble the defensive tail motor patterns of non-rattlesnake colubroids?

Reiserer, Randall S.
rreiserer@gmail.com

Chiricahua Desert Museum
Rodeo, New Mexico USA

Smith, Charles F.
Department of Biology
Wofford College
Spartanburg, South Carolina USA

Chiricahua Desert Museum
Rodeo, New Mexico USA

Schuett, Gordon W.
Department of Biology - Neuroscience Institute
Georgia State University
Atlanta, Georgia USA

Chiricahua Desert Museum
Rodeo, New Mexico USA

Defensive tail vibration is widespread in advanced (colubroid) snakes and has been assumed to represent the ancestral motor pattern from which rattlesnakes derived their rhythmic tail-shaking behavior. Snakes display a variety of rhythmic tail behaviors, including distally traveling waves displayed during caudal luring. We currently are exploring the motion dynamics of defensive tail motion from all clades of rattlesnakes and their outgroups.

Thus far we have examined video footage, including high frame rates (500-1000 fps), of 12 species of *Crotalus*, several *Sistrurus* and copperheads (*Agkistrodon contortrix*) to characterize the movement patterns present in rattlesnakes. Other colubroid species will be investigated. To date we found both similarities and differences in the defensive tail motor patterns of copperheads and rattlesnakes. Our early findings suggest that the rattlesnake tail-shaker bears as much or more resemblance to the rapid undulations seen in caudal luring as to defensive tail vibration in a close pitviper relative, copperheads. Pygmy rattlesnakes (*Sistrurus miliarius*) display at least two types of defensive tail motor patterns that resemble copperhead tail vibrations more than the tail-shaking of advanced rattlesnakes. In general, rhythmic tail motions become more conservative (reduced amplitudes) in more advanced rattlesnakes (e.g., *C. adamanteus*, *C. atrox*, *C. scutulatus*), with single flexion points at or near the tail terminus, whereas copperheads and pygmy rattlesnakes employ variable displays that can involve multiple flexion points. In rattlesnakes, the rattle resonates via prominent distally traveling waves, a motion that resembles the undulations seen during caudal luring rather than the arching oscillations seen in copperheads and other colubroids. Therefore, we preliminarily suggest that the tail motor pattern dynamics involved in rattlesnake rattling involve elements derived from both ancestral defensive behavior and caudal luring, and that the conservative defensive tail motor patterns of more advanced rattlesnakes resemble caudal luring undulations to a greater extent than the tail vibrations and other motor patterns of non-rattlesnake colubroids.

21. Bi-seasonal stress biomarkers in two species of sympatric rattlesnakes (*Crotalus atrox* and *Crotalus ornatus*) in Far West Texas

Rocha, Arturo
arocha3@miners.utep.edu

Mata-Silva, Vicente
Ecology and Evolutionary Program
Department of Biological Sciences
The University of Texas at El Paso
El Paso, Texas USA

There are relatively few studies in the measurement of stress biomarkers free-ranging snake populations; including chronic, or elevated stressed rattlesnakes. The utilization of implants filled crystalline corticosterone (CORT) have been used as a proxy for elevating CORT in terrestrial animals, given the difficulty of assessing chronic stressors in field studies. Plasma CORT and leukocyte profiles (heterophils: lymphocytes) are common, and efficient methods in determining stress profiles in vertebrate ectotherms. Herein, we present an overview in determining seasonal baseline, acute reactivity, and elevated-stress levels effects in body conditions and other spatial variables in monitored, free-ranging Western Diamond-backed (*Crotalus atrox*) and Eastern Black-tailed Rattlesnakes (*Crotalus ornatus*) in Chihuahuan Desert scrub habitats (Indio Mountains Research Station, UTEP). The use of corticosterone implants in snakes will be categorized in two experimental groups: a treatment (CORT implants) and a control group (blank implants). For each species (*C. atrox* and *C. ornatus*), half of the snakes will be randomly selected for treatment of crystalline CORT implantation (while the other half will receive blank implants). Snakes will be monitored via radio-tracking, and blood will be drawn for plasma CORT and leukocyte profiles (blood smears) during two periods (pre-monsoon and post-monsoon months). Seasonal spatial (e.g. movements) and fitness effects (body conditions) will be determined from the changes in CORT at baseline, acute stress reactivity tests, and blood smears will be stained (Wright-Giemsa) to determine the changes in leukocyte profiles in different experimental groups and seasons.

