Table of Contents

Welcome to the Biology of Pitvpers 3 Conference

www.biologyofthepitvipers.com

Welcome to the beautiful bootheel country of southwestern New Mexico to participate in the Biology of Pitvipers 3 Conference (BoPV3), hosted by the Chiricahua Desert Museum (CDM). Thank you for coming. Our Keynote Speaker is Dr. Emily Taylor and the Plenary Speaker is María Elena Barragán Paladines. We have five Invited Speakers (Dr. Laura R.V. Alencar, Dr. Harry W. Greene, Dr. Marcio Martins, Dr. Nicholas Casewell and Vishal Santra). The Banquet Speaker is Dr. William K. Hayes. Our Honored Guest is Dr. Rulon W. Clark. All of these individuals have made significant contributions to our understanding of pitviper biology and in other areas. We are indebted to all the presenters for their valuable oral and poster contributions. With this group of luminaries, we know 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 newly constructed Geronimo Event Center & Apache Museum (GEC). All oral presentations will be conducted inside GEC. The poster sessions will be held inside the Chiricahua Desert Museum (CDM).

Phone service in the area is supported by Verizon only. 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 boasts a large collection of natural history books, maps, and other printed materials.

If you have any questions during your stay, do not hesitate to contact any of the conference organizers (listed below) or other individuals on the BoPV3 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 Commitee
Dr. Gordon W. Schuett, Dr. Chuck Smith, Cristina Jones, Debra Hill, Bob Ashley, Sheri Ashley, and Chelsea J. Smith.

Staff
Dr. Geoffrey C. Carpenter, Joy Marzolf, Michelle Simpler, and Theresa Moran

	Thursday July 11, 2019	Friday July 12, 2019	Saturday July 13, 2019	Sunday July 14, 2019
7:30 AM		Refreshments & Continental Breakfast Provided	Refreshments & Continental breakfast provided	Refreshments & Continental breakfast provided
8:00 AM			Invited Speaker - Dr. Harry W. Greene	Plenary Speaker - Maria Elena Barragán Paladines, MSc.
8:15 AM		Opening Remarks		
8:20 AM		Keynote - Dr. Emily N. Taylor		
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				
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. Rulon W. Clark	Invited Speaker - Dr. Marcio Martins	
2:40 PM				Invited Speaker - Vishal Santra
3:00 PM			Formal Poster Session 1	
3:20 PM				
3:40 PM		Break (20 min); Refreshments		
4:00 PM				Break (20 min); Refreshments
4:20 PM				Formal Poster Session 2
4:40 PM		Invited Speaker - Dr. Laura R. V. Alencar		
5:00 PM			Group Photo Meet in Front of the Geronimo Event Center	
5:20 PM		Dinner on your own		
4:30 PM				
5:00 PM				
6:00 PM	Registration & Ice Breaker. Appetizers & Refreshments Provided by Chiricahua Desert Museum Start Poster Setup		Pulled Pork BBQ Dinner at the Geronimo Event Center. Compliments of Chiricahua Desert Museum. Live Music by "Sky Dog" - Local Folk-Country-Blues Band	
6:20 PM				Banquet Dinner Silent and Live Auctions Banquet Speaker - Dr. William K. Hayes
7:30 PM		Invited Speaker - Vishal Santra		

Honored Guest

Dr. Rulon W. Clark

Dr. Rulon W. Clark earned a B.S. in Biology from Utah State University in 1997. He was fortunate enough to work as an undergraduate researcher in Dr. Edmund D. Brodie Jr.'s research group, which cemented both a love of reptiles and research. He obtained a Ph.D. from Cornell University in 2004 under the guidance of Dr. Kraig Adler, and completed several more years of postdoctoral work at Cornell working with Dr. Harry W. Greene. He has been on the faculty in the Department of Biology at San Diego State University since 1997. His laboratory group focuses mainly on predator-prey interactions between pitvipers and small mammals, examining this relationship from both sides using tools from behavioral ecology, biomechanics, physiology, and functional morphology. Additional research areas include the social behavior of snakes and the conservation ecology of threatened or endangered reptiles. He has published over 50 scientific papers and has mentored 6 M.S. students, 3 Ph.D. students, and dozens of undergraduate students.

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 newly published 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 Berkeley, California. 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!

Joy Marzolf

Joy Marzolf is a full time Naturalist and Educator with Massachusetts Audubon as well as an Affiliate of the Copperhead Institute. She has been working with and educating the public about reptiles for over twenty-one years, specializing in live animal education programs. Her passion of working with reptiles has also included assisting with field research projects with the Copperhead Institute and training other educators how to raise public awareness and increase appreciation of reptiles and protecting their habitats. Joy has also helped to run several herpetology related conferences in recent years including the Biology of Pitvipers 2, the International Herpetological Symposium, the Biology of Snakes, and the Charlie Painter BioBlitz (2016 & 17). She is also a wildlife photographer and particularly loves photographing reptiles in the wild.

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 3 Conference will be operating on New Mexico Time (Mountain Time)

Locations

Registration is at the Geronimo Event Center (Apache Museum). Cash or credit cards accepted.

The Ice Breaker will begin at 1800 (6:00 pm) New Mexico time on Thursday (July 11). There will be appetizers and refreshments.

NOTE: Bring Your Own Booze (B.Y.O.B.) or purchase it locally. See back of program book for list of local stores that sell alcohol.

All oral presentations will be inside the Geronimo Event Center. Two poster sessions will be held (Saturday at 3:00 PM and Sunday at 4:20 PM) inside the Chiricahua Desert Museum. Poster set up begins at 6:00 PM on Thursday.

Information for Oral Presentations

Oral presentations will be uploaded the evening before your talk or no later than 7:00 am of the day of your talk.

Keynote Speaker

Dr. Emily N. Taylor

Dr. Emily N. Taylor is a Professor of Biological Sciences at the California Polytechnic State University in San Luis Obispo, California, where she has been teaching and mentoring students in field-based environmental physiology research for fourteen years. She fell in love with snakes as an undergraduate at University of California - Berkeley, where she conducted research on the Baja California Rattlesnake (*Crotalus enyo*) and wrote the senior thesis for her English major on the representation of the serpent in the Bible. She next got her Ph.D. in Biological Sciences at Arizona State University studying proximate mechanisms responsible for sexual size dimorphism in rattlesnakes. Emily keeps busy teaching classes ranging from herpetology to medical endocrinology, conducting research on lizards and snakes with her students, co-authoring an introductory biology textbook, serving as a faculty fellow for graduate education at Cal Poly, and most recently, opening 7Sisters Brewing Company in San Luis Obispo with her partner Steve. Emily is passionate about her German shepherd dogs, beekeeping, beer and wine, traveling, and anything to do with snakes, especially the pitvipers that initially hooked her into biology and have held on tight ever since.

Talk title: Anatomy of a Pitviper: How These Iconic Animals Inspire Art, Fear, Respect, and Knowledge

Plenary Speaker

María Elena Barragán Paladines, MSc.

Maria Elena Barragán-Paladines is a passionate biologist interested about reptiles and amphibians, especially venomous snakes. Involved in herpetology for 28 years, Maria has worked on various reptile and amphibian conservation projects, and measures toward the prevention and reduction of the impact of venomous snakes on human health. With a wide trajectory in the snake captive management, conservation, management and treatment of snake-bite accidents, she has carried out research on the toxicology of venoms of viperids and elapids. She has designed, coordinated and worked in programs of conservation and environmental education about reptiles and amphibians and she has also had the opportunity to work with several indigenous communities in Oceania, Africa, Canada and Ecuador.

She is currently the Executive Director of the Gustavo Orces Herpetological Foundation and she is part of the institution's technical team. She has a degree in Biology in Ecuador, a diploma in Management of Endangered Species from the University of Kent, United Kingdom, and a Master's Degree in Environment and Education for Sustainability in Brisbane, Australia.

Her efforts and vision of working with reptiles trust on education as a fundamental tool to implement concrete actions toward the conservation of venomous snakes, animals which are widely associated with a long history of cultural negativity.

Talk title: New challenges and Perspectives about Venomous Snake Conservation in Ecuador

Banquet Speaker

Dr. William K. Hayes

Dr. William K. Hayes is a professor of biology and the director of the Center for Environmental Studies and Stewardship at Loma Linda University, California. He developed a passion for biodiversity during his childhood in Maryland, where he devoted most of his spare time to catching herps and chasing birds. He studied rattlesnake predatory behavior while earning B.S. and M.S. degrees at Walla Walla University, Washington, and examined venom expenditure by rattlesnakes for his Ph.D. at University of Wyoming. Since moving to California in 1996, he and his students have studied a variety of venomous animals, including rattlesnakes, spiders, scorpions, and centipedes. They also examine the behavioral ecology and conservation of endangered reptiles and birds, with emphases in the California and Caribbean Islands biodiversity hotspots. In addition to publications in scientific journals, he has written articles about environmental stewardship in an effort to promote a stronger conservation ethic among faith groups, and has co-edited several volumes, including *The Biology of Rattlesnakes*, *The Biology of Rattlesnakes II*, and *Iguanas: Biology and Conservation*.

Title: The Kiss of Death: How Pitvipers Use Their Venom

Invited Speakers

Dr. Laura R. V. Alencar

Dr. Laura R. V. Alencar is Postdoctoral Researcher at the University of Sao Paulo, Brazil, and is an evolutionary biologist interested in understanding what generates and maintains biodiversity. To address this goal, Dr. Alencar mostly uses squamate reptiles as a study group combining natural history, morphological, geographical and phylogenetic information to explore the diversification patterns and potential underlying processes shaping the radiation of these organisms in large temporal and spatial scales. Laura earned her Master's in 2010 and her Ph.D. in 2016, both at the Department of Ecology at the University of Sao Paulo. During her Ph.D., she explored the diversification dynamics of vipers, generating a new molecular phylogeny for the family and elucidating different macroevolutionary patterns and processes driving the evolution of arboreal and terrestrial vipers. Laura is currently working with Dr. Tiago Quental's lab investigating the relevant drivers of species coexistence in snakes and lizards, and how similar continental and island radiations are.

Dr. Nicholas Casewell

Dr. Nicholas Casewell graduated from the University of Liverpool (BSc Tropical Disease Biology), during which time he also studied at the Alistair Reid Venom Research Unit at the Liverpool School of Tropical Medicine. Casewell gained a Ph.D. studentship at Bangor University where he studied the composition, evolution and immunology of saw-scaled viper venoms and their antivenoms with Dr. Wolfgang Wüster. The result of Dr. Casewell's Ph.D. research saw him nominated as a finalist for the Society for Molecular Biology and Evolution's young re-

searcher prize, the Walter M. Fitch Award, in 2011. Subsequently, Casewell became Antivenom Manager for the UK manufacturing company MicroPharm Limited, in a commercial and academic collaboration with the Liverpool School of Tropical Medicine. Since 2013, Dr. Casewell has worked in academia and has studied the evolution of various animal venom systems, including snakes, fish, cnidarians and mammals. In 2016, he was appointed as a Senior Lecturer in the Alistair Reid Venom Research Unit of the Liverpool School of Tropical Medicine and was awarded a Sir Henry Dale Research Fellowship by the Wellcome Trust and Royal Society. His research focuses on understanding variation in snake venom composition and using this information to generate new snakebite treatments.

Dr. Harry W. Greene

Dr. Harry W. Greene graduated from Texas Wesleyan in 1968, served three years as an army medic, then earned a M.A. from University of Texas at Arlington and Ph.D. from University of Tennessee. He was a professor and curator in Berkeley's Museum of Vertebrate Zoology for two decades before moving to Cornell, where he is now professor emeritus of ecology and evolutionary biology. He's taught vertebrate natural history, herpetology, introductory biology, evolution and biodiversity, and field ecology, while studying vertebrate biology and conservation. Harry's honors include U.C. Berkeley's Distinguished Teaching Award, the Edward O. Wilson Naturalist Award, president of the American Society of Ichthyologists and Herpetologists, and Cornell's Stephen H. Weiss Presidential Fellowship. In 2014, Business Insider named him one of Cornell's "Top Ten Professors" and he was elected to the American Academy of Arts and Sciences. His *Snakes: The Evolution of Mystery in Nature*, won a PEN Literary Award, garnered a two-page spread in Time magazine, and made the New York Times' annual list of 100 Most Notable Books.

Dr. Marcio Martins

Dr. Marcio Martins got his degrees of Biologist (1984), MSc in Ecology (1990), and Ph.D. in Ecology (1994) at the State University of Campinas. He is a Full Professor (since 2006) at the Department of Ecology, Institute of Biosciences, University of São Paulo (USP) since 1996. Previously he was a researcher at the National Institute for Amazonian Research (INPA) and a visiting professor at the Federal University of Amazonas (UFAM). He has been a post-doc at the São Paulo State University, Rio Claro (1995-1996), and at the University of Florida, Gainesville (2013). His main research interests are to understand (1) the processes that lead to spatial and temporal patterns of diversity of amphibians and reptiles, and (2) the threats and vulnerabilities of amphibians and snakes. To achieve these goals, he invests heavily in the gathering of good natural history data. Marcio published about 90 research papers and a dozen book chapters on the biology and conservation of amphibians and snakes. He has been participating actively in the production of Brazilian red lists of threatened fauna (2003, 2014, and the ongoing process) and is the regional coordinator for South America of the IUCN Viper Specialist Group.

Vishal Santra

Vishal Santra Born in south Bengal, Vishal spent his childhood in the small north-eastern state of Manipur. It was there that his passion for reptiles formed when a slender copper-colored snake slithered across their front lawn. Returning to West Bengal for his higher studies, he met the famous snake charmers of the state.

Classes were missed and calls made to his parents, but he learned a great deal about his reptilian neighbours in those years. Graduating with an honours degree in English literature, his habit of reading brought him into contact with articles and publications on snakes and their research. Realizing that herpetology was to be an integral part of his life, he was soon mentored by Gerard Martin, Romulus Whitaker, and Kedar Bhide, placing him squarely on the path to research. Constantly involved in numerous herpetological expeditions in the Indian subcontinent, Vishal also engages actively in snakebite research, to understand taxonomy and venom variation both within and between species across the range. His interests lie in behavioural ecology, taxonomy and captive management. He was a consultant herpetologist at Peradeniya University, Sri Lanka, establishing a herpetarium designed for the needs of Sri Lanka-specific antivenom production. Currently collaborating with eminent herpetologists Dr. Anita Malhotra and Dr. Wolfgang Wüster from Bangor University, he is heading a project in the Western Himalayan state of Himachal Pradesh, collecting the very first samples of the region.

Silent Auction Information

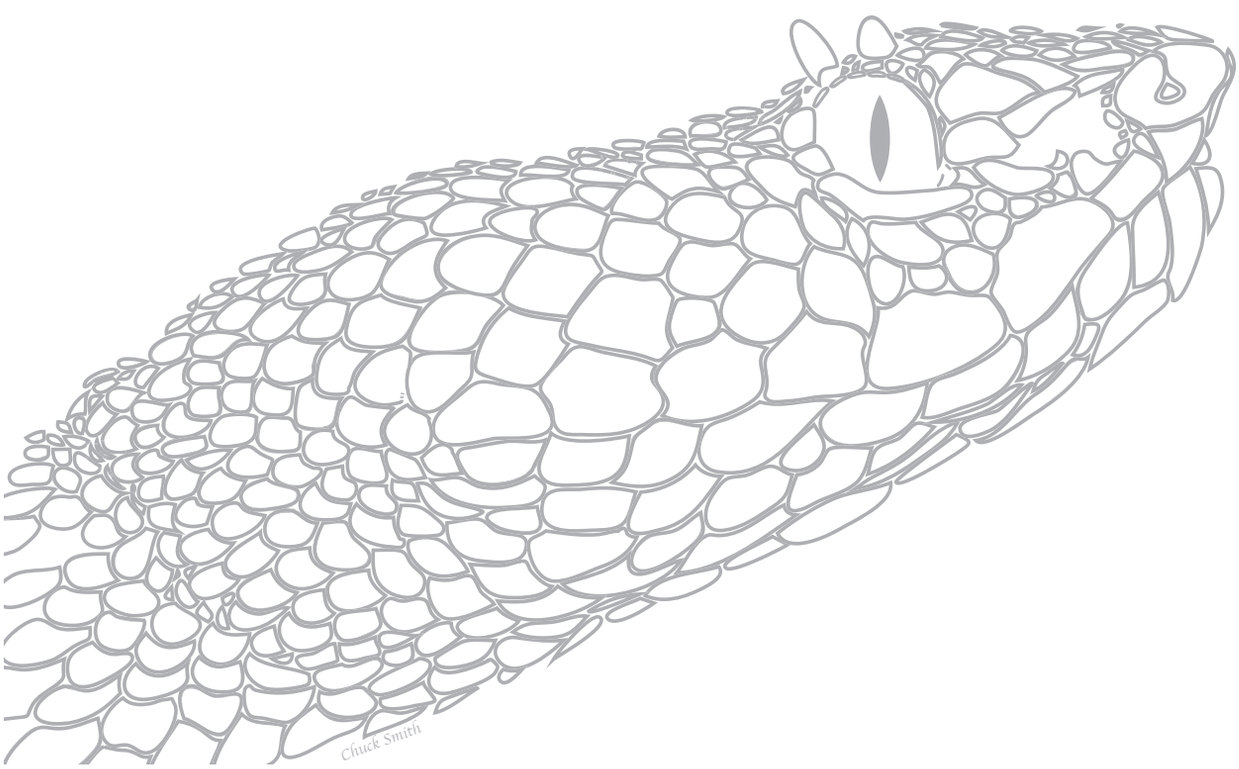
The Biology of Pitvipers 3 (BoPV3) Silent Auction is an opportunity to support a worthy cause – a research grant that is established by the BoPV3 Scientific Advisory Committee to support research on reptiles and amphibians of the Southwest.

http://www.chiricahuadesertmuseum.com/research-grants

This is a chance to clean out your office or home of those interesting and valuable herp-related items. Any donated item (e.g., books, art, sculptures, famous autographs, field equipment, or clothing) is greatly appreciated. Please note that items made from amphibians, reptiles, or parts thereof, should NOT be donated.

Donations are tax deductible. Receipts will be issued on request (please request receipt at the time of your donation).

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.



		Thursday July 11, 2019
6:00 PM		**Registration & Ice Breaker. Appetizers & Refreshments Provided by Chiricahua Desert Museum**
		Start Poster Setup
		Friday July 12, 2019
7:30 AM		**Refreshments & Continental Breakfast Provided at Geronimo Event Center**
8:15 AM		**Opening Remarks**
8:20 AM	1	**Keynote Address** **Dr. Emily N. Taylor** - Anatomy of a Pitviper: How These Iconic Animals Inspire Art, Fear, Respect, and Knowledge
9:20 AM	2	**Atkins, Marcus** - 35 Years on the Northern Frontier: Population Response of Western Rattlesnakes to Land Management Regime Changes in British Columbia
9:40 AM	3	**Winton, Stephanie** - Impacts of Road Mortality on the Western Rattlesnake (*Crotalus oreganus*) in British Columbia
10:00 AM		**Break (20 minutes). Refreshments Provided at the Geronimo Event Center**
10:20 AM	4	**Whitford, Malachi** - Determinants of Strike Success in Rattlesnakes and the Potential Effects of Temperature

10:40 AM	5	**Diaz-Cruz, Kelimar** - Derived Morphology of Ventral-Scale Nanostructure in the Sidewinder
11:00 AM	6	**Pardo, Juanita** - An Ontogeny of Spatial Use in Sidewinders
11:20 AM	7	**Schield, Drew R.** - The Origins and Evolution of Chromosomes and the Recombination Landscape in Rattlesnake Genomes
11:40 AM	8	**Perry, Blair** - And So We Meet Again: Allopatric Divergence and Secondary Contact with Gene Flow is a Recurring Theme in Rattlesnake Evolution
12:00 PM	9	**Castoe, Todd A.** - Well Assembled Snake Genomes – A Foundation for Understanding Many Things about Snakes We Wanted To Know, And Other Things We Didn't Know We Wanted To Know
12:20 PM		**Lunch on Your Own. See List of Restaurants in Back of Program**
2:20 PM	10	**Honored Guest** **Dr. Rulon W. Clar**k - Dynamic Functional Integration of Motor and Sensory Systems During Predator-Prey Interactions
3:20 PM	11	**Eye, Dana** - Female Reproductive Ecology of Western Rattlesnakes (*Crotalus oreganus*) in Southern British Columbia, Canada
3:40 PM		**Break (20 minutes). Refreshments Provided at the Geronimo Event Center**
4:00 PM	12	**Wiley, Kristen** - Natural History and Captive Management of the St. Lucia Pitviper, *Bothrops caribbaeus*
4:20 PM	13	**Booth, Warren** - Recent Advances in the Field of Parthenogenesis in Snakes

4:40 PM	14	**Invited Speaker** **Dr. Laura R. V. Alenca**r - The Radiation of New World Pitvipers: A Macroevolutionary Perspective
5:20 PM		**Dinner On Your Own**
7:30 PM	15	**Invited Speaker** **Vishal Santra** - India: A Pitviper Paradise
		Saturday July 13, 2019
7:30 AM		**Refreshments & Continental Breakfast Provided at the Geronimo Event Center**
8:00 AM	16	**Invited Speaker** **Dr. Harry W. Greene** - Natural History, Evolution, and Conservation of Venomous Snakes: Four Talking Points
8:40 AM	17	**Parkinson, Chris** - The Rattlesnake Tree of Life: A Genome-wide Perspective
9:00 AM	18	**Holding, Matthew** - Assessing the Relationship between Venom Complexity and Diet Diversity in Rattlesnakes Using a Novel, Genome-Wide Phylogeny
9:20 AM	19	**Stiers, Erin** - Characterizing the Gut Microbiome in Rattlesnakes with Divergent Venoms
9:40 AM	20	**Hofmann, Erich** - Characterizing Venom Variation in the Mexican Montane Pitvipers (*Cerrophidion*)
10:00 AM		**Break (20 minutes). Refreshments Provided at the Geronimo Event Center.**

