

The geographical and genomic structure of endemic fish diversity in the Lake Victoria basin – and why it matters

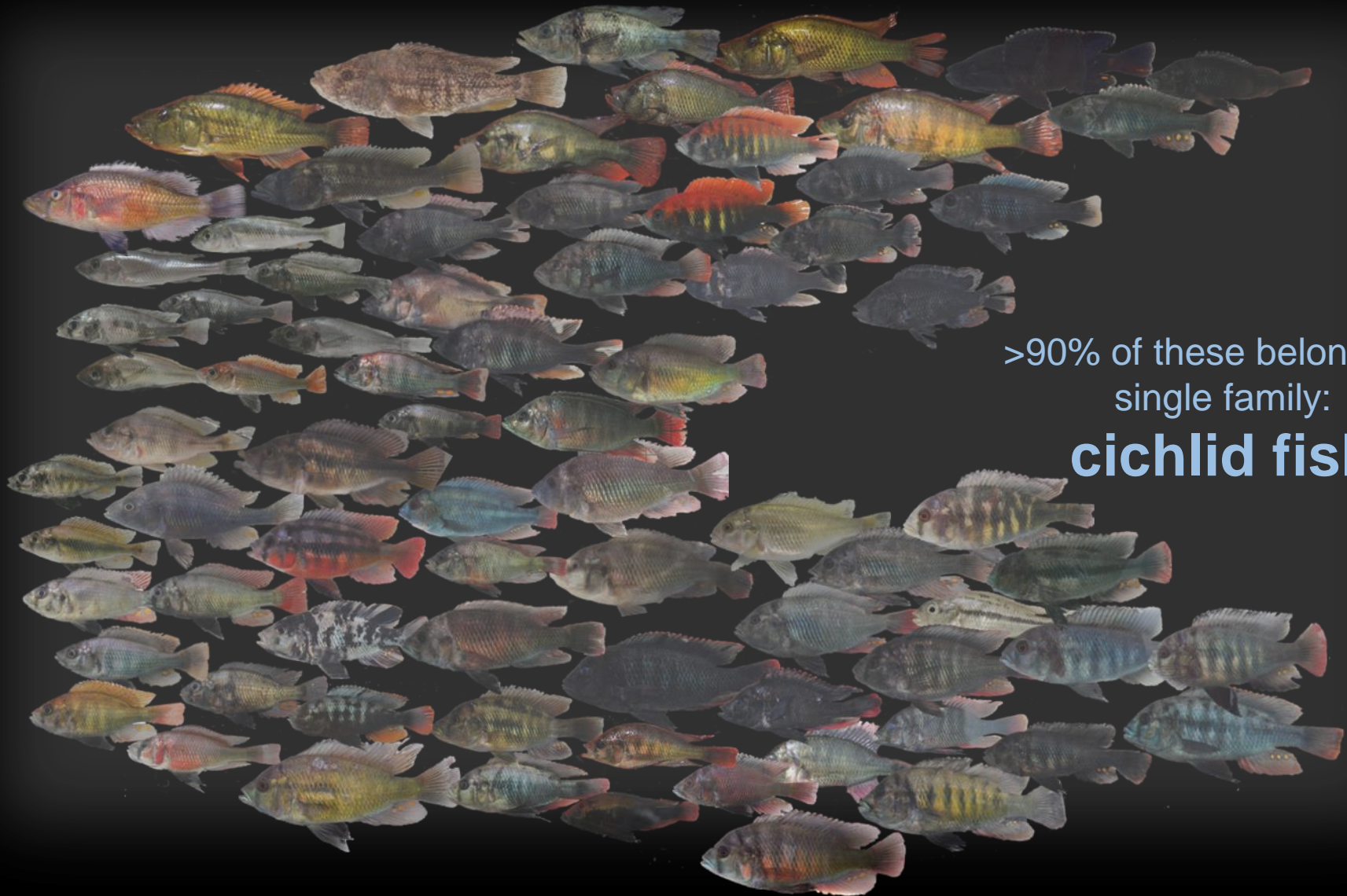


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The AGL region: 15% of the world's 15,000 freshwater fish species

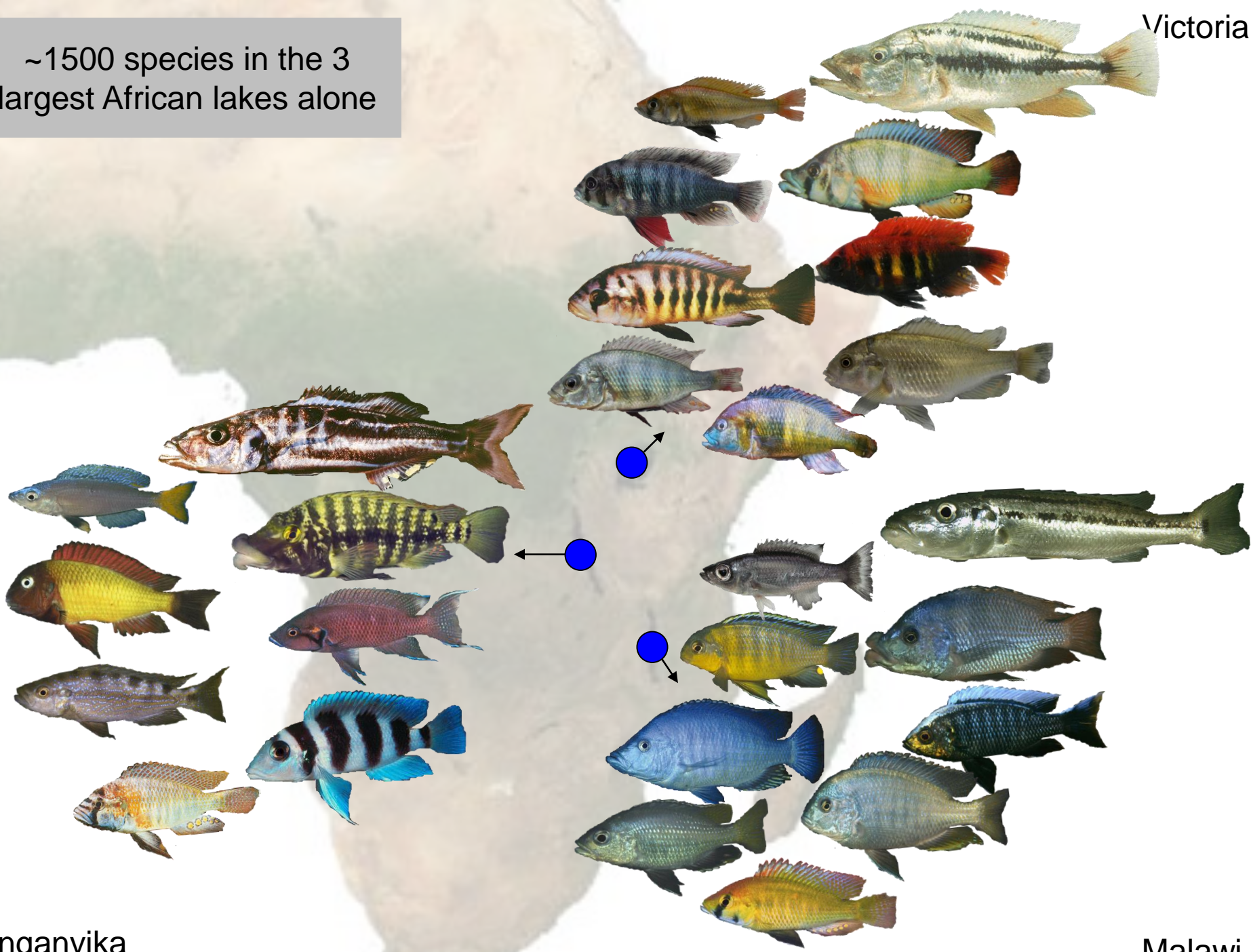


>90% of these belong to a
single family:

cichlid fish

~1500 species in the 3 largest African lakes alone

Victoria



Tanganyika

Malawi

Lake Victoria's spectacular species richness

>550 fish species

>500 of these haplochromine cichlids

99% endemic

(versus ~10% of the other fish)



Biodiversity loss and its impact on humanity

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The most unique feature of Earth is the existence of life, and the most extraordinary feature of life is its diversity. Approximately 9 million types of plants, animals, protists and fungi inhabit the Earth. So, too, do 7 billion people. Two decades ago, at the first Earth Summit, the vast majority of the world's nations declared that human actions were dismantling the Earth's ecosystems, eliminating genes, species and biological traits at an alarming rate. This observation led to the question of how such loss of biological diversity will alter the functioning of ecosystems and their ability to provide society with the goods and services needed to prosper.

The empirical relationship of biodiversity and ecosystem function

Ecosystem Function (Resource capture, biomass production etc.)

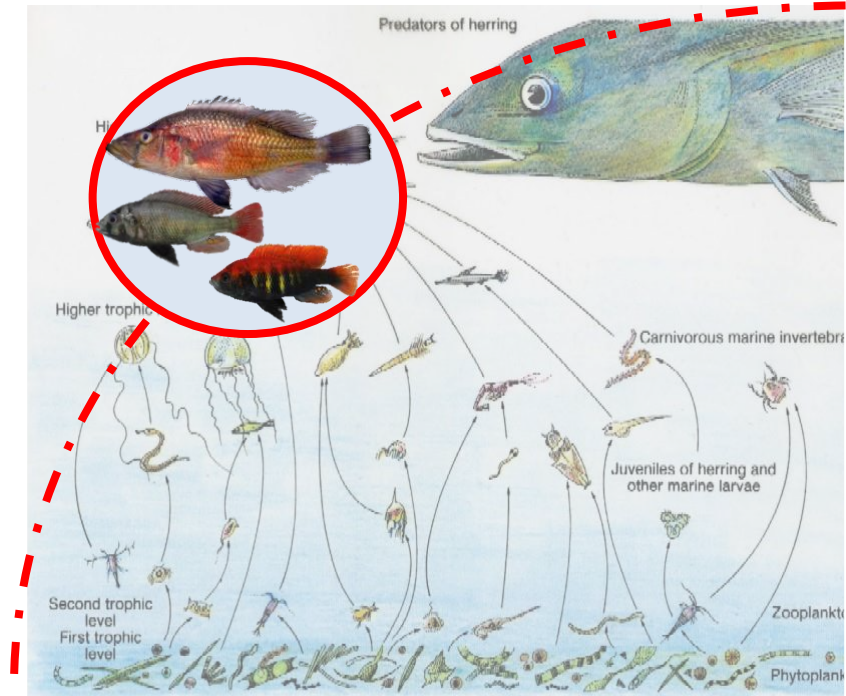


Biological Diversity
(genes, species, functional traits)

Biodiversity does affect ecosystem
functions and an ecosystem's
multifunctionality

