

The little fish fight back

An award-winning documentary portrays Lake Victoria as the site of an ecological disaster. But, says Laura Spinney, the story may yet have a happy ending

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When film director Hubert Sauper showed the mosaic warts on his feet to a Parisian doctor, his reaction was, "Woah! Where did you get those?" Sauper explained that he had just returned from making a documentary in Tanzania, and he thought he had probably picked them up in the fish-bone yard, where barefooted women squelched through a seething mass of maggots, inhaling dense ammonia fumes, to hang skeletal fish carcasses on racks to dry in the sun.

The fish-bone yard is one of the more memorable images in Sauper's brutal film, *Darwin's Nightmare*, which opens in US cinemas this month, having already won 18 first prizes in international film festivals. It shows the social and ecological catastrophe that was set in motion when, in the early 1960s, a man tipped a bucket of Nile perch into Lake Victoria and spawned a fishing industry. It does not have a happy ending. But the sequel, should there be one, just might. Biologists now believe that the lake is balanced on a knife edge between total disaster and possible recovery.

Lake Victoria is the largest tropical lake in the world, the source of the Nile and once upon a time, paradise for evolutionary biologists. Until the 60s, it was home to 500 species of small, colourful cichlid fish, each of which was behaviourally and morphologically specialised to exploit a niche in the lake ecosystem. The majority of the species evolved in a record-setting 15,000 years, making the Lake Victoria cichlid "superflock" one of the world's most spectacular examples of explosive radiation in vertebrates.

Then along came the man with the bucket. Nile perch are not native to the lake. They are beefy, fecund fish that can grow to almost two metres in length, and they eat cichlids. As it happens, he was only the second man with a bucket. The lake, which is the size of Ireland, straddles Tanzania, Kenya and Uganda. The first introduction of species related to Nile perch took place in 1954 in Uganda, when that country was still a British colony, but the predator did not take off.

On both occasions it was introduced with nominally good intentions: to provide local people with a richer source of protein than the bony, bland cichlids they had hitherto lived off. The more cynical view is that it was to improve sports fishing for European expats. Either way, the second introduction was irresponsible, because by then ecologists had warned that the consequences of introducing a top predator to an as yet poorly understood ecosystem were entirely unpredictable.

With the benefit of hindsight, Sauper's film shows what those consequences were - for humans. Within a couple of decades, Nile perch numbers had exploded. Men flocked from the poverty-stricken hinterland of Tanzania to make a living on the lake shore, leaving their families behind. Lawless "fish cities" grew up around the filleting factories, peopled by fishermen, prostitutes and feral, gluesniffing kids. Factory owners grew relatively rich on the proceeds of a thriving export industry, while the locals ate the sundried leftovers. Aids ravaged the fishing settlements and, when the terminally sick limped home to be comforted by their relatives, the inland villages as well.

Meanwhile, the lake itself grew sicker and sicker. By the mid-80s, it was already estimated to have lost two-thirds of its cichlid species in a massive wave of extinction. By the time Sauper

finished filming last year, commercial trawlers had been banned and the Nile perch, overfished themselves, were eating each other - presumably because there were not enough cichlids left to feed them.

The lake is also suffering from creeping eutrophication - an influx of nutrients due mainly to deforestation of the lake shore, industrialisation and human pollution. These nutrients feed large algal blooms that die and sink to the bottom to be consumed by bacteria, which use up oxygen in doing so. The water grows murkier, which suits the perch, because they can see better in low light than cichlids. And crucially, female cichlids can no longer distinguish the markings of males, which is how they select their mates.

As male colour becomes obsolete as a signal for mate choice, Ole Seehausen of the University of Bern, Switzerland and colleagues are finding that the reproductive barriers are breaking down between some cichlid species which sport different colours, and hybridisation is taking place. Red and blue males of different species are giving way to males of a dull brown, and losing their ecological specialisations - the difference in their feeding habits, for instance - in the process.

Hybridisation can lead to a loss of diversity and is, therefore, generally seen by biologists as a bad thing. But it could also be a force for successful adaptation, and eventual recovery of diversity, Seehausen argues. "By reshuffling the genes of two species, it can generate the genetic raw material for new species with new specialisations - a novel combination of a certain feeding behaviour with a particular habitat, say."

