

Molecular Paleoecology

to track the history

of species and

ecosystems

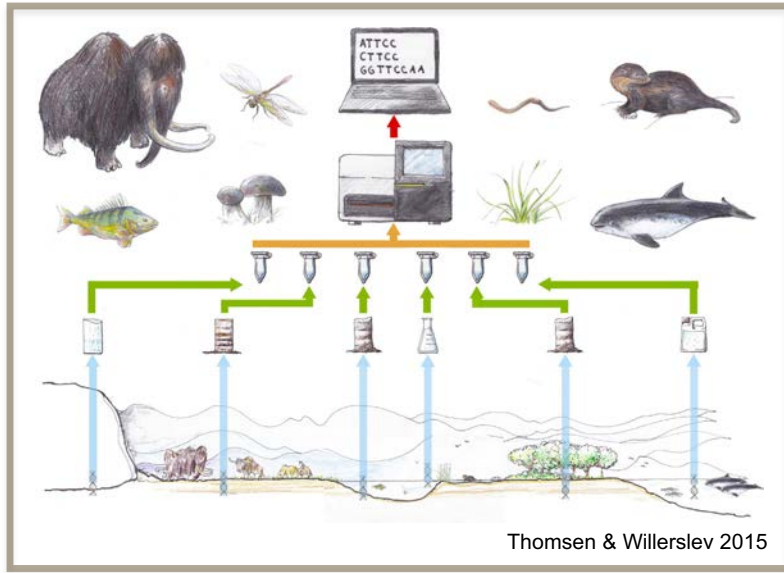
Laura S. Epp

Junior Professor for Environmental Genomics
in Aquatic Systems

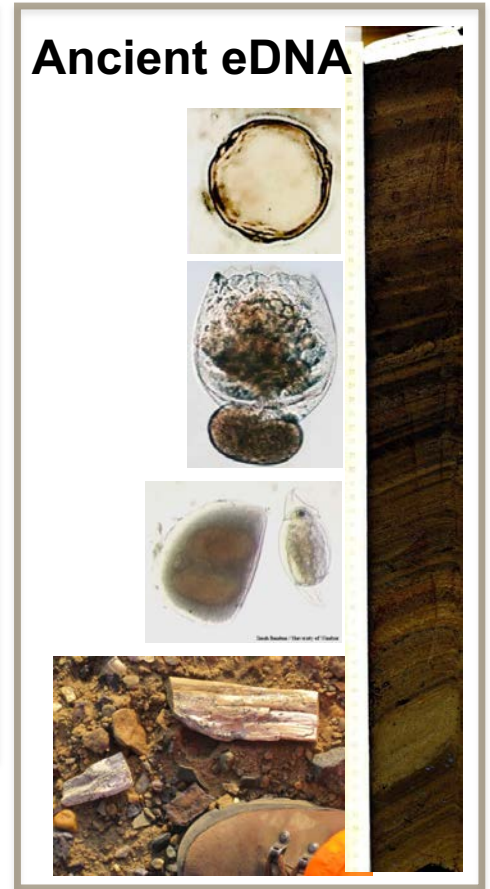


*Just a spoonful
of mud makes
the ice age
world appear?*

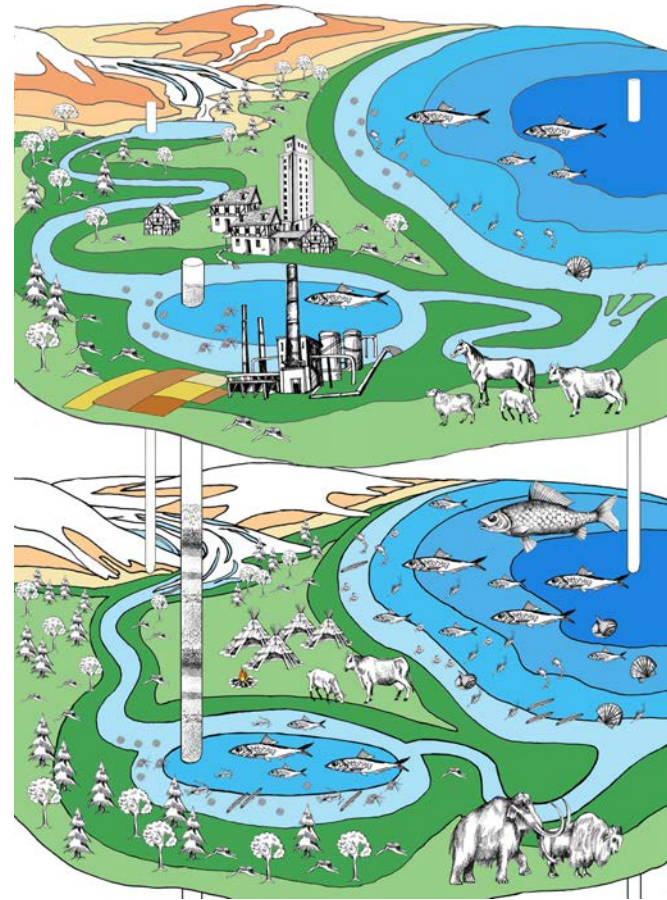




- Survey and monitor biodiversity
- Reconstruct past biodiversity

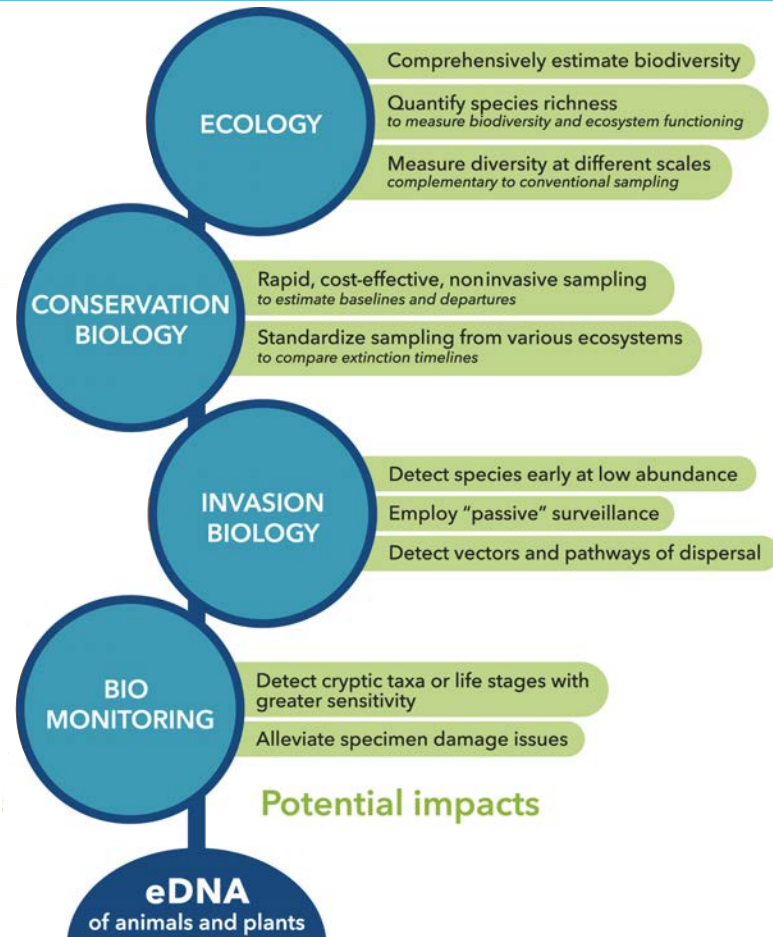


What information can we get from historical / ancient – eDNA?



Trends in Ecology & Evolution

Balint *et al.* 2018, TREE



from Deiner *et al.* 2017, Molecular Ecology

- Process understanding
- Track response & resilience
- Infer rates of change and determine drivers
- Restoration targets
- Historical, pre-impact reference states
- First appearance dates
- Track invading genotypes -> migration routes
- Extend monitoring time series