22. Snakes as ecosystem engineers: secondary seed rescue, germination success, seedling viability, and implications for dispersal in nature

Schuett, Gordon W.
gwschuett@yahoo.com

Department of Biology - Neuroscience Institute
Georgia State University
Atlanta, Georgia USA

Chiricahua Desert Museum
Rodeo, New Mexico USA

Reiserer, Randall S.
Chiricahua Desert Museum
Rodeo, New Mexico USA

Salywon, Andrew M.
Blackwell, Steven
Hodgson, Wendy C.
Desert Botanical Garden
Phoenix, Arizona USA

Foster, C. Drew
Hall, James
Zach, Ryan*
Arizona Center for Nature Conservation - Phoenix Zoo
Phoenix, Arizona USA

Davis, Mark A.
Prairie Research Institute, University of Illinois Urbana Champaign
Champaign, Illinois USA

Greene, Harry W.
Department of Integrative Biology
University of Texas at Austin
Austin, Texas USA

* Zoo Miami
Miami, Florida USA

The importance of vertebrates as seed dispersers (zoochory) has received increasing attention from researchers over the past 20 years yet one speciose group—snakes—remains understudied. Although snakes are among the most abundant predators of granivorous vertebrates, our knowledge of seed rescue and secondary dispersal is almost nil. The phenomenon of diploendozoochory refers to a two-phase seed dispersal system whereby a secondary seed predator (carnivorous vertebrate) consumes a primary seed predator or granivore (rodents, birds) with seeds in its digestive tract (mouth, cheek pouch, crop, stomach, or other organ), which are subsequently eliminated with feces. In our first report using museum-preserved specimens, we showed that three desert-dwelling rattlesnake species consumed heteromyid rodents with seeds in their cheek pouches, and that secondarily ingested seeds occasionally germinated in snakes' colons. More recently, we reported on a study of live snake subjects of the Sonoran Desert (one viperid and two colubrine species) and seeds of the Foothill Palo Verde (*Parkinsonia microphylla*), a dominant tree of the same region. We experimentally tested germination frequency and rate, and seedling viability. Our study provides support for the role of snakes as important agents of seed rescue and dispersal in nature, their potential as ecosystem engineers, and crucial evidence for the investment of field-based studies on diploendozoochorous systems in deserts and other ecosystems. We hope that by highlighting their potential new role as agents of seed rescue and secondary dispersal will encourage both academic and public involvement (e.g., citizen scientists) in generating interest and legislature for their protection and long-term conservation.

23. High throughput venomics

Slagboom, Julien
j.slagboom@vu.nl

Amsterdam Institute of Molecular and Life Sciences (AIMMS)
Division of BioAnalytical Chemistry, Department of Chemistry and Pharmaceutical Sciences
Vrije Universiteit Amsterdam
Amsterdam, The Netherlands

Derks, Rico
Center for Proteomics and Metabolomics
Leiden Universitair Medisch Centrum
Leiden, The Netherlands

Somsen, Govert W.
Amsterdam Institute of Molecular and Life Sciences (AIMMS)
Division of BioAnalytical Chemistry, Department of Chemistry and Pharmaceutical Sciences
Vrije Universiteit Amsterdam
Amsterdam, The Netherlands

Vonk, Freek J. Amsterdam Institute of Molecular and Life Sciences (AIMMS)
Division of BioAnalytical Chemistry, Department of Chemistry and Pharmaceutical Sciences
Vrije Universiteit Amsterdam
Amsterdam, The Netherlands
Naturalis Biodiversity Center, Darwinweg 2, 2333 CR Leiden, The Netherlands

Casewell, Nicholas R.
Centre for Snakebite Research and Interventions
Liverpool School of Tropical Medicine
Liverpool, United Kingdom

Kool, Jeroen
Amsterdam Institute of Molecular and Life Sciences (AIMMS)
Division of BioAnalytical Chemistry, Department of Chemistry and Pharmaceutical Sciences
Vrije Universiteit Amsterdam
Amsterdam, The Netherlands