10:20 AM	21	**Rautsaw, Rhett** - The Flat Adaptive Landscape of Sidewinder Rattlesnake Venom
10:40 AM	22	**Wouters, Roel** - Pitviper Embryology: The Development of the Loreal Pit in *Bothrops jararaca*
11:00 AM	23	**Levine Navarre, Brenna** - Bateman Gradients and Sexual Selection in the Rattlesnake *Crotalus atrox* and other North American Pitvipers
11:20 AM	24	**Rhoads, Dustin** and **Pikstein, Rachel -** Quantifying Color Pattern Mimicry and Background Color-Matching in Rock Rattlesnakes (*Crotalus lepidus*) and Gray-banded Kingsnakes (*Lampropeltis alterna*) Utilizing Digital Photography
11:40 AM	25	**Lazzeroni, Margaret** - Evolutionary Genomics of Reproductive Modes in Pitvipers
12:00 PM	26	**Mead, Jim** - Morphology of the Viper Prefrontal Bone and a New Pliocene *Agkistrodon*
12:20 PM		**Lunch on your own. See List of Restaurants in Back of Program**
2:20 PM	27	**Invited Speaker** **Dr. Marcio Martins** - Vipers on Islands: Ecology, Evolution, and Conservation
3:00 PM		**FORMAL POSTER SESSION – 1. CHIRICAHUA DESERT MUSEUM** **Refreshments Provided at the Chiricahua Desert Museum**
5:00 PM		**Group Photo. Meet in Front of the Geronimo Event Center & Apache Museum**
6:00 PM		**Pulled Pork BBQ Dinner at the Geronimo Event Center. Compliments of Chiricahua Desert Museum. Live Music by "Sky Dog" - Local Folk-Country-Blues Band**

		Sunday July 14, 2019
7:30 AM		**Refreshments & Continental Breakfast Provided at the Geronimo Event Center**
8:00 AM	28	**Plenary Speaker** **Maria Elena Barragán Paladines, MSc.** - New challenges and Perspectives about Venomous Snake Conservation in Ecuador
8:40 AM	29	**Wüster, Wolfgang** - One Snake, Two Venoms: Causes and Correlates of Venom Variation in the Mohave Rattlesnake (*Crotalus scutulatus*)
9:00 AM	30	**Brattstrom, Bayard H.** - Rattlesnakes at Your Feet
9:20 AM	31	**Shipley, Bryon K.** - What's all the Buzz About? Prairie Rattlesnake (*Crotalus viridis*) Movements at Urban Parks and Public Safety
9:40 AM	32	**Kamees, Larry** - Patterns of Survival of a Communally Denning Rattlesnake, *Crotalus viridis*, in a Man-made Hibernaculum
10:00 AM		**Break (20 minutes). Refreshments Provided at the Geronimo Event Center**
10:20 AM	33	**Invited Speaker** **Dr. Nicholas R. Casewell** - New Approaches to Neutralize Haemotoxic Viper Venoms
11:00 AM	34	**Cardwell, Michael D.** - Mohave Rattlesnake: The Deadliest Rattlesnake in North America – If You're a Lab Mouse!
11:20 AM	35	**Crowell, Hayley** - Eat, Prey, Live: Comparative Thermal Ecology and Energy Requirements of Coastal and Inland Pacific Rattlesnakes (*Crotalus oreganus*)

11:40 AM	36	**Mackessy, Stephen P.** - Trends in Venom Composition in Mexican Rattlesnakes
12:00 PM	37	**Smith, Cara F.** - Biochemical Ecology of *Crotalus viridis* (Prairie Rattlesnake) in Colorado
12:20 PM		**Lunch on Your Own. See List of Restaurants in Back of Program**
2:20 PM	38	**Huerta, Diego** - Comparative Ecology of Three Sonoran Desert Rattlesake Species Living in Syntopy
2:40 PM	39	**Invited Speaker** **Vishal Santra** - Exploring the Himalayas: Hidden Pitviper Diversity in an Understudied Hotspot
3:20 PM	40	**Bryan, Danny L.** - Translocations of Nuisance Timber Rattlesnakes (*Crotalus horridus*): A Possible Management Solution
3:40 PM	41	**Maritz, Bryan** - Are Crotaline Population Survival Estimates Representative of Viper Populations as a Whole?
4:00 PM		**Break (20 minutes). Refreshments Provided at the Geronimo Event Center**
4:20 PM		**FORMAL POSTER SESSION – 2. CHIRICAHUA DESERT MUSEUM** **Refreshments Provided at the Chiricahua Desert Museum**
6:20 PM	42	**Banquet Dinner. Silent and Live Auctions** **Banquet Speaker** **Dr. William K. Hayes** - The Kiss of Death: How Pitvipers Use Their Venom

Oral Abstracts

1. Anatomy of a Pitviper: How These Iconic Animals Inspire Art, Fear, Respect, and Knowledge

Taylor, Emily N.
Department of Biological Sciences
California Polytechnic State University
San Luis Obispo, CA USA
etaylor@calpoly.edu

This is the third conference devoted entirely to celebrating the biology of pitvipers, a subfamily of reptiles that represents only 7% of snake species but has inspired a much larger proportion of research, as well as public interest both past and present. I will show several prominent examples of historic, artistic renditions of pitvipers that show how they have simultaneously inspired fear and respect in people, a pattern that pushes them to the forefront of people's minds, sometimes in negative ways and sometimes in positive ways. I propose that our community of scientists is disproportionately interested in pitvipers because they represent excellent model organisms for studies from a multitude of sub-disciplines due to their ease of study in the lab and field, their abundance, and their unique adaptations. Simultaneously, however, I propose that many scientists, myself included, are drawn to pitvipers because we implicitly are attracted to their beauty, to their unique biology, and to their danger. Specifically, many pitviper biologists employ cutting edge technologies while maintaining a solid grounding in natural history such that our studies are ecologically relevant to the organisms we study, a valuable practice that is disappearing in many fields. I will go over several examples of recent and current research on pitvipers—from the snout to the vent—to show how this approach provides data for both basic and applied research that is making big waves in biology today, beyond the scope of just pitviper biology itself. I will then look to the future to ask what questions we will ask next, and how we will we ask them. Who is the pitviper biologist of the present, and who is the pitviper biologist of the future? What methods will they use to build upon the traditions of our group? I am honored and thrilled to kick off our meeting with this homage to pitviper research past, present, and future.

2. 35 Years on the Northern Frontier: Population Level Response of the Western Rattlesnake (*Crotalus oreganus*) to Land Management Regime Changes over Time

Atkins, Marcus
Environmental Science Program
Thompson Rivers University
Kamloops, British Columbia, Canada
atkinsm18@mytru.ca

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

Periodic assessments on the status of wildlife populations rely on the best available science. However, long-term datasets that utilize historical, comparative data are limited. Robust historical comparisons allow for the quantification of long-term impacts and can help prevent a shifting baseline. This study represents the first comparison of long-term population changes of Western Rattlesnakes (*Crotalus oreganus*) in Canada. Temporal comparisons are being conducted through a rigorous mark-recapture study to compare and assess baseline demographic, morphometric, and female reproductive data with a detailed dataset from the 1980s. Since the historical data were collected, the study site has diverged into a 'natural experiment' of contrasting land-use patterns: half within the boundaries of a protected area and half within an active cattle ranch. Spatial comparisons via radio-telemetry and analysis of demographic data between sites aim to determine how long-term, divergent land management regimes influence population size and behaviour over time. Although preliminary, we are suspecting declines among the major denning populations since the last assessment, with the most severe declines appearing to be within the protected area. Preliminary data also suggests snakes occupying ranchlands are both longer ($P = 0.034$) and heavier ($P = 0.055$) than snakes within the protected area. This project is in the midst of its second field season.

3. Impacts of Road Mortality on the Western Rattlesnake (*Crotalus oreganus*) in British Columbia

Winton, Stephanie
Environmental Science Program
Thompson Rivers University
Kamloops, British Columbia, Canada
stephwinton@hotmail.com

Bishop, Christine
Science and Technology Branch
Environment and Climate Change Canada
Delta, British Columbia, Canada

Larsen, Karl
Department of Natural Resource Sciences
Thompson Rivers University
Kamloops, British Columbia, Canada
klarsen@tru.ca

Mortality due to wildlife-vehicle collisions has emerged as a major threat to wildlife. Roadkill may be particularly adverse for populations at the periphery of their range, where existing natural constraints already limit population growth. Thus, conservation assessment and planning for many peripheral species-at-risk will benefit from a fundamental understanding of the impacts of road mortality, yet these can be difficult to isolate due to the interaction of numerous factors. Using population viability analysis (PVA) we evaluated the persistence of a Western Rattlesnake (*Crotalus oreganus*) population impacted by road mortality in a protected area of the dry interior of British Columbia, Canada with relatively low traffic volumes (mean = 350 vehicles/day). We quantified roadkill through methodical road surveys and concurrent assessments of scavenging rates and observer detection probability. Additionally, we conducted intensive mark-recapture and radio-telemetry to establish a detailed database on population demography and functional use of the landscape. After accounting for sources of error, our modelling showed that the estimated number of rattlesnake deaths was 2.7× the number of carcasses detected through unadjusted surveys and incidental observations. Our analysis indicated that, under the current road mortality rate (6.6% of population/year), persistence was likely over the next 100 years (extinction probability <0.01), but with it a continual and substantial decline in population size (stochastic growth rate -0.032, 96% decrease); any increases in road mortality rates would greatly hasten extirpation. Our study adds to the growing body of evidence that low levels of road mortality may still exert a significant effect on healthy populations of long-lived species, and in many cases population recovery will only be possible with reductions in road mortality.

4. The Effects of Temperature and Body Size on Strike Performance in Rattlesnakes

Whitford, Malachi
mwhitford@ucdavis.edu

Freymiller, Grace A
Department of Biology
San Diego State University
San Diego, California, USA

Higham, Timothy E.
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

Predator-prey interactions are major selective forces, and their outcome is responsible for shaping adaptations within organisms and structuring communities. Most interactions are dynamic and interactive across several discrete stages (e.g., searching, evaluation, attack, subjugation, consumption), and the behaviors of both parties can alter the outcome at any given stage. For many systems, the factors that affect the final outcome of the interaction are not well understood because it is logistically difficult to quantify details of the behavior of both predator and prey in concert. We used a tractable field system to study interactions between a specialized ambush predator (Sidewinder, *Crotalus cerastes*) and one of its primary prey items (Desert Kangaroo Rat, *Dipodomys deserti*) to determine how dynamic behaviors at multiple stages influence the outcome. Because these interactions involve an ectothermic predator and endothermic prey, our current and future work is attempting to understand how the asymmetric effects of temperature on ectotherms versus endotherms may lead to changes in the outcome of predator-prey interactions. By examining the kinematics of a large sample of rattlesnake strikes under various temperature treatments, both in the field and the lab, we hope to provide insight into whether higher environmental temperatures and larger body size are associated with increased strike performance in *Crotalus* spp.

5. Derived Morphology of Ventral-Scale Nanostructure in the Sidewinder (*Crotalus cerastes*)

Diaz-Cruz, Kelimar
School of Physics
Georgia Institute of Technology
Atlanta, GA USA

Mendelson III, Joseph R.
Zoo Atlanta
Atlanta, GA USA
jmendelson@zooatlanta.org

School of Biological Sciences
Georgia Institute of Technology
Atlanta, GA USA

Li, Tai-De
Advanced Science Research Center
City University of New York
New York, NY USA

Ventral surfaces of snakes typically contact the substrate during locomotion, with lifting being an important component especially in sidewinding. Studies of the functional and physical properties of the ventral scales of many snakes have found no clear ecological or phylogenetic patterns to contextualize observed variation. We used Atomic Force Microscopy to study the 3-D nanostructure of the ventral scales of the Sidewinder, a species known for distinctive lateral and lifting locomotion and exceptional abilities on granular substrates. Examination of a diversity of related pitviper species documented a conserved morphology of regularly ordered, uplifted, sharply pointed, posteriorly protruding nanostructures with typical dimensions of 3 μm x 0.5 μm x 0.15 μm (length, width, height); small epidermal pits with typical diameter of 0.3 μm but of unknown function are present as has been found in other snakes. This morphology is generally representative of the ventral nanostructure anisotropy seen across virtually all snakes, clearly associated with the plesiomorphic mode of anteriorly directed locomotion. Our outgroup comparisons identified the distinctive morphology of Sidewinders as a derived condition, with a flat surface and modified (1 μm x 1 μm x 0.05 μm), blunted, posteriorly oriented vestiges of the rearward projections of other pitvipers; epidermal pores are present, but larger (300 nm diameter) than any snake yet examined. This unique, phylogenetically derived 3-D nanostructure with low directionality could provide isotropic friction for the derived pattern of locomotion of Sidewinders involving lateral forces, abrupt directional reversals, and lifting.

6. An Ontogeny of Spatial Use in Sidewinders

Pardo, Juanita
School of Biological Sciences
Georgia Institute of Technology
Atlanta, GA USA
jpardo6@gatech.edu

Taylor, Ashley
Department of Herpetology
Zoo Atlanta
Atlanta, GA USA

Dallas, Hannah
Weigel, Emily
School of Biological Sciences
Georgia Institute of Technology
Atlanta, GA USA

Mendelson III, Joseph R.
Department of Research
Zoo Atlanta
Atlanta, GA USA

School of Biological Sciences
Georgia Institute of Technology
Atlanta, GA USA

We reared five full-sibling sidewinders in identical enclosures for one year and monitored their physical position and posture (hunting vs. non-hunting) daily for their first year of life. Pre-printed grid-marked paper substrates and identically designed and situation hide boxes and water bowls were included in each enclosure. We also noted where each snake had a feeding "success" in order to test the hypothesis that these ambush hunters would spend proportionally more time in "successful ambush sites" over the course of the year. Prey was presented in such a way that no scent-trail cues were available to the snakes to use to inform/bias their choice of ambush sites. Data analyses are still underway, but emergent patterns are becoming clear and will be reviewed in the presentation.

7. The Origins and Evolution of Chromosomes and the Recombination Landscape in Rattlesnake Genomes

Schield, Drew R.
dschield@uta.edu

Perry, Blair W.
Department of Biology
University of Texas at Arlington
Arlington, Texas, USA

Smith, Cara F.
School of Biological Sciences
University of Northern Colorado
Greeley, Colorado, USA

Meik, Jesse M.
Department of Biological Sciences
Tarleton State University
Stephenville, Texas, USA

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

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

For years, the quality of reptile genomes has lagged behind those of mammals and birds, but new molecular techniques have made highly-contiguous genomes from non-model organisms possible. Here we present a chromosome-level genome assembly of the prairie rattlesnake (*Crotalus viridis viridis*), which we used to study key features of genome biology and evolution in reptiles. We identify the rattlesnake Z chromosome, including the recombining pseudoautosomal region, and find evidence for partial dosage compensation driven by an evolutionary accumulation of a female-biased upregulation mechanism. Comparative analyses with other amniotes provide new insight into the origins, structure, and function of reptile microchromosomes, which we demonstrate have markedly different structure and function compared to macrochromosomes. Snake microchromosomes are also enriched for venom genes, which we show have evolved through multiple tandem duplication events in multiple gene families. We further leverage this genome in combination with whole genome re-sequencing data from populations to characterize the recombination landscape in snakes for the first time, which further illustrate the unique aspects of microchromosomes and their evolutionary significance. Our findings reveal novel and fundamental features of reptile genome biology, provide insight into the regulation of snake venom, and broadly highlight the biological insight enabled by chromosome-level genome assemblies.

8. And So We Meet Again: Allopatric Divergence and Secondary Contact with Gene Flow is a Recurring Theme in Rattlesnake Evolution

Perry, Blair W.
blair.perry@uta.edu

Schield, Drew R.
Adams, Richard H.
Department of Biology
University of Texas at Arlington
Arlington, Texas, USA

Card, Daren C.
Department of Biology
University of Texas at Arlington
Arlington, Texas, USA

Department of Organismic and Evolutionary Biology
Museum of Comparative Zoology
Harvard University
Cambridge, Massachusetts, USA

Jezkova, Tereza
Department of Biology
Miami University of Ohio
Oxford, Ohio, USA

Pasquesi, Giulia I. M.
Nikolakis, Zachary L.
Row, Kristopher
Department of Biology
University of Texas at Arlington
Arlington, Texas, USA

Meik, Jesse M.
Department of Biological Sciences
Tarleton State University
Stephenville, Texas, USA

Smith, Cara F.
Mackessy, Stephen P.
School of Biological Sciences

University of Northern Colorado
Greeley, Colorado, USA

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

The study of recently diverged lineages whose geographic ranges come into contact can provide insight into the early stages of speciation and the potential roles of reproductive isolation in generating and maintaining species. Such insight can also be important for understanding the strategies and challenges for delimiting species within recently diverged species complexes. Here, we used mitochondrial and nuclear genetic data to study population structure, gene flow, and demographic history across a geographically widespread rattlesnake clade, the western rattlesnake species complex (*Crotalus cerberus*, *C. viridis*, *C. oreganus*, and relatives), which contains multiple lineages with ranges that geographically overlap or contact one another. We find evidence that pervasive gene flow has broadly influenced patterns of present-day genetic diversity. Our results suggest that lineage diversity has been shaped largely by drift and divergent selection in isolation, followed by secondary contact in which reproductive isolating mechanisms appear weak and insufficient to prevent introgression, even between anciently diverged lineages. The complexity of divergence and secondary contact with gene flow among lineages also provides new context for why delimiting species within this complex has been historically difficult and contentious.

9. Well Assembled Snake Genomes – A Foundation for Understanding Many Things about Snakes We Wanted to Know, and Other Things We Didn't Know We Wanted to Know

Castoe, Todd A.
todd.castoe@uta.edu

Schield, Drew R.
Perry, Blair W.
Adams, Richard H.
Department of Biology
University of Texas at Arlington
Arlington, Texas, USA

Card, Daren C.
Department of Biology
University of Texas at Arlington
Arlington, Texas, USA

Department of Organismic and Evolutionary Biology
Museum of Comparative Zoology
Harvard University
Cambridge, Massachusetts, USA

Hales, Nicole M.
Nikolakis, Zachary L.
Orton, Richard W.
Pasquesi, Giulia I. M.
Department of Biology
University of Texas at Arlington
Arlington, Texas, USA

Meik, Jesse M.
Department of Biological Sciences
Tarleton State University
Stephenville, Texas, USA

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

In many ways, genomes represent a nexus of biological context for understanding the evolutionary mechanisms that shape organisms. To date, the relatively poor quality of available snake genomes has prevented a detailed understanding of many basic biological features of snakes. Here, through a series of vignettes, we illustrate how a new and well-assembled rattlesnake genome provides a foundation for fundamentally increasing our ability to address diverse longstanding questions about the biology and evolution of snakes, and rattlesnakes specifically. First, we provide evidence that squamate genomes may function remarkably differently from those of mammals. Second, we demonstrate substantial progress towards understanding the origins of venom, and molecular mechanisms responsible for its precise regulation. Third, we show how new genomic resources may fundamentally increase our ability to understand patterns of speciation, reproductive isolation, and hybridization in rattlesnakes.

10. Dynamic Functional Integration of Motor and Sensory Systems during Predator-Prey Interactions

Clark, Rulon W.
Biology Department
San Diego State University
San Diego, California, USA
rclark@sdsu.edu

Higham, Tim
Department of Biology
University of California at Riverside
Riverside, California, USA

Freymiller, Grace
Whitford, Malachi
Biology Department
San Diego State University
San Diego, California, USA

For most animals, high levels of locomotion and feeding performance require a number of sensorimotor systems to respond dynamically to the surrounding environment. The integration of sensory inputs and motor output is an emerging theme in evolutionary studies focusing on biomechanics and functional morphology of predation behavior. Rich sensory inputs may enhance the ability of predators to integrate complex motor function, as well as offer redundancy to cope with environmental variability. Our detailed studies of predator-prey interactions between ambush-hunting rattlesnakes and small mammals provide a useful exemplar for analyzing dynamic sensorimotor integration in natural systems. Pitvipers are generally ambush foragers, relying on crypsis, the element of surprise, and a short but very rapid strike to effect prey capture. Predation on small mammals requires successful detection, evaluation, pursuit, and subjugation of prey, and pitvipers integrate thermal, visual, chemical, and vibrational information in various combinations to drive success in each phase of this predatory sequence.

11. Female Reproductive Ecology of Western Rattlesnakes (*Crotalus oreganus*) in Southern British Columbia, Canada

Eye, Dana M.
Environmental Science Program
Thompson Rivers University
Kamloops, British Columbia, Canada
danaeye03@gmail.com

Skurikhina, Anna
Department of Natural Resource Science

Thompson Rivers University
Kamloops, British Columbia, Canada

Bishop, Christine
Environment and Climate Change Canada
Delta, British Columbia, Canada

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

Female reproductive success, habitat selection and behaviour are all important elements in rattlesnake ecology. In Canada, a large portion of research on the Western Rattlesnake (*Crotalus oreganus*) has focused heavily on male behaviour (including migration), leaving a large knowledge gap and biasing the development of effective recovery plans. Our study in Osoyoos, BC, is focusing on site selection and movement behaviour by female rattlesnakes during parturition. We are using radio telemetry to track gravid female rattlesnakes (n=15 to date) to their 'rookery sites', identified by the cessation of long-distance movements and the adoption of sedentary behaviour. These sites are being compared to random habitat plots using a matched case-control study design. Vegetation cover, temperature data, and additional features are being assessed at three different spatial scales (1 m, 3 m, & 10 m radius plots). To date, we have identified 14 rookery sites and 7 communal rookery sites. The average distance traveled by gravid females from their hibernacula to their rookery sites is 84.7 m (range 7.4 m to 233.2 m, n= 15). Additionally, 12/15 females moved down slope, following parturition, in the opposite direction of their hibernacula. This spring, gravid female rattlesnakes will be radio-tracked at three different sites in BC, in addition to provisioning experiments, to investigate the potential drivers of post-partum rattlesnake movement. Information from this ongoing study will shed insight into a critical phase of the life history of female rattlesnakes in this region.

12. Natural History and Captive Management of the St. Lucia Pitviper, *Bothrops caribbaeus*

Wiley, Kristen
Harrison, Jim
kentuckyreptilez@bellsouth.net

Kentucky Reptile Zoo
200 L&E Railroad Place
Slade, Kentucky, USA

Smith, Chris
5725 Dogwood Dr.
Highridge Missouri, USA

The Saint Lucia Pitviper (*Bothrops caribbaeu*s) is an endemic native to the island of St. Lucia. Due to its isolated nature, this snake has been largely overlooked and basic information about its biology is largely lacking. In our presentation we will discuss the natural history of this large pitviper, including its diet, occurrence near humans, and current conservation efforts. Reproductive behavior in captivity will be compared to what is known about reproduction in the wild. The feeding behavior of juvenile individuals in captivity also will be discussed. In-depth studies of the ecology of this species, including radio-telemetry, are needed to better understand its role in the island system it inhabits.

