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Author(s): Lara A. Ferry and David S. Shiffman
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The Value of Taxon-focused Science: 30 Years of Elasmobranchs in Biological Research and Outreach

Lara A. Ferry[1] and David S. Shiffman[2,3]

Due to an intense level of interest from the media, the public, conservation NGOs, and policymakers, the scientific study of charismatic megafauna is perceived by some researchers as associated with glory-seeking or other less-than-noble behavior. However, the study of elasmobranchs has led to important discoveries in the fields of physiology, evolution, neurobiology, behavior, and ecology that would not have been possible with other study systems. These animals are ecologically and economically important, and many species are of great conservation concern. Additionally, public interest in these animals can be leveraged for science and conservation education and outreach efforts, and they can be used as ''flagship species'' for conservation and management policy. In this paper, we discuss the value of taxon-focused scientific research using examples from the work of American Elasmobranch Society scientists. We argue for the importance of taxon-based societies, such as the American Elasmobranch Society (AES), and the societies it meets jointly with, including the American Society of Ichthyologists and Herpetologists, the Society for the Study of Reptiles and Amphibians, and the Herpetologists' League. Together these four societies make up the Joint Meeting of Ichthyologists and Herpetologists (JMIH). While this paper will focus on AES, the general principles apply broadly to all members of JMIH as well as other taxon-based societies, and speak to their importance amongst a backdrop of broadly discipline-based research societies.

THE KROGH PRINCIPLE VS. TAXON-FOCUSED RESEARCH

The Krogh Principle states that ''for many problems, there is an animal on which it can be most conveniently studied'' (Krebs, 1975). When this was explained to author DS in a graduate level physiology course, the instructor noted that it means scientists should select a research problem and then identify the best study species for it. Scientists should not, according to this instructor while singling out DS and a student studying marine mammals as examples, pick a species that they ''like'' and then come up with a research question related to it. Author LF had a similar experience in graduate school, as she was also studying elasmobranchs. Both are/were perceived as ''shark-huggers,'' and felt pressure to defend their study organisms. Interestingly, in response to this, author LF found herself often supporting the Krogh Principle, while author DS found himself believing that taxon-focused study has value, and that it is appropriate to choose a study animal for reasons other than their effectiveness at answering a given research question. Despite these differences, the two authors find emergent common ground as they weave their way through their research careers. These emergent themes speak to the importance of taxon-based societies amidst a broadly comparative landscape prominent in research today.

The American Elasmobranch Society (AES) was created as a professional society focused on the multidisciplinary scientific study of cartilaginous fish taxa: specifically, sharks, skates, rays, and chimeras. First discussed in 1983, AES has held an annual conference every year since 1985. Though the European Elasmobranch Association and the Oceania Chondrichthyan Society have been created in recent years, AES remains the largest professional society focusing on scientific research of these animals in the world. Together, AES members have published tens of thousands of scientific papers, technical reports, and textbooks, and have served critical roles in fisheries management and conservation policymaking around the world.

In a survey distributed to the American Elasmobranch Society's members, researchers identified a variety of reasons why they chose to study elasmobranchs. Some reasons would fit under Krogh Principle focused reasoning (Appendix 1), while others demonstrate more taxon-specific research question selection (Appendix 2). Additionally, like the authors, many AES members reported similar experiences to those reported above, receiving criticism for studying ''charismatic megafauna'' a ''sexy'' study animal, and that research on sharks is considered ''too hollywood-ized to be real science.''

Regardless of their reasons for using elasmobranchs as their study system, AES scientists have made many significant discoveries pertaining to evolutionary biology, physiology, neurobiology, and behavior, including some that would not have been possible with other study species. Elasmobranchs represent the missing link in many of these studies and science could not have advanced without them. Elasmobranchs also play important roles in ecosystems, and ecological studies are incomplete without this link. Additionally, they are a taxon of great conservation concern, and one that allows for public engagement in science.

[1] School of Mathematical and Natural Sciences, Arizona State University, 4701 W Thunderbird Rd., Glendale, Arizona 85309; E-mail: lara.ferry@asu.edu. Send reprint requests to this address.
[2] Abess Center for Ecosystem Science and Policy, University of Miami, P.O. Box 248203, Coral Gables, Florida 33124.
[3] RJ Dunlap Marine Conservation Program, University of Miami, 4600 Rickenbacker Causeway, Miami, Florida 33149.
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Appendix 1 indicates that many of the reasons for studying elasmobranchs are in keeping with the Krogh Principle; they are the right organisms for the study at hand. While Appendix 2 illustrates many of the characters that can lead to disrespect or disdain of shark research and shark researchers, it also demonstrates that sharks hold our fascination like few other groups of organisms, and as such they can be used to deliver important messages about conservation and related areas of science. We will elaborate on the advantages, and advances, made via both approaches in the following sections. This is not mean to be a comprehensive review paper of any one field or area of study. Thus, we will only provide brief overviews of the work and point out how it has advanced science as a whole. However, we hope the many examples will expose a bigger picture of how important taxon-based science can be.

