Shock & Awe!

BY HOWARD YOUTH

The new "Electric Fish: Shocking Power" exhibit at Amazonia is generating lots of buzz—in every meaning of the word—and teaching Zoo visitors about these amazing and under-studied animals.

"We want to be safe," says keeper Denny Charlton, standing before a large aquarium in the Amazonia exhibit, "so we wear these big rubber gloves as a precaution. We also wear rubber-insulated boots so it's less likely to conduct electricity through us." Being a keeper is hard work, requiring dedication, discipline, and a nurturing spirit. But if your beat is Amazonia—and specifically the new "Electric Fish: Shocking Power" exhibit, funded largely by donations from FONZ members—now there's an added challenge: avoiding electric shock.

Charlton skewers a raw shrimp onto a long, floppy plastic wand, then slips his hands into rubber gloves. He dips the wand into the aquarium and lets the bait settle near the tank's bottom.

Electric eels can navigate murky rivers, hunt prey, find mates, and even jam the signals of predators—all through electrical charges.

CONNOR MALLON/NZP

Engineers have studied knifefish locomotion, like that of this elephant-nose species, to help design robotic submarines.

COURTNEY SMITH/FONZ

At the tank's floor, a dusky, five-foot-long creature comes to life, making wild loops and swirls in the water.

In an instant, the electric eel strikes at the wand tip and the shrimp vanishes. BVVVVVV! A loud electric zap startles us and a light flashes above the tank. The sounds subside to buzzes, then silence, and four visitors gaze up at the monitor above the tank, which measures charges sent out by one of the world's most electrifying fish. At the moment of the strike, the intensity of the fish's electric discharge spiked from almost nothing to the limits of the monitor's graph. Now, things have calmed down, and the electric eel swims to the tank top for a gulp of air before settling back to the bottom.

Despite their common name and very long bodies, electric eels are not true eels. They belong to a group known as Gymnotiformes, commonly known as knifefish. Species are found principally in South America, though some occur as far north as southern Mexico. Some other fish species can sense electrical signals—like rays and catfish—but knifefish are unique in their ability to generate signals, which they use to hunt, locate mates, navigate in dark and twisting river channels, and even jam the signals of their predators. Until recently, scientists had been left in the dark about these widespread yet mysterious species. But as Amazonia visitors learn, that's changing fast.

Rechargeable Batteries

The electric fish exhibit opened in October 2017, following a seven-year process involving curators, scientists, keepers, educators, exhibit designers, and electronics experts. It's designed to highlight all the amazing features of these fish. The anatomy of an electric eel is built to charge and re-charge, almost like a battery. (In fact, famed scientist Alessandro Volta developed the electric battery based on his work with electric eels.) The eel's head has a positive charge, while its tail runs negative. At the National Zoo exhibit, a bronze model illustrates this fact. When you touch both ends, you complete the circuit, causing the model to vibrate and

a video to start up on a nearby screen. The video compares the electric eel's elongated anatomy with that of a more "standard" catfish.

In the eel, the vital organs are packed up front, while the back four-fifths—the long tail—produces electric signals. That process happens through three organs, which generate low-voltage pulses for communication and navigation and high-voltage zaps for self-defense and hunting prey.

All three organs contain thousands of electrocytes, or disc-shaped cells. Under normal conditions, each electrocyte carries a tiny negative charge on the outside and a positive charge on the inside. When the eel senses something, its motor neurons fire, releasing a neurotransmitter that links the inner and outer part of one side of the cell. Each cell thus acts like a tiny battery, with a negative charge on one side and a positive charge on the other. When thousands of cells fire within milliseconds—zap.

Knifefish, including electric eels, are also unusual in how they get around. Unlike most of the world's 32,000-plus species of fish, knifefish lack pelvic and dorsal fins, and they only have small, vestigial tail fins. However, they have an anal fin that runs the length along the underside, moving like a long, rippling ribbon. This feature gives knifefish precise mobility, allowing them to swim backwards and even hover. (Most fish can only swim forward.) Engineers have studied knifefish locomotion, attempting to mimic the fluidity and precision for robotic submarines and other applications.

In fact, engineers have long admired the design of these fish. The world's first all-electric submarine, launched in France in 1888, was called the Gymnote. Its name referenced the scientific order of knifefish: Gymnotiformes. In Greek, "gymnot-i" means "naked backed," in reference to their lack of dorsal fins.

In their backwater habitats of the Amazon basin, knifefish inhabit waters low in oxygen. Although they do have gills that can process oxygen from water, about 80 percent of their oxygen intake comes from air that they gulp through their mouths and then process through highly vascularized tissues in their backs.