13. Recent Advances in the Field of Parthenogenesis in Snakes

Booth,Warren
Department of Biological Science
The University of Tulsa
Tulsa, Oklahoma, USA
warren-booth@utulsa.edu

Chiricahua Desert Museum
Rodeo, New Mexico, USA

Card, Daren
Department of Organismic and Evolutionary Biology
Harvard University
Cambridge, Massachusetts, USA

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

Vonk, Freek
Naturalis Biodiversity Center
Leiden, The Netherlands

Wüster, Wolfgang
Alistair Reid Venom Research Unit
School of Natural Sciences
Bangor University
Bangor, UK

Chiricahua Desert Museum
Rodeo, New Mexico, USA

Casewell, Nicholas R.
Liverpool School of Tropical Medicine
Liverpool, UK

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

Chiricahua Desert Museum
Rodeo, New Mexico, USA

In recent years it has become clear that snakes may represent an ideal model system for study of vertebrate parthenogenesis. Phylogenetically widespread, parthenogenesis has been reported as obligatory in the basal Brahminy Blind Snake (*Indotyphlops braminus*) and facultative in all of the other lineages. In those taxa demonstrated to exhibit facultative parthenogenesis (FP), a diversity of forms has been discovered with regard to characteristics of the resulting parthenogens. These include differences in sex chromosome morphology and number, viability, and sex of the parthenogens. This, in concert with the first records of viable reproduction by a parthenogen, has shed light on sex chromosome evolution which, in turn, has resulted in the identification of both ZW and XY sex chromosome systems in snakes. Recent findings in pitvipers have informed, and indeed yielded, additional questions regarding the inheritance and complexity of venom. Current research has focused on the levels of heterozygosity retained by individual parthenogens and the genomic regions of retention. New results in our labs bring into question the assumed mechanism of terminal fusion automixis as the pathway for producing FP progeny. This strongly suggests that our understanding of FP (and related phenomena) is likely far from complete.

14. The Radiation of New World Pitvipers: A Macroevolutionary Perspective

Alencar, Laura R.V.
Department of Ecology
University of São Paulo
São Paulo, Brazil
alencarlrv@gmail.com

The arrival of a lineage in a continent can spur rapid species formation. Distinct evolutionary processes could potentially underlie this increase in speciation rates. Moreover, given that ecological and environmental variables vary among different regions, once a lineage expands and diversifies through a large continental area, the diversification dynamics characterizing this radiation could differ in the different parts of the continent. Although vipers originated in the Old World, members of the subfamily Crotalinae (pitvipers) arrived in the New World ~26 million years ago, greatly diversifying throughout the region. In the present talk, I will briefly review what we know about the evolutionary history of the New World radiation of pitvipers, focusing on biogeographic and macroevolutionary aspects. I will also show some results from a very recent study where I am exploring (1) the possible processes underlying the rapid pitviper diversification in the New World; (2) how the climatic and ecological niche changed during the radiation and in the distinct regions of the American continent; (3) if the distinct evolutionary trajectories of those niche axes resulted in different patterns shown by the extant New World pitviper species.

15. India – A Pitviper Paradise

Santra, Vishal
Simultala Conservationists
West Bengal, India
vscaptiveandfieldherpetology@gmail.com

Malhotra, Anita
School of Natural Sciences
Bangor University
Bangor, UK

For thousands of years, India has been known as the "Land of Snakes" with iconic species like the Indian Cobra (*Naja naja*), the infamous King Cobra (*Ophiophagus hannah*), and Indian Python (*Python molurus*) dominating herpetologists' wish-lists when they visit. Being a tropical country and covering several very distinct biogeographical regions, India is home to more than 300 species of snakes. The diversity and abundance of venomous snakes also has earned India the unfortunate title of "Snakebite Capital of the World," with each year almost 50,000 people losing their lives due to snakebite. India has a unique diversity of venomous and nonvenomous snakes living in close proximity to humans. While the biology of India's pitvipers has been relatively neglected by scientists, they are represented by members of at least six distinct lineages with 23 currently described species. Many more species await description; thus, we can truly say this land is a pitviper paradise. In my presentation I will discuss the present and future diversity of India's pitvipers and the threats they face at this challenging time in their history, ranging from widespread use of pesticides to climate-change induced melting of the Himalayan glaciers.

16. Natural History, Evolution, and Conservation of Venomous Snakes: Four Talking Points

Greene, Harry W.
Museum of Vertebrates and
Department of Ecology and Evolutionary Biology
Cornell University
Ithaca, New York, USA
hwg5@cornell.edu

1) The diets of snakes typically cannot be studied by direct observations, because they are secretive and feed infrequently. Instead we more often rely on palpating food from fresh caught animals, examining stomach contents of museum specimens, accumulation of anecdotes, remote photography and videography, and indirect assessment methods, e.g., stable isotope analyses. I will comment on the shortcomings, challenges, and potential for integrative assessments using diverse approaches to understanding the feeding biology of pitvipers. 2) Ontogenetic shifts from ectothermic to endothermic prey, or their lack, present an understudied aspect of venomous snake feeding biology from ecological and evolutionary perspectives, i.e., why and how do these shifts happen? I will provide examples of discrete patterns in the range of prey taken by pitvipers over the course of individual lives, and then place that variation in the context of behavioral ontogeny, phylogeny, and heterochrony. 3) Recent work has enormously increased our notions of behavioral complexity in snakes, especially social relationships, and further revelations will come from both lab and field studies. Along with other examples, I will describe a

surprising field observation of repeated relocation, envenoming, and assessment of a large prey item in the context of results from experiments published by Chiszar et al. > 20 years ago—then emphasize the recent plea from Schuett et al. that we be open to surprising future discoveries, as well as pose questions that until recently would have been dismissed as irrelevant to pitvipers. 4) Conservation of venomous snakes globally will profit from increased recognition that these are indeed dangerous animals, and that primates have experienced roughly 75 million years of co-evolutionary relationships with them in that context. As also is the case with apex predators and megaherbivores, sustained coexistence with venomous snakes will require both substantially reducing the likelihood of danger to people, as well as enhancing appreciation for their positive attributes in the context of human values.

17. The Rattlesnake Tree of Life: A Genome-Wide Perspective

Parkinson, Christopher
viper@clemson.edu
Department of Biological Sciences
Department of Forestry and Environmental Conservation
Clemson University
Clemson, South Carolina, USA

Holding, Matthew L.*
Department of Biological Sciences
Clemson University
Clemson, South Carolina, USA

Strickland, Jason L.
Rautsaw, Rhett M.
Mason, Andrew J.
Hofmann, Erich P.
Department of Biological Science*
Florida State University
Tallahassee, Florida, USA

Borja, Miguel
Facultad de Ciencias Biológicas
Universidad Juárez del Estado de Durango
Av. Universidad s/n. Fracc. Filadelfia, C.P. 35070
Gómez Palacio, Durango, Mexico

Grünwald, Christoph I.
Jones, Jason M
Herp.mx A.C.
Villa del Álvarez, Colima, Mexico

de la Torre-Loranca, Miguel Angel
Instituto Lorancai
Km 32 Carretera Federal Orizaba-Zongolica Ocotepec
Los Reyes, Veracruz, México

Castañeda, Gamaliel Facultad de Ciencias Biológicas
Universidad Juárez del Estado de Durango
Av. Universidad s/n. Fracc
Filadelfia, C.P. 35070
Gómez Palacio, Durango, Mexico

Grazziotin, Felipe
Laboratório de Coleções Zoológicas
Instituto Butantan
São Paulo, Brazil

Junqueira-de-Azevedo, Inacio
Laboratório Especial de Toxinologia Aplicada
CeTICS
Instituto Butanta
São Paulo, Brazil

Gibbs, H. Lisle
Department of Evolution, Ecology and Organismal Biology
Ohio State University
Columbus, Ohio, USA

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

The rattlesnakes (*Crotalu*s and *Sistrurus*) are the most speciose group of vipers, consisting of ~50 currently described species. Rattlesnakes contribute the majority of snakebites in North America and are flagships for curiosity, culture, and conservation of snakes. As such, they have been extensively studied through time from an ecological and evolutionary perspective. Despite being the focus of countless phylogenetic studies, the evolutionary history of rattlesnakes remains clouded and the phylogenetic placement of many species is uncertain. Here, we use the largest dataset assembled and the most complete sampling of putative lineages to infer the phylogeny of rattlesnakes. We used > 1400 coding gene sequences recovered from venom gland transcriptomes of 147 individual snakes, representing 55 putative rattlesnake lineages. We provide strong evidence for 3 major clades within *Crotalus*, the dusky rattlesnakes and rock rattlesnakes, the montane rattlesnakes including *C. willardi*, and the large-bodied rattlesnakes such as *C. durissus* and *C. scutulatus*. We clearly support a monophyletic *C. viridis* complex, a montane radiation that includes *C. pricei*, *C. transversus*, *C. intermedius*, and *C. willardi*, and a monophyletic *C. durissus* complex. Interestingly, we support *C. horridus* as sister to the rest of the clade of large-bodied *Crotalus* species, which differs considerably from its place in previous phylogenies. The recovery of novel relationships, and apparent paraphyly of certain taxa suggest that several groups may be in need of taxonomic revision. Despite the unprecedented size of our dataset, the persistence of a few recalcitrant nodes suggests that the early diversification of rattlesnakes may include hard polytomies, or require targeted whole genome comparisons to resolve. Overall, we provide new, high resolution insight into the evolutionary history of this complex and iconic group to date. We expect that the phylogeny generated here will provide a stalwart backbone for testing a variety of ecological and evolutionary hypotheses in the future.

18. Assessing the Relationship between Venom Complexity and Diet Diversity in Rattlesnakes Using a Novel, Genome-Wide Phylogeny

Holding, Matthew L.
Department of Biological Science
Florida State University
Tallahassee, Florida, USA
matthewholding28@gmail.com

Strickland, Jason L.
Rautsaw, Rhett M.
Mason, Andrew J.
Hofmann, Erich P.
Margres, Mark M.
Department of Biological Sciences
Clemson University
Clemson, South Carolina, USA

Hogan, Michael P.
Ellsworth, Schyler
Nystrom, Gunnar
Department of Biological Science

Florida State University
Tallahassee, Florida, USA

Colston, Timothy J.
Department of Biological Science
Florida State University
Tallahassee, Florida, USA

Borja, Miguel
Facultad de Ciencias Biológicas Universidad
Juárez del Estado de Durango
Gómez Palacio, Durango, Mexico

Grüwald, Christoph I.
Jones, Jason M.
Herp.mx A.C.
Villa del Álvarez, Colima, Mexico

Castañeda, Gamaliel
Facultad de Ciencias Biológicas Universidad
Juárez del Estado de Durango
Gómez Palacio, Durango, Mexico

de Sousa, Lucia A. F.
da Silva, Ana Moura
Laboratório de Imunopatologia Instituto Butantan
São Paulo, Brazil

Azevedo, Inacio
Grazziotin, Felipe G.
Laboratório Especial de Toxinologia Aplicada
Instituto Butantan
São Paulo, Brazil

Gibbs, H. Lisle
Department of Evolution, Ecology, and Organismal Biology
Ohio State University
Columbus, Ohio, USA

Rokyta, Darin R.
Department of Biological Science
Florida State University
Tallahassee, Florida, USA

Christopher L. Parkinson
Department of Biological Sciences
Department of Forestry and Environmental Conservation
Clemson University
Clemson, South Carolina, USA

Organisms are more than the sum of their parts, making the study of complex integrated phenotypes imperative for understanding the interplay between the evolution of traits and the evolution of species. Molecular trait complexity is particularly important in species interactions, where more diverse networks of species interactions may select for molecular complexity in offensive or defensive traits, such as secreted toxins. Animal venoms, as injected secretions with a tractable genetic basis, are optimal systems for testing the hypothesis that the evolution of more complex molecular traits is associated with interacting with diverse prey taxa. The rattlesnakes (*Crotalus* and *Sistrurus*) are the most speciose group of vipers, consisting of ~50 currently described species. Rattlesnakes are medically important as they contribute the majority

of snakebites in North America. Additionally, they are flagships for curiosity, culture, and conservation of snakes. We have collected venom glands of 147 individual snakes, representing most rattlesnake lineages. We use > 1500 nontoxin sequences from venom gland transcriptomes to infer the phylogeny of rattlesnakes, and characterize the composition and complexity of toxin expression in the transcriptomes and in chromatographic profiles of whole venom. We combine a novel, dated phylogeny of rattlesnakes, venom gene expression data, and published diet data to test the hypothesis that more complex venoms evolve in response to a more taxonomically complex diet. Our work provides new insight into the evolutionary history of this complex and iconic group, and relates complexity in patterns of gene expression to the complexity of ecological interactions an organism must face.

19. Characterizing the Gut Microbiome in Rattlesnakes with Divergent Venoms

Stiers, Erin E.
estiers@clemson.edu

Strickland, Jason L.
Department of Biological Sciences
Clemson University
Clemson, South Carolina, USA

Parkinson, Christopher L.
Department of Biological Sciences
Department of Forestry and Environmental Conservation
Clemson University
Clemson, South Carolina, USA

The microbiome is the total microbial community in an environment and can inflict strong ecological and evolutionary pressures on host systems. Compositional and functional changes to the microbiome often precede and may even mediate adaptive evolution and speciation. The gut microbiome has a primary role in digestion and energy acquisition and is expected to be closely linked to dietary specialization. Although many organisms have specialized adaptations for food acquisition, few are as variable and well-characterized as snake venoms. Snake venom variation is highly adaptive and often associated with dietary shifts. Gut microbiomes in other vertebrate systems have been shown to covary with dietary composition. To determine the role of the microbiome as an agent of phenotypic shifts in venom, we have collected cloacal microbiome samples from the Mojave Rattlesnake (*Crotalus scutulatus*) which possesses a well-characterized polymorphic venom phenotype. Over 200 longitudinal microbiome samples from twelve *C. scutulatus* have been collected and sequenced using 16S to determine differential microbiome changes. Utilizing microbial community data in the *Crotalus* venom system will deepen our understanding not only of venom adaptation, but of the animal-bacterial interactions which influence vertebrate traits.

20. Characterizing Venom Variation in the Mexican Montane Pitvipers (*Cerrophidion*)

Hofmann, Erich P.
ehofman@clemson.edu

Rautsaw, Rhett M.
Department of Biological Sciences
Clemson University
Clemson, South Carolina, USA

Grünwald, Christoph I.
Jones, Jason M.
Franz-Chávez, Héctor
Ahumada-Carrillo, Ivan T.
Ramírez Chaparro, Ricardo
Herp.mx AC
Villa del Álvarez, Colima, Mexico

de La Torre Loranca, Miguel Angel
Instituto Lorancai
Km 32 Carretera Federal Orizaba-Zongolica Ocotepec
Los Reyes, Veracruz, Mexico

Strickland, Jason L.
Mason, Andrew J.
Holding, Matthew L.*
Department of Biological Sciences
Clemson University
Clemson, South Carolina, USA

Borja, Miguel
Castañeda-Gaytán, Gamaliel
Facultad de Ciencias Biológicas
Universidad Juárez del Estado de Durango
Av. Universidad s/n. Fracc. Filadelfia - C.P. 35070
Gómez Palacio, Durango, Mexico

Rokyta, Darin R.
Department of Biological Science*
Florida State University
Tallahassee, Florida, USA

Parkinson, Christopher L.
Department of Biological Sciences
Department of Forestry and Environmental Conservation
Clemson University
Clemson, South Carolina, USA

Venom is highly adaptive, changing rapidly between species and between populations of the same species. Changes to venom are the result of adjustments in toxin gene expression and the underlying DNA sequence. However, the venom of many species remains uncharacterized, making it difficult to trace the evolutionary history of venom and provide adequate medical help to those bitten by uncharacterized species. Profiling toxin genes and their expression within and between species allows for the examination of venom variation and provides a better understanding of the full venom arsenal of a species. Here, we attempt to fill gaps in our understanding of venom evolution and variation by analyzing venom of three species of *Cerrophidion* from Mexico. We sequenced the venom-gland transcriptome for 12 individuals (six *Cerrophidion godmani*, three *C. petlalcalensis*, and three *C. tzotzilorum*) collected in southeastern Mexico, and tested for differences in the expression of toxin genes related to age class and locality. We found that the venom transcriptomes of these species are dominated by PLA2s and SVMPs, largely hemorrhagic toxins as expected, but individual variation was present in conspecific individuals. Both *C. godmani* and *C. tzotzilorum* displayed several toxins that were significantly differentially expressed between age classes, suggesting a possible ontogenetic shift. Interestingly, the most highly expressed PLA2 transcripts in *C. godmani* populations north and south of the Chiapan Depression were distinctly different, despite otherwise similar transcriptomic profiles. This might be evidence of local adaptation or early lineage diversification driving venom differences between these disjunct populations. Our data represent a broad examination of the venoms of Mexican *Cerrophidion*, characterizing the toxin gene repertoire of these species for the first time. Further sampling, proteomic confirmation, and additional analyses are underway to provide a more complete understanding of *Cerrophidion* venom evolution and variation across their range.

21. The Flat Adaptive Landscape of Sidewinder Rattlesnake Venom

Rautsaw, Rhett M.
rrautsa@clemson.edu

Hofmann, Erich P.
Margres, Mark J.

Holding, Matthew L.*
Strickland, Jason L.
Mason, Andrew J.
Department of Biological Sciences
Clemson University
Clemson, South Carolina, USA

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

Parkinson, Christopher L.
Department of Biological Sciences
Department of Forestry and Environmental Conservation
Clemson University
Clemson, South Carolina, USA

Snake venom is a polygenic trait that can evolve rapidly due to changes in gene expression or protein-coding sequences. However, these forms of genetic variation can be correlated such that changes to one can influence the other. To examine how gene expression and protein-coding changes influence the evolution of venom, we generated the first venom-gland transcriptomes for the Sidewinder Rattlesnake (*Crotalus cerastes*). Using these data, we characterize the venom of the Sidewinder and test for differential expression between the phylogenetic lineages in the United States. Additionally, we examine the sequence variation within toxins and test for evidence of selection and differentiation by calculating Tajima's D and FST. We compare the results from toxins to nontoxin (e.g. housekeeping) genes. Overall, we find little evidence for differential expression, directional selection, or toxin sequence differentiation between lineages. These results suggest that neither changes to gene expression nor protein sequences strongly influence the evolution of Sidewinder venom. Instead, toxins appear to be under extremely variant selection pressures and low-expression toxins have more standing expression and sequence variation on which selection can act. The lack of differential expression and sequence divergence suggests that Sidewinders – given their generalist diet, moderate gene flow, and environmental variation – are under stabilizing selection which functions to maintain a generalist phenotype. Overall, we demonstrate the importance of examining the relationship between gene expression and protein-coding changes to understand the evolution of a complex trait.

22. Pitviper Embryology: The Development of the Loreal Pit Organ in the Brazilian Pitviper *Bothrops jararaca*

Wouters, Roel M.
woutersroel1@gmail.com

de Bakker, Merijn A.G.
Richardson, Michael K.
Animal Sciences & Health
Institute of Biology Leiden
Leiden University
Leiden, Netherlands

Pitvipers (Crotalinae) are a subfamily of venomous snakes, which are characterized by an infra-red sensing organ called the loreal pit organ. The loreal pit organ is bilaterally located between the eye and nostril and consists of a posterior (inner) chamber and an anterior (outer) chamber septated by a heavily innervated membrane. By detecting infra-red radiation on the pit membrane, the loreal pit organ functions in prey acquisition and behavioural thermoregulation. Here, we study the developmental biology of the loreal pit organ in a rare embryo-series of the Brazilian pitviper *Bothrops* [*Bothropoides*] *jararaca* and the Malayan pitviper *Calloselasma rhodostoma*. The embryos have been stained with phosphotungstic acid before being scanned using X-ray microcomputed tomography (Micro-CT). The scans were used for 3D reconstruction. Afterwards, several embryos were selected and sectioned for paraffin histology. All together these result-

ed in a time-series showing embryonic development of the loreal pit organ. We found the loreal pit organ only forms after the other sensory organs have already well developed. We also found the development of the loreal pit organ starts with an invagination of skin epidermis, forming the outer chamber. Later, posterior of the outer chamber the inner chamber forms consisting of duct-like epithelium. The innervated pit membrane consists of connective mesenchyme and grows thinner during development. Our findings suggest that the outer and inner chamber have different origins with the pit membrane connecting them. We are still investigating whether the inner chamber is part of the lacrimal system. Our study contributes to a better understanding of the complex developmental and evolutionary origins of the loreal pit organ in pitvipers.

23. Bateman Gradients and Sexual Selection in the Rattlesnake *Crotalus atrox* and other North American Pitvipers

Levine, Brenna A.*
Department of Biological Sciences
The University of Tulsa
Tulsa, Oklahoma, USA
levine.brenna.a@gmail.com

Schuett, Gordon W.*
Department of Biology and Neuroscience Institute
Georgia State University
Atlanta, Georgia, USA
gwschuett@yahoo.com

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

Repp, Roger A.*

Herrmann, Hans-Werner*
School of Natural Resources and the Environment
University of Arizona
Tucson, Arizona, USA

Chiricahua Desert Museum, Rodeo, NM, USA*

Sexual selection theory predicts that the sex in greater abundance and with "cheaper" gametes will experience increased reproductive success as a result of an increased number of matings, whereas the sex with more finite numbers of gametes and in lesser abundance will experience no such gain. Empirical data across taxa have supported the prevalence of conventional Darwinian sex roles, with significant relationships between mating success and reproductive success common in males but not females, as gauged by Bateman gradients (i.e., the slope of the least-squares regression line of relative reproductive success on to relative mating success). Yet, few of these studies have explored sexual selection in pitvipers mostly due to their cryptic behavior and complicated internal reproductive processes (e.g., multiple paternity, long-term sperm storage, facultative parthenogenesis) that make it difficult to accurately identify parentage from field observations alone. To help fill this gap, we estimated Bateman gradients and other sexual selection metrics [i.e., opportunities for selection (I) and sexual selection (Is)] in a population of Western Diamond-backed Rattlesnake (*Crotalus atrox*) in Southern Arizona using molecular parentage assignments derived for a previous study. In keeping with patterns of conventional sex roles prevalent across animal taxa, we found males to exhibit significantly higher I and IS than females ($P<0.05$). Yet, contrary to our expectations, both males and females exhibited significant Bateman gradients, and there was no significant difference between them ($P=0.089$). In the population we studied for > 10 years, sexual selection is thus not acting more strongly on male *C. atrox* than female *C. atrox*. This differs from a previous study of Bateman gradients in another North American pitviper, the Copperhead (*Agkistrodon contortix*), and we posit that mating system characteristics contribute to this difference.