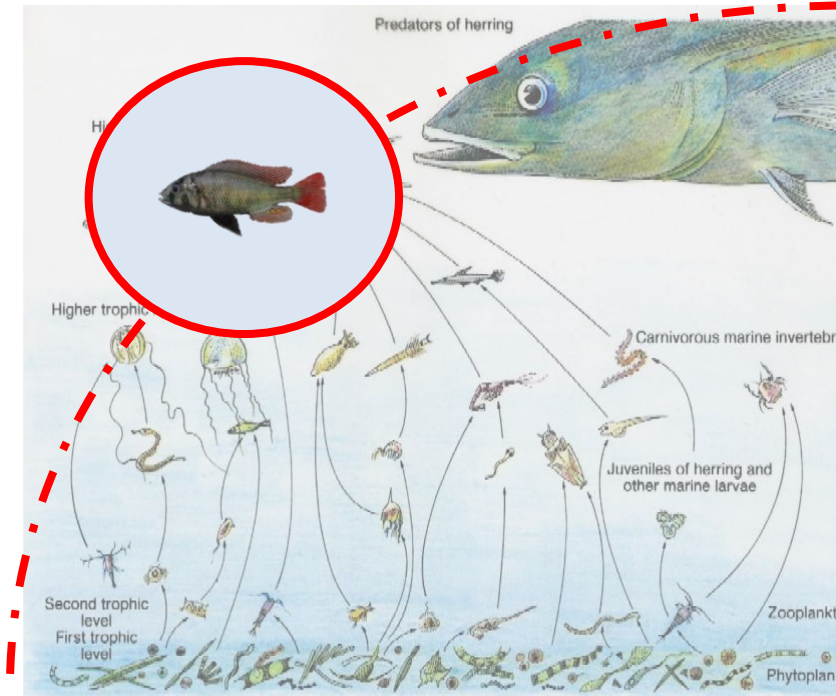
does it affect ecosystem services?

Ecosystem Function (Resource capture, biomass production etc.)



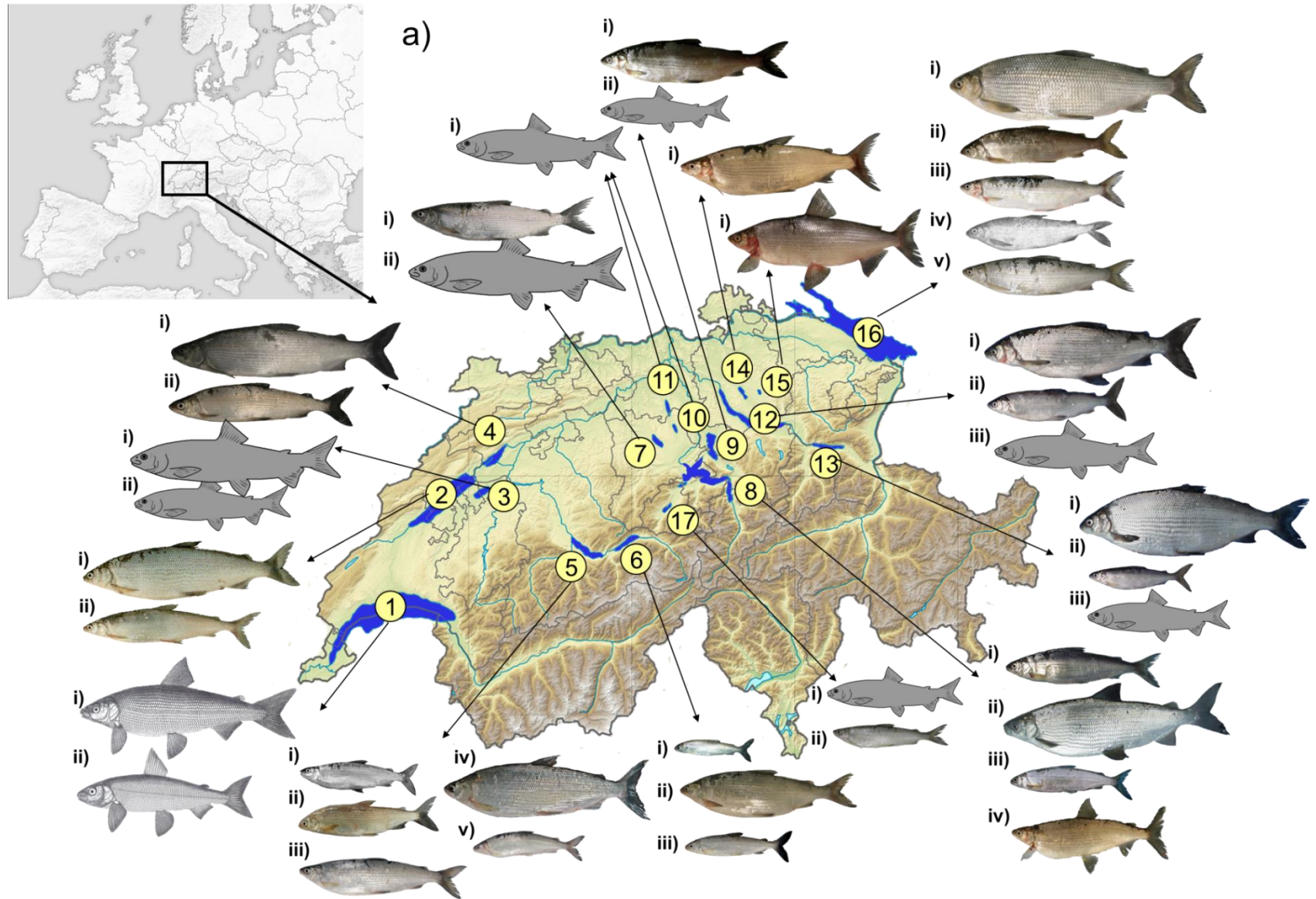
Biological Diversity
(genes, species, functional traits)

Ecosystem Function (Resource capture, biomass production etc.)



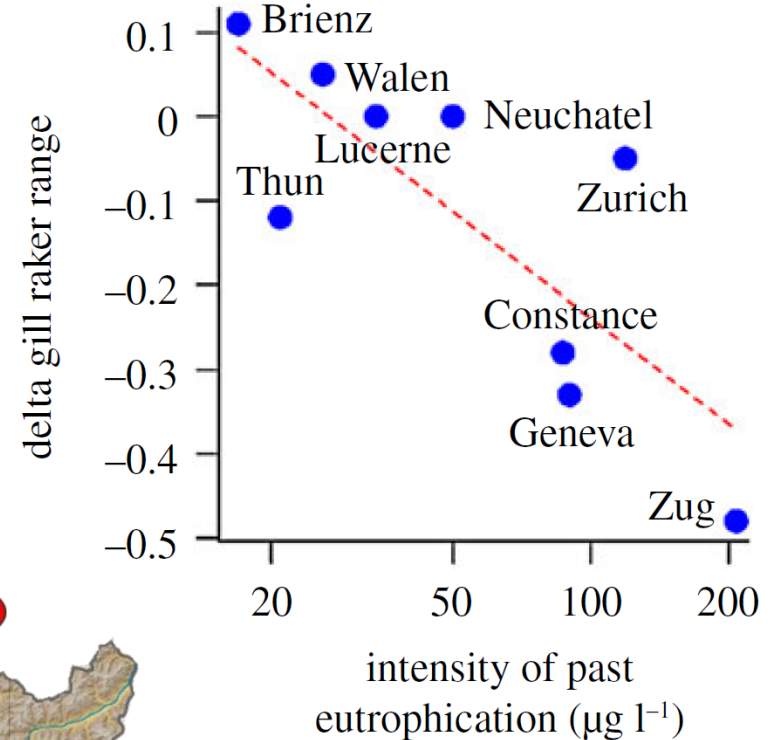
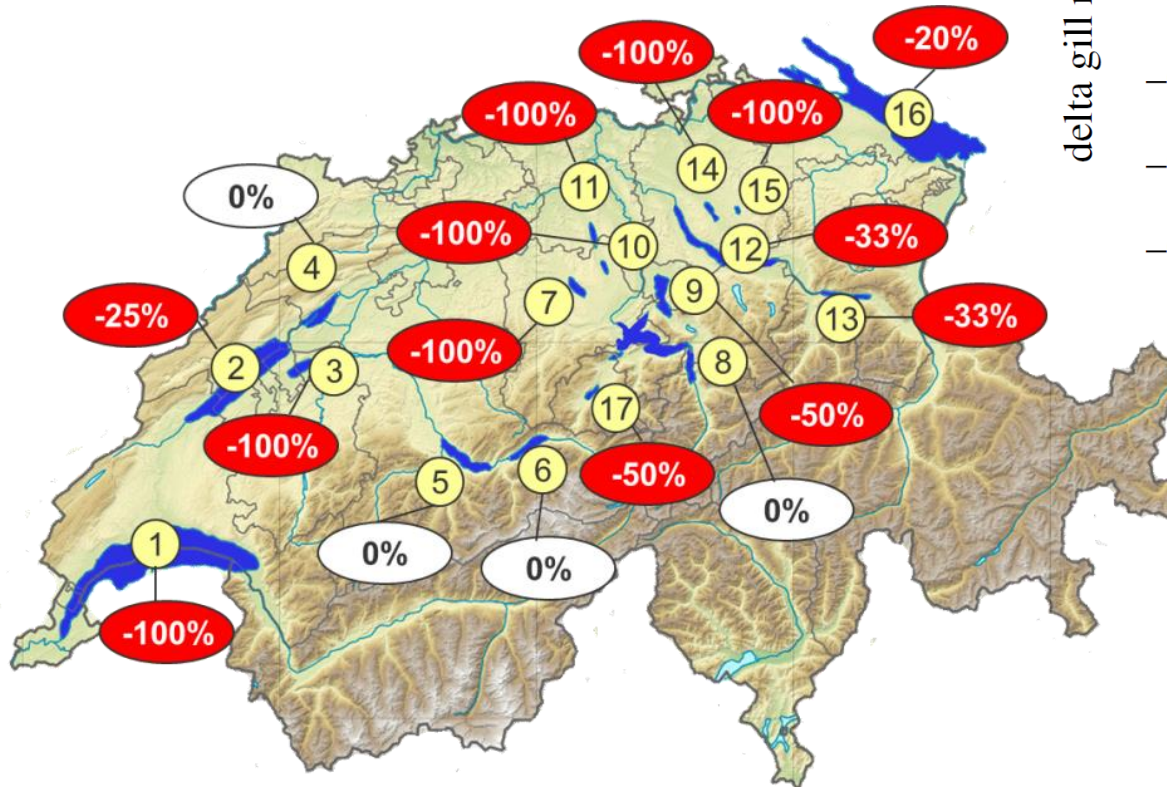
Biological Diversity
(genes, species, functional traits)

endemic whitefish in Swiss lakes: another global biodiversity heritage



Eutrophication led to the collapse of species and loss of functional diversity

Two to six distinct species were replaced by one or a few generalist populations in many lakes