In this study we show high-throughput (HT) venomics capable of performing a full proteomic analysis of a snake venom within 2 days. The workflow starts with subjecting a snake venom to nanofractionation analytics, which involves liquid chromatographic separation of the toxins in a venom followed by mass spectrometry analysis and in parallel high-resolution fractionation on a 384 well-plate. After vacuum-centrifugation of the well plates to evaporate the eluents, automated tryptic digestion of all fractionated toxins is performed. Then, all digests are analysed using a fast-analytical gradient with a total runtime of 14.4 min per well, resulting in 100 nanoLC-MS/MS measurements per day. The data obtained from all wells is then automatically processed and subjected to Mascot database searching. From there using an in-house written script, all Mascot results are automatically compiled into a single Excel sheet containing all the proteomics data of an analysed snake venom. Then, another script plots each of the identified toxins in so called Protein Score Chromatograms. For this, for each toxin identified protein scores are plotted on the y-axis versus retention times of adjacent series of wells in which a toxin was fractionated on the x-axis. This same script integrates the peaks in these chromatograms for semi-quantitation purposes. This new HT venomics strategy was performed on the venoms of *Calloselasma rhodostoma*, *Echis ocellatus* and *Naja pallida*, *Bothrops asper*, *B. multicinctus*, *Crotalus atrox*, *Daboia russelii*, *N. naja*, *N. nigricollis*, *N. mossambica*, and *Ophiophagus hannah*. Our data suggest that high throughput venomics will be a highly valuable tool for increasing the throughput by which we can define venom variation and should greatly aid the future development of new snakebite treatments.

24. Tail movements by late-term fetal pitvipers resemble caudal luring: prenatal development of an ambush predatory behavior

Smith, Charles F.
smithcf@wofford.edu

Department of Biology
Wofford College
Spartanburg, South Carolina USA

Chiricahua Desert Museum
Rodeo, New Mexico USA

Schuett, Gordon. W.
Department of Biology - Neuroscience Institute
Georgia State University
Atlanta, Georgia USA

Chiricahua Desert Museum
Rodeo, New Mexico USA

With the advent of powerful imaging instruments, the prenatal behavior of vertebrates has been discovered to be far more complex than previously believed, especially concerning humans, other mammals, and birds. Surprisingly, the fetal behavior of squamate reptiles (lizards, snakes, and amphisbaenians), a group of over 11,000 extant species, are largely understudied. Using ultrasonography, 18 late-term pregnant copperhead snakes (*Agkistrodon contortrix*) from a single population in Connecticut were inspected for fecundity (number of fetuses). Unexpectedly, during the ultrasound procedure that involved 97 fetuses, we observed sinusoidal tail movements in 11 individuals from eight different copperhead mothers. These movements were indistinguishable from caudal luring, a mimetic ambush predatory strategy which is exhibited by newborn copperheads and other snakes. Caudal luring is initiated shortly after birth and is employed to attract susceptible vertebrate prey such as frogs and lizards. Using the same ultrasound equipment and methods, we tested for this behavior in late-term fetuses of two species of rattlesnakes (genus Crotalus) not known to caudal lure and none showed any type of tail movements. Prenatal movements in humans and other vertebrates are known to be important for musculoskeletal and sensorimotor development. The fetal behaviors we describe for copperheads, and which is possibly present in other snakes, may be similarly important and influence early survival and subsequent fitness.

25. USFWS NM: Ridge-nosed Rattlesnake update—what we've done and where we're going

Smith, Clinton
clinton_smith@fws.gov

US Fish and Wildlife Service
New Mexico Ecological Services Field Office
Albuquerque, NM USA

The New Mexico Ridge-nosed Rattlesnake *(Crotalus willardi obscurus*) was listed as a federally threatened species in 1978. It is one of five recognized subspecies of the Ridge-nosed Rattlesnake (*Crotalus willardi*), a North American pitviper (Crotalinae) belonging to the family Viperidae. This rattlesnake was listed primarily due to its narrowly restricted range, coupled with over collection and habitat modification. Its range includes three isolated populations occurring in the Peloncillo Mountains of southwestern New Mexico and southeastern Arizona, the Animas Mountains in the southwestern corner of New Mexico, and the Sierra San Luis Mountains in northern Mexico. My update includes what recently has been done for *C. w. obscurus* (listing and recovery), and upcoming potential conservation and recovery work.

