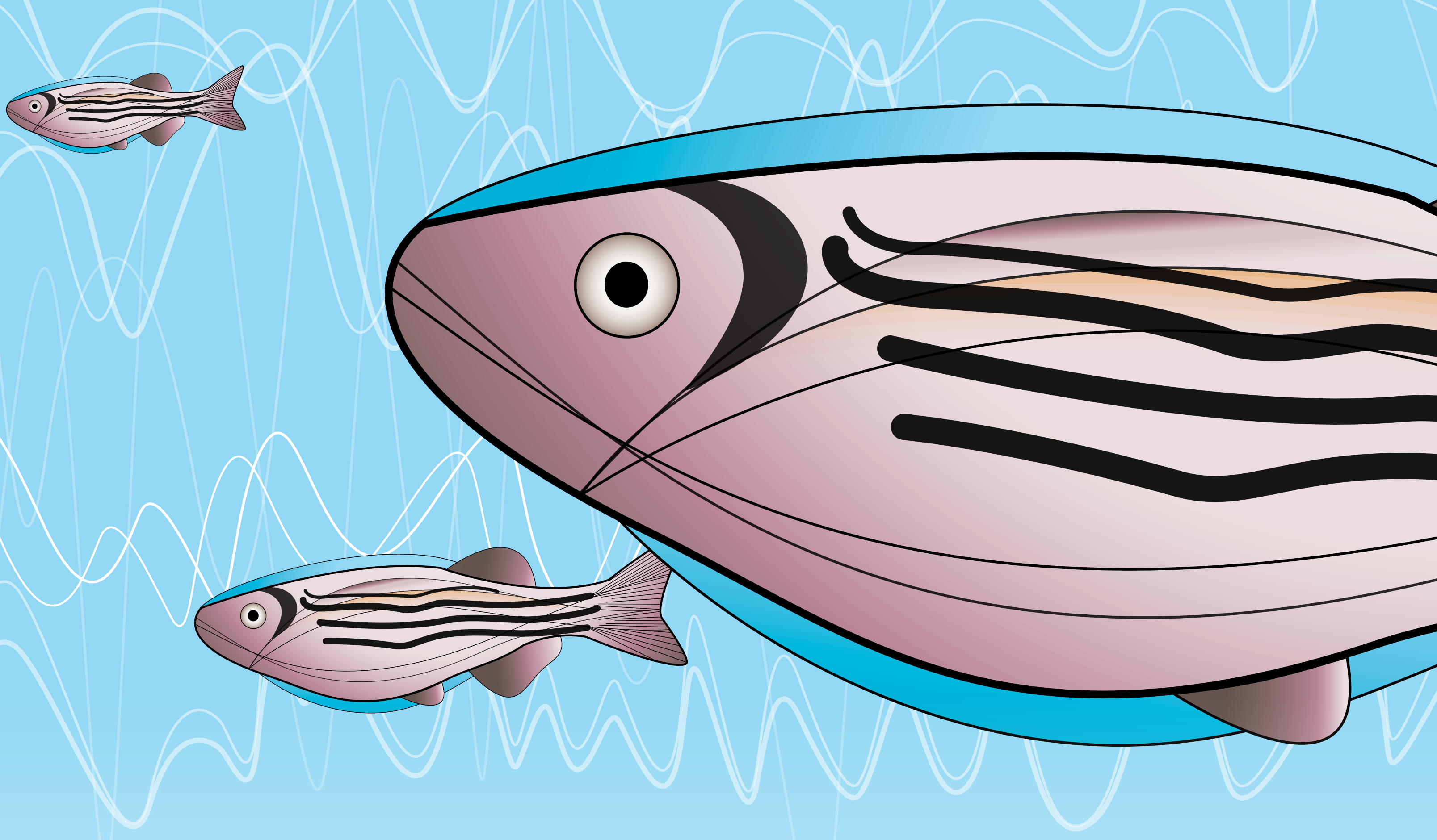


EXAMINING BIOAC

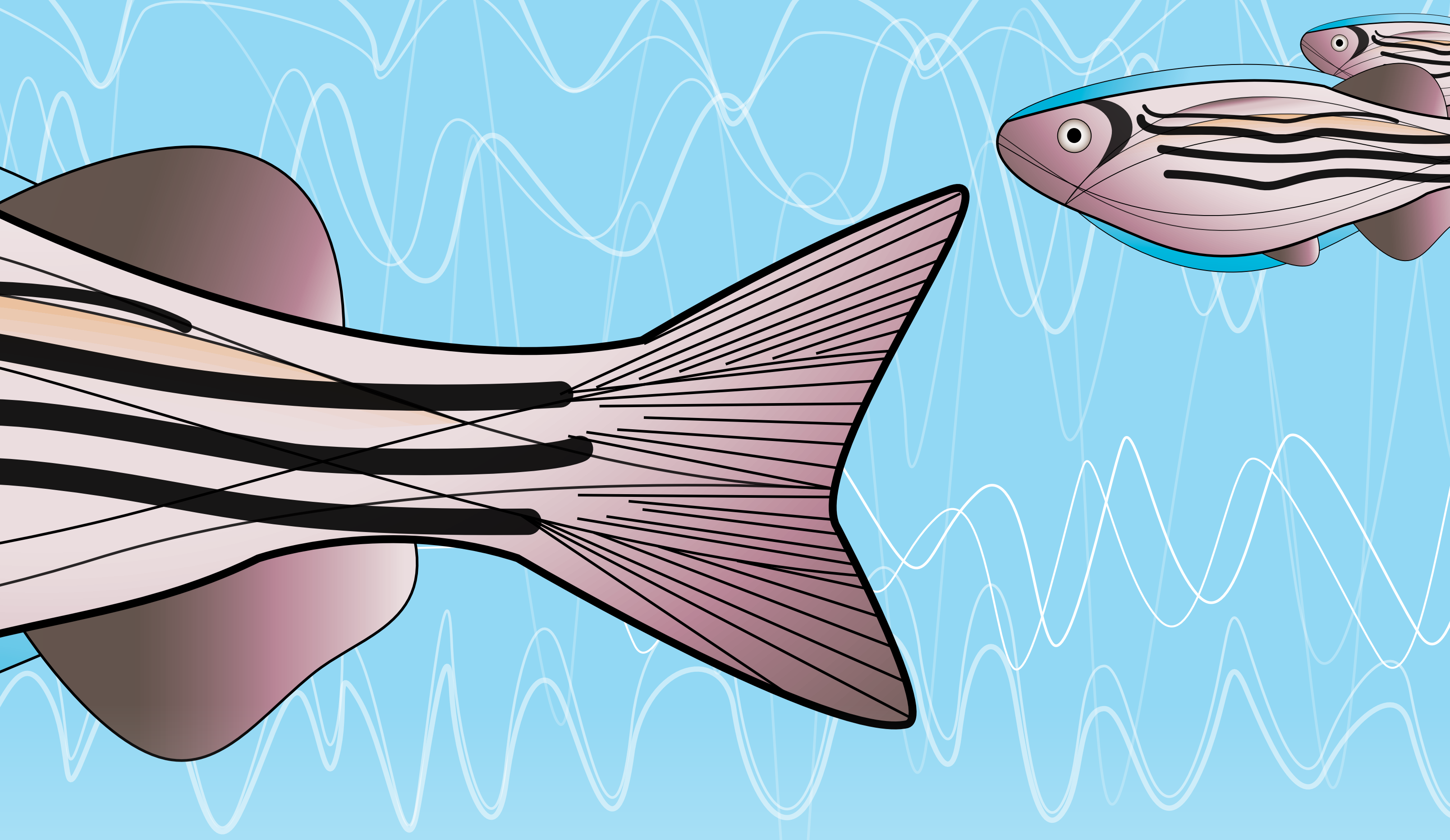
LOCAL RESEARCH, GLOBAL IMPACT

Dr. Michael Smith

CURRENT RESEARCH WITHIN THE DEPARTMENT OF BIOLOGY EXEMPLIFIES WKU'S COMMITMENT TO STUDENT ENGAGEMENT. FOR ASSISTANT PROFESSOR MICHAEL SMITH, WHAT BEGAN AS A CHILDHOOD INTEREST IN OUTDOOR HOBBIES, PARTICULARLY FISHING, HAS EVOLVED INTO YEARS OF PROFESSIONAL RESEARCH. THE RESULTS OF HIS WORK ARE CONTRIBUTING TO ADVANCEMENTS IN BIOMEDICINE, ENVIRONMENTAL SCIENCE, AND THE STUDY OF EVOLUTION.