Different whitefish species extract different resources from a lake



Plankton specialist



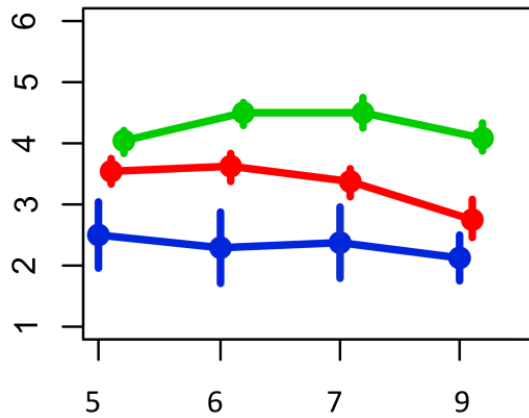
generalist



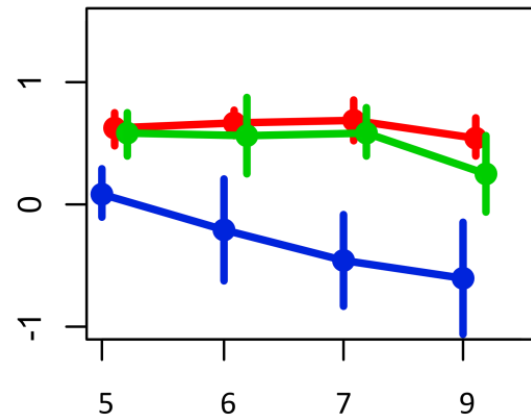
Benthos specialist



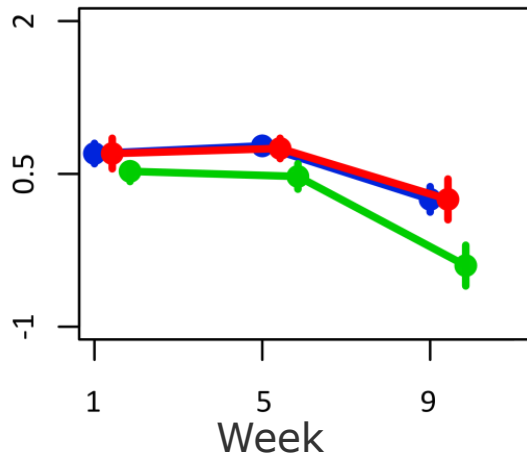
Log (SNA)



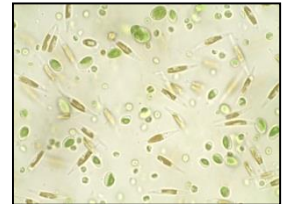
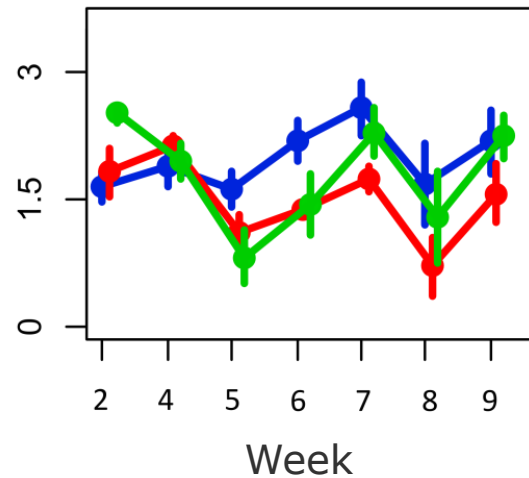
Log (DRA+0.1)



Log (MAZPD)



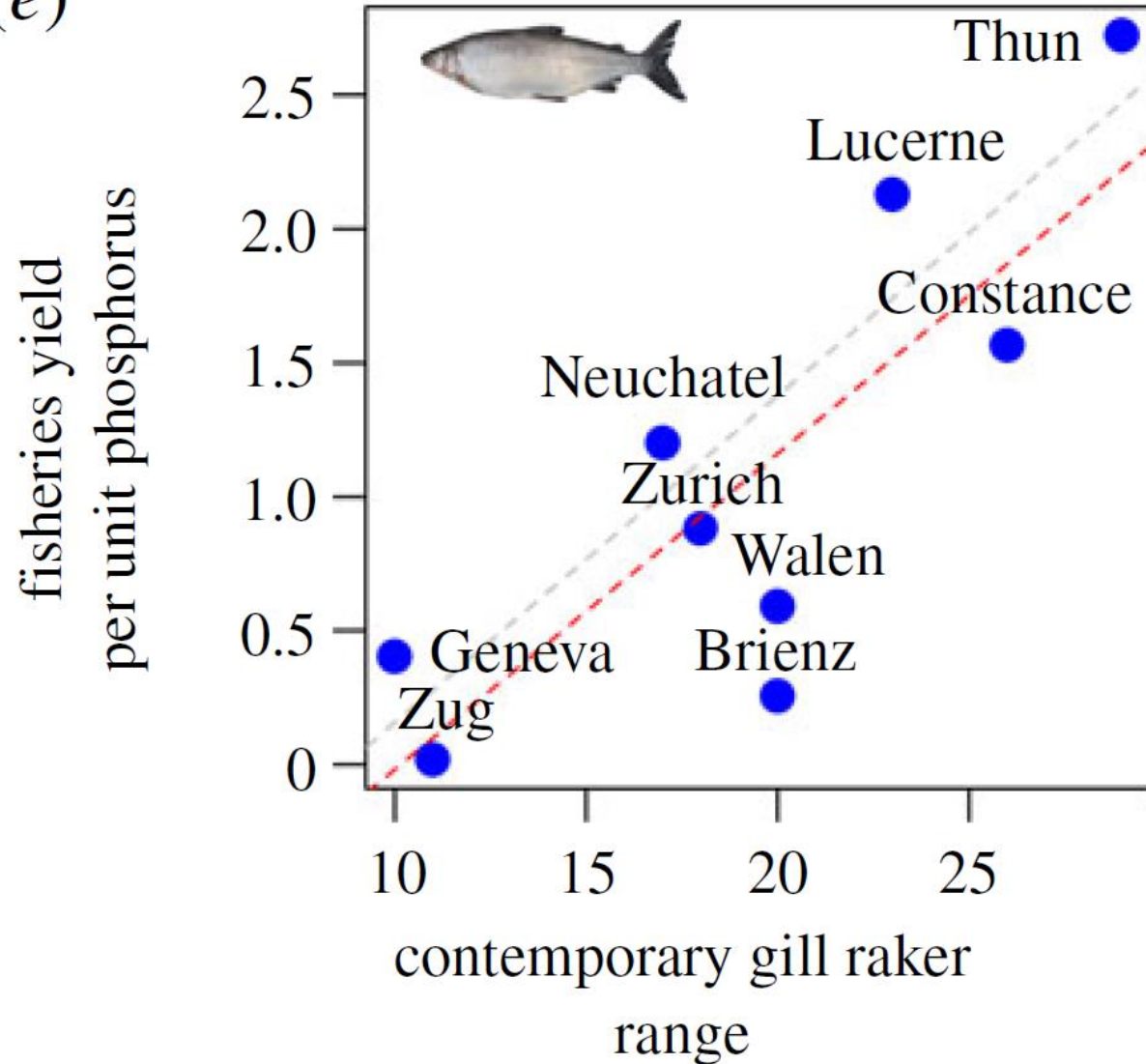
Log (PPC)



Extant functional diversity in whitefish predicts commercial catch



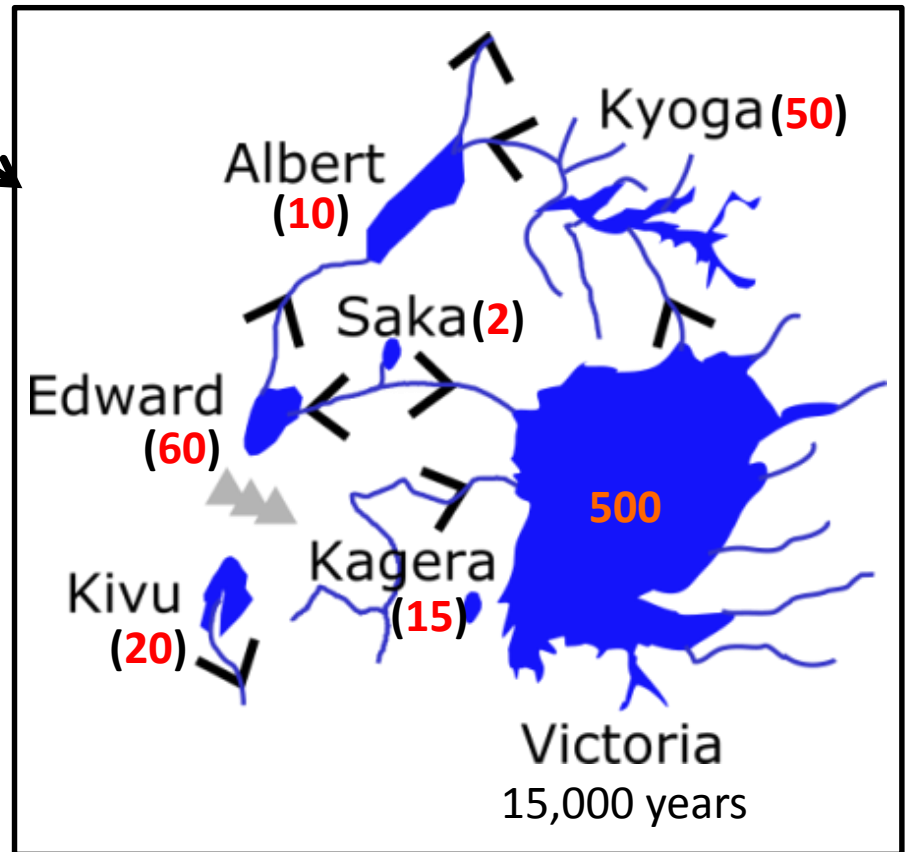
(e)





Colin Neuman 1995

Endemic cichlids dominate assemblages in most lakes of the Lake Victoria Region: total >700 endemic cichlid species



Species diversity has been rapidly declining, about 200 endemic species have already gone extinct in Lake Victoria between 1980s and now



Colin Neuman 1995

Identifying and documenting the species diversity and genetic structure of these cichlids was impossible...

