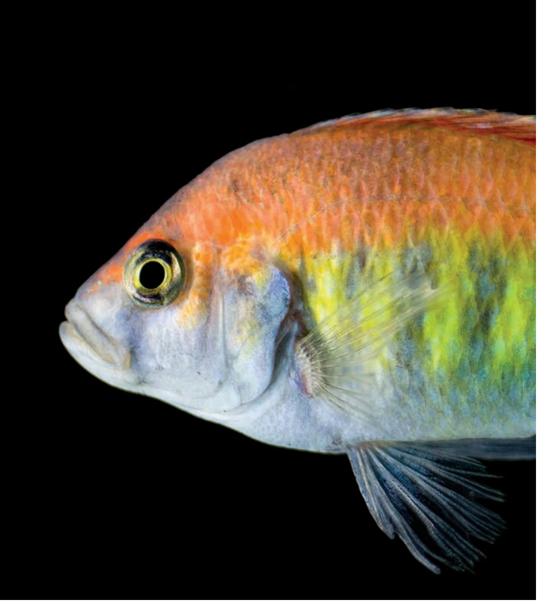

Lake Victoria is home to hundreds of cichlid species, diverse in both appearance and behavior.

PHOTOS (CLOCKWISE FROM LEFT): TIM ALEXANDER (2); MORITZ MUSCHICK

EVOLUTION

Hybrids spawned Lake Victoria's rich fish diversity

Cichlid speciation helped by pre-existing genetic variation

By **Elizabeth Pennisi**, *in Waimea, Hawaii*

In the shallow waters of Lake Victoria, the world's largest tropical lake, swim some 500 species of cichlid fish with a dizzying variety of appearances, habitats, and behaviors. Genomic studies have shown they arose from a few ancestral species in just 15,000 years, a pace that has left researchers baffled about how so much genetic variation could have evolved so quickly. Now, extensive sequencing of cichlids from around Lake Victoria suggests much of it was there at the start, in the cichlids' ancestors. Ancient and more recent dallying between cichlid species from multiple watersheds apparently led to genetically diverse hybrids that could quickly adapt to life in the lake's many niches.

Reported last week at the Origins of Adaptive Radiation meeting here, the work is "a tour de force, with many lines of evidence," says Marguerite Butler, a functional morphologist at the University of Hawaii in Honolulu. It joins other research suggesting that hybridization is a powerful force in evolution (*Science*, 18 November 2016, p. 817). "What hybridization is doing is allowing the good stuff to be packed together," Butler says.

Some of Lake Victoria's cichlids nibble plants; others feed on invertebrates; big ones feast on other fish; lake bottom lovers consume detritus. Species vary in length from a few centimeters to about 30 centimeters; come in an array of shapes, colors, and patterns; and dwell in different parts of the lake. Mutations don't usually happen fast enough to produce such variety so quickly. "It's been really hard to figure out what's going on," says Rosemary Gillespie, an evolutionary biologist at the University of California, Berkeley.

Ole Seehausen, an evolutionary biologist at the University of Bern who has studied cichlids for more than 25 years, wondered whether hybridization could have generated the genetic raw material. In earlier research, his team collected cichlids from the rivers and lakes surrounding Lake Victoria and partly sequenced each species's DNA to build a family tree. Its branching pattern indicated that Lake Victoria's cichlids are closely related to a species from the Congo River and one from the Upper Nile River watershed, the group reported last year in *Nature Communications*.

A close look at all their genomes suggested the two river species hybridized with each other long ago. Seehausen proposed that during a warm spell about 130,000 years ago, water from tributaries of the Malagarasi River, itself a tributary of the Congo, temporarily flowed into Lake Victoria, bringing Congo fish into contact with Upper Nile fish.

To explore the cichlids' genetic history in more detail, Seehausen and postdocs Matt McGee, Joana Meier, and David Marques have now sequenced 450 whole cichlid genomes, representing many varieties of 150 species from the area's lakes, and from the Congo, Upper Nile, and other nearby watersheds. Clues in the genomes suggest multiple episodes of mixing took place. Periods of drying have repeatedly caused Lake Victoria to disappear, and Seehausen and his team propose that fish in the remaining waterways evolved independently until wetter periods reunited them. This "fission-fusion-fission" process restored genetic diversity each time.

About 15,000 years ago, three groups of fish, themselves products of the ancient hybridizations, came together in Lake Victoria as it filled again. Their ancestry provided the "standing variation" that natural selection could pick from to help the fish adapt to a vast range of niches, producing the cichlid bounty seen today. "Hybridization may turn out to be the most powerful engine of new species and new adaptations," Seehausen says.

"It's mind-blowing," says Dolph Schluter, an evolutionary biologist at The University of British Columbia in Vancouver, Canada. "All the variation required for speciation is already there" in the hybrids.

Studies of other species also suggest standing variation can speed evolution. Biologists trying to understand how marine sticklebacks adapted so quickly to living in freshwater have discovered that a crucial gene variant was already present—in low percentages—in the fishes' marine ancestors. At the meeting, researchers offered similar stories of standing variation jump-starting diversification, for example enabling long-winged beetles to evolve into short-winged ones on the Galápagos Islands. "I've never seen so many talks where you have evidence that genes are borrowed from old variation and further evolution is somehow facilitated by that," Schluter says.

Andrew Hendry, an evolutionary biologist at McGill University in Montreal, Canada, cautions colleagues not to completely dismiss new mutations in rapid species diversification: "What's not clear to me is whether [the role of ancient hybridization] is a general phenomenon," he says.

Regardless, "The implications for conservation are blaring," says Oliver Ryder, who heads conservation genetics efforts at the San Diego Zoo in California. Endangered species are currently managed as reproductively isolated units, and conservationists are reluctant to bolster populations by breeding the threatened animal with related species or populations. Eight years ago, however, a controversial program that mated Florida panthers with Texas cougars helped rescue the former from extinction. Studies such as Seehausen's, says Ryder, suggest that in the long run, hybridization is important to preserving a species's evolutionary potential. ■

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