ELASMOBRANCHS CAN BE AN IMPORTANT MODEL SYSTEM FOR MANY FIELDS OF RESEARCH, JUSTIFYING THEIR STUDY UNDER THE KROGH PRINCIPLE

Scientific breakthroughs in sensory biology and neurobiology.— Several researchers have used elasmobranchs to make important breakthroughs, advancing biology as a whole. A key example is a recent study of brain size and its possible correlation with parental investment (Mull et al., 2011). In this study, the researchers looked broadly at elasmobranchs using an existing phylogeny. In this phylogeny, it was equivocal as to whether matrotrophy, or the maternal provisioning of the young, such as through a placental connection, evolved 11 times, or six times with five reversals. Either way, this trait has undergone tremendous selective pressure, with clear evidence of convergent evolution even when using the strictest of criteria. This is not observed in any other vertebrate clade. When you look at tetrapods, for example, the amniotic egg evolved, then placental mammals. You cannot examine the consequences of evolutionary innovation when said innovation evolved just once over the course of evolution. Within chondrichthyans, maternal provisioning happened over and over again, and thus this clade is unique in terms of how you can look at traits that are correlated, or causally related, to maternal provisioning. So, what is the consequence of this? In small-bodied sharks, those species with a maternal contribution to the offspring had larger brains. This is consistent with other clades that have been studied. Interestingly, within larger bodied species, the difference tends to go away, which was attributed to gigantism and the general phenomena that everything is big once you get really, really big. Interestingly, what did change with brain size in many of these larger species was habitat complexity (Yopak et al., 2014).

Elasmobranchs are also an ideal system for the study of complex sensory systems. Elasmobranchs are not the only species to possess an electrosense, but they show, by far, the most diversity in this trait, with nearly 1000 electrosensing species described. This, combined with a uniquely advanced sense of smell and a well-developed sense of sight (McComb et al., 2009), makes elasmobranchs unparalleled for studies of the sensory and related systems. Sharks are described as a layered complexity of multimodal systems (Gardiner et al., 2011). Sharks are often wide-ranging predators, and we might understand their sensory systems better than other comparable sorts of predators (Gardiner et al., 2012).

Studying migration patterns and habitat usage is important for developing effective conservation and management plans, yet many telemetry tools are too large to apply to small organisms. Elasmobranchs, like sea turtles and marine mammals, are therefore an important system for the study of animal migrations (Hammerschlag et al., 2011a). Studies have revealed amazing long distance migrations, distances much farther than researchers previously believed that they traveled. A basking shark, believed to be cold-water, was tracked across the equator (Skomal et al., 2009). A great hammerhead shark was shown to move far north of their known range (Hammerschlag et al., 2011b). This provides evidence that species cross political boundaries, requiring international cooperation for their management. Multisensor tags, also too large to apply to most marine species, have provided insight into elasmobranch physiology and behavioral ecology as well (Whitney et al., 2012).

ELASMOBRANCHS ARE ECOLOGICALLY AND ECONOMICALLY IMPORTANT ANIMALS, AND MANY SPECIES ARE IN DANGER OF EXTINCTION, JUSTIFYING A TAXON-SPECIFIC APPROACH TO RESEARCH

Many elasmobranchs are apex predators in their ecosystem (Cortes, 1999), and population declines have been associated with trophic cascades in several ecosystems (reviewed in Baum and Worm, 2009). Additionally, elasmobranchs have been shown to impact their ecosystems through nonconsumptive effects, which in some systems may be more significant than consumptive effects (Rosenblatt et al., 2013), similar to the role wolves play in terrestrial systems (Wirsing and Ripple, 2010). Elasmobranchs are a valuable draw for SCUBA ecotourism around the world (Gallagher and Hammerschlag, 2011), as well as non-consumptive uses such as catch and release fishing (Shiffman and Hammerschlag, 2014).

Though there is heavy fishing pressure for elasmobranchs (Worm et al., 2013), their life history, which includes slow growth and low fecundity, makes them vulnerable to overfishing (Hoenig and Gruber, 1990). Elasmobranchs are the most threatened class of vertebrates, with nearly one quarter of all species estimated to be threatened with extinction by the IUCN Red List (Dulvy et al., 2014). For some species, population declines exceeding 90% since the 1970s have been measured (Baum et al., 2003). Additional scientific data is needed to generate effective conservation and management plans (Simpfendorfer et al., 2011). The combination of ecological and economic importance of these animals and conservation concerns associated with their population declines should be justification enough to study elasmobranchs.

Additionally, intense public interest in elasmobranchs makes them useful as a tool for conservation education and outreach. Many aquariums feature captive elasmobranchs, which attract the public and can be used as "flagship" species to educate them about related marine conservation issues such as habitat destruction and sustainable seafood. The RJ Dunlap Marine Conservation program (which houses author DS), for example, takes over 1,000 high school students each year into the field to aid in studies of sharks and to learn about local marine conservation issues. DS is also actively involved in online outreach, and has spoken to dozens of school groups around the world about sharks using Skype videoconferencing. DS writes about sharks and marine conservation for Southern Fried Science, one of the most widely read ocean science blogs on the internet (Thaler et al., 2012), and uses twitter (@WhySharksMatter) to reach and educate thousands around the world (Shiffman, 2012; Parsons et al., 2014). Author LF is new to twitter in this capacity, but has joined the effort. While charismatic species like sharks are used to attract the attention of students, the media, and members of the public, related issues can be discussed.

