SOAR Research Proposal
Summer 2014

Kinematics of Prey Capture and Swallowing in Sand Boas: Balancing Conflicting Functional Demands

Faculty Mentor: Dr. Frances Irish, Assistant Professor of Biological Sciences

Student: Elizabeth Mack

Project start date and duration: May 27, 2014 (10 weeks)

Background for the project: Snakes have highly kinetic skulls. The snout and upper jaws are movably attached to the braincase by ligaments, allowing snakes to move the jaws on each side of the head independently. When swallowing, snakes anchor the prey with the jaws on one side of the head while advancing the jaws on the other side, thus "walking" the head over the prey. Because the snout is tied to the upper jaws by connective tissue, the snout passively tracks upper jaw movements. The ability of the snout and upper jaws to move freely is an integral part of the unique unilateral feeding mechanism of snakes. For snakes that keep their heads above ground, this kinetic ability is an advantage. But when the head is used as a shovel for digging, having a collapsible snout becomes a problem. The question addressed in this project is: how do sand boas, a group of small, burrowing boas, balance the conflicting demands of digging and eating?

Relevance: This project explores a question of vital interest to evolutionary morphologists: how do musculoskeletal systems adapt to conflicting functional demands? Most burrowing snakes show some kind of reinforcement of the snout-braincase connection that is presumed to limit snout movement; this project asks 1) is snout mobility is reduced in these burrowing snakes? 2) how does reduced snout movement affect feeding mechanics? But the project has broader implications for the evolution of snakes. Evidence from skull and eye anatomy suggests that snakes may have evolved from burrowing ancestors. How did the highly kinetic, unilateral feeding system of snakes evolve from a skull reinforced for burrowing? Looking at how extant burrowing species have solved this problem may shed light on snake origins.

Results from previous SOAR projects: Data from SOAR projects in 2011 and 2012 indicate that, contrary to our initial expectations, the upper jaws do *not* closely track the snout in sand boas----in fact, when the snout is raised during mouth opening, the upper jaws are depressed (i.e., snout and upper jaws move in opposite directions). This phenomenon has not been observed in any other snake. We also found that snout elevation in sand boas is comparable to published records for non-burrowing snakes, but snout twisting (rotation around a longitudinal axis) is constrained. In summary, our data suggest that in sand boas, the snout and upper jaws show surprising independence of movement, and the snout may be more mobile than previously thought.

Previous SOAR students presented posters summarizing their results at the Lehigh Valley Evolution and Ecology Symposium held at DeSales University in 2012 and at Lafayette College in 2013. I synthesized the results of these projects in a poster presented at the Joint Meeting of Ichthyologists and Herpetologists in Albuquerque in July 2013 and a talk presented at the Northeast Regional Meeting of the Division of Vertebrate Morphology of the Society for Integrative and Comparative Biology held at Yale University in October 2013.

Description of proposed summer 2014 SOAR project:
Results from previous SOAR projects are intriguing, but we need more analyzable data. The proposed 2014 project will address challenges encountered in previous projects and will attempt to relate observed snout and jaw movements to the anatomy of the skull. The student will:

1. Read relevant literature on snake feeding mechanics.
2. Record strikes to live prey on high-speed video (500 frames per second).
3. Record prey manipulation and swallowing at "normal" speed (60 frames per second) with high-definition video camera.
4. Do frame-by-frame analysis of video records, measuring snout and upper jaw movements.
5. Examine the connections between the braincase, snout, and upper jaws in dried skulls and relevant preserved specimens in order to discover the relationship between form and function in these animals.
6. Place the data in a comparative context by comparing sand boa kinematics with feeding in other snakes.
7. Synthesize results for presentation and eventual publication.

Experimental animals: Forty-one live specimens of 10 species of sand boas, currently housed in the animal facility at Moravian College. Species to be used for comparison will be borrowed from the snake facility at Lehigh University. The student will help maintain experimental animals and their prey (mice) during the course of the study. Protocols for the previous phases of this project, conducted with SOAR funding in summer 2011 and 2012, were approved by the IACUC committee at Moravian College, and approval will be sought for summer 2014 as well.

Roles and responsibilities of faculty and students:
Faculty role & responsibilities: I have been filming snakes feeding for the past 15 years, and have studied snake anatomy extensively through gross dissection, histological study, and skeletal preparation, and I am a co-author on two book chapters on the snake skull and prey capture kinematics. I will guide the student in her search for background literature, instruct her in experimental techniques, use of specialized equipment, data analysis, and appropriate care of animals, and assist her in preparing her results for presentation.

Student role and responsibilities: The proposed project is part of an on-going research program, but Elizabeth will participate in all aspects of the work, from animal

maintenance to experimental design, data gathering, data analysis, and presentation, as outlined above.

Project timetable:

Week 1: Instruct student in animal maintenance chores; supervise literature search; familiarize student with snake head anatomy; prepare experimental arena.

Week 2: Travel to the American Museum of Natural History to borrow skulls of relevant species.

