

Herpetological Research at Primarily Undergraduate Institutions

A tradition exists, extending from colonial days into the 20th and 21st centuries, of herpetologists who have done remarkable work, but who have no formal training in herpetology. Individuals such as Raymond Ditmars, Lawrence Klauber, Joseph Slevin, Roger Conant, Hubert St. Giron, and Ernest Liner come quickly to mind, but many other people could be aligned with this group. These individuals, of course, were never the academic mentors of Ph.D. students in herpetology, but they greatly influenced research in herpetology. Likewise, many other herpetologists in the past and present have held academic positions at institutions where the focus is not on research, publishing, getting grants, and training Ph.D. students. In this perspective, we demonstrate that herpetologists holding positions at strictly undergraduate institutions or those in which the terminal degree is a Master's can nevertheless have productive careers in research. Also, herpetologists at primarily undergraduate universities can impact the future of herpetological research by inspiring undergraduate students to take up herpetology early in their careers.

Collectively, the contributors to this essay have nearly 100 years of experience working for various institutions of higher education. One of us (RP) has spent his entire career at a liberal arts college, another's (SJM) career has been entirely at regional comprehensive universities (RCU) where the M.S. degree is the highest awarded, and the lead author (DMS) has taught at both types of schools. In thinking about what has contributed to our relative levels of success (and enjoyment) in each of our positions, we decided to focus on three elements of maintaining a research program at schools that place greater emphasis on high-quality teaching: 1) Sustaining a long-standing research program; 2) attracting high-quality students (with emphasis on those seeking graduate degrees) to participate in the lab's research productivity; and, 3) collaborations and publishing with student authors. Instead of generating a step-by-step "how-to" guide for our colleagues at primarily undergraduate institutions, we use our experiences to illustrate means of achieving success.

FUNDING UNDERGRADUATE RESEARCH – SEVER

My lab has concentrated for 40 years on using histological and ultrastructural techniques to study the comparative anatomy and phylogeny of primary and secondary sex characters of

amphibians and reptiles. I spent the first 30 years of my career at Saint Mary's College, Notre Dame, Indiana, which is a small comprehensive college (1500 total students, all women) that grants only Bachelor's degrees, and since 2004 I have been at Southeastern Louisiana University (SLU), at which the Masters is the terminal degree. My teaching load has always been 9–12 contact hours per semester, and in addition, I served as department head at both institutions for a total of 16 years. Neither institution has great demands on faculty to do research. Indeed, at both schools, an assistant professor after six probation years can obtain tenure with only one or two publications during that period. I have never been pushed by administrators to get grants or publish papers. Whenever either activity occurred, however, administrators were pleased because they recognized that research, especially involving students, should be an integral part of the undergraduate curriculum.

I will emphasize three ideas in this section: 1) Create a research program that can work at an undergraduate institution. This research program should have the potential to grow and attract funding and students. 2) Submit grants at all levels, from \$1,000 travel grants to \$400,000 NSF grants. Many granting agencies like to see stipends for undergraduates listed on proposals, and NSF even has a special niche (RUI) for proposals from undergraduate institutions. 3) Get undergraduate students involved in your research. Powell will expand on this topic later in this article, but I will show how success in funding of grants leads to opportunities for undergraduates. The wide-eyed enthusiasm of undergraduates can be contagious around a lab and can make even routine fieldwork more enjoyable. These three ideas are not independent of one another and are interwoven in the narrative below.

I became a "histo-herpetologist" during my doctoral work at Tulane University, where my research involved the light and electron microscopy of secondary sexual characters of salamanders. When I arrived at Saint Mary's College in 1974, the fundamental instruments needed to do histological research were present and all I needed was expendable supplies. As such, my "start-up" cost the school less than \$1,000. I needed to obtain some grants to provide money for travel to collect specimens and to replenish expendable items. I also saw the need to explore ways of obtaining an electron microscope for Saint Mary's. I realized that it might help to be unique—I also needed to make my work compelling; why should NSF support this?