24. Quantifying Color Pattern Mimicry and Background Color-Matching in Rock Rattlesnakes *(Crotalus lepidus*) and Gray-Banded Kingsnakes (*Lampropeltis alterna*) Utilizing Digital Photography

Rhoads, Dustin
Department of Biology
Texas Christian University
Fort Worth, TX USA
subocs@gmail.com

Pikstein, Rachel
College of Science, Engineering & Technology
Grand Canyon University
Phoenix, AZ USA
rpbiologist@gmail.com

Quantifying color-matching among organisms and their environments has been a challenge for ecologists due to the qualitative nature of the variable and a lack of affordable technology for such assessments. Many longstanding hypotheses regarding color-pattern mimicry and crypsis remain untested due to these constraints. Here, we test a previously proposed hypothesis that Gray-Banded Kingsnakes mimic sympatric pit vipers in the Trans-Pecos and Big Bend regions of the Chihuahuan Desert using a newly available and affordable technology for measuring color-matching. We also utilize the same method to measure the influence of background color-matching between these snakes and their natural substrates, as their color-pattern phenotype is likely reflective of an interplay among varying selective pressures in these taxa. Results aim to address these hypotheses while providing further implications for the use of this technology in fields such as evolution and conservation biology.

25. Evolutionary Genomics of Reproductive Modes in Pitvipers

Lazzeroni, Maggie
mlazzeroni@amnh.org

Hayashim, Cheryl
Burbrink, Frank
Department of Herpetology
The American Museum of Natural History
New York, New York, USA

Squamates (snakes and lizards) are an ideal system for studying the evolution of reproductive modes because viviparity has arisen as many as 115 times in this group, twice the amount than in any other vertebrate group. Although the ecological conditions impacting viviparity has been widely studied, we know relatively little about the genomics and physiological changes underlying transitions in reproductive modes. Debate surrounds the evolutionary possibility of reversals back to oviparity. Evidence of alternative genetic mechanisms, for reproductive processes in taxa that are purported reversals, would serve as strong evidence that these species are true reversals. Pitvipers have oviparous and viviparous species peppered throughout their phylogeny, making them an excellent group to study. To elucidate the genomics underlying evolutionary transitions between reproductive modes, we identified 758 candidate genes involved with the evolution of reproductive modes. We then sequenced 8 whole genomes of pit vipers (one of which is a purported reversal) and compared them to 5 published pit vipers genomes and 9 outgroups representing 6 snake families. We located our candidate loci in each species using BLAST+ and performed gene family analyses using BedTools and IQTree. This information will serve as a foundation for further research on the evolution of viviparity and oviparity.

26. Morphology of the Viper Prefrontal Bone and a New Pliocene *Agkistrodon*

Mead, Jim I.
jmead@mammothsite.org

Swift, Sandra L.
The Mammoth Site
Hot Springs, SD USA

The earliest record of the family Viperidae arose perhaps in Eurasia during the late Oligocene. The rugged structure of a snake vertebra and their abundance per animal permits these skeletal remains to be commonly preserved in the fossil record. Lab technicians have come to easily distinguish these remains as belonging to snakes when sorting fossils, thus fossils are selected for identification. Consequently, vertebrae are the predominant skeletal element when identifying fossil snakes. The ability to identify genera and species of snakes based solely on vertebral characters has varying levels of success and acceptance within the research community. North American researchers have concentrated on vertebral remains when analyzing fossil snake faunas. European researchers also target vertebral remains but often include cranial remains. Cranial remains have proven diagnostic to genus and to species with varying success. A hindrance to using the various cranial elements for identification of fossil remains includes lab personnel do not always recognize a number of the cranial elements, therefore specimens are not consistently made available for identification. The recovery of fossil snake cranial bones (earliest Pliocene) leads us to study the prefrontal of viperine snakes from Western Hemisphere and Eurasia. Here we assess the morphological attributes and variation of the prefrontal from extant Eurasian Viperinae (5 genera) and Azemiopinae (1 g.), along with members of Crotalinae from Asia (7 g.) and the Americas (11 g.) for a total of 184 specimens. Results indicate that isolated and complete prefrontal bones typically can be identified to genus (e.g., *Agkistrodon*) and occasionally to species. At this time the prefrontal within specious genera (*Crotalus*) cannot be identified to species. We have identified a new, Pliocene-age species of *Agkistrodon* within the Copperhead group, yet distinct from the clade containing the other species.

27. Vipers on Islands: Ecology, Evolution, and Conservation

Martins, Marcio
Departamento de Ecologia
Instituto de Biociências
Universidade de São Paulo
São Paulo SP, Brazil
martinsmrc@usp.br

About 100 species of vipers occur on 300 islands throughout the world. About half (51%) of these islands are oceanic and half (49%) are continental (or land-bridge). The size of islands inhabited by vipers vary from tiny (0.038 km2) to very large (743,330 km2), and elevation varies from 1 to 4095 m a.s.l. Up to eight vipers may be found in sympatry in continental islands, with Sumatra (8 spp.), Taiwan (7), Sri Lanka (6), and Borneo (6) being the richest islands regarding vipers. In oceanic islands, up to 5 species occur in sympatry, with Langkawi (Malaysia) being the richest one (5 spp.). Vipers occur in 1 (45 spp.) to 34 islands (*Vipera ammodytes*). About 20% of island vipers (19 spp.) are endemics to a single island, and an additional 11 species occur only in islands. Both island area and island maximum elevation (a proxy for habitat diversity) explain very little of the variation in viper richness (only 5% and 8%, respectively). The origin of vipers on islands is related to the type of island where they occur. Vipers from continental islands are probably relictual portions from once widespread populations on exposed continental shelf during Pleistocene glaciations. On the other hand, viper populations from most oceanic islands probably resulted from colonization-driven processes. Similar biotic conditions on islands inhabited by vipers apparently led to several cases of convergent evolution. Of 62 species of island vipers present in the IUCN red list, seven are listed as threatened (15% of all threatened vipers in the list), two as Near Threatened," and one as Data Deficient. Illegal captures, habitat loss, fire, and drought are the main threats to island vipers. A global conservation action plan is urgently needed for island vipers.

28. New Approaches to Venomous Snake Conservation in Ecuador

Paladines, María Elena Barragán
Vivarium de Quito
Av. Amazonas 2925
Quito 170135, Ecuador
malenairka@puntonet.ec

Ecuador is home to 10% of the world's snake species. Of these, 36 are a potential source for deadly bites (families Viperidae and Elapidae). These particular species occur in different ecosystems in Ecuador: coastal regions, Amazonia, and the mountains. Unfortunately, snake-bite accidents are a serious health issue in the population. Data in reports reveal around 10,000 cases annually with 0.01% resulting in fatalities. Therefore, our new approach to education includes the social impact of snakes, snakebites, and the implication to snake conservation.

Venomous snakes are facing threats related to ecosystems destruction (e.g., high rates of deforestation). Snakes, in general, are not a high priority for conservation research in any region. Since 1993, the Gustavo Orces Herpetological Foundation has implemented hands-on education and involvement of isolated local communities. This effort consists of developing protocols that measure the extent to which fear of snakes determines and influences their conservation. One main goal is to identify problems that communities face about fears and beliefs which can be adjusted (re-valuation) through artistic, linguistic, and religious representations. As a result, small-scale economic activities linked to the production of souvenirs that represent and rescue the beauty of these animals were implemented, but a clear identification of the communities associated with these venomous animals was maintained. This empowerment of communities has resumed the possibility of developing positive learning through organized groups, mainly women. I view this work as a starting point for the development of a program for the conservation of venomous snakes through active participation of people of these rural and isolated communities.

29. One Snake, Two Venoms: Causes and Correlates of Venom Variation in the Mohave Rattlesnake (*Crotalus scutulatus*)

Wüster Wolfgang
w.wuster@bangor.ac.uk

Zancolli, Giulia
Mulley, John F.
Wüster, Catharine E.
Molecular Ecology and Fisheries Genetics Laboratory (MEFGL)
School of Natural Sciences
Bangor University
Bangor, United Kingdom

Calvete, Juan J.
Libia Sanz
Evolutionary and Translational Venomics Laboratory
Instituto de Biomedicina de Valencia
Valencia, Spain

Cardwell, Michael D.
Department of Biology
San Diego State University
San Diego, California, USA

Greene, Harry W.
Department of Ecology and Evolutionary Biology
Cornell University
Ithaca, New York, USA

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

Hegarty, Matthew J.
Institute of Biological, Environmental and Rural Sciences
Aberystwyth University,
Aberystwyth, United Kingdom

Herrmann, Hans-Werner
School of Natural Resources and the Environment,
University of Arizona
Tucson, Arizona, USA
Holycross, Andrew T.

Natural History Collections
Arizona State University
Tempe, Arizona, USA

Lannutti, Dominic I.
Department of Biological Sciences
University of Texas at El Paso
El Paso, Texas, USA

Whorley, Joshuah R.
Seattle Central College
Science, Technology, Engineering & Mathematics Division
Seattle, Washington, USA

The snake venom forms an important part of the interface between the organisms and their environment, particularly in the context of foraging and defence. As a complex molecular phenotype with a direct genetic basis and clear fitness consequences, venom also represents an ideal model system for understanding the link between selection, phenotype and genome. Rattlesnakes are notable for displaying two alternative, largely mutually exclusive venom strategies, emphasising either highly neurotoxic phospholipases A2 (PLA2 – Venom A or type II venom) or hemorrhagic metalloproteases (SVMPs – Venom B). Both types are found within some species, e.g., the Mohave rattlesnake (*Crotalus scutulatus*). Based on multiple case studies, selection to optimise foraging efficiency is generally assumed to be the main driver of the evolution of venom composition. However, the role of diet composition in driving the extreme venom dichotomy in rattlesnakes has not been rigorously tested. Here, we use the Mojave-Sonoran clade of *C. scutulatus* to test whether variation in venom composition in this species is driven by neutral factors (genetic population structure), selection for difference in diet composition across its range, or other environmental factors. Unexpectedly, neither diet composition (at class, family, genus or species level) nor neutral population structure explain venom variation in this species. Instead, venom divergence is strongly correlated with environmental and climatic conditions. Individual toxin genes correlate with distinct environmental factors, suggesting that different selective pressures can act on individual loci independently of their co-expression patterns or genomic proximity. Our results challenge common assumptions about diet composition as the key selective driver of snake venom evolution. Moreover, while current research often emphasises the elucidation of broad patterns across a phylogeny, this example illustrates the need for in-depth studies of individual species to understand the diversity of ways in which selection and genome interact to generate phenotypic diversity.

30. Rattlesnakes at Your Feet

Bayard H. Brattstrom
Horned Lizard Ranch,
P. O. Box 166
Wikieup, AZ 85360 USA
bayard@hughes.net

On October 18-19 (2018), at the Rattlesnake Mini-symposium and *Rattlesnakes of Arizona* Book Signing, Chiricahua Desert Museum (www.geronimoevent.com), I pointed out that biologists are always looking down at rattlesnakes. I gave a homework assignment to the audience. It was this: Try to see the world like a rattlesnake sees it. I told them to lie down on the ground, put their eyes as close to the ground as possible, like a rattlesnake, and lie there for 20 minutes to "think" and "see" and "feel" like a rattlesnake. Then, come up with new ideas, hypotheses, and perspectives about rattlesnakes that we have not previously thought about. I will see how many did their homework, what ideas were generated, and present some of my own results regarding this "field experience" homework assignment.

31. What's All the Buzz About? Prairie Rattlesnake (*Crotalus viridis*) Movements at Urban Parks and Public Safety

Shipley, Bryon
Adaptation Environmental Services, LLC
Denver, CO USA
basnakluvr@gmail.com

Bonnell, Mary Ann
DuBois, Andrew
Jefferson County Open Space
Golden, CO USA

Triece, Kelly
Borgmann, Ryan
Ehrenberger, Joseph
Adaptation Environmental Services, LLC
Denver, CO USA

Public visitation in Colorado's Jefferson County Open Space (JCOS) parks is projected to increase annually. In 2017, an estimated 6.9 million visitors enjoyed the 28 JCOS parks. Contact with potentially dangerous wildlife, such as the Prairie Rattlesnakes (Crotalus viridis), has raised concerns for public and pet safety on trails and other landscape features in both parks as visitor usage grows. Adaptation Environmental Services (AES) investigated the potential for negative visitor interactions with rattlesnakes in at JCOS parks, North Table Mountain (NTM) and South Table Mountain (STM) in Golden, CO. We did this by determining locations of over-wintering dens and identifying areas of snake movements relative to trails. At NTM and STM we also conducted media interviews, contacted hikers, provided public presentations, produced a safety video and investigated visitors' knowledge, opinions, and beliefs about rattlesnakes. In addition, 26 visitors accompanied Adaptation Environmental Services staff on guided rattlesnake tracking experiences with pre- and post-tracking surveys given to measure changes in knowledge of Prairie rattlesnakes. Biological and social sciences surveys are important for species conservation and ecosystem health. Information about snake movements and denning locations will also be incorporated into park infrastructure development plans to minimize snake/human contact.

32. Patterns of Survival of a Communally Denning Rattlesnake (*Crotalus viridis*) in a Man-made Hibernaculum

Bruckerhoff, Lindsey A.
Division of Biology
Kansas State University
Manhattan, KS USA

Kamees, Larry K
Department of Biological Sciences
University of Arkansas
Fayetteville, AR USA
lkkamees@uark.edu

Holycross, Andrew T.
Department of Biology
Mesa Community College
Mesa, AZ USA

Painter, Charles W.
New Mexico Game and Fish
Santa Fe, NM USA

Carpenter, Geoffrey C.
Herptech Metalworks
Bosque Farms, NM USA

Avoiding thermal stress by utilizing hibernacula is fundamental to the survival of snakes occupying temperate environments. Snakes may overwinter alone or aggregate in communal dens to avoid temperature extremes. Limited information is available regarding the denning ecology of pit vipers mainly because of the inaccessibility of snakes in dens, yet basic demographic information is crucial for understanding population dynamics, habitat requirements, and management of pit viper species. Even less is known about the demographics of

species and populations utilizing man-made hibernacula which may become increasingly important as habitat becomes more fragmented. The objective of our study was to utilize long-term mark recapture data from Prairie Rattlesnakes (*Crotalus viridis*) at a man-made hibernaculum to estimate the annual apparent survival rate and investigate factors influencing it. We used multistrata mark-recapture models to estimate encounter rates, apparent survival, and transition rates between states across body condition strata. Over 1,400 captures of 901 individual snakes were made during the course of the eight-year study. Predicted encounter rates varied between males and females and between snakes with different body conditions. The interaction between body size and resident status influenced annual apparent survival rates, with high apparent survival of average sized resident snakes (Mean = 0.95 ± 0.12). This study contributes to basic knowledge about population dynamics of communally denning pit vipers and factors influencing their survival.

33. New Approaches to Neutralise Haemotoxic Viper Venoms

Casewell, Nicholas
nicholas.casewell@lstmed.ac.uk

Albulescu, Laura-Oana
Alomran, Nessrin
Hale, Melissa
Softley, Rowan
Alsolaiss, Jaffer
Crittenden, Edouard
Ainsworth, Stuart
Harrison, Robert
Centre for Snakebite Research & Interventions (CSRI)
Liverpool School of Tropical Medicine
Liverpool, UK

Slagboom, Julien
Xie, Chunfang
Kool, Jeroen
Division of BioAnalytical Chemistry
Amsterdam Institute for Molecular Medicines and Systems
VU University Amsterdam
Amsterdam, The Netherlands

Snakebite causes upwards of 138,000 deaths every year, and is now recognised by the World Health Organization as a priority neglected tropical disease. The majority of these deaths are caused by snakes that inject haemotoxic venom, predominately viperids, and which result in cardiovascular, haemorrhagic and coagulopathic disturbances. Conventional snakebite therapies, known as antivenoms, consist of polyclonal antibodies harvested from the serum or plasma of animals immunised with venom. While these therapies save tens of thousands of lives every year, they exhibit considerable deficiencies relating to their species-restricted efficacy, poor dose efficacy, high incidence of adverse reactions, and low affordability to the world's tropical snakebite victims. To begin to address these issues, we first characterised the coagulopathic and enzymatic activities of a wide variety of haemotoxic snake venoms, including representatives from every continent. We then explored the immunological binding and neutralising capability of existing and experimental polyclonal antibody-based antivenoms against these venoms. Our findings revealed surprisingly high levels of cross-reactivity among snake venoms that cause life threatening coagulopathy, and thus raise the potential for developing 'pathology-specific', rather than geographical, approaches for conventional antivenom therapy. Finally, given that many haemotoxic venoms rely on snake venom metalloproteinase, serine protease and phospholipase A2 toxins to cause pathology, we investigated the neutralising potential of small molecule-based inhibitors against these enzymes. We find that mixtures of these inhibitors protect against venom-induced lethality for a variety of viperids, and that certain inhibitors show great promise as early, community-based, treatments for particular haemotoxic envenomings.

34. Mohave Rattlesnake: The Deadliest Rattlesnake in North America – If You're a Lab Mouse!

Cardwell, Michael D.
Department of Biology

San Diego State University
5500 Campanile Drive
San Diego, California 92182, USA
mikecardwell31@gmail.com

Even against the backdrop of the near universal fear of snakes, the Mohave Rattlesnake (*Crotalus scutulatus*) is unique in the variety of myths associated with it. And the number of people who believe and repeat these myths, including journalists and individuals viewed as authorities by the lay public – including some physicians and biologists, is extraordinary. Even popular field guides and medical references commonly describe Mohave Rattlesnakes as the "most aggressive," "most dangerous" and/or "most toxic" of rattlesnakes. This presentation will discuss the most common and the most mind-boggling beliefs about this misunderstood animal, including the likely origins of these myths and what first-hand experience and scholarly studies tell us about each of them.

35. Eat, Prey, Live: Comparative Thermal Ecology and Energy Requirements of Coastal and Inland Pacific rattlesnakes (*Crotalus oreganus*)

Crowell, Hayley
hylacrowe@gmail.com

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

Understanding the effects of changing temperatures on ectothermic species is crucial if land managers and researchers are to make informed decisions about how to mitigate the predicted loss of diversity as a result of anthropogenic climate change. Using body temperature data from free-ranging snakes, the field metabolic rates, and therefore basic energetic requirements, can be calculated to determine average annual energy expenditure of a given ectotherm. However, few studies exist that examine the effects of climate across multiple populations within a single given species, especially snakes. The goal of this study is to use field active body temperature data from four distinct populations of *Crotalus oreganus* from central California (two inland and two coastal) to compare field and preferred body temperatures, estimated metabolic rates and annual energy expenditure across varying habitat types. Snake body temperature data were collected via internal implantation of Thermochron iButton temperature loggers from 2010 to 2017 during the snakes' active season (April-Oct). Despite dramatically different ambient temperatures at the field sites, snakes at inland and coastal sites thermoregulate such that they experience similar mean daily body temperatures within the same year. However, inland snakes are significantly larger in mass than their coastal counterparts and therefore have higher overall metabolic rates. Operative temperature models were used throughout each of the four field sites in order to characterize microhabitat temperatures available and calculate thermal quality of the landscape. In combination with predicted increases in ambient temperature, probable changes in body temperatures, activity times, and energy requirements were extrapolated for each site through for a 1°C and 2°C increase in ambient temperature

36. Trends in Venom Composition in Mexican Rattlesnakes

Mackessy, Stephen P.
School of Biological Sciences
University of Northern Colorado
Greeley, Colorado USA
stephen.mackessy@unco.edu

México is a large country with diverse terrain, currently supporting a diverse assemblage of more than 30 species of rattlesnakes. Although several species have ranges extending into the United States, many are endemic, particularly in montane regions, with several species showing isolated and narrowly circumscribed distributions. Venoms from medically important species, including *Crotalus atrox*, *C. basiliscus*, *C. molossus*, *C. scutulatus* and *C. simus*, have been extensively studied, but relatively little is known of montane rattlesnake venoms. Using protein chemistry and proteomic techniques, we analyzed venoms of *Crotalus lepidus*, *C. polystictus*, *C. pricei*, *C. scutulatus* and *C. willardi* from various locations within México and the US. Several distinct patterns emerge, but in general, the type I/type II dichotomy in venom composition is observed in all of these species. None of the montane rattlesnakes (from

populations sampled) showed the presence of crotoxin/Mojave toxin homologs, a hallmark feature of type II venoms, and compositional patterns in general were rather conserved among all montane species. Among *C. lepidus*, Mexican populations (*C. l. maculosus*, *C. l. morulus*) showed higher levels of venom metalloproteinases, while northern populations (*C. l. klauberi*, *C. l. lepidus*) produced venoms more toxic to mice and lizards. *Crotalus pricei* venoms showed high metalloproteinase levels also, and the venom was quite toxic toward mice and lizards, but no neurotoxins were present. Additional trends will be presented, but overall venom compositional trends followed patterns typical for many other rattlesnake species. This lack of unique diversification of venoms again underscores the observation that rattlesnake venoms, which may show local adaptation and some variation in composition, share a majority of venom toxins.

37. Biochemical Ecology of Crotalus viridis (*Prairie Rattlesnake*) in Colorado

Smith, Cara F.
cara.smith@unco.edu

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

Schield, Drew R.
Castoe, Todd A.
Department of Biology
University of Texas Arlington
Arlington, TX USA

Parker, Joshua M.
Biology Department
Fresno City College
Fresno, CA USA

Snake venoms are complex mixtures comprised primarily of potent bioactive proteins used for prey incapacitation. Venom composition has been shown to vary taxonomically, geographically, with age, and with dietary preference. North America's most widely ranging rattlesnake, *Crotalus viridis* (Prairie Rattlesnake), is found from northern Mexico through the plains of the western United States to southern Canada. Coupled with its wide species range, *C. viridis* is also a habitat generalist and inhabits areas in close proximity to humans, increasing the likelihood of human encounters and bites from this snake. *Crotalus viridis* venom is known to induce hemorrhage and muscle degradation due to the presence of larger enzymes like snake venom metalloproteases (SVMPs) and snake venom serine proteases (SVSPs) and smaller nonenzymatic toxins targeting muscle (myotoxins). Though previous research on *C. viridi*s has shown geographic variation in some venom toxins, to date, no analysis has done a deep investigation into variation in the entire venom proteome of this species. The current project investigates venom variation in the *C. viridi*s throughout its range in Colorado by determining population-level patterns in abundance of major toxins and examining the relationship between venom phenotype and localized prey sources. SDS-PAGE, toxicity assays, high performance liquid chromatography, mass spectrometry and biochemical assays were used to characterize venom composition. The compositional patterns observed demonstrate an inverse relationship between highly enzymatic and nonenzymatic venom phenotypes, which broadly aligns with the typical type I-type II rattlesnake venom compositional dichotomy. In the future, we will examine the relationship between geographic variation in toxin abundances and differences in available prey species. Ultimately, the patterns of venom variation in *C. viridis* can help inform snakebite treatment in addition to providing clues about foraging ecology and venom evolution of this wide-ranging rattlesnake.