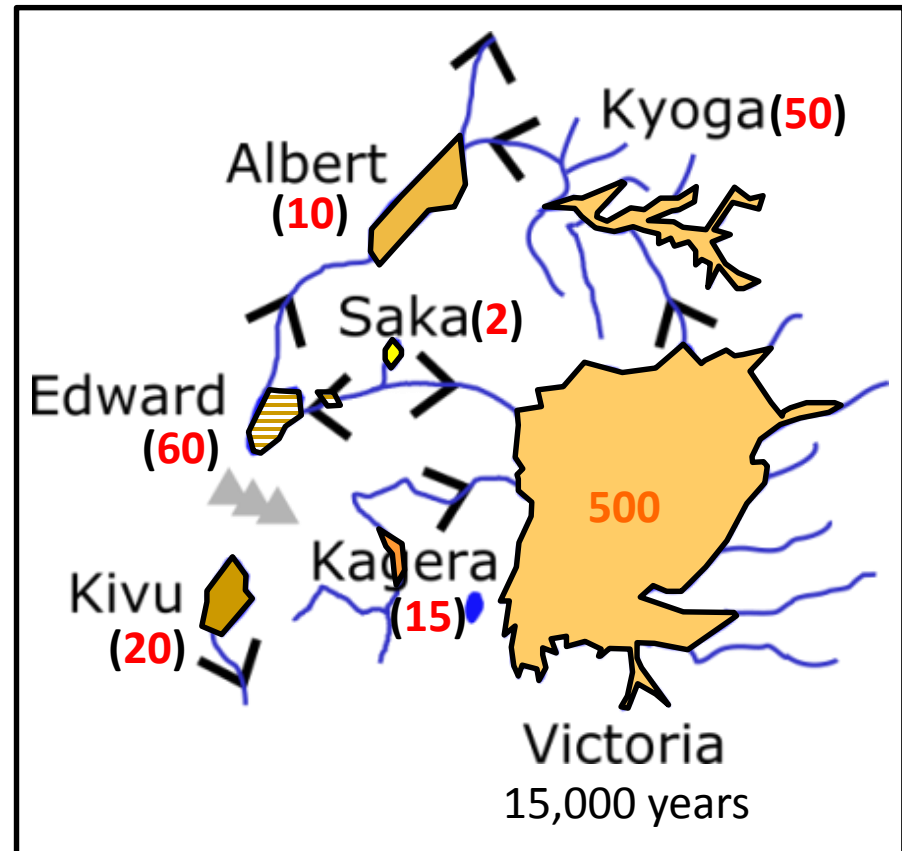
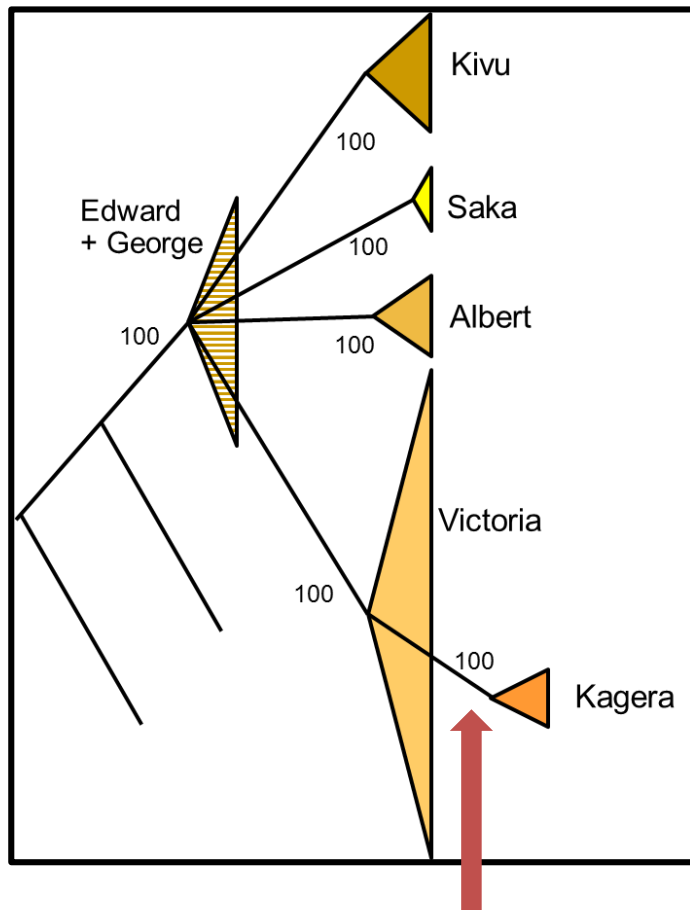
now it is possible for the very first time

....

it takes Next Generation DNA Sequencing

1. The relationships among the lakes in the region

Lake Victoria Region Superflock (700 cichlid species)



Every lake in the region has its own endemic fauna

From the lake-wide pattern to the species
at the very local scale



Makobe Island



Makobe Island



Igombe

Busu

2. The local scale **among the species** in a single assemblage:
Makobe Island (Speke Gulf, Tanzania)



1 km





Neo. omnicaruleus



Neo. rufocaudalis



Neo. sp. «unicuspid scraper»



Neo. gigas



Pundamilia nyererei



Pundamilia pundamilia



Pundamilia sp. «pink anal»



Lipochromis melanopterus



Mbipia lutea



Mbipia mbipia



Labro. sp. «stone»



Harpargo. cf. serranus



Paralabido. sp. «rockkribensis»



Paralabido. sp. «short snout scraper»



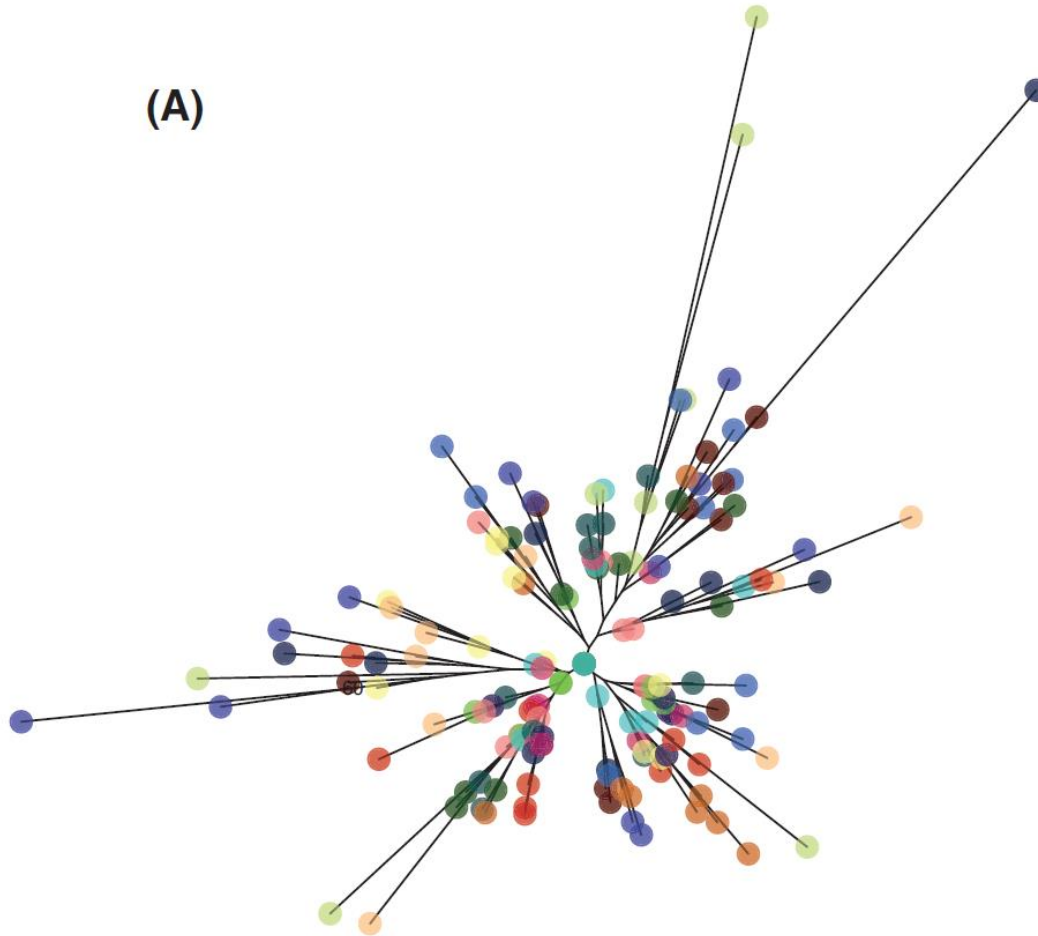
Paralabido. cyaneus



Paralabido. chilotes

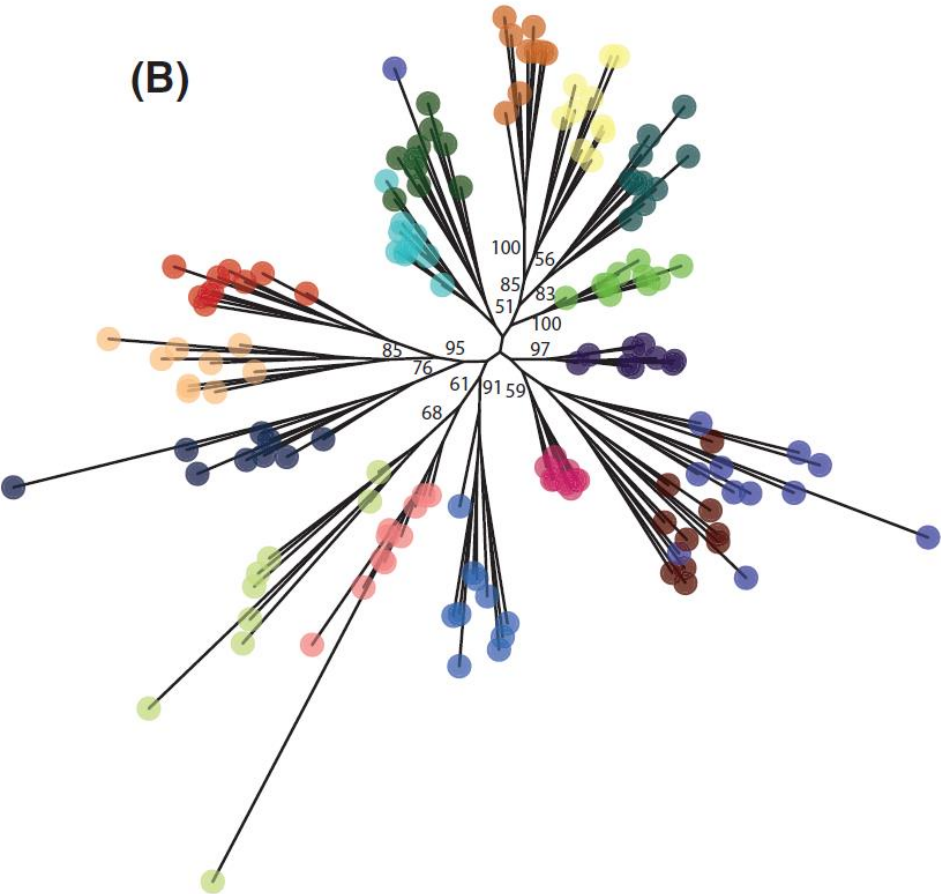
Genome-wide relationships among species: 3'500 bp