My first grant at Saint Mary's came from the Highlands Biological Station, where I had worked during my doctorate, and allowed me to obtain more samples of salamander tissues. Then I discovered that the Indiana Academy of Science was quite generous in awarding modest grants to work on the local fauna, and I started what turned out to be long-term studies on a population of *Ambystoma tigrinum* near campus. Saint Mary's, like many colleges, also had its own internally funded faculty research grant program, and I applied for these frequently. Funds were also obtained from the state Department of Natural Resources and the American

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Philosophical Society. So I actually had enough money to sustain my modest histology lab. The first papers co-authored with undergraduates on *A. tigrinum* (DeNeff and Sever 1977; Couture and Sever 1978) were published in the *Proceedings of the Indiana Academy of Science*. The student authors not only had a publication but also the experience of presenting their work before the Academy.

During the mid-1980s, the College started a renovation project on the Science Hall, and I convinced them that they needed to include an electron microscopy suite. The commitment of the College probably helped the success of my 1987 proposal to NSF, "Electron Microscopy in the Undergraduate Biology Curriculum," which resulted in the addition of a transmission electron microscope (with a scanning electron microscope attachment) and the necessary peripheral pieces of equipment. I immediately began teaching an electron microscopy course in which the undergraduates were trained to conduct ultrastructural research (on amphibians and reptiles, of course). The same year that I received the grant for the electron microscope, I received my first NSF research grant, "Comparative Anatomy and Phylogeny of Cloacal Glands in Salamanders." So 1987 was a pretty good year.

Undergraduate students continued on various projects, including research on *Ambystoma tigrinum* from our study pond (Sever et al. 1987; Platt et al. 1993), but a number of students began working for me on my cloacal gland grant, including some who served as full-time research assistants during the summer. When that grant ended, I received NSF funding in 1991 for a new project, "Comparative Cytology of Sperm Storage Organs in Female Salamanders (Amphibia: Caudata)." This research involved ultrastructural studies on the spermathecae in all families of salamanders that possess the glands. The presence of an electron microscope, made possible by NSF funds, probably was a factor in the success of the proposal. The research included considerable undergraduate student involvement, starting with papers by Sever and Kloepfer (1993) and Sever and Brunette (1993) in the *Journal of Morphology*. During this period, I also began collaborations with graduate students working at the Savannah River Ecological Laboratory (SREL), including John Krenz, Travis Ryan, and William Hopkins. The Department of Energy had a simple process that provided ample travel grants (that included airfare, rental car, and motel) for work at SREL.

Toward the end of my time at Saint Mary's, I became interested in squamate reproductive anatomy. Travis Ryan sent me samples of *Seminatrix pygaea* collected throughout 1998. Tissues harvested from these samples provided the data for seven papers between 1999 and 2010, making *S. pygaea* the most intensely studied reptile in terms of urogenital organ ultrastructure. Again, undergraduate students were critical to accomplishing this research—four from my electron microscopy class were co-authors on one paper (Sever et al. 2000).

I left Saint Mary's to become Department Head of Biological Sciences at SLU in 2004. I will not dwell on my experience with Master's students at SLU, as Mullin will discuss graduate students in the next section. I am pleased, however, that the five MS students I mentored between 2005 and 2011 have gone on to Ph.D. programs, and three have completed their doctorates. Also, I have continued to receive funding from internal sources; such grants are available from SLU and the Louisiana Board of Regents. From NSF I received funding for a proposal, "The Evolution of Sperm Ducts and Accessory Sex Glands in Squamate Reptiles: An Empirical Study of Cellular Complexity." This support

once again allowed me to hire undergraduate students (as well as Master's students) to assist with my research and become co-authors on papers.

In summary, I carved out a niche in comparative anatomy of reproductive structures of amphibians and reptiles that has proved to be very productive over the years. I am pleased that I have mentored students like Dustin Siegel and Justin Rheubert who will carry on this work. My message to graduate students looking for academic positions and to young assistant professors who find themselves at largely undergraduate institutions is simple: If you love your research, you will find time and funding to do it, and you will find undergraduate students who will be eager to participate. You will be as productive as you want to be.

