Reconstructing trophic diversification in Lake Victoria Cichlids using Computer vision

Moritz D. Lürig[1], Nare Ngoepe[1], Moritz Muschick[1], Jukka Jokela[2], Jan Wegner[3], Ole Seehausen[1]

Background

Lake Victoria is the largest lake in Africa and harbors more than 500 endemic species of haplochromine cichlids. These fish species have evolved over the last 15 000 years, which is an extremely rapid case of a large adaptive radiation. Despite increasing knowledge of the circumstances under which this stunning ecological diversity emerged, many **key questions** remain unanswered.

Research questions

The Sinergia project:

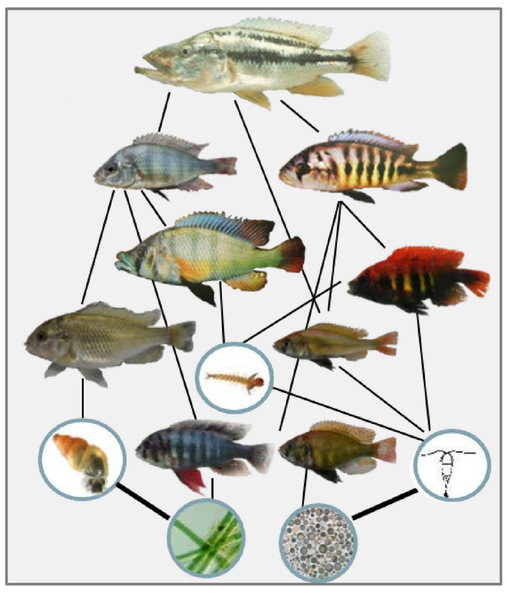
Digging deep into Lake Victoria's past: 20,000 years of evolution and ecosystem dynamics in the world's largest tropical lake reconstructed from sediment cores, fossils and ancient DNA

Key question:

How do physical environments and species interact during the emergence and maintenance of a biodiversity hotspot?

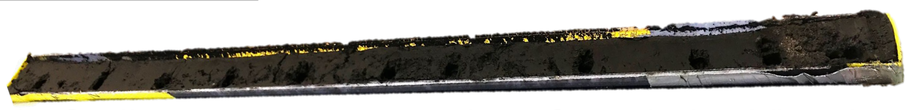
Specific Research question:

When and in what order did the more than 20 trophic guilds emerge and what was the timing of other major events in the adaptive radiation? *(Sinergia module ii / Question 4)*

