Lake Victoria's Lightning-Fast Origin of Species

By CAROL KAESUK YOON

Viewed as an evolutionary treasure chest, crowded with hundreds of closely related fish species that can be found nowhere else in the world, Africa's Lake Victoria has long attracted biologists to its shores. But while scientists probed and prodded these cichlid fish, as they are known, in the vast watery expanse of this continent's largest lake, Victoria yet managed to conceal their most magnificent secret.

Now an international team of researchers, using remote sensing to probe the sediments at the lake's bottom, have found evidence that what is now Lake Victoria was a dry, grassy plain just 12,000 years ago. For evolutionary biologists, the implications are enormous. The discovery means that the 300 unique fish species that have been documented in the lake must have evolved in the unthinkably short interval since the current lake began to form, a geological instant ago.

"All these species, this whole universe of cichlid fishes, that all this could have evolved in 12,000 years," said Dr. Ernst Mayr, the Alexander Agassiz Professor Emeritus at Harvard University in Cambridge, Mass., "as improbable as it seems — the facts force you to accept it."

Calling the conclusions, reported in the current issue of the journal Science "ironclad," Dr. Amy McCune, an evolutionary biologist at Cornell University in Ithaca, N.Y., said, "It's amazingly exciting. We're talking about rates of speciation that have not even been imagined." She added, "I think everybody is going to be surprised."

But now even more perplexing questions arise, as researchers ponder how so many species could have evolved in such a

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Lake Victoria's Lightning-Fast Origin of Species Took Just 12,000 Years

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short period of time and what there is about cichlid fishes that makes them prone to such excesses of evolutionary speed.

"It's a world record, no question," said Dr. Axel Meyer, an evolutionary biologist at the State University of New York at Stony Brook, L.I.. In fact, these cichlids make evolutionary laggards of other groups much celebrated for their speed of evolution, like Darwin's finches on the Galapagos Islands. On those islands, Dr. Meyer said, fewer than 20 species of finches have evolved over four million years or more. In contrast, Lake Victoria has churned out more than 10 times as many cichlid species in less than one-hundredth the time.

The team of nine researchers that made the discovery had no particular scientific interest in the cichlids that swam alongside their boats. They were drawn to Lake Victoria in the hope of gathering clues about long-term climate changes from the lake's history of fluctuating water levels. The team was led by Dr.

Cichlid fish can spawn new species in 20 generations.

Thomas C. Johnson, director of the Large Lakes Observatory at the University of Minnesota in Duluth; Dr. Christopher Scholz, of the University of Miami; Dr. Michael Talbot, at the University of Bergen in Norway, and Dr. Kerry Kelts, at the University of Minnesota in Minneapolis.

Setting out in a fishing boat, the researchers used a method of remote sensing in which an air gun is discharged into the water, sending sound waves down into the ground. A series of sound detectors capture the returning echoes, which are used to determine just what lies below the surface, in a process known as seismic reflection profiling. Just as the sound waves of an ultrasound monitor can reveal the contours of a baby that lies below the surface of a pregnant woman's abdomen, the geologist's seismic profiling can reveal what sorts of sediments lay hidden beneath a lake bottom.

But instead of a long, continuous record of changes in the lake's size, which would help the climatologists, the researchers' seismic profiling indicated that the layers of lake mud seemed to disappear entirely not far below the surface. To see what they were detecting, researchers took cores from the lake bottom, sometimes extracting columns of sediment 30 feet long. Researchers were then able to decipher past events as they looked into the muddy accumulation of history.

Beneath the top layers of the sediment laid down by the current lake, they found a layer that held cattail pollen, which suggested a drier, more marshlike setting. Just below that, they saw the really dramatic change their profiling had detected: a layer of grassland soil, complete with plant rootlets, grass pollen and dried, cracking mud. A remnant of a time of complete drying, the soil layer apparently stretches the entire reach of the lake, appearing even at its deepest point. Researchers used radiocarbon dating to date the refilling of the lake to around 12,000 years ago. Beneath the soil, the researchers say, they detected yet more lake sediments, deposited by even earlier incarnations of Victoria.

"The seismic data are very good," said Dr. Andy Cohen, a paleobiologist at the University of Arizona at Tucson. "This pretty well puts the nail in the coffin about whether the lake really dried up or not."

The new study corroborates data from the fish themselves as to how fast they evolved. In a previous study, Dr. Meyer and his colleagues used DNA from the fish to estimate how much time the Lake Victoria cichlids had to diverge into hundreds of different species. What they found was that the cichlids in Lake Victoria were extremely closely related, having diverged very recently; surprisingly few genetic differences were detected among them.

In fact, so few genetic differences had accumulated among the species that the lack of such data made it difficult to estimate how old this species flock, as these large groups of fish species are known, really was. Dr. Meyer said he and colleagues had been able to narrow down the range to between 200,000 and 14,000 years — a finding that is now nicely corroborated on its most rapid end by the newest geological work.