ATTRACTING GRADUATE STUDENTS – MULLIN

For the foreseeable future, certain elements of the screening process for graduate students will be constants—things like GPAs, GRE scores, personal essays, and letters of recommendation. Through experience, we assume that successful faculty members have arrived at their own mechanisms by which they comfortably prioritize these metrics in a manner that helps them gauge each student's potential (so I will not write about it here). Having already read Sever's recommendations for supporting a research program through sustained grantsmanship, I have also included little mention about how the successfully recruited student should be funded. Instead, this portion of our article identifies aspects of recruiting and qualitatively evaluating prospective graduate students, with emphasis on elements worth considering for those researchers at RCUs. I focus on four particular attributes: Independence and motivation, good communication skills, prior experience in a related setting, and good camaraderie. In many respects, these attributes are also useful when involving undergraduates in the lab group's research endeavors.

A recurring sentiment of the recent Master's graduates from my lab is that attending an RCU has a distinct advantage over an R-1 school—after the major professor, the Master's students are typically the "top dogs" among lab members. From discussions with their peers in larger labs (that have hierarchies that include post-doctoral researchers and doctoral students), my graduate students find themselves in a fortunate position for several reasons (items worth mentioning as you get to know prospective students): 1) Consistent access to their major professor, without needing to yield time to more senior members of the lab group. 2) First priority in selecting research assistants. Like most researchers conducting field projects, few efforts in my lab are completed without a small army of undergraduate researchers. In the absence of post-docs or Ph.D. students who might pull rank to work with the "pick of the litter," Master's students at RCUs can rarely complain about not having enough assistance available. 3) Greater opportunities for funding research. This might seem counter-intuitive, but Master's students in my lab typically appreciate trying their own hand at writing grant proposals instead of structuring their thesis research to fit within the scope of an existing grant authored by their professor. Whereas RCUs typically do not have as much funding from major agencies like NSF and NIH (see, however, Sever's comments above), opportunities for Master's students to acquire their own funding (especially from intramural sources or extramural agencies that do not allow the school to siphon off overhead costs) can be more numerous than at R-1 schools. 4) More opportunities for intellectual independence and growth. This is a corollary of the

previous point in that, by completing a project that is not tied to an existing research grant (often one with a much larger scope), Master's students at an RCU typically have a little more freedom to pursue those interests that crank their intellectual engines the most.

Implicit in Sever's contribution to this essay is a fortunate paradox—although much of the general public cares little for the organisms that we study (especially snakes; Seigel and Mullen 2009), our focal animals are endowed with a charisma that attracts a steady stream of interest from undergraduates in our academic units. Faculty working at RCUs can exploit this interest when needing help on either their research projects or those of their graduate students. Convincing undergraduates that studies involving amphibians or reptiles are both fun and fulfilling is an easier task than assuring that your lab benefits from steady and reliable help from those students. Two strategies have helped maintain my lab's productivity: 1) I identify students early by recruiting them from lower-division courses; and, 2) I assess the student's commitment level and aptitude by involving them in lab activities that do not necessarily involve interactions with our focal animals. For instance, weekly lab meetings provide the opportunity to discuss a recent publication or critically review a grant proposal. Initial levels of enthusiasm from recruited undergraduates might wane in the face of such activities, and I often use this as a surrogate measure for their level of dedication to an actual project.

Students maintaining or increasing their interest levels in all lab activities gain additional experience, and assure some continuity in the lab's operations—whether a long-term project or the husbandry of a research colony of animals, students who are new to the lab group receive effective training from both experienced undergraduate and graduate students. Herein lies another advantage, but this time for the student: engaged in this manner, research-minded undergraduates gain a variety of experiences, thereby enhancing their chances at succeeding beyond their bachelor's degrees. I not only use this as a selling point when recruiting undergraduates, but I look for evidence of breadth and depth of experience among prospective graduate students, even if they were not able to pursue their own project independently.