(A)



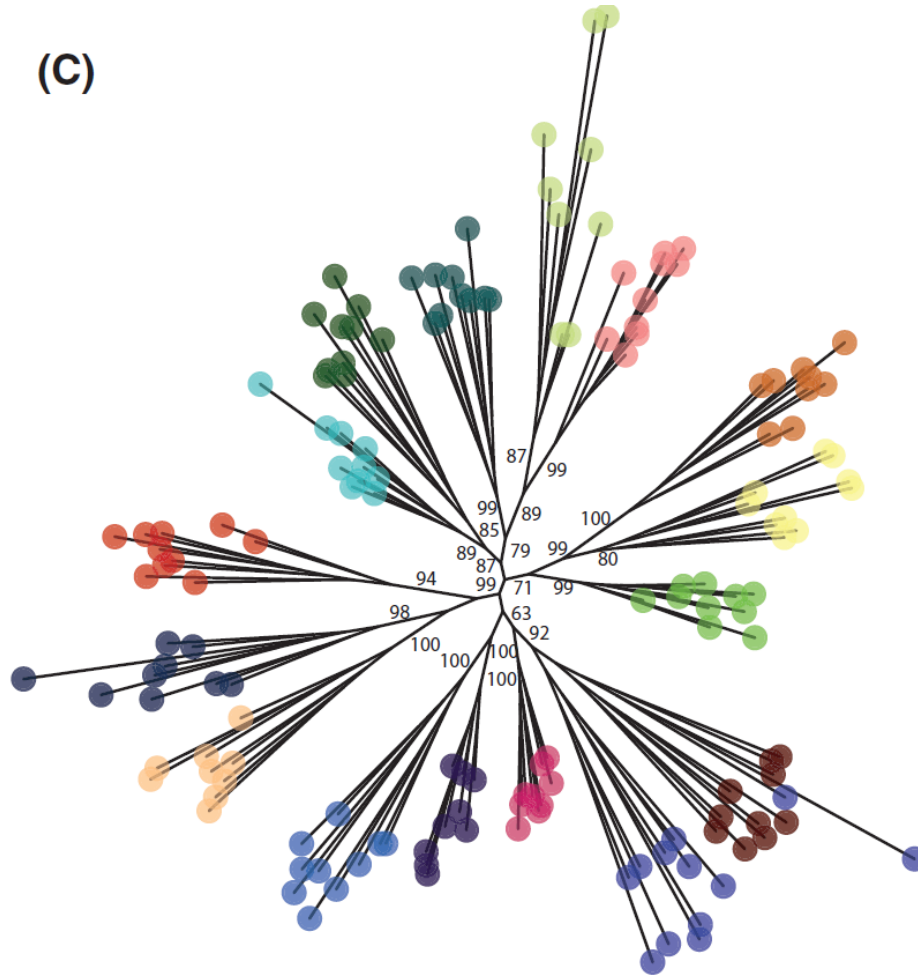
A mess, are species not real?

Genome-wide relationships among species: 30'000 bp

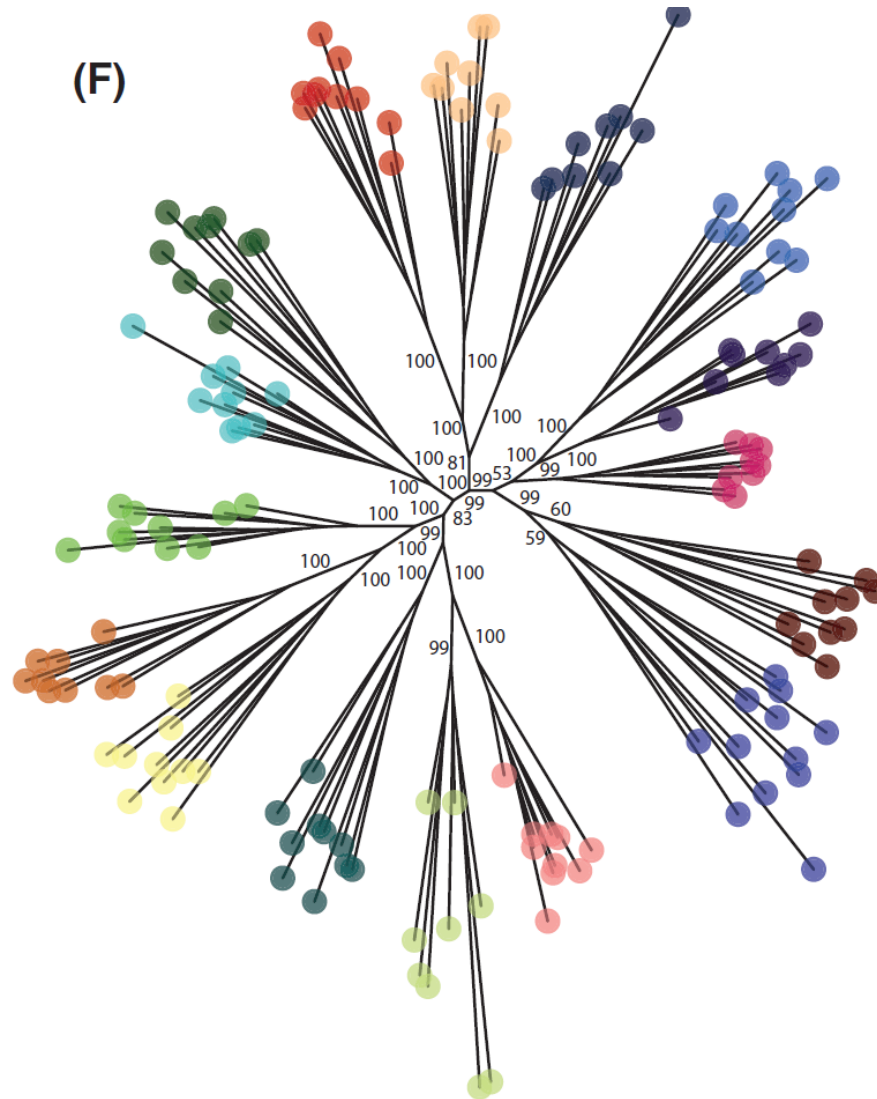


Genome-wide relationships among species: 300'000 bp

(C)