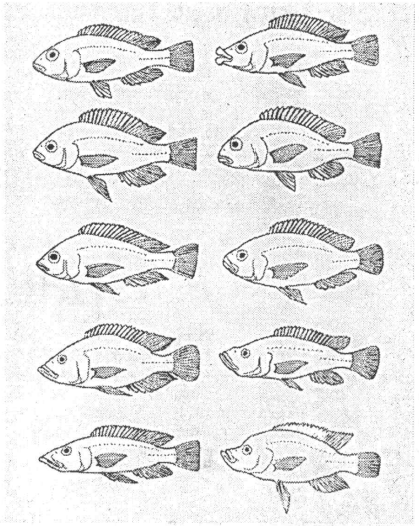
But the question arises: Could many cichlid species have survived the drying of Lake Victoria by hiding out in other lakes or rivers, recolonizing it when it formed again, which would make them much older than the lake itself?

The new study appears to rule out such a possibility. The topography of this very flat area is such that any rivers that feed the lake feed the deepest part first. Researchers say they can make a very convincing case that, with the deepest point dry, there was no satellite lake or pond in which a cichlid could have hidden.

As for the fish, they tend to be open-water fishes, not adapted to life in rivers or small ponds and unlikely to have survived well outside their lake. But researchers say it is theoretically possible that a handful of species, perhaps 10 at most, might have survived in very small, nearby bodies of water and might have recolonized the lake later. If so, that would have little effect on the count of species that did arise in Lake Victoria.

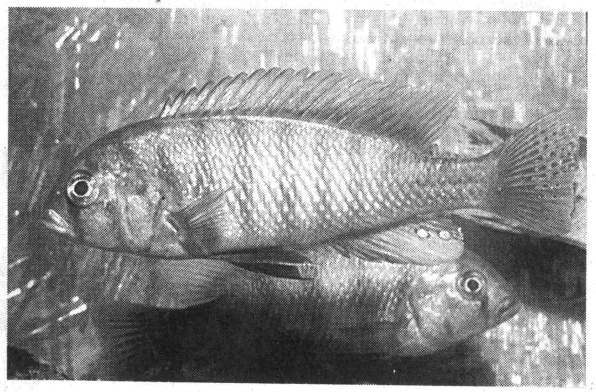
The last out for the skeptic is the suggestion that the species count itself is wrong, mistakenly elevated in the sometimes difficult business of delineating one species from another. But the researchers interviewed were in easy agreement that the more likely scenario for Lake Victoria, many of whose species remain poorly studied, is that the count of unique species that have evolved over the 12,000 years is higher than 300, rather than lower.

So if all these cichlids came to be in a blink of evolution's eye, how did they do it? "Well, if any group was going to do it," said Dr. Melanie L. J. Stiassny, curator of fishes at the American Museum of Natural History in Manhattan, "it was going to be cichlids." Dr. Stiassny said there was abundant anecdotal evidence that these fish could evolve extremely rapidly. Fish caught in the wild and kept in captivity become markedly different in shape from the original stock in just 20 generations, she said.



Humphrey Greenwood

Photographs by Ole Seehausen



Lake Victoria in eastern Africa has 300 unique and diverse fish species. Clockwise from the top are a chart comparing shapes of some lake fish and two of the species: Haplochromis rockkribensis and Haplochromis chilotes.

The real puzzle, as posed by Dr. Mayr, arises because the most common way in which species are thought to evolve is by being isolated from one another geographically and slowly evolving to become two distinct species. How could groups of fish all swimming together in Lake Victoria ever be isolated enough to produce 300 species?

One hint, Dr. Meyer said, comes from the fact that cichlids are weak swimmers and have very specific preferences for certain kinds of habitats. By clinging, for example, to sandy bottoms and never crossing a rocky area to reach the next sandy stretch, he said, groups of neighboring cichlids might well have been able to be as isolated from one another as if they had been living in separate lakes.

But Dr. McCune said that even with such isolation, a mere 12,000 years was still very little time for so many species to be generated without something else being added to the soup.

What researchers have suggested is that cichlids may have a predisposition for rapid evolution in their mating preferences, which has led quickly to small populations isolated not by geography, but by a tendency not to interbreed. This is just the sort of change that could lead to the evolution of new species.

But while cichlids are the speediest of all, evidence is accumulating from both living and fossil species that fish, on the whole, seem to spin off new species extremely rapidly. Yet why fish might be so inclined is, at least for the moment, entirely mysterious.

"It's such a new question," Dr. Mayr said, "that nobody has really looked into it."

Meanwhile, in all of this excitement, Dr. Stiassny said, many of the cichlids are being driven to extinction just as biologists are figuring out what has been going on with these species flocks.

She said that Lake Victoria's edges were being deforested, that there was a good deal of runoff from agricultural lands bordering the lake and that much of the depths of Victoria were no longer even well oxygenated enough to maintain the species that once lived there.

Added to that problem is a kind of biological terminator, the Nile perch. A voracious predator introduced by humans into Lake Victoria to help the fishing industry, it has driven at least half of the lake's cichlid species extinct already and has laid many others so low there is little hope for their recovery.

There are now only about 150 cichlid species left, and scientists studying the evolution of these fishes must often work on specimens saved in museums or research collections.

"It's so ironic," she said. "We discover this wonderful thing, this fabulous laboratory for the study of evolution, only to find that the whole system is collapsing."