*Just a spoonful
of mud makes
the ice age
world appear?*



*Just a spoonful
of mud makes
the ice age
world appear?*



(Lake) sediment cores



Lake sediment



DNA in sediments

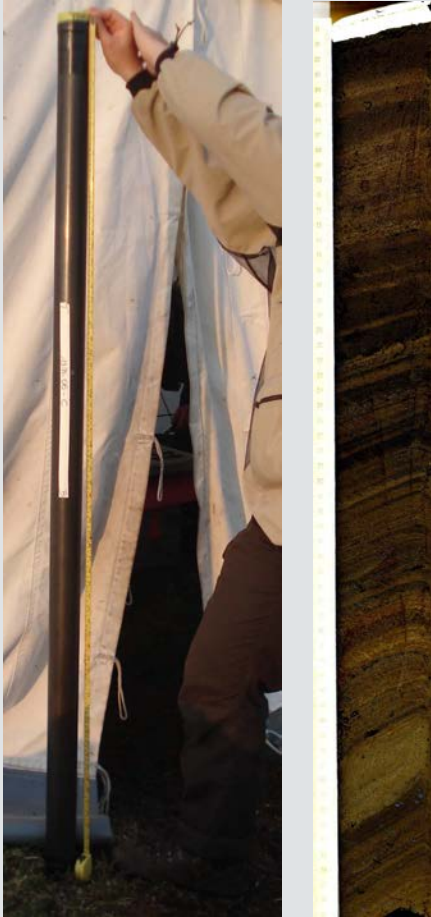
Extracellular & intracellular

Binds to clay, sand, humic and organomineral substances.

- Records surrounding biodiversity at sedimentation
- DNA stored in the sediment
 - + temporal deposition of sediments