One of the best, albeit indirect, pieces of advice from my undergraduate advisor was to experience different settings for my graduate degrees. Compared to continuing an association with what was already familiar to me, exposure to new teaching and mentoring paradigms and to the herpetofauna in different ecosystems better prepared me for a successful academic career. Completing each of my degrees at different universities also helped me develop a sense of independence and self-motivation. I now offer this advice to my own students: Although undergraduate assistants in my lab might have stellar GPAs and an acumen for research that would rival most doctoral students (such that I would enjoy continuing as their mentor), I nevertheless encourage them to move on to another school for their Master's degrees. I also look for the traits that would typically be cultivated by such a move—*independence and motivation*—in prospective graduate students. When considering students from other schools, I find that those who want to complete a Ph.D. (whether immediately after their tenure in my lab or eventually) are the same individuals who are most successful as Master's students. They recognize that working in my lab group will be a training ground for the greater demands expected at a doctoral program. This recognition also manifests itself in the motivation

needed to see a research project through to its logical conclusion (i.e., a peer-reviewed publication).

To end up with the best possible graduate students in a lab, successful professors must first ensure that their efforts are on the radar of the community at large. In addition to a steady publication record, I have found that one of the best ways to make this happen is to attend the joint meetings of the three North American herpetological societies (JMIH). Not only do I renew friendships with colleagues who “grew up” with me as graduate students at previous iterations of this conference, but I typically learn about promising undergraduates from other labs who have expressed an interest in getting experience in other programs. Meeting prospective students in this setting might include opportunities to get a sense of how the students discuss their science (say, if they are presenting undergraduate projects). Given that graduate students are regularly the public face of your lab, you will want to recruit students who can speak clearly and confidently about their own work. Interacting with prospective students at meetings like the JMIH also gives you more information about their potential fit into the current composition of the lab than could be obtained from an email inquiry with an attached CV.

At some point during the bi-directional screening process, I encourage prospective graduate students to visit my lab. A few colleagues at other universities (ranging from R-1s to RCUs) insist on this sort of interview visit as part of the application process, perhaps as a means of assessing the degree of student commitment. I do not feel comfortable making this demand because, typical of an RCU, the school has no funds to help offset the costs of such trips. I do what I can to lessen the outlay in the form of providing housing (usually imposing on a current graduate student) and a few meals. The prospective student not only comes to understand the potential academic aspects of joining your lab, but also learns more about the domestic and social life of a typical graduate student. To help the prospective student realize the most from investing the time and effort into the trip, I arrange brief interviews with other faculty having some overlap in research interests. Thus, the student can appreciate the diversity of expertise that would be available during his or her degree program; meanwhile, I learn of any “red flags” that are raised in the minds of my colleagues that might not have been apparent during my own interactions with the student. As helpful as such a visit can be in ascertaining the chemistry between the major professor and student, it is equally important for me to know that the prospective student will get along well with current lab members. As I have already invested resources into the existing make-up of the lab (and have established good working relationships with those students), I would be doing the group a disservice by accepting a new student whose ideology (e.g., Gregory and Ellis 2009) or personality clashed with those of other lab members.

COLLABORATIONS AND PUBLISHING WITH STUDENTS – POWELL^[1]

At small schools that lack graduate programs in the sciences, herpetologists are considered rather generic biologists who are asked to teach courses ranging from introductory biology to upper-level courses such as anatomy, embryology, ecology, and evolution. Once exposed to the charms of amphibians and reptiles, however, reverting to generic biology can be a bitter pill. Furthermore, because teaching is the primary responsibility of

[1] Portions of my contribution are adapted from an essay published in 1998 in *The Newsletter of the Herpetologists' League* 5(1):5–6.

faculty at such institutions, heavy course loads, plus ancillary responsibilities such as advising and committee work, leave little time for research. That said, “doing” herpetology at a small school is not impossible, but constraints like time, space, and funding are real and must be acknowledged. The impacts of these constraints are lessened by the fact that many small institutions are tuition-driven—meaning that any activity that attracts, involves, and retains students will be viewed positively by administrators. The obvious solution, of course, is to engage students in herpetology. One of the most powerful attractants is participation in field trips. These need not be to exotic climes (although that is nice); local and regional trips are inexpensive, take little time, and can open the eyes of students to realities of nature that most have never experienced.