38. Ecology of Three Sonoran Desert Rattlesnake Species at an Urbanizing Site

Huerta, Diego
diegohuerta@email.arizona.edu

Goode, Matt
Wildlife Conservation and Management
University of Arizona
Tucson, Arizona 85721, USA

Among snake species, rattlesnakes are one of the most studied groups. However, there exist significant gaps in our knowledge of how urban development affects rattlesnakes. Understanding anthropogenic impacts associated with urban development is critical for developing effective conservation strategies. We examine responses to urban development among three rattlesnake species: Western Diamondback Rattlesnake (*Crotalus atrox*), Tiger Rattlesnake (*Crotalus tigris*), and Black-tailed Rattlesnake (*Crotalus molossus*). Since 2002, we have conducted repeated surveys at Stone Canyon, an urbanizing residential development located at the base of the Tortolita Mountains near Tucson, Arizona. Making use of our long-term dataset, we compare relative abundance, growth rates, reproduction, body size, and other aspects of rattlesnake ecology. We discuss our results as they relate to rattlesnake ecology in general, and to the influence of anthropogenic factors on populations over time.

39. Phylogenetic and Morphological Analysis of the Western Himalayan Pitviper, *Gloydius himalayanus*

Santra, Vishal
Simultala Conservationists (Foundation for Wildlife)
West Bengal, 712407, India

Captive and Field Herpetology
Wales, UK
vscaptiveandfieldherpetology@gmail.com

Kuttalam, Sourish
School of Natural Sciences
Bangor University
Gwynedd, UK

Benjamin Owens, John
Captive and Field Herpetology
Wales, UK

Selvan, Melvin
Endangered Wildlife Trust
Tamil Nadu, 624103, India

Kumar Bharti, Omesh
State Institute of Health and Family Welfare
Shimla, Himachal Pradesh, India

Malhotra, Anita
School of Natural Sciences
Bangor University
Gwynedd, UK

Despite the increase in effort in resolving relationships of Asian pitvipers in the last few decades, there remain some uncertain relationships and many new species descriptions, particularly in the genus *Gloydius*. In particular, the position of *Gloydius himalyanus* remains unknown since there has been no previous phylogenetic analysis of this species. We collected DNA samples of *G. himalayanus* from the Indian state of Himachal Pradesh during 2017 and 2018. Three mitochondrial genes (16S, 12S and ND4), were sequenced and a concatenated Bayesian inference phylogeny was created. Along with this, one nuclear gene (PRLR) was also sequenced and a median-joining haplotype network was created to compare with the data obtained from the mitochondrial genes. The results from the mitochondrial analysis show that *G. himalayanus* forms the sister group of all other species of this genus and is distantly related to them. Also, that there are two distinct and highly differentiated mitochondrial lineages within *G. himalayanus* in Himachal Pradesh. However, the PRLR haplotype network did not provide support for the presence of distinct species, instead showing no distinct haplotypes between specimens from either lineage. Morphological data are also being collected to find any diagnostic features for the identification of the species. While currently the sample size for this is small, it does show some significant differences in two morphological traits, i.e., the shape of the internasal scales at the boundary with the prefrontal scales, and the presence or absence of a notch in the outer edge of the supraocular scales. To gain more clarity on the taxonomic status of *G. himalayanus*, we intend to add more nuclear loci to the analysis, as well as obtaining morphological data from additional museum specimens.

40. Translocations of Nuisance Timber Rattlesnakes (*Crotalus horridus*): A Possible Management Solution

Bryan, Danny
Department of Biology
Cumberland University
Lebanon, TN USA
dbryan@cumberland.edu

As human populations expand and encroach upon wildlife habitat, conflicts between humans and wildlife and destruction of habitat will increase, resulting in species decline worldwide. Translocation of many vertebrate and endangered plant species for augmentation of declining populations or repatriation of extirpated populations have been attempted, with varying degrees of success. Translocation of timber rattlesnakes (*Crotalus horridus*) offers an opportunity to remove snakes from areas near human habitation and restore or augment populations in more remote locations. Eleven, apparently healthy, nuisance timber rattlesnakes were captured or provided by Tennessee Wildlife Resources Officers and were implanted with radio transmitters. Nuisance rattlesnakes were released at known hibernacula of resident snakes at the time of ingress. All translocated snakes were moved > 2 km from their original capture site. Snakes were tracked using radio-telemetry periodically to determine if ingress occurred, and they were monitored to determine over-winter survival and movement patterns. All but one translocated rattlesnakes in this study survived the winter and three were killed shortly after egress. Sufficient data were collected for three translocated snakes to estimate home ranges. Over half of translocated rattlesnakes in this study appeared to establish residence in the area and displayed typical foraging patterns during the active season. They were also frequently observed in close proximity to resident snakes, perhaps indicating that conspecific trailing was occurring. These findings were consistent with other studies, indicating that translocation of adult rattlesnakes has potential as a management strategy.

41. Are Crotaline Population Survival Estimates Representative of Viper Populations as a Whole?

Maritz, Bryan
bryanmaritz@gmail.com

Maritz, Robin A.
Department of Biodiversity and Conservation Biology
University of the Western Cape
Private Bag X17
Bellville, South Africa

Glaudas, Xavier
Alexander, Graham J.
School of Animal, Plant and Environmental Sciences
University of the Witwatersrand
Johannesburg
PO Wits, South Africa

Estimates of annual survival rates can inform understanding of gene flow, trophic ecology, population ecology, and the conservation and management of organisms. Among vipers (family Viperidae) numerous studies have estimated annual survival rates for populations of pitvipers (subfamily Crotalinae). These estimates, together with a small number of estimates from European viperine species (subfamily Viperinae), dominate our understanding of viper life history. However, it remains unclear how representative these estimates are for other vipers. Here, we draw on a 7-year radio-telemetry dataset encompassing more than 120 individuals, and use a known-fate model to estimate annual survival for a population of African viperine, the Puff Adder (*Bitis arietans*). Our findings, along with a review of other estimates of viperine survival, suggest that African viperines may experience substantially lower survival rates than crotalines and non-African viperines. We discuss the major drivers of mortality in our study population and close by examining the implications of our findings for viperid life-history theory.

42. The Kiss of Death: How Pitvipers Use Their Venom

Hayes, William K.
Department of Earth and Biological Sciences

Loma Linda University
Loma Linda, California, USA
whayes@llu.edu

Venomous animals usually rely on their venom to secure food and/or defend themselves, though other functions of venom exist. As a limited commodity and a costly investment, venom should be deployed judiciously. Insufficient venom expenditure will fail to achieve the desired outcome, and excessive use can result in unnecessary metabolic costs of venom regeneration and ecological costs of venom depletion. Thus, natural selection should favor strategies whereby animals modulate, or meter, the quantities of venom expended. This talk will review the assumptions, mechanisms, evidence, and clinical and evolutionary importance of venom-metering by pitvipers and other snakes. Ample studies clearly indicate that the amount of venom a snake injects into a target varies with snake size, bite context (predatory or defensive), target identity (species and size), and a host of other factors. Causes for variable quantities of venom expenditure vary, but a number of studies support the interpretation that snakes possess the cognitive (decision-making) capacity to meter venom expenditure during both predatory and defensive contexts. Although objections have been raised regarding the capacity of snakes to modulate venom expenditure, neurologically much simpler organisms (cnidarians, mollusks, and arthropods) similarly deploy variable quantities of venom in ways that appear to be adaptive. When considered in a larger context, selection should act on multiple features of the venom apparatus, including venom production and storage (venom yield), venom composition, delivery structures, and venom deployment. Although venom composition is often viewed as the critical factor for efficacious venom use, especially in light of shifting prey bases and coevolutionary counter-adaptations of prey, the behavioral capacity of snakes to meter their venom should give them opportunities to "experiment" with venom composition.

Poster Abstracts

1. Metabolic, Immune, and Reproductive Responses to an Immune Challenge in the Pygmy Rattlesnake (*Sistrurus miliarius*)

Agugliaro, Joseph
Department of Biological and Allied Health Sciences
Fairleigh Dickinson University
Madison, New Jersey, USA
jaguglia@fdu.edu

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 growing body of literature supports the notion that mounting an immune response is energetically costly, and that energetic tradeoffs associated with increased immune activity may have fitness consequences via negative sublethal effects on host growth and reproduction. Nevertheless, relatively few studies have examined energy allocation tradeoffs mediated by immune system activation in reptiles, and direct documentation of a metabolic response to immune challenge in reptiles is largely lacking. Furthermore, it is currently unknown how reproductive condition influences the metabolic response to immune challenge in reptiles. We measured the effect of a lipopolysaccharide (LPS) challenge on resting metabolic rate (RMR) and immune function in male, non-reproductive female, and pregnant female Pygmy Rattlesnakes (*Sistrurus miliarius*) from central Florida. We measured RMR (as CO2 production rate) before and after treatment (LPS injection or vehicle control) via flow-through respirometry, and quantified immune response as change in plasma bactericidal ability (BA) and change in heterophil:lymphocyte (H:L) ratio before and after treatment. After parturition, we also compared live litter mass between LPS-challenged and control pregnant females. We found that LPS challenge caused a significant increase in mean RMR of males and non-reproductive females, but did not significantly affect RMR of pregnant females. Furthermore, we found that the effects of LPS challenge on immune response varied between measures of immune activity. Pairwise comparisons indicated that LPS decreased mean BA of pregnant females relative to non-reproductive individuals. In contrast, LPS significantly increased mean H:L ratio regardless of reproductive condition. Finally, we documented a significant reduction in mean live litter mass associated with LPS challenge, suggesting a possible negative effect of mounting an immune response on fitness despite the absence of a measurable metabolic response to LPS in pregnant females.

2. Come Closer, Go Away: The Conflicting Dynamic of Rattlesnakes and Their Use and Avoidance of Development Features

Andrews, Kimberly M.
Odum School of Ecology
University of Georgia
Brunswick, Georgia, USA
kma77@uga.edu

Colbert, Joseph E.
Jekyll Island Authority Conservation Department
Jekyll Island State Park
Jekyll Island, Georgia, USA

While much of the story about how rattlesnakes (*Crotalus* spp.) interact with development is yet to be told, existing research has provided clear examples of both the avoidance of and attraction to develop-

ment and habitats with active human presence. Understanding the circumstances that certain species may be attracted to or deterred by human-associated structures and activities is necessary to inform practitioner's how to develop or manage natural features, and design or mitigate infrastructure, such as roads and buildings. Our investigation of the responses of pit vipers to development has been on-going for over 15 years and includes multiple studies of Timber Rattlesnakes (Canebrake, *Crotalus horridus*) and Eastern Diamondback Rattlesnakes (*Crotalus adamanteus*) in South Carolina and Georgia. We will feature results for these two species from our past and current field research and how habitat use can vary with landscape and the degree of human use, and species. Additionally, we will provide a qualitative summary that is observational in nature in order to facilitate discussion with other pit viper experts on their experiences and observations of rattlesnake response in or near development. If collaborative interests with other species found in or around development occur from discussions related to this research, there may be opportunities to pursue a multi-author synthesis on snake response in developed landscapes that considers options for habitat management and infrastructure design that reduce the conflicts between snakes and people.

3. Evolving Trends in Snake Venom Research: A Review of the Last 60 Years of Publications

Avella, Ignazio
Faculty of Sciences
University of Porto
Porto, Portugal

Wüster, Wolfgang
Molecular Ecology and Fisheries Genetics Laboratory
School of Biological Sciences
Bangor University
Bangor, United Kingdom

Calvete, Juan J.
Evolutionary and Translational Venomics Laboratory
Institute of Biomedicine of Valencia
Valencia, Spain

Martínez-Freiría, Fernando
CIBIO
Research Center in Biodiversity and Genetic Resources
University of Porto
Vairão, Portugal
fmartinez-freiria@cibio.up.pt

Snakebite is a globally neglected disease, only recently recognized by the World Health Organization. Despite the still low attention paid by health agencies and pharmaceutical companies to snakebite-related issues, venom research has grown consistently in recent years, being revolutionized by the introduction of new analytical tools (e.g. genomics, transcriptomics and proteomics). In this work, we aim to identify the trends and changes of snake venom research over time, and relate findings to the diversity of medically important venomous snakes. We reviewed 184 articles published between 1960 and 2019, related to this topic. We defined macro-categories describing both the topics and the analytical approaches reported in each article, identified the most studied taxa and detected the countries where snake venom research was developed. By cross-checking different databases, we looked at which dangerousness category the about 200 medically important venomous snake species are assigned to and which and how many effective antivenoms are reported for each. Snake venom research sharply increased in the early 2000s, with articles focusing on venom characterization and comparative venomics. Most of them focused on American species, with Crotalinae being the most studied group. The analysed databases reported fragmented information about most of the medically important snakes and available antivenoms. Despite the increasing trends in snake venom research, public databases need to be updated and future studies should increasingly focus on antivenom development and analysis of venom from more diverse snake taxa, particularly in countries where snakebite impact is the most severe.

4. Disentangling the Effects of Season and Temperature on Hematological Values in Prairie Rattlesnakes (*Crotalus viridis*)

Baker, Sarah J.
Wildlife Epidemiology Lab
College of Veterinary Medicine
University of Illinois
Urbana, Illinois 61802, USA

Arizona Game and Fish Department
Phoenix, Arizona 85086, USA

Kessler, Ethan J.
Illinois Natural History Survey
Champaign, Illinois 61820 USA

Schnelle, Amy
Department of Veterinary Clinical Medicine
University of Illinois
Urbana, Illinois 61802 USA

Allender, Matthew C.
Wildlife Epidemiology Lab
College of Veterinary Medicine
University of Illinois
Urbana, Illinois 61802, USA

Hematologic assessment is the most common clinical tool used to characterize both individual and population health. In reptiles, the hematologic response can be influenced by factors such as temperature and season, especially in temperate species. To improve the diagnostic utility of hematology in reptiles, it is imperative to evaluate and characterize the normal range of physiologic variation. Our objectives were to: 1) determine the impact of temperature and time of year on complete blood count parameters; and 2) create subject-based reference intervals for 20 Prairie Rattlesnakes (*Crotalus viridis*). Animals were randomly assigned to either a control group housed at a constant temperature (25ºC) or a treatment group housed in an environmental chamber with the temperature altered to reflect average ambient temperature throughout the year (5-32ºC). Twice monthly for one year, blood samples were collected and the following hematologic parameters were measured: total white blood cell count (WBC), packed cell volume (PCV), total solids (TS), and white blood cell differential counts. WBC decreased and PCV increased as the mean previous 14-day temperature increased, with no effect of season. Total solids were higher in the control group, but there was no direct effect of temperature or season. Therefore, we found environmental temperature, rather than season, drives hematologic parameters. Our results indicate that ambient temperature should be considered when interpreting and comparing hematologic assessments of wild reptiles.

5. Physiological Venom Resistance of Colorado Rodents to Desert Massasauga and Prairie Rattlesnake Venoms

Balchan, Neil R.
neil.balchan@unco.edu

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

The Red Queen hypothesis describes the coevolutionary dynamic between predator and prey where both partners must evolve in tandem to remain competitive. In several cases, rodents have demonstrated resistance to the venoms of their snake predators. For example, the California Ground Squirrel (*Otospermophilus beecheyi*) exhibits high resistance to the venom of the Pacific Rattlesnake (*Crotalus oreganus*). Conversely, cases exist where a prey species apparently lacks physiological resistance to the venom of its predator - the Cape Ground Squirrel

(*Xerus inauris*) lacks venom resistance to the predatory Puff Adder (*Bitis arietans*) and Snouted Cobra (*Naja annulifera*). My research evaluates patterns of venom resistance in a Colorado grassland ecosystem, where the Desert Massasauga (*Sistrurus tergeminus edwardsii*) and Prairie Rattlesnake (*Crotalus viridis*) predate upon a suite of rodent species. Field sites are located in northern (one snake predator) and southern Colorado (two snake predators) to investigate patterns of resistance between and within locations at the geographic level. Median lethal dose assays are used to assess venom resistance of select rodent populations to specific rattlesnake venoms. Serum-based assays determine the protective effect that a rodent's serum exhibits against specific venom components. Preliminary results indicate a moderate protective effect of the serum of Deer Mice (*Peromyscus maniculatus*) and Meadow Voles (*Microtus pennsylvanicus*) against Prairie Rattlesnake venoms, but not Desert Massasauga venom. Studying patterns of venom resistance in a system with two predators and multiple prey species allows us to understand better the evolution of such defenses and to evaluate whether local adaptation exists.

6. Biogeographic History of Cerastes Vipers of the Sahara and Arabian Deserts

Barros, Margarida
Velo-Antón, Guillermo
CIBIO/InBIO *
Centro de Investigação em Biodiversidade e Recursos Genéticos da Universidade do Porto
Instituto de Ciências Agrárias de Vairão.
R. Padre Armando Quintas, 4485-661
Vairão, Portugal

Carranza, Salvador
Institute of Evolutionary Biology (CSIC-UPF)
Passeig Marítim de la Barceloneta
37-49, E-08003
Barcelona, Spain

Crochet, Pierr-André
CEFE UMR 5175CNRS
Université de Montpellier - Université Paul-Valéry Montpellier – EPHE
1919 route de Mende, 34293
Montpellier cedex 5, France

García-Cardenete, Luis
Carrera de San Agustín
24, 18300 Loja
Granada, Spain

Brito, José *

Departamento de Biologia
Faculdade de Ciências da Universidade do Porto
Rua Campo Alegre 4169-007
Porto, Portugal

Martínez-Freiría, Fernando*
fmartinez-freiria@cibio.up.pt

Pleistocene climatic oscillations have influenced biogeographical patterns of species worldwide, affecting distributional ranges and shaping genetic diversity. The Sahara and Arabian deserts are outstanding regions to study the influence of climate in the genetic structure and variability of species given their accentuated and dynamic climatic history, and the diverse life history and habitat traits of taxa inhabiting such extreme regions. This study aims to address the role of Pleistocene climatic oscillations in the evolutionary histories of the three *Cerastes* viper species (Viperinae): *C. cerastes* and *C. vipera* from the Sahara Desert, and *C. gasperetti* from deserts of the Arabian Peninsula. Phylogenetic structure was inferred using Bayesian inference over sequences (68 samples mostly covering species ranges) for one mtDNA (COI) and three nuDNA (PRLR, NT3, VIM) gene markers. Paleoclimatic models combined 318 occurrences and five climatic variables in Maxent to infer climatic suitabil-

ity for current and past (mid Holocene, Last Glacial Maximum and Last Inter Glacial) events, and stability over time. Mitochondrial inferences show *C. cerastes* and *C. gasperetti* as sister taxa, while *C. vipera* is identified as a phylogenetically more distant species. Further levels of mtDNA structure within the three species were originated along the middle and late Pleistocene. Nuclear inferences, however, resulted in important discordances to mtDNA patterns. Paleoclimatic models identified warm events as major drivers of range reduction and isolation for the three species we studied. Areas of high climatic stability across the Sahara and Arabian deserts likely acted as Pleistocene climatic refugia for species and lineages.

7. The Biogeology of a Population of Prairie Rattlesnakes (*Crotalus viridis*) at a High Elevation Site in Northwestern Colorado

Boback, Scott M.
Department of Biology
Dickinson College
Carlisle, Pennsylvania, USA
bobacks@dickinson.edu

Edwards, Ben
Hayes, Jorden
Department of Earth Sciences
Dickinson College
Carlisle, Pennsylvania, USA

During seasonal weather extremes, many temperate animals enhance survival by seeking out temporary or semi-permanent shelters/refugia during weather extremes. Such places may have greater significance for animals living at high elevations and/or latitudinal extremes. We studied a population of the Prairie Rattlesnake (*Crotalus viridis*) using a high elevation (2225 m) hibernaculum/den in northwestern Colorado and document the geology and overwintering biology of this population. Remote cameras, with thermistors, were positioned at den entrances to document the timing of ingress and egress as well as basking activities around the den. Maternal rookeries were documented and monitored for parturition. We also employed radio-telemetry and drone photogrammetry to characterize seasonal dispersal to and from the den and to generate a digital elevation model of the study site. Lastly, we initiated work aimed at mapping the subterranean geometry of the den using ground-penetration radar (GPR). A digital elevation model produced from drone photogrammetry and GPR data indicate the den is poised within an igneous sill or dike with some significant subterranean structural features. Our preliminary data demonstrate this population of *C. viridi*s exhibits a short active season with egress in late May/early June and ingress from late August through October. Females begin parturition in late August and continue into September. Non-gravid females and males disperse moderate distances (> 3 km) during spring egress. The significance of these results within the context of den permanence/predictability and global temperature increases will be discussed.

8. Ontogenetic Venom Variation in Black-tailed Rattlesnakes (*Crotalus m. molossus*, *C. molossus oaxacus*, and *C. ornatus*)

Borja, Miguel
Facultad de Ciencias Biológicas
Universidad Juárez del Estado de Durango
Gómez Palacio, Mexico
alessandro_53@hotmail.com

The Black-tailed Rattlesnake complex includes two species (*Crotalus ornatus* and *C. molossus*) and four subspecies (*C. m. molossus*, *C. m. nigrescens*, *C. m. oaxacus* and *C. m. estebanensis*) distributed across the United States and Mexico. Venom of these taxa has not been well characterized. Recently, we demonstrated that there is intraspecific variation in *C. m. nigrescens* venom related to the total body length (TBL) of the individual. However, it is unknown if the other subspecies or species also undergo the same ontogenetic change in venom phenotype. To evaluate this, we collected venom from two individuals (one <60 cm TBL and other >70 cm TBL) of *C. m. molossus* (Texas), *C. m. oaxacus* (Puebla), and *C. ornatus* (Texas). We separated components by HPLC and SDS-PAGE and evaluated the proteolytic activity. In addition, we analyzed the toxicity of venoms in a mouse model. Similar to what we found in *C. m. nigrescens*, juvenile individuals of the three taxa displayed venoms with more

crotamine-like myotoxins than adult venoms. In addition, venoms of individuals with a total body length (TBL) of less than 60 cm were less proteolytic than venoms of individuals with a TBL larger than 70 cm. This likely coincides with sexual maturation in these taxa. Variation in proteolytic activity might be related to the observed variation in the amount of metalloproteinases in the venoms. Interestingly, venoms of the same age class were similar in protein profile and proteolytic activity among the three taxa. Our data suggest similar ontogenetic changes for juvenile and adult life stages of the Black-tailed Rattlesnakes, *C. molossus* and *C. ornatus* which may be due to similar selection pressures at the different life stages.