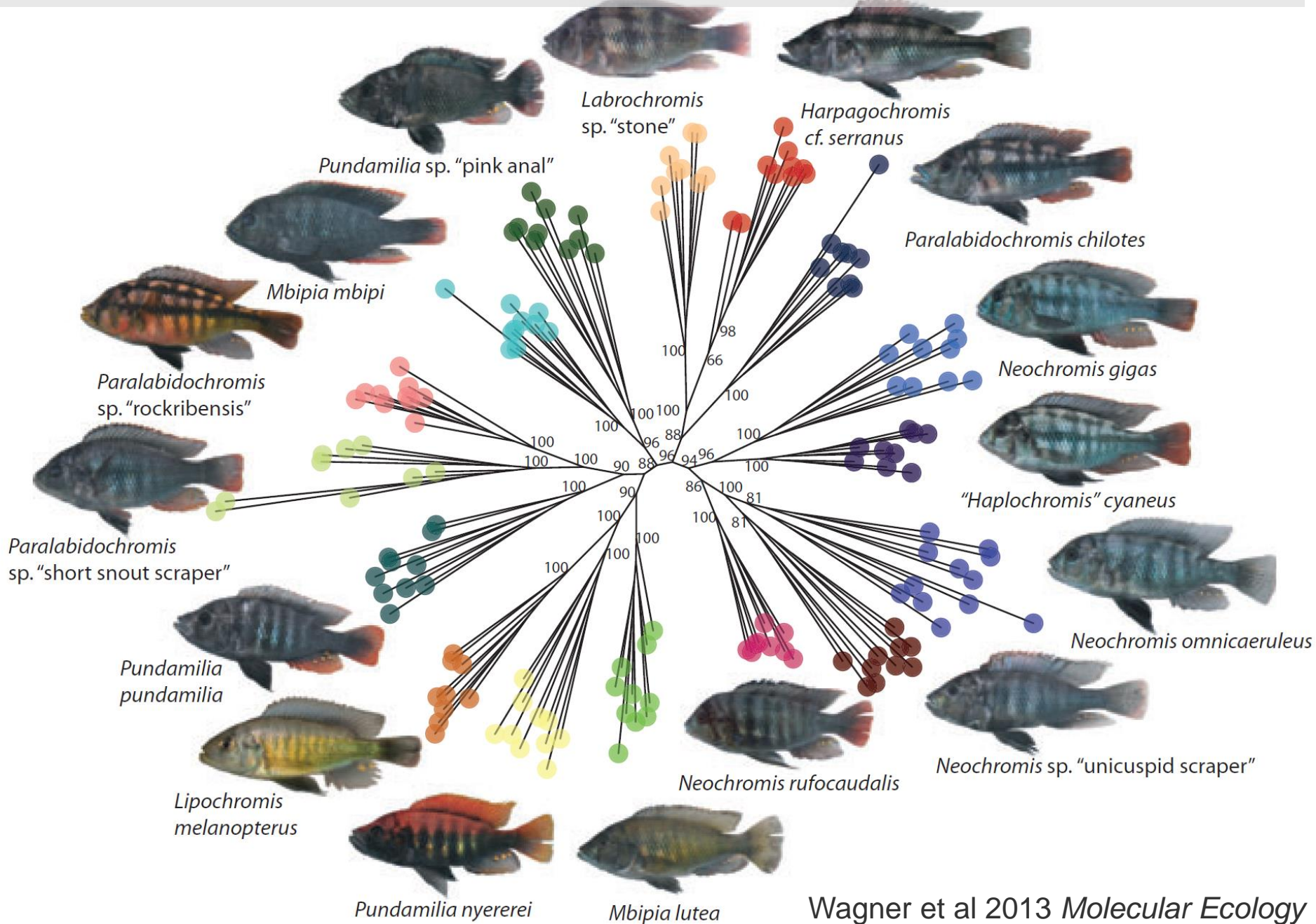


Genome-wide relationships among species: **3'000'000 bp**

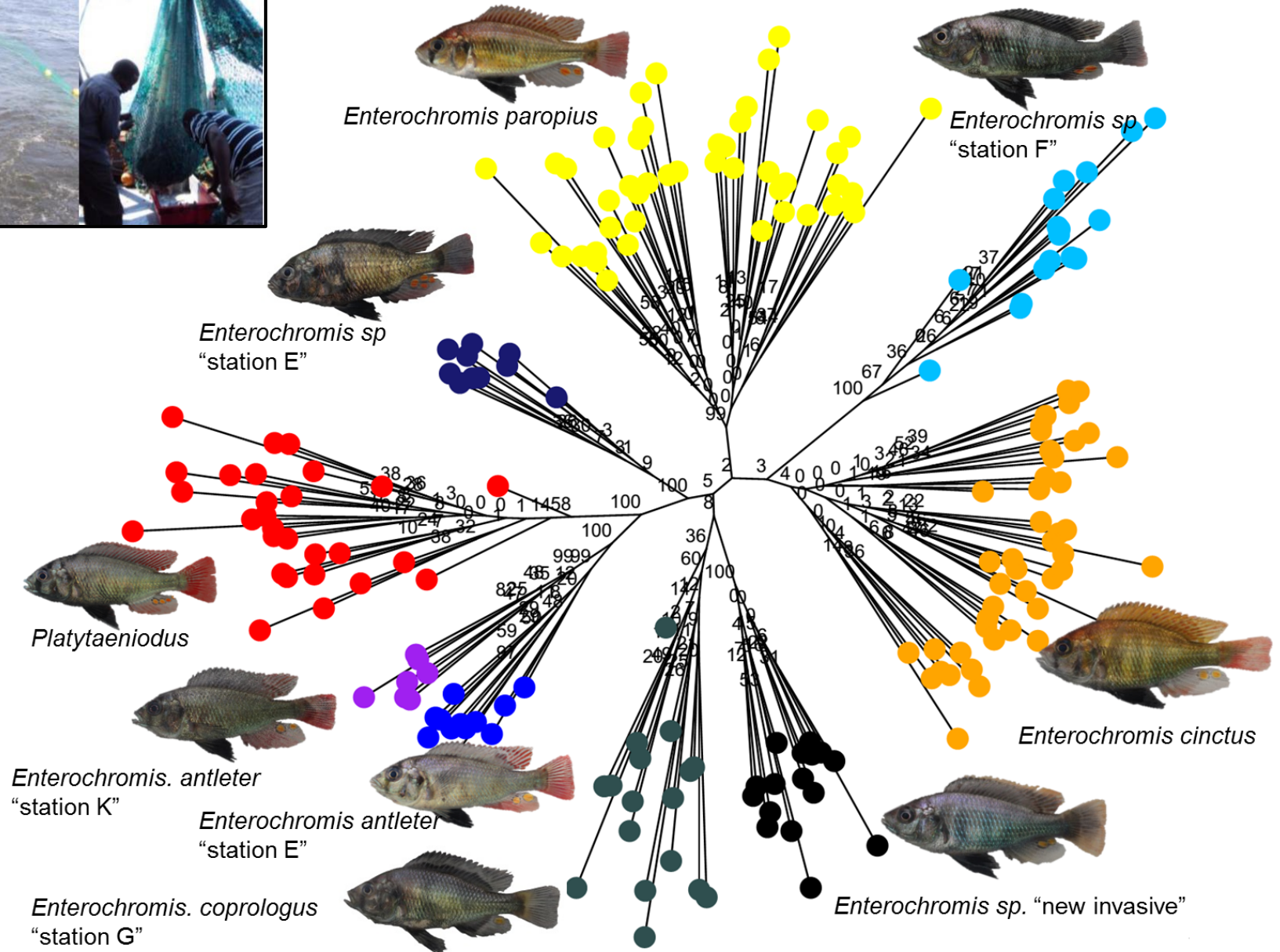


Species are VERY real

The Makobe Island species assemblage completely resolved



An offshore demersal assemblage completely resolved to



Where did all the genetic variation come from in merely 15'000 years of Lake Victoria history?

The entire flock of cichlid radiations in the Lake Victoria region has evolved from an ancient hybrid swarm

Five-population test

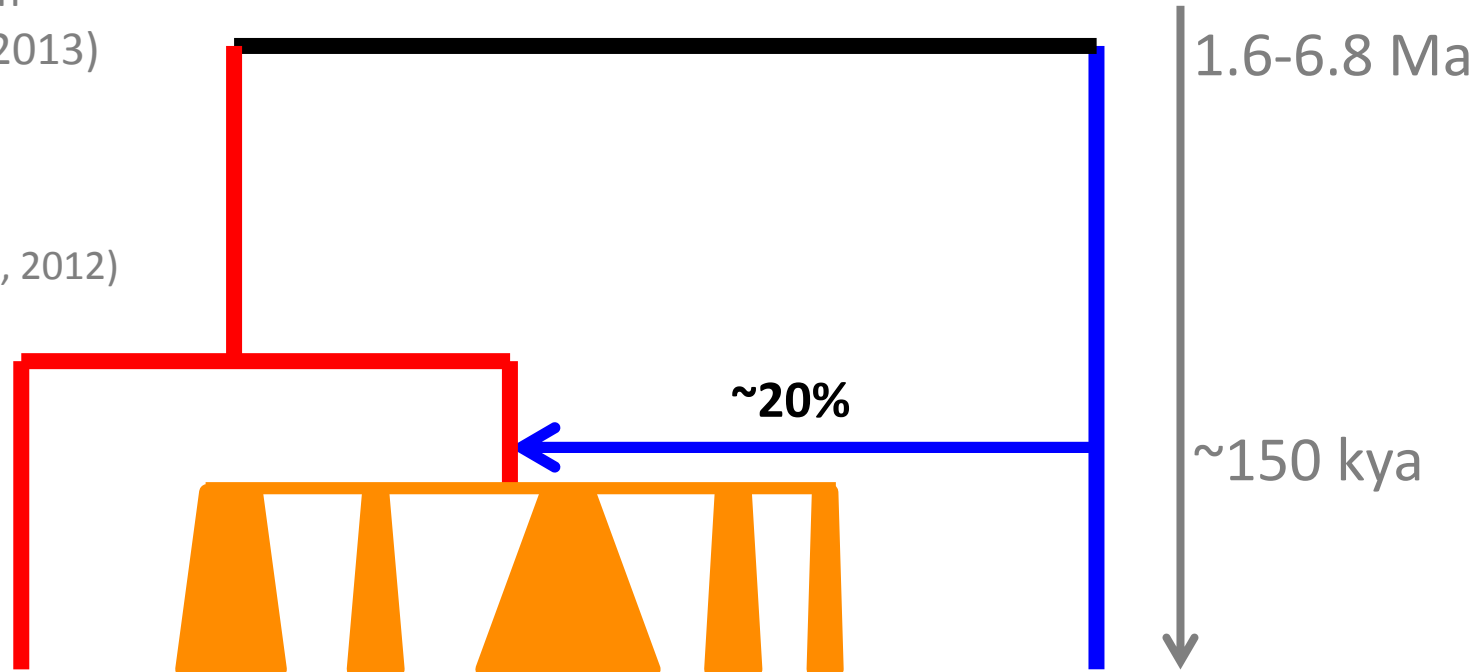
(modified from Eaton & Ree, 2013)

F4-ratio test

(Patterson et al., 2012)

BEAST

(Bouckaert et al., 2014)



Congo

Kivu

Albert

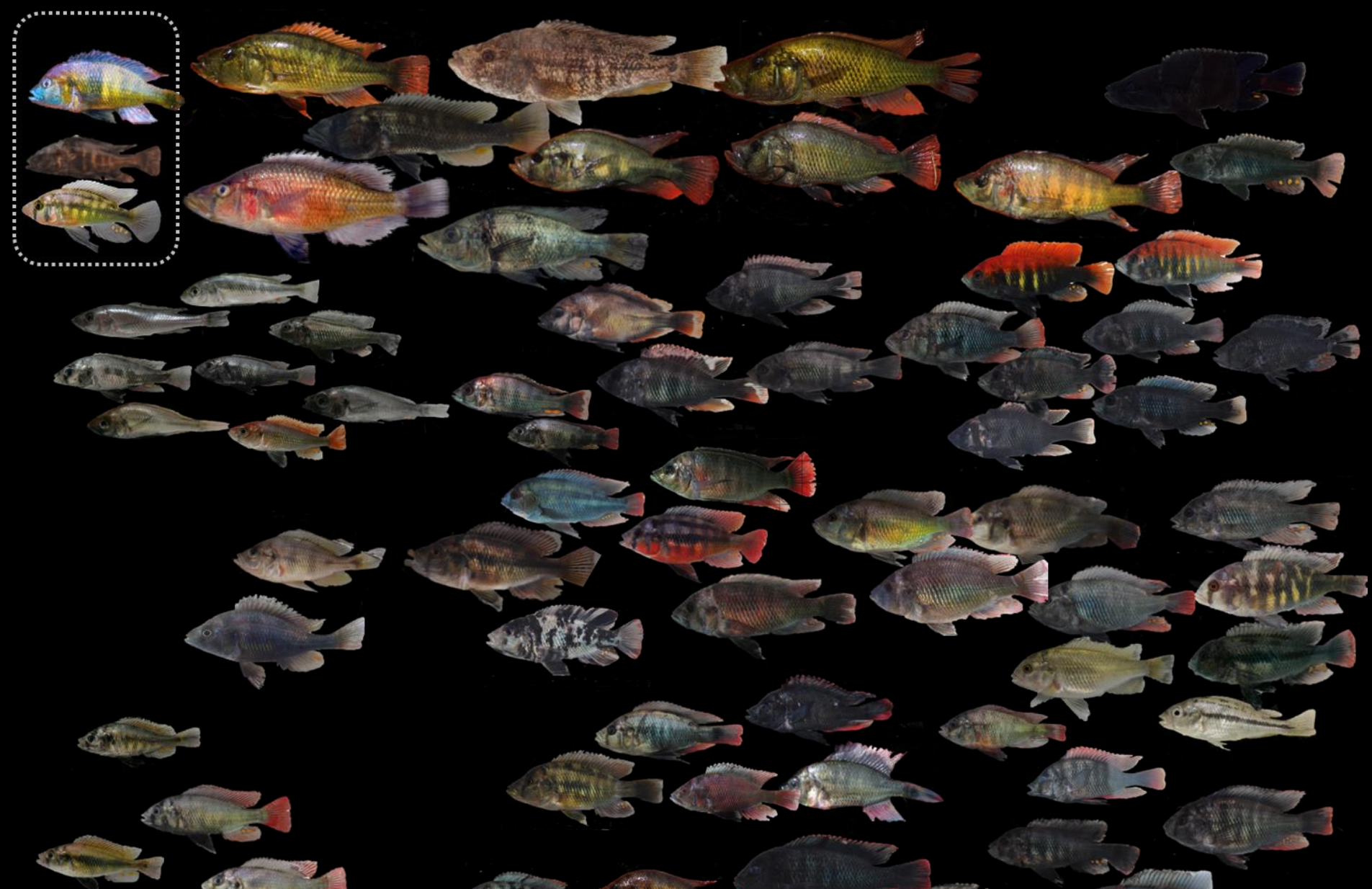
Victoria

Kagera

Saka

Upper Nile





Hundreds of unique endemic species are made of ancient genetic variation

The Structure of Biodiversity in the Lake Victoria Region

What have we learned so far ?