26. Historical species distribution model for the Eastern Massasauga (*Sistrurus catenatus*) in Illinois

Stewart, Tyler M.
tyler11@illinois.edu

Dreslik, Michael J.
Illinois Natural History Survey
Champaign, Illinois USA

Crawford, John A,
National Great Rivers Research and Education Center
East Alton, Illinois USA

Predictions from species distribution models allow researchers to designate critical habitats for conservation and identify suitable habitats on the landscape where new populations may be discovered. Species distribution models are also valuable tools for modeling the potential distribution of imperiled species that have few extant populations or for elusive species difficult to detect. The Eastern Massasauga is an endangered species in Illinois that has undergone substantial population declines due to habitat loss and alteration. We developed a species distribution model for the Eastern Massasauga in Illinois using an ensemble approach within the R package "BIOMOD2" to average the predictions from several modeling algorithms. Using a combination of climatic and landscape predictors, we predicted the relative importance of environmental variables for Eastern Massasauga distributions in Illinois.

27. Influence of nearby basking opportunities on Eastern Massasauga hibernacula selection

Sunnucks, Emily
sunnucks@illinois.edu

LaGrage, Seth
Dreslik, Michael J.
Illinois Natural History Survey
University of Illinois Urbana-Champaign
Champaign, Illinois USA

Identifying and designating critical habitat is vital to the long-term survival of threatened and endangered species. However, evaluating habitat requirements can be challenging for species whose habitat choices are seasonally or ontogenetically influenced, such as snakes. In particular, data regarding hibernacula selection remains limited for many snake species. Using 21 years of spring emergence data, we studied the influence of environmental characteristics on hibernacula selection in the Eastern Massasauga. Specifically, we tested the significance of nearby basking opportunities by calculating vegetation height, vegetation density, and solar radiation using high-resolution Lidar (Light Detection and Ranging) data. Values for emergence sites were compared to those from randomly generated points within the study extent. We found emergence locations significantly differed from the random points for all variables; however, only vegetation density demonstrated a significant effect. Vegetation density was higher in areas where hibernacula occurred, suggesting available cover may be more important than basking during ingress and egress. Based on our study, we would suggest continuing habitat management to include areas of dense vegetation. However, future research should consider incorporating other sites with more terrain and canopy variation to properly assess the effect of solar radiation and vegetation height on hibernacula selection.

28. Population dynamics of a Timber Rattlesnake *(Crotalus horridus*) population studied for over 40 years

Tetzlaff, Sasha
sashatetzlaff@gmail.com
Ecological Processes Branch US Army ERDC-CERL
Champaign, Illinois USA

Hileman, Eric
Department of Wildlife, Fisheries and Aquaculture
Mississippi State University
Starkville, Mississippi USA

Davis, Mark A.
Illinois Natural History Survey
Prairie Research Institute
Champaign, Illinois USA

Schuett, Gordon W.
Department of Biology
Georgia State University
Atlanta, Georgia USA

Chiricahua Desert Museum
Rodeo, New Mexico USA

Simon, Matt
New York, New York USA

Brown, William S.
Biology Department
Skidmore College
Saratoga Springs, New York USA

The Timber Rattlesnake (*Crotalus horridus*) is a long-lived North American pitviper that has slow maturation, infrequent reproduction, and low fecundity. This species is of conservation concern throughout much of its existing range. However, long-term data for adequately characterizing population dynamics to inform conservation management actions are lacking. We are investigating the demography of a Timber Rattlesnake population in New York, USA that William S. Brown initiated studies on over four decades ago. In this area, the species was historically subjected to intense harvesting via a bounty system. Preliminary findings suggest this population experiences roughly decadal cycling in annual apparent survival estimates that range from approximately 0.7 to nearly 1.0. We intend to model additional parameters, such as abundance and population growth, that will be helpful to the ecology and management of this and other populations of *C. horridus*. Our analysis highlights the importance of long-term data for long-lived species with slow life histories.

29. Urates of colubroid snakes are different from those of boids and pythonids

Thornton, Alyssa M.
at1145@georgetown.edu

Department of Chemistry
Georgetown University
Washington, District of Columbia USA

Schuett, Gordon W.
Department of Biology - Neuroscience Institute
Georgia State University
Atlanta, Georgia USA

Chiricahua Desert Museum
Rodeo, New Mexico USA

Swift, Jennifer A.
Department of Chemistry
Georgetown University
Washington, District of Columbia USA

Uricotelic species, such as squamate reptiles, birds and insects, effectively eliminate nitrogen as uric acid in a solid form commonly called urates. Observations made over a decade suggested that the voided urates produced by colubroids (modern snake species) exhibit remarkable differences from those of boids and pythons (ancient snake species). Here, we compare the urates generated by eight captive snake species fed the same diet. Although all fresh urates were wet at the time of excretion, those produced by modern snakes dried to a powdery solid, whereas those of ancient species dry to a rock-hard mass that tightly adhere to surfaces. Powder X-ray diffraction and infrared spectroscopy analyses performed on voided urates produced by five modern and three ancient snakes confirmed their underlying chemical and structural differences. Urates excreted by ancient snakes were amorphous uric acid, whereas urates from modern snakes consisted primarily of ammonium acid urate, with some uric acid dihydrate. These compositional differences indicate that snakes have more than one mechanism to manage nitrogenous waste. Why different species use different nitrogen-handling pathways is not yet known, but the answer might be related to key differences in metabolism, physiology or, in the case of ancient snakes, the potential use of urates in social communication.