Conclusions.—Old-school undergraduate curricula included such topics as zoology, as well as herpetology, ichthyology, and so on. Now we teach General Introductory Biology and Comparative Physiology. This is certainly an understandable and defensible approach; however, the focus on the organism is disappearing. Interestingly, there seems to be a trend emerging that such taxon-based topics are viewed as 'specialty-topics,' which might be offered at the upper division level at a university, but more often than not, students travel to small field stations and take these courses as part of intensive summer course work, for example.

How does this translate to societies like the AES? Like the field stations, we are smaller in membership numbers than larger, broader comparative societies, yet we offer an intense and concentrated educational experience. At the annual American Elasmobranch Society conference, session topics include disciplines as diverse as "Genetics and Systematics," "Morphology and Physiology," and "Ecology." If an elasmobranch ecologist attended an ecology-focused conference, they would undoubtedly learn research techniques that could be applied to their own studies from researchers studying other taxa. However, they would not learn about the evolution or physiology of their study organism from AES researchers with drastically different specialties.

Elasmobranchs have numerous properties that make them excellent model animals. Additionally, elasmobranchs are ecologically and economically significant animals, and many species are threatened with extinction. The organism-based research approach can and should be used to complement Krogh Principle style discipline-based research. There is value in learning about such a study species from the perspective of multiple independent research disciplines, something only possible with taxon-specific research societies like AES and its sister societies such as the American Society of Ichthyologists and Herpetologists, the Society for the Study of Reptiles and Amphibians, and the Herpetologists' League.

Lara Ferry is the Immediate Past-President of the American Elasmobranch Society, and David Shiffman is the Editor. A version of this paper was presented as a plenary talk at the 2012 Joint Meetings of the Ichthyologists and Herpetologists held with the World Herpetology Congress in Vancouver, B.C. The survey of values and opinions regarding elasmobranchs in research was conducted with the approval of the University of Miami, IRB protocol 20130730.

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APPENDIX 1

Selected responses to the survey questions ‘‘Why did you choose to study elasmobranchs?’’ and ‘‘What value do elasmobranchs have as a study system or model organism?’’, which support the Krogh principle. These researchers believe that elasmobranchs are an ideal model organism to answer their research questions.

‘‘They possess primitive characters not found in other living gnathostomes. Their jaw mechanics are unlike those of other jawed fishes. Both living and fossil forms may reveal clues to the origin of gnathostomes.’’

‘‘Unique place in evolutionary history’’

‘‘Elasmobranchs are an under appreciated model comparative system for evolution and ecophysiology.’’

‘‘unique characteristics relevant to questions in my field (biomechanics)’’

‘‘Strong interest in electroreception and the use of this sense’’

‘‘Unique physiological adaptations not found in any other organism’’

‘‘They are large animals and can take larger amounts of sensors than other fishes.’’

APPENDIX 2

Selected responses to the survey questions ‘‘Why did you choose to study elasmobranchs?’’ and ‘‘What value do elasmobranchs have as a study system or model organism?’’, which support a taxon-based approach. These researchers believe that extrinsic factors, including conservation concerns as well as public fascination and personal interest, justify scientific research of elasmobranchs.

‘‘Because they are at such a high risk due to exploitation.’’

‘‘Not much was/is known about them and they fascinated me’’

‘‘Because sharks are cool!’’

‘‘I have had an innate fascination with the group since childhood’’

‘‘Fell in love with them at a young age and have made it a goal to teach the world about their importance’’

‘‘They are a really interesting group of animals’’

‘‘I enjoy (get personal happiness) from interacting with elasmobranchs more than any other taxa.’’

‘‘Elasmobranchs are my personal favorite. I would FIND any excuse to study elasmobranchs.’’

‘‘It has allowed me to study a system that I have been interested in for a long time.’’

‘‘Highly charismatic and seriously misunderstood’’

‘‘In general, public support of elasmobranch conservation seems to be increasing. The attention elasmobranchs are receiving is a tremendous benefit to researchers’’

‘‘They offer a great amount of community engagement opportunities.’’

‘‘My method is: ‘Let’s find an excuse to play with/learn about X species?’ ’’

‘‘They are the most interesting, engaging, and memorable group of organisms considered to be ‘charismatic megafauna,’ and yet are surprisingly fragile. People know so little about them, and I’ve experienced very positive responses from people when they hear what I’m doing as a scientist to answer questions about elasmobranchs’’

‘‘easier to engage the public and therefore educate them about conservation issues’’

‘‘Easy to teach someone about Elasmobranchs and get the conversation started. Much harder with other organisms/systems. Everyone loves sharks!’’