Reconstructing paleo-fisheries and the paleoenvironment of Lake Turkana, Kenya, to understand drivers of ecosystem change and fisheries resilience

Overview/Abstract

Climate change is rapidly impacting the structure and functioning of Earth's ecosystems. Lakes are known to be particularly sensitive to climate change as physical, chemical, and biological properties of their ecosystems rapidly respond to environmental changes (Adrian et al., 2009; Woolway et al., 2020). Understanding how lake ecosystems respond to climate change is necessary to make informed management decisions. One of the greatest difficulties in quantifying ecosystem change, and its associated drivers, is the lack of consistent, long term data sets. Paleoecological data can be used to inform relationships between climate states and both ecosystem and population-level responses. The Turkana Basin, located between Kenya and Ethiopia in the East African Rift Valley, is home to Lake Turkana, the world's largest permanent desert and alkaline lake, and a rich fossil record documenting >20 million years of biotic evolution driven by a changing climate. Over one million people rely on Lake Turkana's fish as a source of food and income in an otherwise food-scarce region; thus, it is critical to assess how Lake Turkana's fish populations may respond to future climate change. It may also be considered a 'canary in the coal mine' for other East African Rift lakes with even larger fisheries. Climate is a main driver of fish productivity, and as fish evolve, their life history strategies (i.e., longevity and growth) change in response to environmentally driven energy tradeoffs. The Turkana Basin's fossil record contains fossils from the fish families Characidae and Latidae, with emphasis on *Hydrocynus forskahlii* and *Lates niloticus*, that have persisted from the Miocene (23 Ma) to present, providing a unique opportunity to collect paleoecological data on the effects temperature and precipitation on fish life history (i.e., growth rate and maximum size). The consistent presence of these fish over time allows us to compare growth rates from the Miocene to present under different climate regimes.

We propose to evaluate the life history responses of Characidae and Latidae fish to fluctuations in precipitation and temperature from the Miocene to present by collecting life history data from fossilized fish teeth and vertebrae archived in the National Museums of Kenya and Turkana Basin Institute collections, coupled with stable oxygen isotope ($\delta^{18}O$) and clumped isotopes analyses of fossil fish tooth enamel to reconstruct the paleolake water conditions in which the fish lived. Life history data on fish growth rates will be obtained by counting growth rings on fossilized fish vertebrae, and maximum size will be estimated using allometric relationships between vertebrae size and total fish length. Our life history and environmental analyses of paleo-fish populations will be ground truthed using fish teeth and vertebrae from Characidae (i.e., *Hydrocynus forskahlii*) and Latidae (i.e., *Lates niloticus*) collected from modern Lake Turkana. We hypothesize that Characidae and Latidae fish growth rates are positively correlated with lake water balance and negatively correlated with paleotemperature, represented by differences in maximum fish size, number of vertebral growth bands, and enriched $\delta^{18}O$ values in fossil fish teeth during periods of elevated precipitation and temperature. We expect to observe higher fish growth rate in samples from periods of Plio-Pleistocene lake progression and Holocene lake highstand (12 Ka, 9 Ka, 6 Ka), relative to growth rates of fishes from the Miocene and Plio-Pleistocene floodplain periods and Holocene lake lowstands. The relationships between environmental conditions and fish life history, built using paleoecological data, will then be used to inform ecosystem models aimed at forecasting Lake Turkana's fish productivity under future climate regimes. The paleoenvironmental data collected will also help contextualize paleontological and archaeological discoveries in the Turkana Basin. The results of this study will be used to secure funding for a long-term monitoring and ecological modeling study proposed to the National Science Foundation's Long Term Research in Environmental Biology Program.