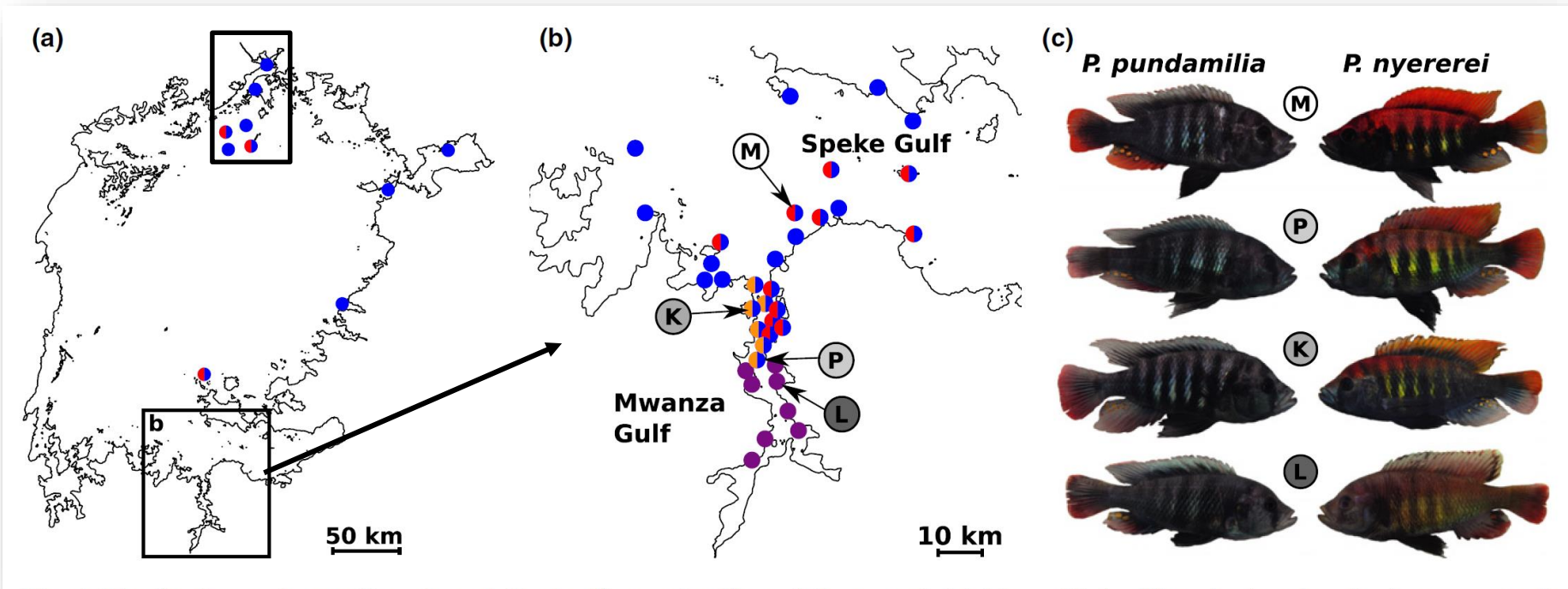
- Each lake in the region has unique endemic species assemblages
- >500 species are real - can be objectively verified with genomic data
- The Lake Victoria region cichlids contain much more genetic diversity and differentiation than previously thought:
the species are young but their genes are old
- each habitat in Victoria - unique set of species with little sharing between habitats
- within macrohabitats, distributions are microhabitat-specific

The Structure of Biodiversity in the Lake Victoria Region

What do we still not know ?

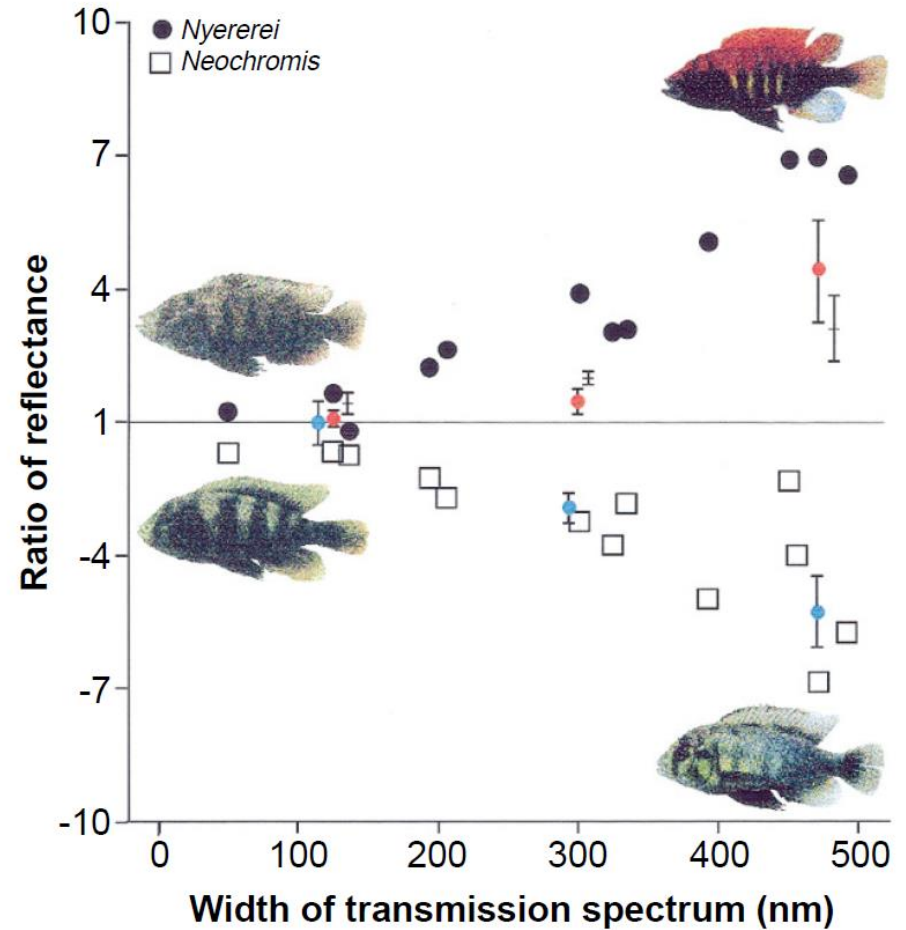
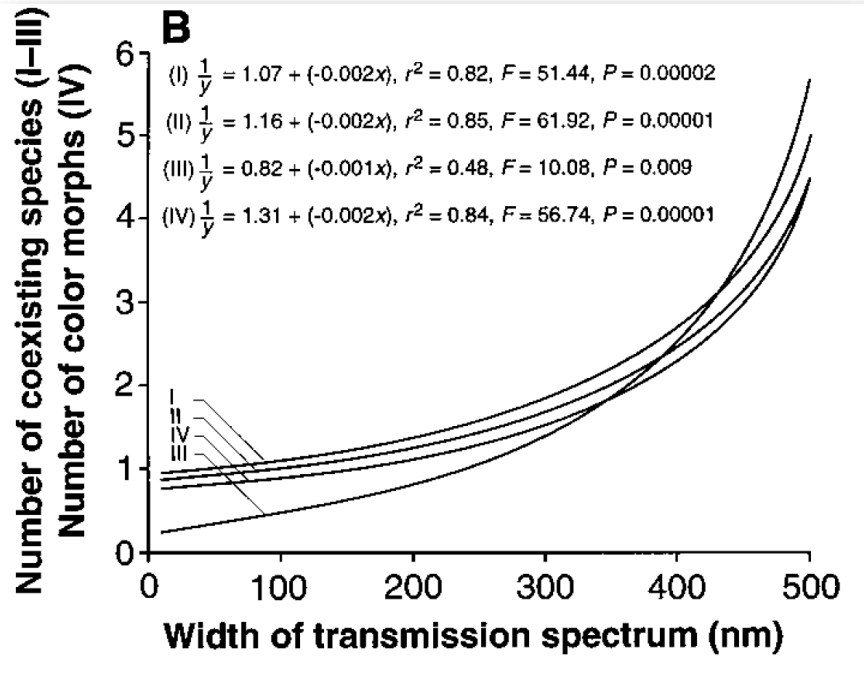
- the geographical distribution of species WITHIN Lake Vic

Spatial mapping of diversity – current knowledge is patchy



but generates some strong predictions

strong predictions: 1. water turbidity leads to biodiversity loss



strong predictions 2: many more species await to be discovered

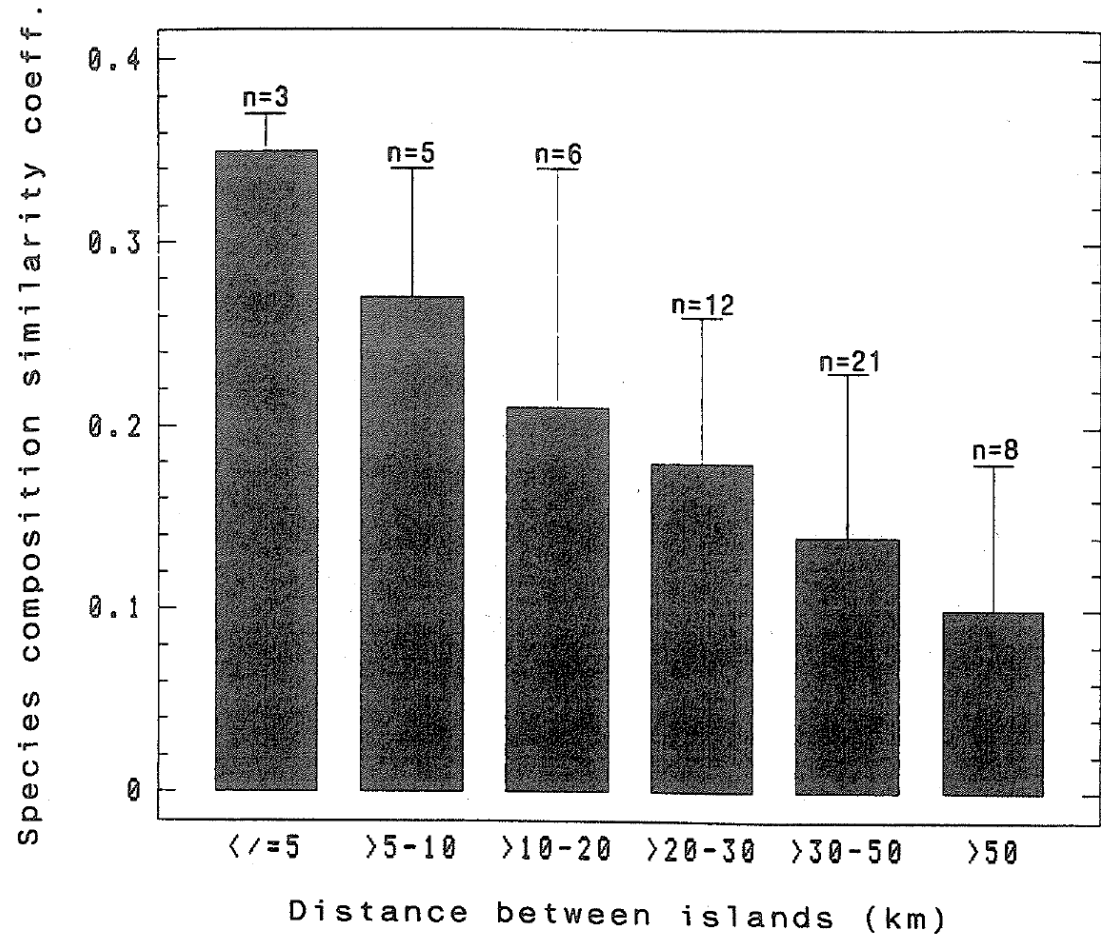
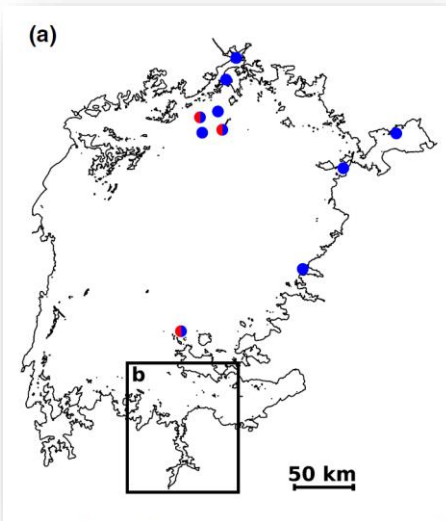