Weeks 2-8: Record snakes capturing and swallowing prey; analyze resulting data on snout and upper jaw movements each day; relate observed kinematics to head anatomy.

Week 9: Travel to the American Museum of Natural History to return skulls of relevant species.

Weeks 9-10: Finish data analysis, synthesize experimental and anatomical data for presentation, draft poster.

Student engagement in scholarly research and contributions to the discipline:

Elizabeth is currently planning to go to dental school, so familiarity with the techniques of gross dissection and experimental morphology should have particular relevance for her. Elizabeth took General Zoology (Biology 112) and Vertebrate Anatomy (Biol 310) from me, so she has had important background material that should help her understand the context of this study. However, this project will require her to elucidate the anatomy without the aid of a dissection manual, as the anatomy of these small snakes is poorly known, and the aspects we wish to study are not known at all. Hands-on research experience and formal presentation of the results should make Elizabeth more competitive in applying to dental school, and better prepared to succeed. She will present her work for scholar's day at Moravian College, as required, and for an audience of peers beyond Moravian College, such as the National Conference on Undergraduate Research and the Lehigh Valley Evolution and Ecology Symposium.

This project stems from observations made during a long-term study of prey capture behavior in boas and pythons that I have been pursuing in collaboration with Dr. David Cundall of Lehigh University. Early data have been published, but given the fact that these animals are ectothermic and are adapted to going without food for long periods of time, amassing a large data set takes time, patience, and ingenuity. A critical part of my job is mentoring undergraduates in a research setting. The project outlined here is publishable material; data collected this summer will be vital to finishing the experimental aspects of the research so results can be submitted for publication in a peer-reviewed journal.

In today's world, where we enjoy many of the benefits of scientific discovery, it is vital that our students understand the nature of science and the process by which scientific discoveries are made. Having our biology-bound undergraduates actively engaged in scientific discovery brings hands-on science into the community of undergraduate scholars at the college. Formal presentation and eventual publication of student-faculty collaborative research enhances the reputation of Moravian College, and is a selling point for prospective students.

Student Statement of Purpose

Kinematics of Prey Capture and Swallowing in Sand Boas: Balancing Conflicting Functional Demands

Student: Elizabeth Mack
Major: Biology
Expected date of graduation: May 2015
Faculty Mentor: Dr. Frances Irish
Request for on-campus housing: Yes

As a junior at Moravian College, I am actively involved as a student leader in the college community. While being a disciplined, hardworking student is my first priority, I am also a dedicated athlete competing as a Division III softball player, a resident advisor, a member of the Pre-Health Club and a sister of Sigma Sigma Sigma Sorority. I consider myself to be very involved and I quickly developed a strong work ethic and time management skills in order to achieve a successful and rewarding college experience. I am studying biology and it is my dream to continue my education into dental school after graduating from Moravian College. While in dental school, I will continue striving for knowledge and drive towards my goal of becoming a family dentist or an oral surgeon and ultimately opening my own practice.

I am interested in participating in the SOAR program this summer because I feel that hands-on research is an incredible opportunity to fine tune and advance the skills needed to be a scientist. Research experience would further benefit my educational career because dental school is focused on professional training. I value the opportunity as a pre-dental student to study a vertebrate that is drastically different from humans, since I will be working solely on humans in dental school. A competitive undergraduate research program, such as the SOAR program, offers more than just the scientific research experience; it offers the opportunity to work closely with an expert faculty advisor and an elite peer group. I believe teamwork and hard work go hand-in-hand. I will be the first to admit that I do not know everything, but I will do everything I can to find the answer or solution, utilizing all of my resources. I feel that the more experience I can obtain performing original research, the more successful I will be as a student and as a health professional.

It would be a great honor to be accepted into the SOAR program. I look forward to the opportunity this intensive study offers while expanding my knowledge of science and research. As I am always striving to better myself, I feel the skills that I would develop from working with highly skilled faculty and peers, and current technology, would further enhance my educational experience at Moravian College. I also look forward to the opportunity to present my results to a broader audience beyond Moravian, an experience that will help me to develop communication skills that I will use in the field of dentistry. In the world of science, opportunities such as the SOAR program are simply irreplaceable and the experience opens wonderful possibilities for me to not only grow as but as a scientist, a professional and a human being.

Expense proposal

Project title: Kinematics of Prey Capture and Swallowing in Sand Boas: Balancing Conflicting Functional Demands

Faculty mentor: Dr. Frances Irish

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$ 140	Bus fare for 2 trips to American Museum of Natural History, New York City, for student ($46.00) and faculty mentor ($24.00) to examine skulls and preserved specimens of sand boas in the herpetology collection.
$ 160	Expendable supplies. Includes dissection materials, animal food, bedding, additional research animals, etc. The primary research equipment for this project (cameras, lights, etc.) is available in house. The Department of Biological Sciences will supply additional equipment and supplies if required.
$ 300	Total