30. Integrating radio-telemetry and accelerometry to provide a more robust evaluation of snake movement behavior: a case study with Timber Rattlesnakes (*Crotalus horridus*) in central Georgia

Tipton, Anna F.
annatipton72@gmail.com

Thompson, Morgan L.
DeSantis, Dominic L.
Department of Biological and Environmental Sciences
Georgia College & State University
Milledgeville, Georgia USA

Animal movement is heavily influenced and defined by the interaction of internal factors, such as sex and behavioral season, and external factors, such as natural and anthropogenic landscape features that impact the distribution of fitness determining resources throughout the environment. These internal and external factors influence the behavioral decisions and ultimately the movement and space use of the organism. Historically, radio telemetry derived spatial data has been used to estimate the total extent of space used by individual snakes (i.e., home range size) and has represented an important tool for inferring movement-based responses to prominent landscape features, such as roads, but radio telemetry derived spatial data alone largely ignores the equally important temporal dimension of animal movement as individuals can alter the frequency and duration of movements independent of spatial shifts in home range sizes. To allow for a more comprehensive evaluation of the impact of sex, behavioral season, and anthropogenic landscape features (i.e., roadways) on snake movement, we are using an integration of radio telemetry derived spatial data and tri-axial accelerometry derived temporal data with a population of Timber Rattlesnakes (*Crotalus horridus*) in central Georgia. The total space use of each individual will be determined by calculating seasonal home ranges using minimum convex polygons, kernel density estimators, and dynamic Brownian bridge movement models. The tri-axial accelerometers will simultaneously provide long-term and continuous activity budgets to quantify "real-time" movement patterns. Generalized linear mixed effect models will be used to investigate the influence of sex, behavioral season, and distance to roadways on the spatial and temporal movement patterns of *C. horridus*. We hope to provide a widely applicable and improved methodological framework for investigating snake movement behavior.

Local Restaurants & Nearby Stores

Sky Islands Grill & Grocery (across the street from the museum)
37 Portal Rd
Rodeo, NM 88056
(575) 557-1234
ATM

Portal Peak Lodge, Store & Cafe (7 miles from meeting site)
www.portalrodeo.com/portal-store--restaurant--.html
Address: Portal Road (2358 S. Rock House Rd, Portal, AZ 85632)
Phone: (520) 558-2223 Beer and wine sales

ANIMAS, NEW MEXICO

Animas Mercantile (14 miles from meeting site)
www.valleymercantileinc.com/home
1326 NM-9, Animas, NM 88020
Phone: (575) 548-2839

CLOSEST FUEL: Unleaded Gasoline, Diesel & Propane; 24-hr Service (credit & debit cards)
Grocery Store & Hardware NO ALCOHOL SOLD

Ward's Tire Service (16 miles from meeting site)
www.yellowpages.com/animas-nm/mip/wards-tire-service-10558584

PW's Pizza 'n' Wings (17 miles from meeting site)
www.google.com/#q=P's+pizza+wings+animas
2417 NM-338, Animas, NM 88020
Phone: (575) 548-2000 (Monday-Friday, 11 am-6 pm)

DOUGLAS, ARIZONA (50 miles from meeting site)

Wal-Mart (www.walmart.com/store/1846/whats-new)
199 W 5th St
Douglas, AZ 85607
(520) 364-1281

Restaurants (www.tripadvisor.com/Restaurants-g31210-Douglas_Arizona.html)

Bank (www.wellsfargo.com/locator/bank/1825__E__9TH__ST_DOUGLAS_AZ_85607/)

LORDSBURG, NEW MEXICO (50 miles from meeting site)

Restaurants (www.tripadvisor.com/Restaurants-g47095-Lordsburg_New_Mexico.html)

Banks (www.bootheelbank.com)

Notes