9. Phylogeny and Evolutionary Morphology of Neotropical Pitvipers

Carrasco, Paola Andrea
Universidad Nacional de Córdoba
Facultad de Ciencias Exactas
Físicas y Naturales
Centro de Zoología Aplicada
Rondeau 798
Córdoba 5000, Argentina
ammodytoides@gmail.com

Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)
Instituto de Diversidad y Ecología Animal (IDEA)
Rondeau 798
5000 Córdoba, Argentina

Grazziotin, Felipe G.
Laboratório de Coleções Zoológicas,
Instituto Butantan
São Paulo, Brazil

Koch, Claudia
Zoologisches Forschungsmuseum Alexander Koenig
Adenauerallee 160
53113 Bonn, Germany

Mattoni, Camilo I.
Gerardo C. Leynaud
Universidad Nacional de Córdoba
Facultad de Ciencias Exactas
Físicas y Naturales
Centro de Zoología Aplicada
Rondeau 798
Córdoba 5000, Argentina

Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)
Instituto de Diversidad y Ecología Animal (IDEA)
Rondeau 798
5000 Córdoba, Argentina

Scrocchi, Gustavo
UEL-CONICET
Fundación Miguel Lillo
Miguel Lillo 251
San Miguel de Tucumán, Argentina

The Neotropical pitvipers display an enormous diversity and their systematics, at different taxonomic levels, is complex. However, the integrated approach of morphological, genetic and ecological aspects allows us to recreate evolutionary scenarios from which to infer historical processes involved in their current diversity, to express this diversity in the taxonomy of the group, and to evaluate whether the classifications reflect the relationships adequately. We show

the results of a phylogenetic analysis of nine Neotropical pitvipers genera, which included newly identified species and candidate species within the genus *Bothrops*, and a total of 22 genera representing the three subfamilies of Viperidae (Viperinae, Crotalinae and Azemiopinae). The phylogenetic inference was based on characters from external, hemipenial and cranial morphology, and five mitochondrial and four nuclear gene sequences. Combined and partitioned analyses were performed for 87 terminal taxa, using maximum parsimony methodology and *Pareas carinatus* (Pareidae) for rooting the trees. The results confirmed the monophyly of a large part of the lineages currently recognized, such as groups of genera and species groups; however, the position of some taxa was unstable. Additionally, we optimized the morphological characters in the total-evidence phylogeny obtained to interpret inter- and intra-generic transformations, and to detect synapomorphies, convergences, and correlations with ecological characteristics. The results also highlighted the need to analyze other aspects of Neotropical pitvipers, such us geographical patterns in some intraspecific morphological variation and the taxonomic status of some species with wide distributions.

10. The Rattlesnakes of the Gila Region of Southwestern New Mexico

Christman, Bruce L.
nattybrew@hotmail.com
736 Cardenas SE
Albuquerque, New Mexico, USA

Jennings, Randy D.
Department of Natural Sciences
Western New Mexico University
Silver City, New Mexico, USA

Giermakowski, J. Tomasz
Department of Biology
University of New Mexico
Albuquerque, New Mexico, USA

The Gila and Apache National Forests of southwestern New Mexico are home to several species of rattlesnakes but the extents of their distributions are poorly studied. We use historic and recent records of occurrence from different sources to examine potential ecological boundaries between different species of rattlesnakes in that region. To this end, we map the distribution of different species of rattlesnakes in relation to biotic and abiotic features of the landscape, including geological and topographical characteristics. Are particular focus has been on the distribution of the Arizona Black Rattlesnake *(Crotalus cerberus*), primarily because available data for this species are limited and indicate that, despite the prevalence of seemingly suitable habitat throughout the region, it has a relatively small area of occurrence in New Mexico. In addition, despite many historically significant records, we identify major spatial gaps in the knowledge of distribution of rattlesnakes in southwestern New Mexico.

11. Extrinsic and Intrinsic Factors Influencing the Detectability of Eastern Diamondback Rattlesnakes (*Crotalus adamanteus*)

Colbert, Joseph E.
Jekyll Island Authority Conservation Department
Jekyll Island State Park
Jekyll Island, Georgia, USA
jcolbert@jekyllisland.com

Andrews, Kimberly M.
Odum School of Ecology
University of Georgia
Brunswick, Georgia, USA
kma77@uga.edu

The Eastern Diamondback Rattlesnake (*Crotalus adamanteus*) ranges throughout the lower southeast Atlantic Coastal Plain of North America. Throughout their range, habitat destruction and loss to human development, agriculture, fragmentation, and direct persecution have resulted in their range-wide population decline. As a

result, in 2011 the species was petitioned for federal listing under the Endangered Species Act. In response, to provide much needed information related to their populations where they still exist, we began radio-tracking eastern diamondbacks on Jekyll Island State Park in 2011. They can be found in habitats ranging from upland sandhills to high marsh and barrier islands throughout the southern Atlantic coastal plain. In 2014, at Biology of the Pit Vipers II, we presented information related to their habitat use on Jekyll Island, a partially developed barrier island on the Georgia coast. Eastern diamondbacks specialize in using habitat structure with dense vegetation at the ground level and limited to no canopy. This provides them needed concealment from prey they consume and megafauna that threaten them, including humans. Being a cryptic predator that resides in densely vegetated habitats, these snakes are extremely covert, which greatly complicates the ability of even trained herpetologists to detect individuals. Detectability is one of the most important information needs that can help facilitate population estimates and has the potential to support population modeling in the future. This year we present information related to detectability in varying habitats that they are found in throughout Jekyll Island. We assessed the frequency of visual detection of 31 telemetered individuals, and cumulatively found the snakes to be visibly exposed 26.2% of the time throughout 3,796 snake relocations. Here, we present these results along with factors that influence their detection assessments, including habitat type, density of ground and canopy cover, season, sex, and other factors that influence their detectability.

12. Does Anthropogenic Disturbance Influence Defensive Behavior of Radio-Telemetered *Crotalus atrox* in National Monuments?

Cocks, Karina
Department of Biological Sciences and
Colorado Plateau Research Station
Northern Arizona University
Flagstaff, Arizona, USA
karina.yvonne7@gmail.com

Nowak, Erika M.
School of Earth and Sustainability and
Department of Biological Sciences
Northern Arizona University
Flagstaff, Arizona, USA

Calvo, Christopher
Colorado Plateau Research Station
Northern Arizona University
Flagstaff, Arizona, USA

Rattlesnakes employ multiple well-documented defensive behaviors as a response to approach or attack by potential predators, including human predators. However, there is a popular theory, rarely if at all backed up by experimental or observational data, that rattlesnakes may habituate to human presence and thus be less likely to exhibit defensive behaviors, including rattling, in situations where there is frequent contact. In this study, we assess historical behavioral data collected from adult Western Diamond-backed Rattlesnakes (*Crotalus atrox*) during 2002-2007 during radio-telemetric studies at two Arizona national monuments, to determine: 1) if the frequency of defensive behaviors differs between sites; 2) if individual rattling or other defensive behaviors decreases with duration of study (i.e., telemetered period for each individual); and 3) if telemetered animals living in close proximity to visitor centers and staff housing have diminished defensive behaviors relative to individuals. Behavioral data is standardized by body temperature. Based on preliminary analyses of the data, we hypothesize that: 1) there will be no difference in frequency of defensive behaviors (tongue flicking, freezing, duration of rattling, escaping) between sites; 2) defensive behaviors are highest in the first two weeks of telemetry; and 3) there is no difference in behavior resulting from proximity to anthropogenic areas. Implications of this research for rattlesnake management in national parks and monuments will be discussed.

13. Framework for Long-term Accelerometer Monitoring of Activity in Small and Secretive Terrestrial Species: A Case Study with a Cryptic Pitviper (*Crotalus atrox*)

Desantis, Dominic L.
dldesantis@miners.utep.edu

Department of Biological Sciences
Department of Mathematical Sciences
University of Texas at El Paso
El Paso, TX USA
dldesantis@miners.utep.edu

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

Wagler, Amy E.
Department of Mathematical Sciences
University of Texas at El Paso
El Paso, TX USA

A series of movement steps or decisions made by an animal is an important reflection of the interactions between internal state and external conditions. For many small, cryptic, and secretive animals, an understanding of the various causes and consequences of these fine-scale behavioral decisions is often precluded by methodological limitations. Among the many recently developed animal-borne datalogger technologies, the use of miniature accelerometer dataloggers for remote and continuous recording of animal activity is becoming increasingly common. However, accelerometer applications remain largely biased toward large-bodied species due to body size limitations with smaller animals. We took advantage of ongoing miniaturization and advancement of devices and associated computational techniques to develop a robust and flexible framework for long-term accelerometer monitoring in small and secretive terrestrial species in natural settings. We internally implanted radio transmitters and tri-axial accelerometers in rattlesnakes (*Crotalus atrox*) for field data collection periods ranging from one to 289 days. During these field deployments, we conducted frequent field-validation observations of behavior to train and validate supervised learning models (Random Forest (RF) and GLMNET). GLMNET model recall was 95%, and RF was 99% for classifying periods of coarse behavioral mode (inactivity vs. activity) in rattlesnakes. We applied validated models to full acceleration datasets for automatized activity classification to establish and visualize long-term, fine-scale activity budgets. We demonstrate the utility of this data collection, processing, and analysis pipeline for placing behavior in an ecological context by examining timescale-dependent environmental drivers of activity decisions in this cryptic pitviper.

14. Assessing Abundance of a Cryptic Viper Using N-Mixture Models

Dreslik, Michael J.
dreslik@illinois.edu

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

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

Baker, Sarah J.
Arizona Game and Fish Department
Phoenix, Arizona, USA

For effective conservation and recovery, an adaptive management framework is often best when paired with monitoring population-level responses. In many species, monitoring abundances over time using traditional capture-mark-recapture (CMR) methods is logistically challenging. N-mixture models are an extension of the occupancy and detection probability framework and can estimate abundances across

multiple populations. The models use raw abundance counts taken during surveys, model the distributions of capture frequencies, incorporate density-dependent effects, and can provide population estimates when recaptures are too few. When validated with traditional CMR estimates, they can provide robust estimates for multiple populations across the landscape. We chose to determine the effectiveness of an N-mixture modeling approach to generate population size estimates for the Eastern Massasaugas within the Carlyle Lake region in Illinois. Our results will be used to determine regional population trends and provide a foundation to assess the effectiveness of conservation actions.

15. Conservation Status of the Lance Head Rattlesnake (*Crotalus polystictus*) of Aguascalientes, México

Eloy, Gustavo
eloyhouse@gmail.com

Armas, Zavala
Najil Kaan Herpetarium
Aguascalientes, Ags, México

The populations of Lance Head Rattlesnakes (*Crotalus polystictus*) in the state of Aguascalientes, México are extremely fragmented and insufficiently studied due to the damage that their ecosystems have suffered. Also, these populations lack formal protection. The objective of this project is to try to conserve the species in the state of Aguascalientes with both reproduction and ex situ conservation. Snakes for this project were acquired in the aforementioned area, as well as specimens that were found and rescued by locals. These specimens were transferred to Najil Kaan Herpetarium where they went through respective medical examinations and were quarantined. They were subsequently placed in ex situ conditions such as those to simulate their native habitat. These natural conditions help to stimulate their natural behavior culminating with the reproduction in captivity. With this project the successful reproduction of the species has been achieved on one occasion, resulting in two viable offspring. We hope to reintroduce those offspring into a protected area within their locality. We consider ex situ conservation and reproduction very important to this and many other species of reptiles and amphibians. These species will require assistance and intervention for their preservation; we ourselves are the ones who have brought them to the brink of extinction.

16. Ambush Site Selection by Eastern Black-tailed Rattlesnakes (*Crotalus ornatus*) in the Northern Chihuahuan Desert

Emerson, James D.
jdemerson@miners.utep.edu

DeSantis, Dominic
Johnson, Jerry
Department of Biological Sciences
University of Texas at El Paso
El Paso, Texas, USA

As organisms move throughout their environments, chemical signatures are left behind which are used by other species to mediate interspecific interactions. Most studies examining how these signatures influence behavior involve the use of predator chemical signatures by prey animals. However, predators often use these signatures to source information about potential prey as well. *Crotalus ornatus* is an ambush predator in the Chihuahuan Desert, selecting ambush sites where it is likely to encounter prey and remaining immobile for long periods of time. I am investigating the innate ambush behavior of captive-reared *C. ornatus*. With no prior hunting experience, it is expected that these ambush predators will discriminate among prey chemical cues for ambush site selection. Chemical cues will be presented as aqueous extracts from the integument of potential prey items, including an invertebrate, amphibian, and multiple lizard and mammal cues. Neonates (N = 10) were obtained from gravid females (N = 4) that were part of an ongoing telemetry study at the Indio Mountains Research Station, located in Hudspeth County, Texas. Ambush site selection will be quantified based upon the lingual response and time spent oriented towards the prey cue coiled in stereotypical ambush position.

17. Himalayan Pitviper (*Agkistrodon himalayanus*): Conservation, Ecology, Snake Bite, and Human Awareness in Lesser Himalayas, Azad Kashmir, Pakistan

Faiz, Abul Hassan
sabulhussan@gmail.com

Faiz, Lariab Zahra
Zahar, Mashal
Women University of Azad Kashmir
Bagh, Pakistan

Natural ecosystems are facing rapid declines of biodiversity on a global level, which has critical implications for ecosystem functions and services. Successful conservation efforts to slow this decline rely on our ability to monitor species and understand their ecological roles. Such efforts are often hindered by a lack of knowledge regarding arcane interactions. In the territories of Azad Kashmir (Pakistan), snakes are represented by 25 species and are facing anthropogenic, climatic, and natural predator pressures. Among 25 species, the Indian Python (*Python molurus*) and Indian Cobra (*Naja naja*) are threatened species of reptiles in Pakistan (IUCN 1990). This study was designed to document the altitudinal distribution of the Himalayan Pitviper, *Agkistrodon himalayanus* Gunther, 1864. We also obtained records of snake bites by this species. The Himalayan Pitviper is widely distributed throughout the Himalayas and inhabits regions 2000 to 3600 m in elevation. It finds refuge under fallen timber, clefts in rocks, beneath boulders, stones, fallen leaves, and among marginal grasses. We estimated the population density of this species to be 5 snakes per km2. The mortality rate with human snake bite was 0.92 % This species seems to require high humidity (60%); we did not find snakes at levels below 60%. Global warming and anthropogenic pressure are factors that may lead to the extirpation (or even extinction) of this species.

18. Rapid Geographic Spread of Invasive Pentastome Parasites in Pygmy Rattlesnakes (*Sistrurus miliarius*) indicates an Emerging Conservation Threat to North American Pitvipers

Farrell, Terence M.
Department of Biology
Stetson University
DeLand, Florida USA
tfarrell@stetson.edu

Parasite spillover, the spread of nonindigenous parasites to native species, can be an important impact of nonnative species. *Raillietiella orientalis*, an Asian pentastome (endoparasitic crustacean), was introduced in south Florida with Burmese Pythons (*Python bivittatus*). This parasite has spread to native snakes. From August 2018 to February 2019, we found R. orientalis in Pygmy Rattlesnakes (*Sistrurus miliarius*) in central Florida, more than 160 km north of this parasite's published geographic range. In winter 2019, we examined 34 *S. miliarius* using dissection, endoscopy, lung washes, or cloacal washes to determine the prevalence of *R. orientalis* at two central Florida locations that were separated by 34 km. There was a significant difference between the two sites in pentastome prevalence, with 65.9% and 8.3% of all *S. miliarius* infected at the northern and southern sites, respectively. The parasites appear to have major negative health consequences in *S. miliarius*, including causing mortality. The mean length of the adult female parasites removed from the lungs of Pygmy Rattlesnake (59.0 mm) and the mean number of adult females (3.1 individuals/snake) were both greater than that reported in published records for Burmese Pythons, a species with which *R. orientalis* shares a coevolutionary history. Heavy pentastome loads often coincide with snake fungal disease, both may be energy drains on the hosts, and snakes with both issues are often emaciated. The impact of this invasive parasite on native snake populations will be a function of a variety of unknown aspects of its biology, including its rate of spread, identity of the intermediate hosts consumed by snakes, and the extent of lethal and sublethal effects of pentastome infection on host fitness.

19. Tests of Antipredator and Alarm Cue Functions for Musk Gland Secretions of Northern Cottonmouths (*Agkistrodon piscivorus*)

Greene, Brian D.
briangreene@missouristate.edu

Meinders, Alex
Department of Biology
Missouri State University
Springfield, Missouri, USA

Paired cloacal musk glands are ubiquitous in snakes and produce aromatic substances that are secreted during defensive encounters with predators. Musk gland secretions have been mainly considered to be antipredator adaptations but have also been suggested to function as alarm cues in rattlesnakes. We conducted experiments to evaluate the effects of musk secretions of Northern Cottonmouths (*Agkistrodon piscivorus*) as both predator deterrents and as alarm cues. To evaluate the alarm cue hypothesis, we tested responses of captive juvenile cottonmouths in two behavioral contexts related to predation risk: foraging conflict and predatory encounters. In foraging trials, cottonmouths increased their rate of movement and tongue flick rates approximately two-fold in musk cue treatments compared to trials involving controls. Similarly, cottonmouths exposed to musk secretions exhibited a two-fold increase in defensive responses in standardized simulated predatory encounters relative to controls. We evaluated potential antipredator function of musk in palatability tests where domestic dogs were allowed to sample musk and non-musk treated food items. Test subjects spent significantly longer investigating musk-treated food than controls but did not exhibit differences in any other response variable. All dogs that consumed food ate all samples and did not consume in any pattern related to treatment. Our results provide additional support for pit viper musk acting as an alarm cue, which is particularly interesting given recent developments concerning cryptic sociality of pit vipers. However, cottonmouth musk did not seem to deter consumption by a mammalian predator, in contrast to palatability tests in some colubrid snakes.

20. Behavior, Habitat Usage, and Status of Southwestern Speckled Rattlesnakes (*Crotalus pyrrhus*) in the Tinajas Altas Mountains, Yuma County, Arizona

Grimsley, Ashley A.
agrimsley@azgfd.gov

Wildlife Contracts Branch
Arizona Game and Fish Department
Phoenix, Arizona, USA

Piest, Lin A.
Region 4
Arizona Game and Fish Department
Yuma, Arizona, USA

Jones, Tom R.
Terrestrial Branch
Arizona Game and Fish Department
Phoenix, Arizona, USA

The Arizona Game and Fish Department is responsible for managing the wildlife resources in the State of Arizona. The Southwestern Speckled Rattlesnake (*Crotalus pyrrhus*) of the Tinajas Altas Mountains in Yuma County, Arizona, has a very light, attractive color variation that is not found anywhere else in the species' distribution. The light variation of this snake occurs in a small area and is highly sought after in the pet trade. Limited data exist on the behavior, habitat usage, and status of this unique population. The Arizona Game and Fish Department conducted preliminary mark-recapture surveys from 2015 through 2017 in three separate canyons of the Tinajas Altas Mountains. Telemetry surveys were carried out in order to document the daily and seasonal activity and habitat usage of this snake, in the canyon suspected to have high traffic for collection. The study was carried out from fall of 2017 through spring of 2019. We captured snakes through visual encounter surveys throughout the study area and surgically implanted radio transmitters in a total of 19 snakes. During the active season (March through May) individual snakes were tracked twice a day, in morning, afternoon, or evening survey periods, to assess diurnal and nocturnal movement. Snakes were tracked less intensively from June through February. Telemetry data will be analyzed in May of 2019.

21. Toxicity of Venom from a Japanese Pitviper (*Gloydius blomhoffii*) to Centipedes

Hamanaka, Kyosuke
kyo@ethol.zool.kyoto-u.ac.jp

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

Most vipers usually feed on vertebrates, but several species of rattlesnakes and pit vipers sometimes eat centipedes. Centipedes have been also found occasionally in stomach contents of a Japanese pit viper, *Gloydius blomhoffii*. Like many other vipers, *G. blomhoffii* usually injects its venom to prey animals to kill or incapacitate them before eating. Toxicity of the venom of *G. blomhoffii* to mammals has been well studied, but there is no information concerning its toxicity to centipedes. Here, we studied the toxicity to the Red-headed Centipede, *Scolopendra subspinipes*, by comparing with the toxicity to two other common prey animals; House Mouse (*Mus musculus*) and Pond Frog (*Pelophylax nigromaculatus*). To evaluate the toxicity of the venom that is actually injected to prey animals when snakes strike them in the wild, the injection was carried out using raw venom collected from fangs, and mortality rate three hours after injection was examined. The lethal doses for mice weighing around 21.5 g and frogs weighing around 3.8 g were both less than 5 µl, which corresponds to an estimated dose of one envenomation by *G. blomhoffii*. On the other hand, centipedes weighing 0.8–3.2 g needed 10–35 µl of the venom to die. There was no significant correlation between the lethal dose and their body mass. Our results indicate that it is difficult for *G. blomhoffii* to kill or incapacitate centipedes by a single envenomation. Thus, *G. blomhoffii* may eat centipedes in a way different from that for eating mice and frogs.

22. 50 Shades of Clay: Rattlesnake Coloration Affects Detection by Predators

Harmel, Mallory
malloryharmel@gmail.com

Crowell, Hayley
Taylor, Emily N.
College of Sciences and Mathematics
California State University at San Luis Obispo
San Luis Obispo, CA USA

Crypsis, or the ability of an animal to avoid detection by other animals, is strongly related to the organism's coloration. Southern Pacific Rattlesnakes (*Crotalus oreganus helleri*) vary in coloration within and among populations, suggesting selection on coloration within specific habitats and environments. The purpose of this study was to investigate the effect of coloration on likelihood of being attacked by a predator, on latency to attack, and to observe where on the snake body predators tend to attack. Clay snake models representing four commonly observed color morphs of rattlesnakes (light, dark, intermediate color with white pattern, intermediate color with dark cream pattern) were placed in grassy and wooded habitats at a reserve in central coastal California, and marks made on the models by predators' teeth, beaks, and claws were quantified. We found that model type was a significant predictor of the overall number of attack marks, with dark colored snakes being attacked significantly more often than light-colored snakes. The latency to attack did not differ significantly among model types. Model type was related to where on the models the marks were made although the location of the marks on the models was not significantly different. Using open platform color analysis programs our data show that coloration can play a large role in crypsis, and suggest that dark-colored rattlesnakes, which have the most contrast with the golden-colored grasses and therefore have the lowest crypsis, are most at risk from predation.