As a new faculty member at Avila University, I sought to provide my students with some of the same experiences responsible for leading me to a career in academia. I developed what I called a “field biology” course, for which students could earn credit for having a great time and gaining experience. Our first trip was to the Big Bend, and it went so well, I immediately began planning trips to more esoteric destinations even farther south. Over the next few years, I taught field biology classes around trips to Baja California, the Yucatan Peninsula, and various other destinations in México. As acquiring permits in México became increasingly difficult, I began looking for alternative destinations. At the time, I knew no one working in the West Indies, but Bob Henderson, with whom I had corresponded regarding our work in the Yucatan, had been focusing his work on Hispaniolan treesnakes (*Uromacer*). I gave him a call to ask if he thought the Dominican Republic (DR) would be a good place to take students. He not only said it was, he sent me a thick packet of information regarding whom we should see about permits, where to stay, and from whom to rent vehicles. My wife and I took a short “vacation” that January, and I took my first field biology class to the DR that spring.

The early trips were all about finding critters, but I soon began looking for projects that could be implemented during short periods—and these gradually became more sophisticated and elaborate as I became more familiar with the herpetofauna. One day, the advancement office at Avila forwarded an NSF document announcing criteria for a new program titled “Research Experiences for Undergraduates” (REU). I immediately recognized the potential to do an even better job of what we had been doing all along. I sat down with John Parmerlee, who had been a student during my early days but had since earned a graduate degree, returned to the area, and had accompanied me on many of the field biology trips—and we wrote a proposal in a day and a half.

As might be expected, that first effort was pretty marginal. We learned from reviewers’ comments, however, and took considerably more time the following year, which resulted in many positive comments—but no grant. So, I contacted the program director and asked for an explanation. I learned that no one on the review panel knew me or had ever heard of Avila. That, combined with the “unusual” nature of our proposal—we proposed keeping the student cohort together in the DR, have them engage in individual or collaborative projects, and publish their results—led to the lack of funding. I think my conversations with the program director led to her giving us a chance.

Focusing on natural history and establishing publication as a goal from the very beginning, we selected our first cohort in 1991. Every participant became an author, we collectively contributed to a growing knowledge base concerning the West

Indian herpetofauna, and clearly demonstrated to NSF that we could achieve what we had proposed. We have now conducted 11 iterations involving 101 students from 68 different colleges and universities, all of whom have been at least coauthors of at least one of over 150 publications in peer-reviewed journals^[2]—and the great majority have matriculated to graduate programs. Furthermore, several former students have served as faculty in subsequent programs, either while still in graduate school or after having become faculty members at institutions of various types.

Although I still have students developing and implementing projects locally, often relying on museum specimens borrowed for that very purpose, I have adapted much of my research to the REU programs. This allows me to remain actively engaged while simultaneously providing my students with a leg-up toward research careers of their own. I would further suggest that our type of program is not only beneficial to the participating students, but unique to an undergraduate institution. Because I do not have to maintain a lab that meets the needs of graduate students or postdoctoral fellows, I can devote entire summers to research involving undergraduates. Furthermore, by focusing on natural history in its various guises, I can provide students with an entire research experience, from developing and implementing hypothesis-driven projects to publishing the results of their work.

Publication is an important and worthwhile goal for undergraduate research. It represents the culmination of the research process, provides opportunities for teaching (and learning) relevant and essential skills, and it generates a product that not only enhances a student’s CV, but validates the research experience and makes a contribution to science. Not all research is appropriate for publishing with undergraduates and hurdles can be substantive. Sometimes the undergraduate lacks the necessary competence, some research protocols are too complex to provide undergraduates with more than a small portion of the process, and the time involved can be daunting—but these obstacles are not insurmountable, especially if publication is established as a goal from the very beginning.