After completing bachelor's and master's degrees in zoology at Brigham Young University, the Houston native earned his Ph.D. in marine science from The University of Texas at Austin in 2001. "As part of my dissertation research, I tested various behavioral capabilities of marine fish larvae," he states. "One of these capabilities is called a 'startle response' that larval fish use to escape from predators. I used acoustical and visual cues to initiate these responses and so became familiar with the sensory development of the visual and auditory systems of fishes."

Between 2002 and 2005, Smith conducted post-doctoral research at The University of Maryland in College Park. During that time he worked with Dr. Arthur Popper, a world renowned authority on the fish auditory system, and



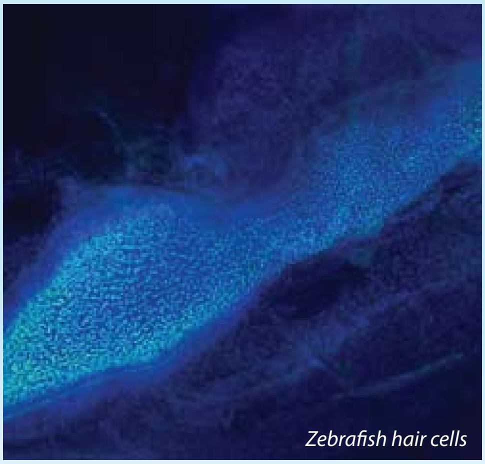
coustics in Fishes

BY AARON S. DUGGER

Illustration by Karen Ford

learned how to conduct hearing tests on fishes. "I submitted two grants my first year, both of which were funded. One was a Maryland Sea Grant that proposed to examine the effects of loud sounds on fishes in terms of hearing and physiological stress response," Smith explains. "The other was a National Institutes of Health (NIH) National Research Service Award to use zebrafish as a model of aging in the auditory system. Essentially, my current research is an extension of my postdoctoral research experiences." In the fall of 2005, the neurobiologist joined the faculty at WKU. "My overall research goal is to examine various aspects of the bioacoustics of fishes, that is, how they receive and produce sounds. The current main project in my lab is to examine the process of auditory sensory cell regeneration in zebrafish." Smith's research can be divided into three categories, the first of which may lead to cutting edge biomedical applications.

Auditory sensory cells are commonly referred to as hair cells. They are responsible for converting acoustic signals into neural signals, thus allowing an organism to hear. While the hair cells found in fish and mammals are structurally similar and function in much the same way, they differ in one crucial aspect. "When inner ear mammalian hair cells are lost due to loud noise or ototoxic chemicals, such as some antibiotics, they do not come back; in other words, we are deaf for good," Smith explains. "In fish and birds," however, "auditory hair cells will grow back, or regenerate, and allow for a recovery of hearing."



Zebrafish hair cells

His experimentation with goldfish has demonstrated that intense noise exposure results in a decrease in the number of inner ear hair cells and consequent hearing loss. "Within two weeks following the exposure, hair cell densities and hearing capabilities are close to control levels," Smith reports. Understanding such hair cell regeneration in fish may eventually allow scientists to replicate the process in humans. Dr. Smith, the students in his lab, and fellow researchers, such as Dr. Nigel Cooper of the University of Louisville, are potentially paving the way toward treating deafness in humans. "If we can find out which genes are being expressed in fish hair cells that are undergoing regeneration, then perhaps genetic manipulation or injections of specific proteins into the inner ear could produce hair cell regeneration in mammals," says Smith. He also points out that scientists have experienced some initial success with hair cell regeneration in mice. The process, however, is still in its infancy.

Smith's ongoing research is primarily undertaken at WKU's Biotechnology Center, although he has collaborated with fellow researchers at the University of Washington, Auburn University, and the University of Louisville. Students are a vital component of his work. "I have had one postdoctoral, three graduate, and eight undergraduate researchers working in my lab," he states. "I also have a postdoctoral colleague from China visiting my lab and working on a project this spring." Smith's commitment to preparing students for lifelong success is palpable. "I hope to affect my students by giving them important laboratory opportunities — learning specialized techniques, learning how to analyze data and present it in oral and poster formats, and how to write scientific papers," he says. "This will give them an edge when applying for graduate or professional programs. I also feel that students should have a fun time doing their research. If they are not, then they should switch projects." To that end, Smith offers learners a variety of innovative and relevant research opportunities.