23. Development of an Automated Radio-Telemetry System to Study the Spatial Ecology of Eastern Diamondback Rattlesnakes (*Crotalus adamanteus*) on a Barrier Island

Heimerdinger, Alex
abheimerdinger@gmail.com

Andrews, Kimberly M.
Applied Wildlife Conservation Lab – Odum School of Ecology
University of Georgia UGA Marine Extension
Brunswick, Georgia, USA

Norton, Terry M.
Jekyll Island Authority Georgia Sea Turtle Center
Jekyll Island, Georgia, USA

Understanding the spatial ecology of a species is of the utmost importance in managing and ultimately promoting the conservation of that species. Manually tracking organisms using radio telemetry has proven useful to study the spatial ecology of a variety of taxa, including snakes. However, the amount of time and effort required to determine the location of the tracked organism presents a logistical hurdle, a substantial expense, a possible disturbance to the animals, and inevitably yields less data than some of the emerging tracking technology. Automated radio telemetry has been used in very few studies involving snakes. In this study we are field-testing an automated radio telemetry system that will triangulate location "fixes" more frequently than is possible with manual tracking. We attached an ultra-light, solar-powered, UHF transmitter to Eastern Diamondback Rattlesnakes (*Crotalus adamanteus*) on Sapelo Island. Transmitters were attached externally using a modified sub-dermal stitch technique that is less invasive than internal implantations and should not interfere with ecdysis. A grid of transmission nodes was deployed throughout the estimated home range of the snakes. Nodes will act as satellites, relaying the location of tracked snakes to a base station where location data will be received and stored. Nodes attempt to detect transmitters every 2 to 4 seconds, potentially providing thousands of location fixes every day. From this study, we hope to determine if automated radio telemetry is a viable tool for collecting spatial ecology information on snakes. We will present our experiences on the external attachment technique and the implementation of the automated system in the field along with pilot data on the detection success of three snakes from the first season of data.

24. Assessing the Influence of Stress and Behavior on Susceptibility to and Recovery from Snake Fungal Disease in the Timber Rattlesnake (*Crotalus horridus*)

Hewlett, John B.
Biology Department
Murray State University
Murray, Kentucky, USA
jhewlett@murraystate.edu

Since 2006 an emerging fungal pathogen (*Ophidiomyces ophiodiicola*), the causative agent of Snake Fungal Disease (SFD), has been documented as causing mortality in populations of wild snakes. How stress reactivity affects susceptibility to and or ability to clear SFD remains unknown. Here we investigate the effects of baseline as well as elevated Corticosterone on disease dynamics and 2nd and 3rd order habitat selection in a population of Timber Rattlesnakes (*Crotalus horridus*) in the Land Between the Lakes National Recreation Area. During the 2018 field season between May and September 10 *C. horridus* were captured, surgically implanted with radio-transmitters, and followed every 72 hours. Blood and tissue biopsies were sampled from each individual and habitat attributes were obtained from both used and random locations once a month. CORT was analyzed using an enzyme-linked immunosorbent assay (ELISA) and the presence of *O. ophiodiicola* was determined using quantitative polymerase chain reaction (qPCR). Results will be forthcoming.

25. Fang Length Evolution in Vipers is Predicted by Furred and Feathered Diets

Holding, Matthew
Department of Biological Science
Florida State University
Tallahassee, Florida, USA
matthewholding28@gmail.com

Trevine, Vivian C.
Instituto Butantan
São Paulo, Brazil

Zinenko, Oleksandr
Museum of Nature
V. N. Karazin Kharkiv National University

Kharkiv, Ukraine
Strickland, Jason L.
Rautsaw, Rhett M.
Mason, Andrew J.
Hofmann, Erich P.
Parkinson, Christopher L.
Department of Biological Sciences
Clemson University
Clemson, South Carolina, USA

Grazziotin, Felipe G.
Instituto Butantan
São Paulo, Brazil

Summers, Adam P.
Department of Biology and School of Aquatic and Fisheries Sciences
University of Washington
Friday Harbor, Washington, USA

Santana, Sharlene E.
Department of Biology
University of Washington
Seattle, Washington, USA

Davis, Mark A.
Illinois Natural History Survey
Champaign, Illinois, USA

Rokyta, Darin R.
Department of Biological Science
Florida State University
Tallahassee, Florida, USA

Fangs, stingers, spines, and harpoons are used by diverse animal taxa to inject venom into their prey. Strong selection on venom composition has been repeatedly documented, and we might expect the venom injection apparatus to be under similarly strong selection to meet specific functional demands. Snakes in the family Viperidae (true vipers and pitvipers) consist of ~320 species widely studied by both ecologists and evolutionary biologists. Vipers provide an opportunity to determine how the venom injections systems evolve in response to functional demands of prey killing. Utilizing museum collections, we obtained measurements of fang length in >2000 individual specimens representing 200 viper species. We document the mode and tempo of fang length evolution across this diverse family, and test for relationships between ecology and the rate of fang length evolution across clades. We then leverage data collected from over 100 published diet studies to test the hypothesis that longer fangs evolved in response to demands associated with feeding on prey with coverings of fur or feathers. We find support for this hypothesis, where the percentage of mammals and birds in viper diets is positively correlated with relative fang length. Finally, when controlling for head size, the Gaboon Viper is dethroned as the snake species with the longest fangs, and overtaken instead by the Speckled Forest Pitviper of South America. Venom and the venom delivery system merit further work to determine if they are part of a broader functional and evolutionary module that facilitates feeding in venomous animals.

26. Detection of Snake Fungal Disease Caused by *Ophidiomyces ophiodiicola* Among Timber Rattlesnakes (*Crotalus horridus*) in Pennsylvania

Januszkiewicz, Eric
Northeast Wildlife DNA Laboratory

East Stroudsburg University
East Stroudsburg, Pennsylvania, USA
ericjanuszkiewicz@gmail.com

LaDuke, Thomas C.
Department of Biology
East Stroudsburg University
East Stroudsburg, Pennsylvania, USA

Chinnici, Nicole
Northeast Wildlife DNA Laboratory
East Stroudsburg University
East Stroudsburg, Pennsylvania, USA

Snake Fungal Disease (SFD) is a recently emerging disease caused by infection from *Ophidiomyces ophiodiicola*. Free-ranging snake populations are being affected by this fungal pathogen throughout many Eastern and Midwestern U.S. states. Characteristically, infected individuals display swelling, lesions, crusts, and nodules of the skin that are generally found on the head but can also be found throughout the body. The fungus is difficult to identify based solely on symptoms and was not definitively identified in the state of Pennsylvania prior to this analysis. One hundred and thirty-five total Timber Rattlesnakes (*Crotalus horridus*) from twelve different counties in the northeastern and north-central regions of Pennsylvania were captured and swabbed to test for the presence of SFD. Real-time PCR was used to detect the pathogen DNA. Of the 135 snakes, 24 (18%) tested positive with six individuals being infected on both the head and body, nine individuals infected on just the head, and nine individuals infected on just the body. There were no relationships found between infection rates and color phase, sex, length, or county captured. The cause of emergence and spread of this pathogen is largely unknown. Timber rattlesnakes have been listed as a candidate species in Pennsylvania in the past and are currently considered a species of special concern. The presence of SFD in these populations raises concerns. Long term monitoring studies may be helpful to examine the effects this fungal pathogen may have on individuals and populations.

27. Triggers and Timings of Spring Emergence for the Timber Rattlesnake (*Crotalus horridus*) in Illinois

Jesper, Andrew C.B.
ajesper2@illinois.edu

Dreslik, Michael J.
Illinois Natural History Survey
Prairie Research Institute
Champaign, Illinois, USA

Colder periods in temperate regions force many reptiles to retreat into insulated hibernacula to survive. Reduced activity and metabolic rates during this period, paired with low internal hibernacula temperatures, results in extreme lethargy, limiting a reptile's capacity to avoid potential threats including predation, fire mortality, and human persecution. Spring emergence amplifies such threats when reptiles leave the relative safety of hibernacula and become exposed on the surface. Communally hibernating reptiles, such as the threatened Timber Rattlesnake (*Crotalus horridus*), which emerge and congregate in the immediate denning area are at greater risk due to artificially high densities. Information regarding the timing and triggers of spring emergence for the Timber Rattlesnake is required to inform conservation and land management. Here, we report our findings on the phenology and temperature triggers of spring egress for the Timber Rattlesnake at 9 hibernacula across the latitudinal gradient of Illinois during 2018 and 2019.

28. Vertebral Variation and Identification of Eastern North American Pitvipers (Viperidae, Crotalinae) Using Geometric Morphometrics

Jessee, Lance D.
jesseel@etsu.edu

Gause, Austin R.J.
Schubert, Blaine W.

Department of Geosciences and
Center of Excellence in Paleontology
East Tennessee State University
Johnson City, Tennessee, USA

Within Pleistocene cave deposits, snake fossils tend to be relatively common and generally occur as disarticulated vertebrae. However, identification of vertebrae is often hindered by significant intra- and interspecific morphological variation along the precloacal vertebral column, a subject that has largely been neglected in fossil snake identifications. Such identifications are typically based on mid-trunk vertebrae, comparison to disarticulated modern specimens, and an over reliance on modern distributions. This study examines vertebral variation and the utility of specific viperid vertebrae in making identifications. We use 2-D geometric morphometrics to examine vertebral variation along the precloacal vertebral column of *Crotalus horridus* and *Agkistrodon contortrix*, two crotalines that are sympatric in much of the eastern United States and have similar vertebral morphologies. The focus here is to examine morphological regionalization patterns of the precloacal vertebral column. One individual of each species was chosen and every third vertebra was analyzed in anterior view using geometric morphometrics, and relative warp analyses were computed. The relative warp analyses show continual variation with mid-trunk vertebrae showing less variation than anterior and posterior trunk vertebrae. Both species show the same trends in columnar variation and that mid-trunk vertebrae can be distinguished from other vertebrae. Our next step in this study is to perform discriminant function analysis on mid-trunk vertebrae in an attempt to distinguish the two taxa. Further, we plan to incorporate other members of these genera into our analyses to assess specific and generic classifications. If this is successful, we will implement our methods on fossil specimens from Pleistocene cave sites to better understand the distribution of these snakes through time. This study also demonstrates the need for more modern snake skeletons in collections and that efforts should be made to preserve the vertebral order of those specimens.

29. Estimating Timber Rattlesnake (*Crotalus horridus*) Populations in Pennsylvania Based on Mark-Recapture Data

Johnson, Tianna R.
trj13@pitt.edu

LaDuke, Thomas C.
Department of Biological Sciences
East Stroudsburg University of Pennsylvania
East Stroudsburg, Pennsylvania, USA

The Timber Rattlesnake (*Crotalus horridus*) is a large species of venomous pit viper native to the state of Pennsylvania. In 1978, the Timber Rattlesnake was listed as a candidate species for listing under the Endangered Species Act in the state. In 2011, after a long-term site assessment study concluded the species was more widespread than initially thought, the species was removed from this candidate status. Though Timber Rattlesnakes are widely distributed throughout Pennsylvania, more information is needed on their numbers overall within the state. Timber Rattlesnakes are listed as threatened, endangered, or as a species of special concern in all states to the north and east of Pennsylvania. In Pennsylvania, the species is listed as a species of special concern. The species is susceptible to disease, habitat changes and loss, poaching, and human persecution. This ongoing study aims to use long-term mark-recapture data acquired from PIT tagging to estimate Timber Rattlesnake population sizes and predict population trends in five designated study regions in Pennsylvania. Data on the number of snakes marked and recaptured will be analyzed in Program MARK and will be used to make population-specific estimates of abundance and demographic parameters such as growth rate. Population studies such as this are crucial in providing the basis for species regulations and management plans at small and large spatial scales. The resulting population estimation data from this study will then be used to create a less invasive rapid assessment procedure based on detectability parameters as a means of long-term population monitoring in Pennsylvania.

30. Generalist Habitat Selection by Cottonmouths (*Agkistrodon piscivorus*) in Middle Tennessee

Kauphusman, John
jkauphusman@my.apsu.edu

Department of Biology and Center of Excellence for Field Biology
Austin Peay State University
Clarksville, Tennessee, USA

Fulbright, Michael C.
Department of Biology
University of Louisiana at Lafayette
Lafayette, Louisiana, USA

Gienger, C. M.
Department of Biology and
Center of Excellence for Field Biology
Austin Peay State University
Clarksville, Tennessee, USA

Many snake species exhibit an ontogenetic shift in habitat preferences, as this can potentially reduce interspecific competition. We investigated the habitat selection of a Tennessee population of the Cottonmouth (*Agkistrodon piscivorus*) inhabiting an isolated wetland system. Principle component analysis was used to elucidate intraspecific trends in habitat selection between male, female, and juvenile cottonmouths (N = 96). We found that cottonmouths exhibited non-random habitat use, with respect to available habitat features, although there were no significant habitat differences among intraspecific groups. Previous studies of cottonmouth habitat use have observed ontogenetic shifts in habitat preferences, yet, our study detected little to no differences. The results suggest that cottonmouths do not always change habitat use through ontogeny as a mechanism to reduce intraspecific competition, and in large and/or structurally diverse wetlands, they may be habitat generalists utilizing a wide variety of resources. We suggest that trends in ontogenetic shifts in habitat use may be associated with certain landscape features, and the resources available within our system may limit spatial resource partitioning within the isolated wetland system.

31. Feeding Ecology of a Fish-eating Pitviper, *Gloydius tsushimaensis*: Seasonal Change of Foraging Sites and Prey Types

Kodoma, Tomonori
Laboratory of Ethological Zoology
Department of Zoology
Graduate School of Science
Kyoto University
Kyoto, Japan
asukamasuku@gmail.com

The Tsushima Mamushi (*Gloydius tsushimaensis*) is a pitviper endemic to Tsushima Islands, Japan. I conducted a field survey of foraging ecology of *G. tsushimaensis* by route-census in a mountainous area along Nita river on the northern Tsushima Island from spring to autumn in 2017 and 2018. I set four census routes: one along the main stream of Nita river and three along road-side-ditches near the river. Whenever I collected snakes, I examined their stomach contents by forced-regurgitation and marked them by ventral clipping for individual identification. In spring I also collected snakes in other small streams in distant places to examine stomach contents. In the route-census, I obtained a total of 89 prey items from stomach contents, including 50 amphibians and 29 fishes. In the side-ditches amphibians were the main diet, whereas in the river fishes were predominant. In spring and autumn amphibians mainly occupied the diet, whereas in summer fishes did. The number of snakes in the river increased in summer and decreased in spring and autumn, whereas that the number in the side-ditches showed the opposite tendency. Twenty of 39 individuals that appeared in the side-ditches in spring and autumn were found in the river in summer. In the small streams, lotic salamanders mainly occupied the diet: seven adult salamanders and four egg sacs of them were contained in 14 stomach contents. These results demonstrate *G. tsushimaensis* changes foraging sites and prey types seasonally. In addition, the large portion of the diet of the snake consisted of highly aquatic preys; fishes, lotic salamanders and their egg sacs. Taking features as a prey of them into account, *G. tsushimaensis* may have some morphological specializations. Future study should examine the relationship between the unique foraging ecology and morphological adaptations of the snake.

32. If You Build It Will They Come? Snake Use of Artificial Refugia within an Industrial Scale Vineyard

Law, Valerie
Department of Natural Resource Sciences
Thompson Rivers University
Kamloops, British Columbia, Canada
valerie-law@hotmail.com

Bishop, Christine
Climate Change and Environment Canada
Richmond, British Columbia, Canada

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

The Okanagan region of British Columbia (BC) has been subjected to large-scale agricultural expansion due to a land base and climate optimal for agriculture. The subsequent conversion of the native shrub steppe habitat directly impacts snake populations endemic to the area. Finding ways to enable snakes to use vineyards for hunting has obvious benefits to both snakes and vineyard production through predation on small mammals. However, for venomous rattlesnakes, this can be a significant challenge requiring ways to ensure the safety of both snakes and vineyard workers. This study has been investigating a novel way to approach this situation through the creation of artificial pockets of habitat ('refugia'). Eight refugia composed of subterranean chambers, artificial rock piles, and native flora were built within a vineyard in Oliver, BC. Over the spring/summers of 2015-2017 chamber external air temperatures were monitored. Internal chambers became cooler like due to the establishment of vegetation provided stable temperatures below the voluntary maximum of snakes. Wildlife cameras within the chambers reveal relatively higher levels of visits by snakes (rattlesnakes, gophersnakes, and racers) in refugia near the periphery of the vineyard. Rodents (snake prey) also utilize the refugia quite extensively. However, analysis of these data revealed no significance between snake use, rodent use, or ambient air temperature. Behavioural analysis of camera footage suggests snakes are predominantly utilizing these spaces for their foraging opportunities rather than thermal refuge. Spaciousness of chambers has been suggested to reduce suitability for snake use. Overall, with further modification, these areas could offer the potential to provide spatial separation between snakes and workers.

33. Seasonal Steroid Hormones in Relation to Vitellogenesis, Mating, and Pregnancy in Free-Ranging Pygmy Rattlesnakes, *Sistrurus miliarius*

Lind, Craig M.
Department of Natural Science and Mathematics
Stockton University
Galloway, New Jersey, USA
craig.lind@stockton.edu

Moore, Ignacio T.
Vernasco, Ben J.
Department of Biology
Virginia Tech
Blacksburg, Virginia, USA

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

Steroid hormones regulate reproductive investment and play a critical role in mediating the reproductive response to both short (e.g. seasonal) and long-term environmental change. Laboratory studies typically examine

the mechanistic relationships between steroids and reproductive processes under tightly controlled conditions and may fail to identify any seasonal modulation of regulatory mechanisms. Thus, field-based research remains important in testing the predictions of laboratory studies under the full range of environmental conditions experienced by an organism. In snakes, seasonal relationships between steroids and male reproduction are prevalent. However, comparatively less work has been conducted on free-ranging female snakes. We described seasonal estradiol, corticosterone, and plasma metabolites (total protein, albumin, phosphorus, and glucose) in relation to seasonal events of the reproductive cycle in free-ranging Pygmy Rattlesnakes, *Sistrurus miliarius*. We expected elevated estradiol and plasma metabolites during the spring vitellogenic season. Based on previous studies, we did not expect elevated estradiol during the fall breeding season or during pregnancy. We also predicted that corticosterone would be elevated during late pregnancy and hypothesized that corticosterone may play a role in parturition. In *S. miliarius*, plasma estradiol and metabolites were significantly elevated during both the breeding vitellogenic seasons. However, no palpable follicles were observed in the fall and no breeding behavior was observed in the spring, suggesting that the link between estradiol and these processes may be seasonally uncoupled. As predicted, corticosterone was elevated during late pregnancy compared to early pregnancy, postpartum, and compared to non-reproductive females sampled in the field. Corticosterone was not associated with elevated estradiol in any season. Our results indicate the potential for seasonal modulation of endocrine regulatory mechanisms in pygmy rattlesnakes and highlight the need for further study of the seasonal regulation of reproductive processes in female snakes.

34. Spatial Ecology and Habitat Selection of the Pygmy Rattlesnake (*Sistrurus miliarius*) in Southwestern Missouri

Maag, Dylan W.
dmaag3229@sdsu.edu
Maher, Sean P.

Greene, Brian D
Department of Biology
Missouri State University
Springfield, MO USA

Current Affiliation (DWM):
Biology Department
San Diego State University
San Diego, CA USA

Despite a wide distribution throughout the Southeastern United States, research on pygmy rattlesnakes (*Sistrurus miliarius*) has been largely restricted to Florida populations. We studied *S. miliarius* in a managed forested landscape on an 809-ha state conservation area in Southwest Missouri, near their northern range limit, during 2016 and 2017. We captured 54 individuals of *S. miliarius*, primarily during evening road driving surveys, and retained 19 (6 males and 13 females: 9 gravid, 4 nongravid) for a radio-telemetry study. Telemetered snakes were relatively sedentary, making short, infrequent movements that resulted in small minimum convex polygon home range estimates (range: 0.01–2.6 ha). Reproductive status of females strongly affected activity with mean movement distances and home range sizes of gravid females increasing five-fold following parturition. Parturition dates ranged from August 11–25 and maternal attendance of litters for 1–3 days was observed in five post-partum females. We encountered *S. miliarius* in all available habitat types, suggesting that habitat selection was mainly occurring at the microhabitat scale. Snakes were very secretive but typically concealed themselves within vegetation (89% of observations) or beneath surface cover (8.5% observations) rather than underground. Snakes selected microhabitats with more vegetative cover and woody debris, and less leaf litter, than random sites. Our *S. miliarius* used a variety of habitat types suggests that it is well adapted to the Ozarks landscape. We provide novel information on spatial patterns and habitat selection for the ecology of *S. miliarius* ecology that hopefully will stimulate comparative studies in other geographic regions.

35. Conspecific Scent Trailing in Juvenile Cottonmouths (*Agkistrodon piscivorus*)

Martin, Chelsea
martin94@live.missouristate.edu

Greene, Brian D.
Department of Biology
Missouri State University
Springfield, Missouri, USA

In temperate regions with severe winters, successful location of suitable hibernacula has important survival advantages for neonate snakes. Orientation and navigation to hibernacula has been suggested to occur via scent trailing of conspecifics in neonatal rattlesnakes. We examined the ability of captive-born juvenile Northern Cottonmouths (*Agkistrodon piscivorus*), from a population close to the species' northern range limit, to trail cutaneous cues from conspecifics in y-maze trials. Juveniles 2-3 months old trailed maternal cues significantly more often than a blank (odorless) control (P=0.01, n=16), but also preferred to trail cues from unrelated adult conspecific females compared to cues from their own mothers (P=0.04, n=16). An 18 month old cohort (n=16) of snakes from the same population did not exhibit any preference (P=0.37) for cues of adult female conspecifics over a blank control, suggesting that trailing behavior of juveniles has an ontogenetic component. Overall, our results are consistent with reports of scent trailing of adult conspecifics by neonate rattlesnakes to hibernacula. However, the apparent preference of young juveniles for non-maternal conspecific cues has not, to our knowledge, been reported in snakes. Given the occurrence of post-partum mother-offspring affiliations in cottonmouths, an attraction to non-maternal cues is not obviously explained and may be an interesting topic for future research.

