20,000 years of evolution and ecosystem dynamics in the world’s largest tropical lake reconstructed from sediment cores, fossils and ancient DNA

Main applicant   Seehausen Ole
Number   183566; http://p3.snf.ch/Project-183566
Funding scheme  Sinergia
Start/End   01.03.2019 - 28.02.2023

Abstract

The mutual influence between the biodiversity and the structure and functioning of ecosystems is a central and pressing question at the interface between evolutionary ecology and environmental sciences. Evolution is a population dynamic process that plays out in an ecosystem context of changing species interactions and abiotic conditions. Reciprocal interactions between evolutionary and ecosystem processes are fundamental for understanding the origin, assembly, and maintenance of species diversity, spanning micro- and macroevolutionary timescales. However, tracking such dynamics in natural ecosystems over long periods of time is largely out of reach for most research programs. Here, we have assembled a highly innovative and interdisciplinary research team that will deploy an integrative paleobiological approach to dig back into time and reconstruct the evolutionary history of the Lake Victoria ecosystem. Among the East African Great Lakes, Lake Victoria harbours one of the most globally impressive examples of the rapid origination of hundreds of new fish species through the processes of speciation and adaptive radiation. An entire endemic food web has assembled over the Holocene, and is comprised of fish species with adaptations to a multitude of ecological niches (Fig. 1). Decades of research on this cichlid dominated food web have revealed key mechanisms of speciation and ecological adaptation - fundamental processes omnipresent across the tree of life. Less often appreciated is that cichlid fish dominate not only the biodiversity but also the biomass of this food web, and hence provide a unique system to study the interdependencies between biodiversity dynamics and ecosystems over evolutionary timescales. So far, work on this global hotspot of freshwater biodiversity has only considered extant biodiversity. Information coupling fossil assemblages with past environments is lacking, severely limiting our understanding about the timing of the emergence of new ecological guilds of fish, and possible feedbacks between the rapid evolution of food web complexity and ecosystem dynamics. Because Lake Victoria and its endemic species diversity are only about 15,000 years old, evolutionary and ecosystem dynamics are unfolding at broadly overlapping time scales, making it possible to couple paleoecological, paleontological and paleogenomic reconstruction methods. The Lake Victoria ecosystem has also undergone dramatic environmental changes over the past 15,000 years, which have been documented with classical paleolimnological approaches. We recently discovered fish fossils in large abundance in previous sediment cores dating back to the filling of the lake during the last glacial-interglacial transition. These fossils can be used to reconstruct past species assemblages of fish in considerable detail in order to study ecological and evolutionary changes through time (Fig. 2, Fig. 3). Combining this with information about past environmental conditions, recorded in the same layers of those same sediment cores, we can make exciting and novel reconstructions using a wide range of paleoecological and limnological proxies. We have already obtained funding for a coring expedition to Lake Victoria in the summer of 2018 to collect a series of piston cores along an onshore-offshore gradient in Lake Victoria, which will likely yield tens of thousands of fossil fish teeth, bones and
scales, as well as fossils of other organisms. Here we apply for an interdisciplinary investigation of these new cores, and further cores to be taken in the proposed project, in order to perform detailed reconstructions of past ecosystems from the filling of the lake to the modern day. We will combine this with detailed ecological, evolutionary and genomic analyses of the evolving fish assemblage as it changed over millennia from one with few species to one with hundreds of endemic species. Through finely resolved time series of ecosystem properties and biodiversity, we will for the first time be able to ask how external drivers of the ecosystem affected the evolution and ecology of a species assemblage, whether the changes in the species assemblage affected the ecosystem and whether there were feedback loops between the two. At the same time, we will be able to study in detail the ecosystem changes associated with lake eutrophication and mass extinction in the Anthropocene of Lake Victoria.