Hearing tests and microarray analysis are examples of such projects. "We do hearing tests in fishes by electrophysiologically measuring auditory evoked potentials, which are brain waves that result when the auditory system detects sound signals," Dr. Smith explains. The fish is held in place in the water by means of a mesh sling. One electrode is attached over the brainstem area, another near the nose, and a ground

electrode is affixed to the tail. "The technique is similar to that used to check the hearing of newborn baby humans," Smith adds. Short tone bursts are then delivered via an underwater speaker. "When a tone is played that is loud enough for the fish to hear, an auditory evoked potential is evident." In other words, the electrodes record the brain's response to sound. The results are then displayed on a computer screen.

"To examine hair cells, we dissect out the ears of the fish under a microscope. Then we trim off the patches of sensory hair cells, called maculae, and mount them on microscope slides after staining them with various markers," Smith explains. Certain chemical markers, such as phalloidin, bind to the hair cell bundles and fluoresce green. This fluorescence allows the researcher to obtain an accurate hair cell count. To determine which genes play a significant role in the regeneration process, Dr. Smith and graduate student Julie Shuck exposed zebrafish to noise, and then dissected ear tissue at specified intervals following that exposure.

Dr. Smith's study of hearing in fishes will likely benefit global aquatic habitats as well. In recent decades there has been a significant increase in the level of manmade noise pollution in oceans, lakes, and rivers. Sources of these loud sounds include sonar, seismic surveys, shipping, and construction. Concern for this phenomenon is growing. "While the focus of research on underwater anthropogenic sound has been on marine mammals, little is known about the effects of loud sounds on fishes," Smith points out. "My goal is to develop predictive models to assess hearing loss in fishes resulting from various sound sources," he adds. The results will be useful for the creation of environmental impact statements.

Dr. Smith & Reagan Gilley

"In general, hearing loss increases with increased sound exposure levels, but patterns are species and frequency dependent since species vary as to which frequencies they are most sensitive to." Undergraduate honors student Reagan Gilley is a participant in this aspect of Smith's research. He recently tested the Equal Energy Hypothesis using rainbow trout, channel catfish, and goldfish. "This hypothesis states that the amount of hearing loss expected is dependent upon the total amount of acoustic energy the ear receives," Smith explains. "The conclusion from his experiments is that while the Equal Energy Hypothesis may be valid for some situations, it is not very robust for a number of species over a wider array of sound levels."

The study of bioacoustics in fishes contributes to yet another field of scientific endeavor: the study of evolution. It is widely believed that the sense of hearing first evolved in fishes, some of which have undergone adaptations to improve their hearing. "Most of these adaptations involve the coupling of an air-filled structure to the inner ear," Smith explains. He and his students are seeking to shed light on the evolution of such morphological structures. They are presently studying loricariid catfishes. "These fishes have reduced their swim bladder to two smaller swim bladders on either side of their ears. The skull structure adjacent to these swim bladders is full of holes that are filled with lipids. We hypothesize that this anatomical set-up amplifies sounds coming into and/or away from the fish." This research focuses not only on loricariid hearing but also on the sounds they produce: click-like noises resulting from a process known as stridulation. Smith defines this process as "the rubbing of ridges at the medial tip of the pectoral spine and the pectoral girdle." He adds that three honors students, Brian Rogers, Amanda Webb, and Patrick Stewart, are currently conducting research on this family of fishes.


Fish brain and ears

When asked what motivates his research projects, Smith is quick to answer. "What is exciting about my research is the novelty of each topic and the thrill of discovering something no one else has discovered." For example, "With the hair cell regeneration I am learning new, cutting edge molecular biology techniques. With the loricariid work it is a challenge to design experiments to test the acoustical functionality of their 'head holes'. It is completely unknown what the functions of these holes are." Although he is by no means at a loss for ideas, Smith's future research is dependent on several factors. "I am waiting to hear about a pending NIH grant to continue my hair cell regeneration research. My research will also depend partially upon the interests and capabilities of my students and collaborators." ■