36. Examining Venom Diversification through Comparative Venom Gland Transcriptomics of Palm-Pitvipers

Mason, Andrew
Department of Biological Sciences
Clemson University
Clemson, South Carolina, USA
ajmason@clemson.edu

Sasa, Mahmood
Instituto Clodomiro Picado
Facultad de Microbiología
Universidad de Costa Rica
San José, Costa Rica

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

Parkinson, Christopher
Department of Forestry and Environmental Conservation
Clemson University
Clemson, South Carolina, USA

Identifying the evolutionary mechanisms generating diverse phenotypes is key to understanding the origins of biodiversity through speciation and adaptation. Pitviper venoms are composite phenotypes of 10-100 individual toxins, most of which are the product of single genes. This allows for each toxin's protein phenotype to be linked to their genetic origins with relative ease, facilitating evolutionary inference. Venoms are often highly variable among species, as is seen in Middle American palm-pitvipers (*Bothriechis* spp), though patterns of interspecific venom evolution and toxin diversification have been difficult to discern. To examine venom evolution in palm- pitvipers we generated venom gland transcriptomes from each of the 11 species of Bothriechis. We examine these data in relation to the species phylogeny and biogeography and identified orthologous groups of toxins to infer relative frequencies of toxin gains/losses. Venoms compositions were highly variable among species at the toxin-family and transcript-specific levels. The apparent prevalence of species-specific toxins suggested that toxins genes gains and/or loss occur relatively frequently, though the identification of toxins conserved among nearly all lineages suggests a primary role of regulatory evolution in shaping venom phenotypes. These results have further demonstrated that venom evolution occurs through multiple molecular mechanisms, all of which must be considered for a thorough understanding of the evolution of complex phenotypes.

37. Repeatable patterns of behavioral traits are correlated with sprint speed but not thermal preference in Northern Cottonmouths (*Agkistrodon piscivorus*)

Medley, Kenzie
kenzie.medley66@gmail.com

Greene, Brian D.
Department of Biology
Missouri State University
Springfield, Missouri, USA

Behavioral ecologists have traditionally assumed that populations adapt to environmental conditions with one or more optimal strategies. However, recent evidence has shown that behavioral, life historical, and physiological tendencies often vary consistently among individuals, forming syndromes of responses. Behavioral syndromes, in particular, have been characterized in diverse taxa. However, relatively few studies have investigated snake personality. We evaluated a cohort of juvenile cottonmouths (*Agkistrodon piscivorus*) for consistency in individual performance across two behavioral measures: assertiveness (represented by foraging tasks) and boldness (represented by the defensive responses toward a predator), and thermal performance (sprint speed) and temperature preference in a thermal gradient. Individual responses were highly repeatable for behavioral measures, consistent with the concept of personality in these snakes. Thermal performance also varied consistently among individuals. However, thermal preference was not correlated with thermal performance or behavioral traits. Our results suggest that, unlike some heliothermic lizards, cottonmouths personality types do not logically correspond to thermal types.

38. The Assessment of Repeatable Behavior and Personalities in Juvenile Cottonmouths

Medley, Kenzie
kenzie.medley66@gmail.com

Greene, Brian D.
Department of Biology
Missouri State University
Springfield, Missouri, USA

Behavioral ecologists have traditionally assumed that populations adapt to environmental conditions with one or more optimal strategies. However, recent evidence has shown that behavioral tendencies often vary consistently within individuals and are therefore analogous to personality traits. These pervasive behavioral tendencies, or behavioral syndromes, have been characterized in diverse taxa, including all vertebrate classes and many invertebrate animals. However, the taxonomic scope of behavioral syndromes and their various ecological consequences have been evaluated for few taxa. The objectives of this study are to 1) evaluating the consistency of individual responses across two ecologically relevant contexts: assertiveness (represented by foraging behavior) and boldness (represented by the defensive behavior of individuals toward a predator), as well as the repeatability of behaviors related to temperature, and 2) assess possible structures of behavioral syndromes involving repeatable behaviors by determining correlations between the behavioral and thermal responses previously mentioned.. Our data suggests high levels of individual repeatability in terms of boldness, assertiveness, and thermal performance, but low repeatability was calculated for thermal preference. Further statistical analysis is needed to assess the structures of possible behavioral syndromes.

39. Characterization of Innate Immunity of the Prairie Rattlesnake (*Crotalus viridis*)

Merchant, Mark
Department of Chemistry
McNeese State University
Lake Charles, Louisiana, USA
mmerchant@mcneese.edu

Baker, Sarah*
Illinois Natural History Survey

1816 S Oak Street
Champaign, Illinois, USA

* Present Address:
Arizona Game and Fish Department
5000 W Carefree Highway
Phoenix, Arizona, USA

The innate immune system functions to respond quickly to pathogenic challenge and is likely the primary line of defense for ectothermic vertebrates. Snake populations are declining globally, and disease has been identified as a significant threat. However, few studies have been done investigating snake immune systems. To characterize innate immunity, we measured the antibacterial properties and complement activity of plasma collected from 20 captive Prairie Rattlesnakes (*Crotalus viridis*). Results from antibacterial studies showed that rattlesnake plasma was effective at killing six Gram-negative and two Gram-positive bacterial species in vitro. The antibacterial activities were rapid, inhibiting 73% of E. coli growth within 20 minutes of exposure. The antibacterial activities were also protease-sensitive, heat labile, and inhibited by chelators of divalent metal ions, suggesting that these activities were due to the presence of serum complement activity. We employed a spectrophotometric sheep red blood cell (SRBC) hemolysis assay to assess serum complement activity in rattlesnake plasma. The complement-mediated hemolysis of SRBCs showed the same concentration-dependent, kinetic, and mechanistic characteristics as the antibacterial activities, confirming that the antibacterial activities observed were primarily due to the action of serum complement activity.

40. In-Silico Discovery of Small-Molecule Snake Anti-Venoms: Prospects for Re-purposing FDA-Approved Drugs as Snake-Venom Antagonists

Ridgway, Harry
Institute for Sustainable Industries and Livable Cities
Victoria University
Melbourne, Australia
ridgway@vtc.net

Orry, Andrew
MolSoft, LLC
San Diego, CA, USA

While snake-bite envenomation is relatively rare in the US, the potential health effects can be serious and long-lasting, including chronic neurological dysfunctions and risk of necrotizing infections, possibly leading to fatality. Immunological (anti-venom) approaches continue to be the prescribed therapy for treating poisonous snake bites. Disadvantages of immunotherapies include: (1) the high cost of anti-venom production, and (2) reduced access to immediate treatment in many rural areas where most snake bites occur. A promising alternative to conventional anti-venom treatment is onsite administration of stable small-molecule drugs that can (in theory) be produced relatively inexpensively and readily deployed in rural areas. Discovery and development of such drugs by pharmaceutical companies and university research laboratories has been the subject of considerable investigation over the past several decades. Though generally promising, this approach has been hindered by the high cost of de-novo drug design and protracted regulatory approval combined with a low return on investment (due to low demand). One strategy that has been explored in recent years to circumvent the above marketplace and regulatory barriers is the application of bioinformatics and computer-aided drug discovery (CADD) to identify medications already approved for human use by the US Food and Drug Administration (FDA) that also show potential for re-purposing as snake-venom antagonists. We have recently employed this strategy for several venom components of the western diamondback rattlesnake Crotalus atrox, including: (1) several metalloproteinase and hemorrhagic toxins, such as Atrolysins-c/d; and (2) neuro-inflammatory acidic phospholipase A2s (snPLA2s). Results of virtual ligand screening (VLS) studies in which the active sites of the above (and related) modeled protein targets were challenged with a database of drugs approved by the FDA since 1939 yielded several promising candidate compounds that exhibited tight-binding to the target receptor catalytic sites. These molecules therefore could be explored further in laboratory bioassays and their FDA approvals possibly accelerated as repositioned drugs for snake bite envenomation.

41. Adaptive Interplay between Feeding Habits and Digestive Physiology for Pitvipers

Secor, Stephen M.
Department of Biological Sciences
University of Alabama
Tuscaloosa, Alabama, USA
ssecor@ua.edu

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

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

The sit-and-wait foraging tactic of pitvipers is characterized by extended episodes of fasting between potentially large meals. An adaptive correlate that has evolved with their infrequent feeding is the capacity to widely regulate gastrointestinal performance with feeding and fasting. For pitvipers, feeding triggers a dramatic increase in metabolic rate, hypertrophy of organs, and the rapid up-regulation of gastric acid production, digestive enzymes, and intestinal nutrient transport. Upon the completion of digestion, metabolism is depressed, tissues undergo atrophy, and function is down-regulated. It is hypothesized that the selective force driving the down-regulation of tissue performance between meals resides in achieving a low standard metabolic rate, therefore enhancing the capacity to survive between infrequent meals utilizing endogenous energy stores. The cellular mechanism employed by pitvipers to regulate intestinal function involves altering the functional surface area of the intestinal epithelium via the modulation of microvillus length. Driving this remodeling response are gene and protein expression patterns that cascade through trafficking, cytoskeletal, cell cycling, and membrane pathways. An adaptive interplay between feeding habits and digestive physiology, and their underlying mechanisms, has evolved independently through snake evolution. This has generated an apparent dichotomy between frequently feeding species (acrochordids and colubrids) that modestly regulate organ performance and infrequently feeding species (boas, pythons, and pitvipers) that widely regulate digestive performance.

42. Conserving the Needle in The Haystack: Developing a Field Conservation Program for the Black-headed Bushmaster (*Lachesis melanocephala*)

Spear, Stephen F.
The Wilds
Cumberland Ohio, USA
sspear@thewilds.org

Carvajal, Marcelo
Independent researcher
Puerto Jimenez, Costa Rica

Saborio-R., Guido
SINAC
Golfito, Costa Rica

Andrews, Kimberly M.
Odum School of Ecology
University of Georgia
Brunswick, Georgia, USA

Orozco, Carlos
Hablemos de Perros
San Jose, Costa Rica

The Black-headed Bushmaster (*Lachesis melanocephala*) is restricted to southwestern Costa Rica and has the smallest range of the four bushmaster species. Like other bushmasters, the species is thought to rely on primary, closed-canopy forest, although its exact natural history is poorly known. Despite the presence of a globally important protected area within its range, black-headed bushmasters have lost a high percentage of historic habitat and verified sightings are extremely rare. Our collaborative team has been working to understand the conservation status of this species since 2012, and in particular, we have worked toward developing a survey methodology to help assess the species status. We used a video scope to search burrows on multiple surveys from 2012-2015 in areas with recent bushmaster observations. These surveys did not yield any bushmaster observations but did provide opportunities to discuss bushmasters with local landowners; these connections yielded two bushmaster observations in May-June 2015. We radio-tracked one of these individuals from May-August 2015, a 2-meter female. The area moved by this individual was very small, with a 95% MCP of 1.3 hectares, and a 50% core MCP of just 0.2 hectares. We observed frequent short movements and an association with pocket gopher mounds. Currently, we are focused on three main strategies to identify important bushmaster habitat: conservation detector dogs, soil environmental DNA, and community outreach to document local observations. Our detector dog protocol has already showed promise, with a fresh shed found on a test survey in January 2017. Our ultimate goal is to identify the most important forest patches for black-headed bushmaster populations to target for protection and community outreach efforts.

43. Additive Expression Suggests Mendelian Inheritance of Polymorphic Venom Phenotypes in Mojave Rattlesnakes (*Crotalus scutulatus*)

Strickland, Jason
Department of Biological Sciences
Clemson University
Clemson, South Carolina, USA
jlstrck@clemson.edu

The combination of phenotypes inherited from parents partially determines fitness of an individual. Monomorphic phenotypes under strong selection tend to move to fitness optima but polymorphic phenotypes that can be inherited in different combinations will result in offspring with fitness that differs from one or both parents depending on the complexity of the genotype to phenotype pathway. Venom is a polymorphic phenotype that is under strong selection and highly tractable from the genotype to phenotype. In rattlesnakes, particularly Mojave Rattlesnakes (*Crotalus scutulatus*), a venom dichotomy exists. This dichotomy was initially defined based on proteomic characteristics but recently, a genomic definition has been proposed. Some *C. scutulatus* have neurotoxic venom that lacks hemorrhagic activity (Type A) and others have high hemorrhagic activity and no neurotoxic activity (Type B). Rarely, individuals have a third venom type, Type A+B, where they have neurotoxic and hemorrhagic venom. We used the proteomic definition to identify putative Type A+B *C. scutulatus* to test the applicability of the genomic definition of venom type. To do this, we used comparative transcriptomics of the venom-gland on 31 *C. scutulatus* and tested for differential expression between venom types. We then applied the genomic definition and were able to identify the genotype for the phospholipases and snake venom metalloproteinases responsible for the venom phenotypes. The heterozygous individuals expressed toxins at approximately half of the level found in homozygous individuals. Additive expression in the eight toxins tested suggests the phenotypes in *C. scutulatus* are inherited in a Mendelian fashion and cis-regulation is responsible for differences in expression. We identified six of the nine possible genotypes for a dihybrid cross including five from at least the F2 generation. We were able to determine that Type A+B venom is not unique and is generated through interbreeding between Type A and Type B individuals.

44**. Kleptoparasitism and the Possibility of Chemical Crypsis in Rattlesnakes**

Teshera, Mark S.
msteshera@miners.utep.edu

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

Clark, Rulon W.
Department of Biology

San Diego State University
San Diego, California, USA

Greenbaum, Eli
Department of Biological Sciences
The University of Texas at El Paso
El Paso, Texas, USA

While some aspects of rattlesnake and rodent predator-prey dynamics have been well documented, others are in need of further investigation. Although there is a large body of work documenting the ability of rattlesnakes to detect and follow chemical cues from envenomated prey, one area of research that has not been investigated is the possibility that rattlesnakes might use this heightened chemosensory ability to "steal" prey envenomated by others (kleptoparasitism). We used an experimental setup to examine the propensity of rattlesnakes to locate mice envenomated by either conspecifics or heterospecifics. We hypothesized that rattlesnakes would respond more strongly to conspecific-envenomated prey over heterospecific-envenomated prey of a closely related species, which would in turn be preferred over heterospecific-envenomated prey of a non-closely related species, followed lastly by non-envenomated prey. In a separate experimental study, we investigated the possibility that rattlesnakes, like puff adders, might be chemically cryptic in order to facilitate their ambush foraging strategy. We hypothesized that, if rattlesnakes show enhanced chemical crypsis, rodents would display fewer alarm behaviors to rattlesnake scent than to scent from an active foraging snake species. We examined rodent responses to two rattlesnake species and three active foraging snake species. Preliminary results from these experiments suggest 1) no difference in preference for rodent carcasses envenomated by different types of venoms, and 2) rattlesnakes do not appear to be more chemically cryptic than active foraging snakes. We believe these studies will constitute important contributions to our detailed understanding of the foraging ecology of these important predators.

45. Organ-specific Cytotoxicity of Pitvipers (Crotalinae)

van Thiel, Jory
Institute of Biology Leiden
Leiden University
Leiden, Netherlands
joryvthiel@gmail.com

Snakebite envenomation is designated as a neglected tropical disease. The disease involves multiple pathophysiological effects which often lead to amputations and other loss-of-function injuries or death. In addition to causing suffering, it also causes significant economic and social burdens in developing countries. Many of these effects are caused by cytotoxic snake venoms. Many crotaline [pitviper] species are known to cause irreversible, cytotoxic damage to a variety of organs after envenomation. Many separate studies on this topic have been conducted yet a large overview study is still lacking. This study aims to assess the organ-specific cytotoxicity of the venoms of the crotaline genera *Bothrops*, *Calloselasma*, *Crotalus*, *Deinagkistrodon* and *Trimeresurus*. The in vitro cytotoxicity will be accessed after 24 h exposure of primary cells of the kidney, liver, skeletal and heart muscles of the chicken embryo. Cytotoxicity will be quantified using the colorimetric 3-(4,5-Dimethylthiazol-2-yl)-2,5-Diphenyltetrazolium Bromide (MTT) assay. The results of this study will contribute to the understanding of the evolutionary selection pressures shaping cytotoxins. They will thereby increase our understanding of the cytotoxic potency of snake venoms.

46. Illegal Commercialization of Rattlesnakes in Mexico

Villalobos-Juarez, Ivan
lepidushunter@gmail.com

Sigala-Rodriguez, Jesus
Colección Zoológica de la Universidad Autónoma de Aguascalientes
Aguascalientes, México

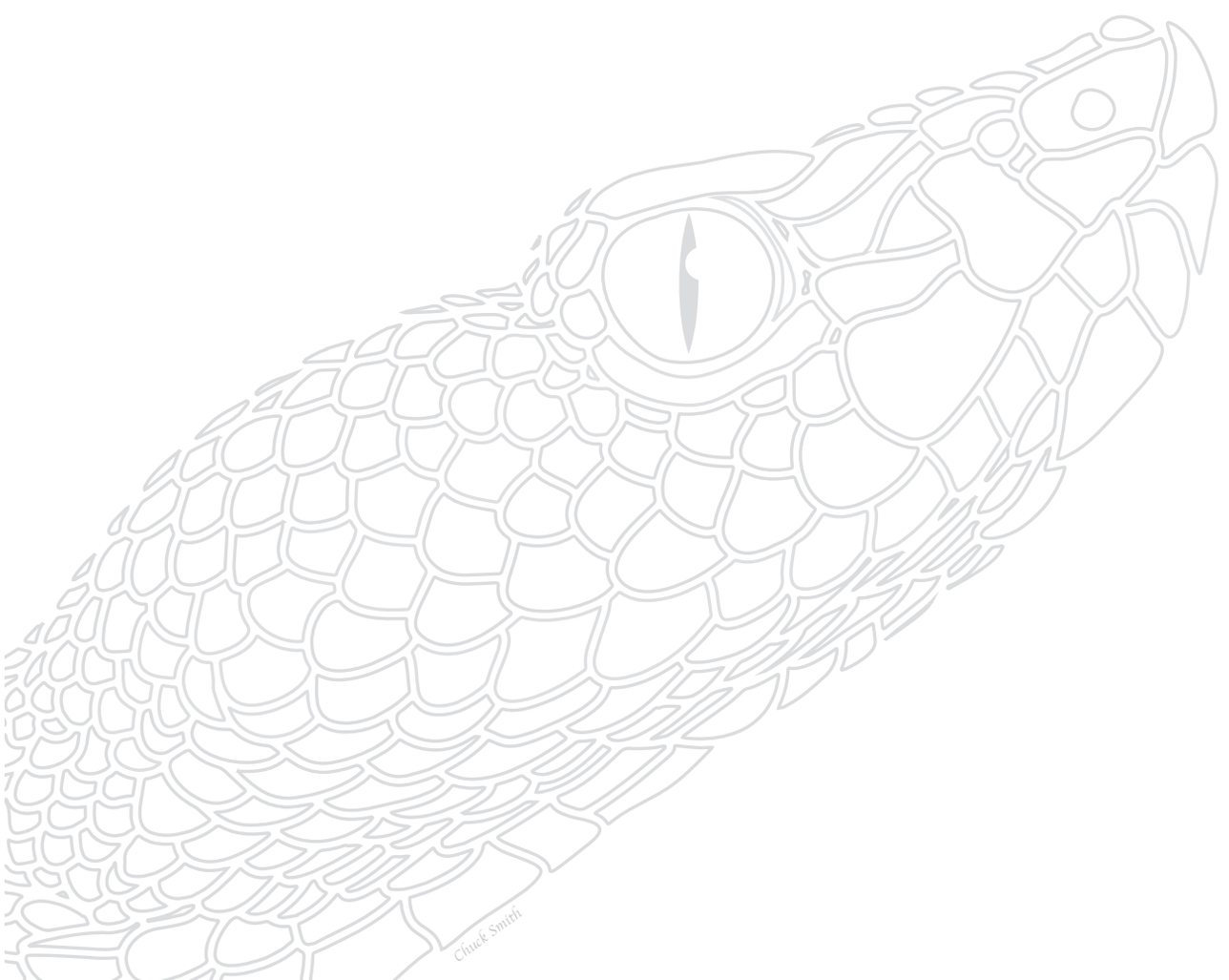
México has about 37 species of rattlesnakes of the genus *Crotalu*s of which 24 are endemic. Although all species are listed by the Mexican government as endangered, threatened or under special protection, the populations are

still being heavily exploited. The illegal trade of rattlesnakes is colossal and unfortunately few investigations have been done in Mexico to estimate the number of organisms commercialized, and the goals of this investigation were to examine the illegal use of native rattlesnakes, their prices and the distribution channels in Mexico. We surveyed dealers from Mexico, USA and Europe, some interviews were held with private collectors and native people from Mexico, we also visited pet shops and local markets to find snakes on sale. In total, 33,400 persons were interviewed between 2016 and 2018. The results obtained showed that rattlesnakes are being used mostly in traditional medicine, as food, for the production of articles using their skins, and recently, as pets. We estimate that the number of rattlesnakes captured annually in Mexico amounts to at least 9,632 individuals. People in Mexico think that rattlesnakes cure cancer, HIV/AIDS and skin disorders, but there is no scientific evidence to support these statements; rattlesnakes and some other snakes are used for the manufacturing of boots, belts and purses. In the case of rattlesnakes used as pets, the traffickers look for endemic species, some of which are found only on islands, and these snakes are mostly shipped to USA and Europe. The rattlesnakes *Crotalus molossus*, *C. atrox*, and *C. scutulatus* are the most frequently sold species. It is necessary to do more research for each state in Mexico as the situation varies greatly per region.

47. A Mechanism for Eye and Pit Protection During a Strike?

Werman, Steven D.
Department of Biology
Colorado Mesa University
Grand Junction, Colorado, USA
swerman@coloradomesa.edu

There is evidence that the facial pit and eye are protected by skin and scales during predatory strikes in Bushmasters (*Lachesis* spp.) and Jumping Vipers (*Atropoides* spp.). In this study I investigated a possible mechanism for this event based on the presence of a postorbital-maxillary ligament found in these taxa. The formal description of this mechanism and the examination of additional pitviper taxa will be forthcoming. My initial hypothesis is that the postorbital-maxillary ligament may have more than one function in these snakes.



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 8802
Phone: (575) 548-2000 (Monday-Friday, 11 am-6 pm)

Bootheel Grocery (18 miles from meeting site)
bootheelgrocery.com/
Phone: (575) 548-2290
Beer, booze & gas (unleaded and diesel)

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