Figure 3 The relationship between the similarity in species composition between communities at patches of rocky habitat and the geographical distance between them. Species composition similarity coefficients are calculated as number of joint species divided by total number of species at two rocky islands

The Structure of Biodiversity in the Lake Victoria Region

What do we still not know ?

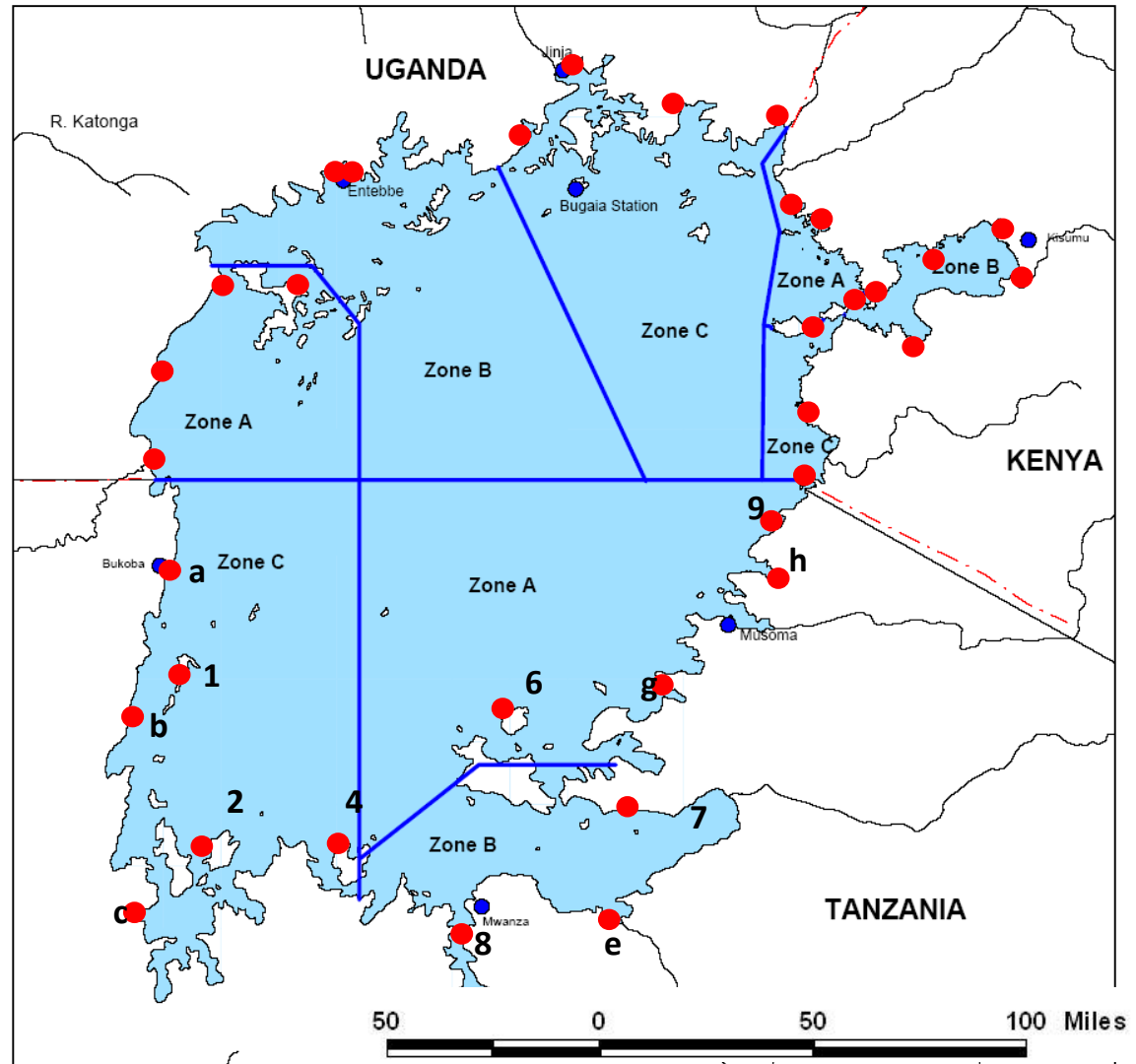
- the geographical distribution of species WITHIN Lake Vic
- the spatial turnover of diversity WITHIN Lake Vic
- the true number of endemic species
- the true number of extinct species
- The effect of cichlid diversity on ecosystem function and ecosystem services

Needed: geo mapping of within-lake diversity at the **species level**

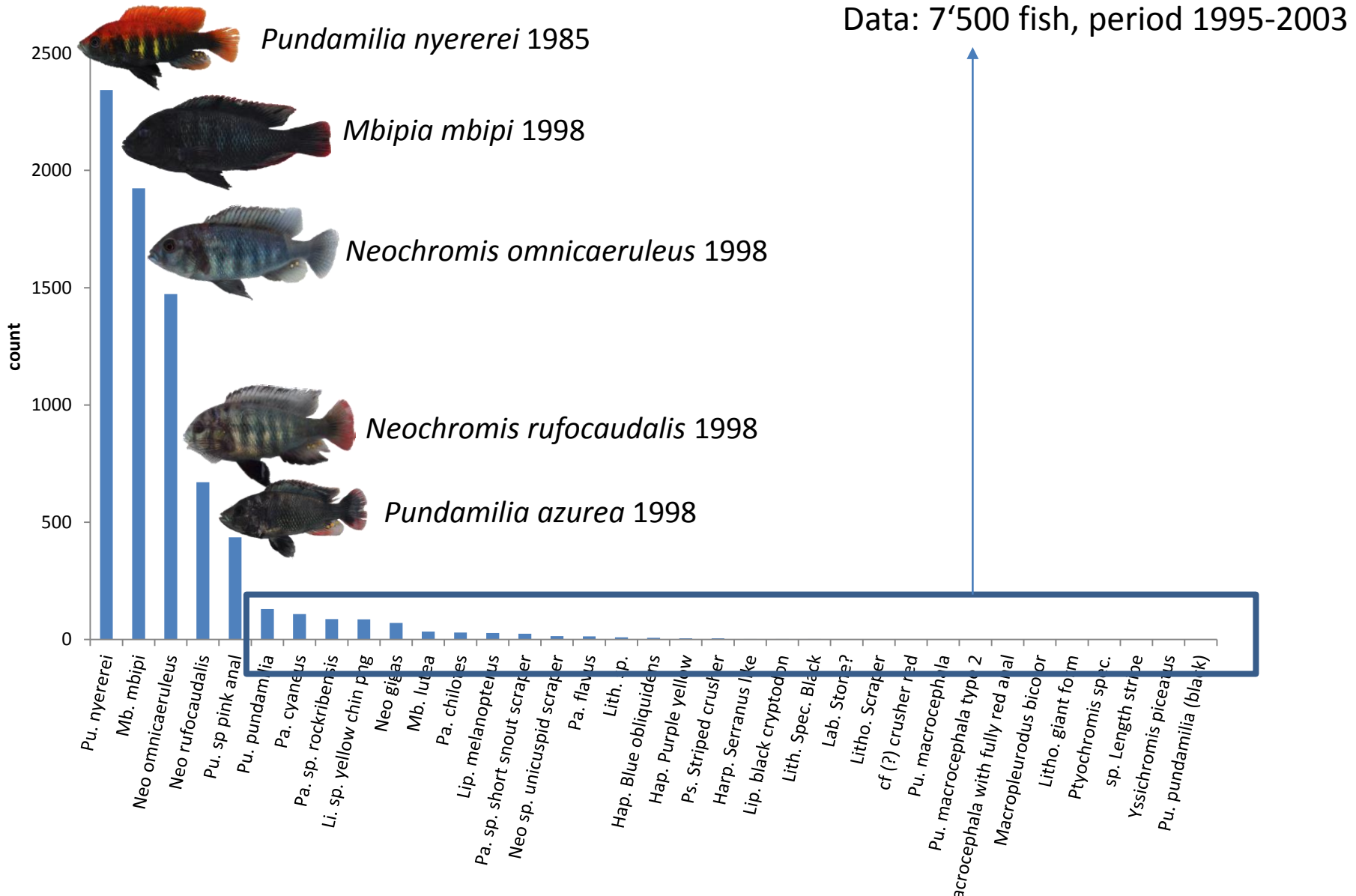
- lake-wide data on the distribution of individual species and alpha diversity
- A better understanding of the rate and extent of geographical turnover of diversity WITHIN Lake Victoria (beta, gamma div)



- Key Biodiversity Areas, key regions for conservation, key species and species groups
- The role of diversity in the food web and ecosystem



Major challenges in species rich systems: Difficult taxonomy, uneven abundances



Hope ... «people are the solution»



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TAFIRI, Tanzania



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KMFRI, Kenya



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Les Kaufman, Boston U



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Sarah Glaser / U Denver

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