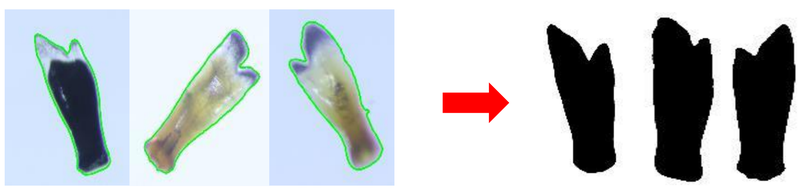


Contemporary food web in Lake Victoria

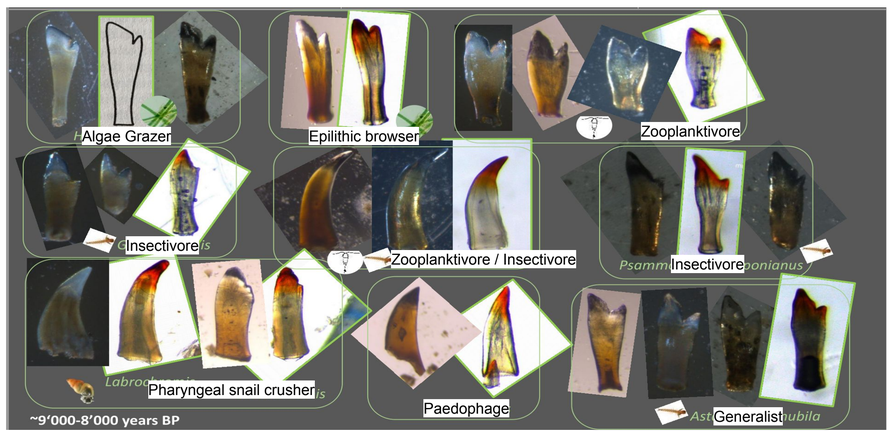
Methods



1. Sediment cores are taken from Lake Victoria and systematically sifted for fossil teeth.



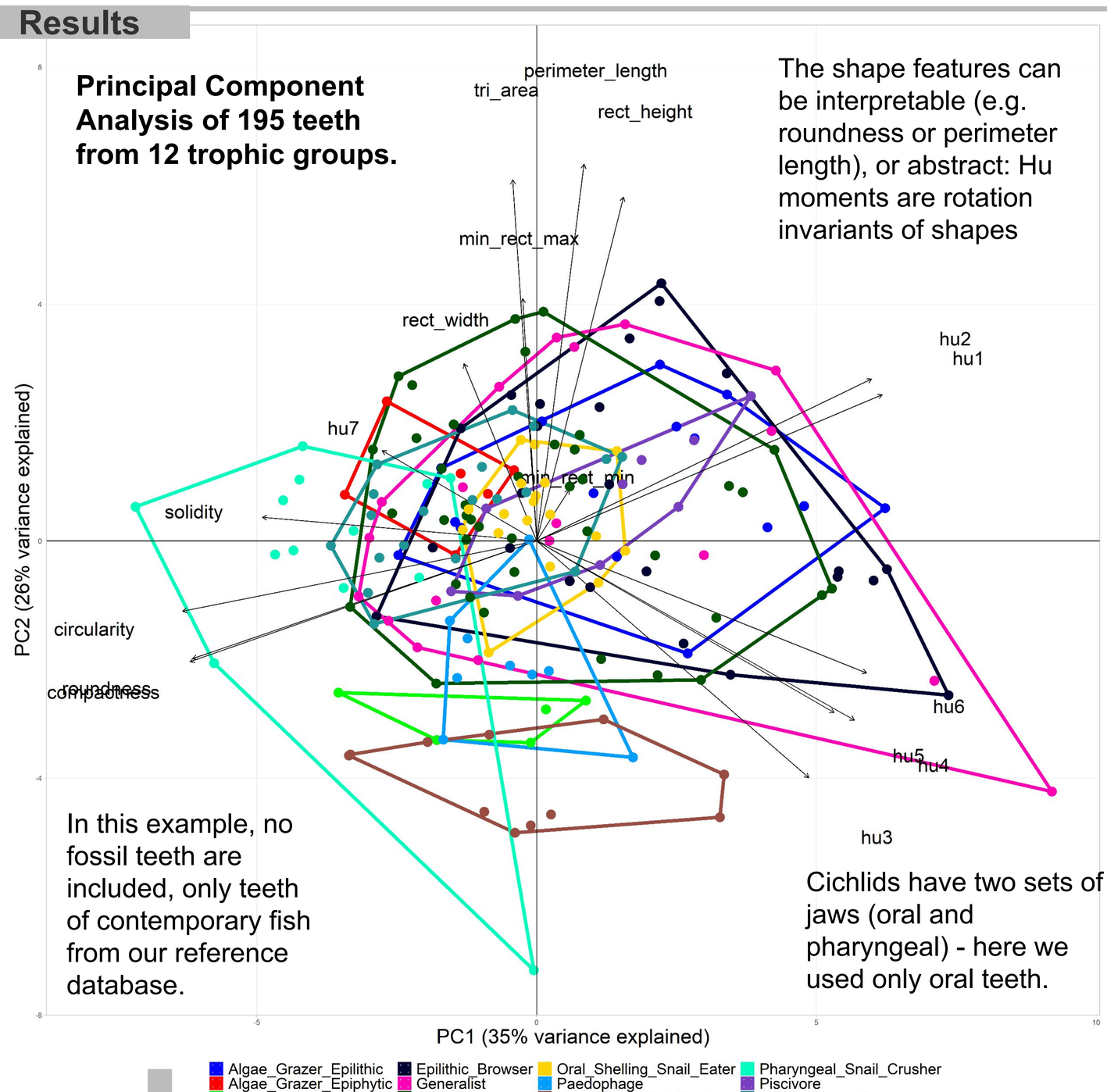
2. The extracted teeth are photographed and phenotyped using our own Python package (*https://mluerig.github.io/**phenopype**/*). Key metrics here are the shape features (e.g. circularity, perimeter length, bounding rectangle size, Hu moments - texture is not important).



3. A reference tooth collection from extant LV cichlid species is used to classify fossil teeth (dark background = fossil tooth, light background = contemporary reference).

Results

Principal Component Analysis of 195 teeth from 12 trophic groups.



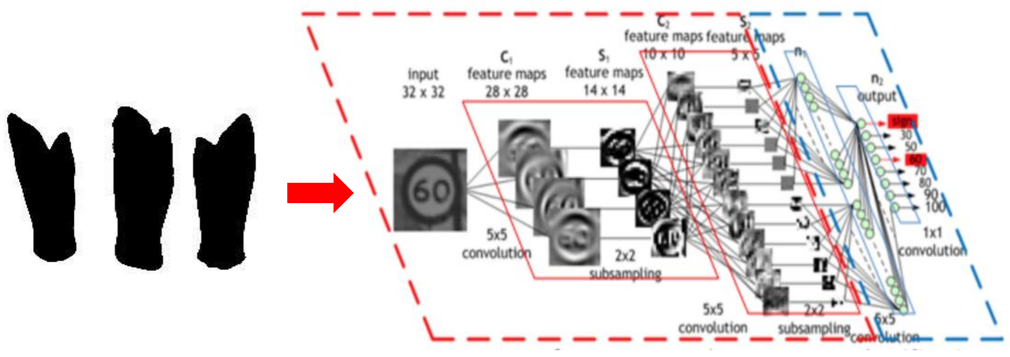
The shape features can be interpretable (e.g. roundness or perimeter length), or abstract: Hu moments are rotation invariants of shapes

In this example, no fossil teeth are included, only teeth of contemporary fish from our reference database.

Cichlids have two sets of jaws (oral and pharyngeal) - here we used only oral teeth.

Conclusions and outlook

We have begun the construction of a reference for tooth phenotypes of different trophic groups of cichlids currently found in Lake Victoria. The database is currently not big enough to robustly categorize fossil teeth into extant trophic phenotypes, but it serves as a promising starting point. We will continue to integrate teeth from extant trophic groups, hopefully soon encompassing several hundred teeth per trophic group. This will allow us to implement more advanced classification techniques like artificial neural networks in the near future.



Classification of tooth shapes using Convolutional Neural Networks

Affiliations:
1 Eawag, Department of Fish Ecology & Evolution, Seestr. 79, 6047 Kastanienbaum, Switzerland
2 Eawag, Department of Aquatic Ecology, Überlandstr. 133, 8600 Dübendorf, Switzerland
3 ETH Zürich, Dept. of Civil, Environmental and Geomatic Engineering, Stefano-Franscini-Platz 5, CH-8093 Zürich