If that combination can fill an ecological niche not yet fully exploited by other species, the hybrid could establish itself and thrive. There is evidence that that is happening in Lake Victoria. A handful of the 200 or so species once thought to be extinct seem to be reviving. But, says Seehausen, "Many of the reviving populations look like recombinants of pre-existing species."

Until the early 90s, most was known about the bigger, fish-eating cichlids that swam in open waters and were the first to become extinct. But then Seehausen's group discovered more than 100 previously unknown rock-dwelling cichlids that kept to the shallower, coastal areas, where Nile perch do not stray. They covered a broad spectrum of cichlid niches - from small plankton-eaters to large algae-scrapers and fish-eaters. Since then, cichlids have been found further out in open waters. Some of them could be hybrids derived from these rock-dwellers.

Seehausen speculates that the lake's coastal bays and gulfs, where the water is murkiest, act as a "hybridisation belt". Individuals of novel genetic makeup are engendered here, and those that are well-adapted to life in the altered lake may then move out into clearer, open waters, where there is a greater choice of niches to exploit, and the females can see. Both ecological and sexual selection then act to enforce their genetic isolation one from the other - creating new species.

The key, then, is to have this balance between hybridisation and diversifying pressures, between murky and clear. The lake is grossly over-murky now. But, says Seehausen, "If the water clarity can be improved again, it may yet be pushed back to levels where more diversity would again be promoted."

That is not such an unrealistic goal. But while there have been some reforestation projects, and attempts to change farming practises in the region, these have not yet halted the decline. So cichlid diversity hangs in the balance. "It is always tricky to predict evolution, particularly in cichlids," says Walter Salzburger, an evolutionary biologist at Konstanz University in Germany. But he thinks it likely that new cichlid species will adapt to the perch's presence. He and his colleagues have found cichlids hiding in floating islands of papyrus in the lake, which are too dense for the bulky perch to penetrate, and he thinks they probably have other refugia - areas

where the local conditions are favourable to them, and where they can hang out until it is safe to leave and radiate again.

Victoria's satellite lakes may also act as refugia, he says. Some of these are connected to the lake, some are not. Over geological time, connecting channels may have formed and dissolved due to fluctuating water levels. But even the fact that two lakes are presently cut off from one another does not prevent cichlids from hopping between them. One explanation is that they are carried by birds. Cichlids are mouth brooders, which means that females can carry up to 30 juveniles in their mouths. Even if the mother dies in a cormorant's beak, the fry could potentially survive to repopulate a new lake. That hypothesis has yet to be proven. But, says Salzburger, "Cichlids have colonised all the lakes - remote lakes, satellite lakes, crater lakes - and they must have got there somehow."

So if hybridisation does not drive a new radiation, then recolonisation from refugia could, but over a much longer time course - millennia as opposed to decades. The two scenarios generate two very different short-term outcomes for the lake and the people who live off it. But they could also work in concert, says Salzburger, just as they may have done during the initial Lake Victoria cichlid radiation.

Tijs Goldschmidt, a Dutch biologist who worked at the lake in the 80s, says he is now careful about predicting the lake's future, since he warned that once the cichlids were gone, the Nile perch population would crash, and their corpses would be seen floating on the surface. That never happened, and it was only in retrospect that he understood why not: with most of the cichlids removed, prawns in the lake took their chance and boomed. Small Nile perch ate prawns, slightly bigger perch ate prawns and a sardine-like fish native to the lake, and the largest perch became cannibalistic, feeding off the smaller ones. "That is a very unstable system, but so far it works," says Goldschmidt.

Even if the lake does recover its former diversity quickly, it will not be the same diversity. For one thing, it will never now be rid of Nile perch. There is also the major threat posed by eutrophication to consider. Human beings, like cichlids, are distinguished by their adaptability, but if eutrophication continues at the rate it is, then the lake will one day stop providing both drinking water and protein. "A lake without oxygen would be a disaster for about 30 million people," says Goldschmidt.

In that case, the misery portrayed in Sauper's film would only be the tip of the iceberg, and recovery would be delayed by a major human catastrophe on a scale that is, perhaps, impossible for us to imagine.

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