Undergraduate research is more likely to be publishable if it addresses subjects about which little is known, reducing the burden of breaking new ground. Good research does not have to be “cutting-edge” science. My collaborators and I address this in our field-based work by going places where little research has been done, where many of the basic questions remain unanswered (e.g., diets, distributions in variously altered habitats, some aspects of behavior and performance), and abundant data can be generated in relatively short periods of time. Collaborative endeavors further enhance data collection (although they inevitably lead to discussions regarding senior authorship) and conserve time. Time constraints also dictate investigative protocols with shallow learning curves. Those, however, allow us to supplement a core of more advanced and experienced students with bright freshmen and sophomores or students from institutions that lack the means or facilities for research.

Mentors must be willing to invest huge amounts of time and must resist the temptation to simply take over and do the job themselves (although a more heavy-handed approach may be necessary when tackling a first experience with statistical techniques). They also must avoid imposing unrealistic expectations. Like learning any other skill, practice is necessary and

[2] Additional information and a list of publications is available at www.avila.edu/bobpowell/7powreu.htm.

opportunities to practice must be provided. Mentors must work with students as they learn the necessary investigative skills, but be willing to step back when students are capable of taking charge of a project. Finally, even the best students must learn to write for publication. During this process, mentors must be patient—reviewing draft after draft, criticizing without discouraging, encouraging without demeaning, and not streamlining the process to the extent that they think it is easier than it actually is. This often extends well beyond the 10-week summer program, explaining why we schedule our trips in alternate years.

From the early days of weekend field trips and publications dealing primarily with range extensions or county records to increasingly sophisticated studies demonstrating, for example, relationships of laboratory-generated data on performance to real-world situations, the scope of my research has changed—but the emphasis on student engagement has remained the same. So, being a herpetologist at a small undergraduate institution can be challenging, but it can be done and done well. Hard work and accepting and overcoming the inherent obstacles are essential.

CONCLUSION

Woven into our essay is the important theme of research experience—whether yours or that of students in your lab. We enjoy conducting it, our students enjoy helping us, and, even when the recognition rarely comes in the form of release time or infrastructure improvement, our administrators love to tout the fostering of critical thinking skills in our students when we involve them in research. In this sense, we get some of the same benefits from being research-active without the stress of the “publish-or-perish” environment that typifies most R-1 programs. The lower pressure at a college or RCU also increases the likelihood that a researcher can be successful in the particular niche of conducting long-term studies (e.g., decadal in scale). Prospective students not only express interest in conservation-related research with increasing frequency, but they are easily convinced that long-term studies can better inform conservation strategies because such a perspective accounts for more environmental variability. Because teaching excellence is favored over research output at our institutions, we can publish more comprehensive views of particular systems based on data compiled over multiple years.

Engagement in research provides you with the mechanisms to stay abreast of advances in your field (e.g., through presentations at meetings, current literature, publishing with students, etc.), informs your teaching, and, in theory, keeps you intellectually sharp (responding either to questions or feedback from manuscript reviewers). For students in your lab group, training in a research environment builds critical thinking skills, invests them in the process of scientific discovery (Moslemi et al. 2009), and will help prepare them for many of the next steps in their careers (Fleet et al. 2006). We expect our colleagues have also realized that, by involving students in research early in their development as biologists, the students quickly recognize that careers in herpetology are equally valid to those that focus on other taxonomic groups—our field would perish if new cohorts of students were not impressed by the processes of answering questions about amphibians and reptiles and generating the results that lead to new questions. Admittedly, we have not covered every single aspect that will allow you to remain research-active at a non-R1 institution. Rather, our hope is that the coming cohorts of newly-minted Ph.D.s and post-doctoral fellows will be

encouraged by the opportunities at primarily undergraduate institutions, and take comfort in the fact that, in these settings, they can continue to contribute in meaningful ways to our understanding of amphibian and reptilian biology.

Acknowledgments.—We thank our own advisors for sharing a few insights on mentoring student researchers. Feedback from S. Boback, R. Brodman, M. Dorcas, and N. Ford improved previous drafts of this paper. Most of all, we thank the students who have worked in our lab groups (both undergraduate and graduate) for their enthusiasm and perseverance in many research endeavors with such fascinating animals.

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