Shocking Discoveries

In the Amazon region, people fish and bathe with caution for fear of startling electric eels. If you study fish in that part of the world, you also need to watch where you step or dip your hands. Just ask National Museum of Natural History biologist David de Santana. Much of the science in the new Zoo exhibit relates to de Santana's field work in South America. During his career, de Santana has traveled throughout the Amazon region. He and his colleagues first described 79 of the more than 230 knifefish species found there. And, yes, he's been shocked while working in the field.

"Some fishermen and I were collecting black ghost and glass knifefish with a seine net in a small, murky river in Brazil," he explains. "Back then, in 2000, we weren't using fish detectors that can easily detect the presence of an electric eel, and together with the knifefish we unexpectedly caught a five-foot-long electric eel that shocked me in the legs. I fell into the water and, as a result, lost several knifefish I had in my tray." Although electric eels' shocks are highly painful and could potentially incapacitate someone in water, presenting a drowning threat, electric eels do not intentionally attack nor kill people.

Thanks to recent research by de Santana and his colleagues, we know that there is not just one species of electric eel, but at least eight, one of

"Current" Affairs

The Zoo's five-foot-long electric eel arrived in 2015 from the Houston Zoo and is about ten years old. You can see a demonstration and keeper talk at the exhibit each day at 1:30 p.m. The electric eel is fed four days a week, usually on Tuesdays, Thursdays, and weekend days. In addition to the electric eel, you can see black ghost, elephant-nose, and bluntnose knifefish, along with rare underwater footage of wild electric eels taken in the field by de Santana and Douglas Bastos (a PhD student at a university in Brazil). Keep checking back—de Santana hopes to update the exhibit from time to time with new information from his studies.

COURTNEY SMITH/FONZ

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The new exhibit, largely funded by FONZ members, includes interactive features that show how the anatomy of electric fish generates a charge.

The electric eel is built to charge and re-charge, almost like a battery.

which can deliver a charge up to 850 volts—about seven times the voltage of a typical household appliance.

An Electrifying Start

Amazonia Senior Curator Ed Bronikowski was key in proposing and developing the exhibit (along with Amazonia Assistant Curator Ed Smith). But for Bronikowski, the initial spark came decades ago. When he was just seven years old, Bronikowski visited a similar electric eel exhibit at the Greater Cleveland Aquarium. "It was a real 'shocker', pun intended," he says. As an adult, Bronikowski's passion for fish perhaps could be measured in aquaria. He had 33 at home, housing a wide variety of fish, including electric catfish from Africa. At age 20, he returned to the aquarium to discuss a plan he had drawn up to rig the aquarium that housed his pet African electric catfish so that audio and a strobe light would trigger when the fish discharged electricity.

"Director Dan Moreno graciously looked at my electronics schematic and showed me where I had the wiring wrong on the amplifier. I thanked him and left his office," says Bronikowski. But before Bronikowski left the aquarium, he felt a tap on his shoulder. "The director asked, 'Are you looking for a job?' That's how I entered the zoo/aquarium industry, as an entry-level, algae-scraping aquarist," says Bronikowski.

De Santana also got his start raising fish at home. As a teen in Brazil, he had ten aquaria, plus an outside pond. While visiting his grandparents' farm in Amazonia, he would comb the streams and lakes for fish to add to his collection. "My interest in fish started in my childhood and became more serious during adulthood," he says, adding that his quest to learn more led him to a master's then a doctorate degree in zoology. "I saw a gap in studies of diversity and evolution in this group of fish, so I built my professional career filling those gaps in the knowledge of the Gymnotiformes," he says.

There seems to be more than a lifetime of work left to answer many puzzles about these fish. Although many knifefish species are common—in Amazon and Orinoco river channels between two and 30 meters deep, these fish constitute between a quarter and 85 percent of the biomass — very little is known about them. "I'm now

COURTNEY SMITH/FONZ

The electricity-generating organs make up four-fifths of an eel's body and can fire in milliseconds.

leading a five-year project between the National Museum of Natural History and the Museum of Zoology at the University of São Paulo that aims to discover new species of Gymnotiformes and place them in the tree of life," De Santana says.

Discovering new species is important not only for biodiversity but also because they can reveal a variety of hidden substances and functions, some of which could have modern applications. The recharging capabilities of some knifefish, for example, have been studied for possible ways to develop recharging pacemakers.

The interactive exhibit is linked with ground-breaking research done by Smithsonian Institution scientists. De Santana hopes to regularly update the exhibit with new findings from the ongoing field and lab work he and his colleagues conduct as they paint a clearer picture of the diversity and evolution of South America's knifefish.

Like a reluctant movie hero cloaking super powers, these under-studied, understated fish are now getting the attention they deserve. As with so many Smithsonian exhibits, visitors may be left inspired and curious to learn more about electric fish and their habitats, just like the amateur hobbyists who grew up to become a curator and a biologist, given the rare opportunity to pursue what they love and share it with so many others. SZ

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