Not limited to organisms with visible remains

Lake sediment



Integration over the ecosystem

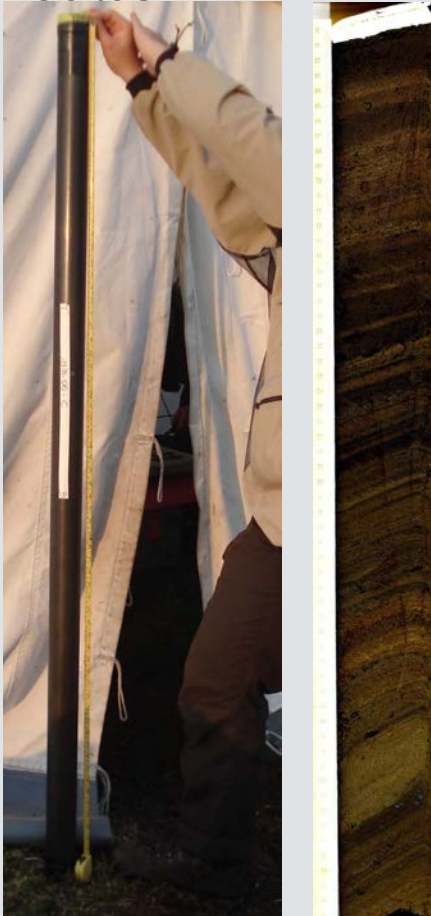
Terrestrial surroundings



Aquatic ecosystems

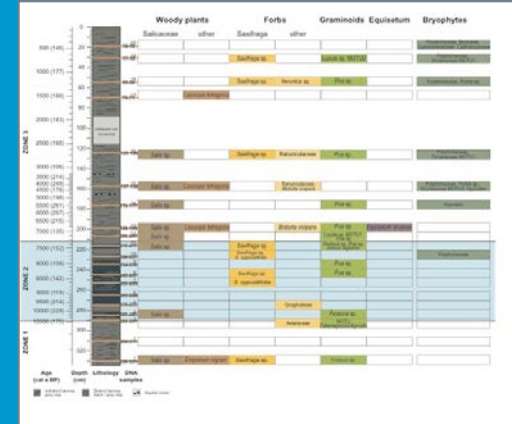


Lake sediment

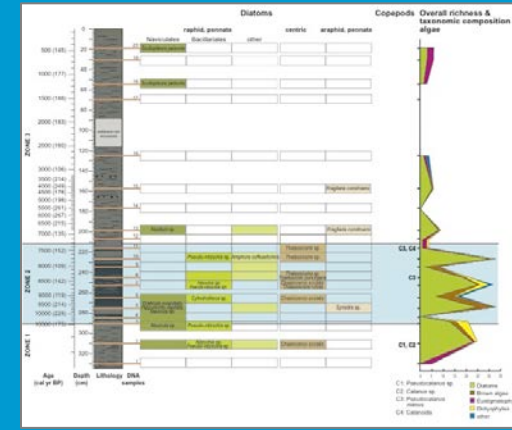


Integration over the ecosystem

Terrestrial surroundings

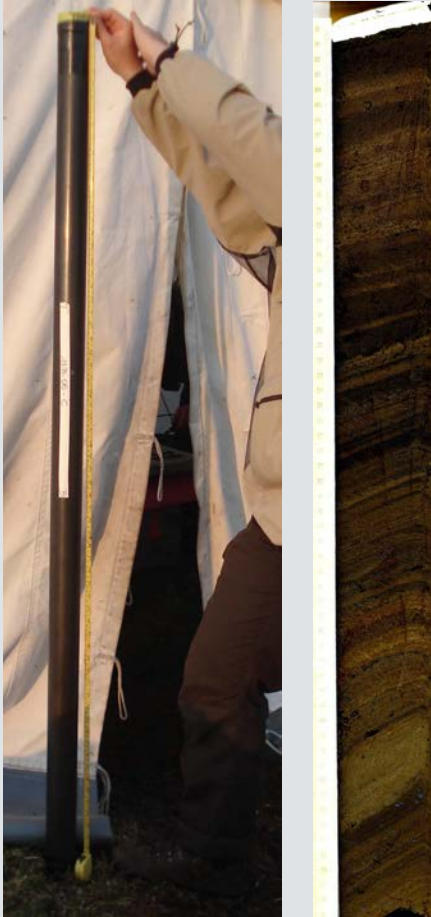


Aquatic ecosystems



Epp et al. 2015 QSR

Lake sediment



Ancient DNA Lab



(Ancient) eDNA



DNA Extraction



PCR set-up / Shotgun Library

eDNA Lab



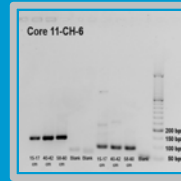
Lake sediment



Ancient DNA Lab



Post-PCR Lab



eDNA Lab

(Ancient) eDNA



DNA Extraction



PCR set-up / Shotgun Library



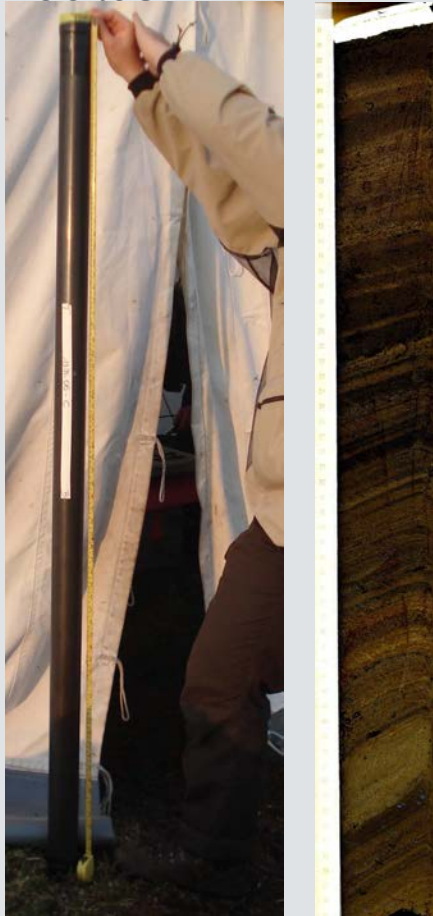
PCR,
Prep for sequencing



Post-PCR Lab



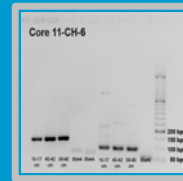
Lake sediment



Ancient DNA Lab



Post-PCR Lab



Bioinformatic filtering

1. 5604993	G	A	C	T	G	G	G	G	G	G	G	C	A
2. 5604994	G	A	C	T	G	G	G	G	G	G	G	C	A
3. 5604995	G	A	C	T	G	G	G	G	G	G	G	C	A
4. 5604997	G	A	C	T	A	T	G	G	G	G	G	C	A
5. 5604998	G	A	C	T	A	T	G	G	G	G	G	C	A

eDNA Lab

(Ancient) eDNA

DNA Extraction

PCR set-up / Shotgun Library

PCR,
Prep for sequencing

Sequencing

Sequence information

- ID through comparison to databases
- Analyses
- ...



Post-PCR Lab



DNA metabarcoding



AGTGGGCCTAATACGATAAGGAACGAAACGTAGCA



GGTCCGGCTGGCACGATAAGGAACCCACGAAGCA



TTTGGGCCTAATACGATAAGGTACGAATTCTAGCA



Courtesy of Illumina, Inc.



High throughput DNA-based identification of multiple species.

DNA metabarcoding



AGTGGGCCTAATACGATAAGGAACGAAACGTAGCA



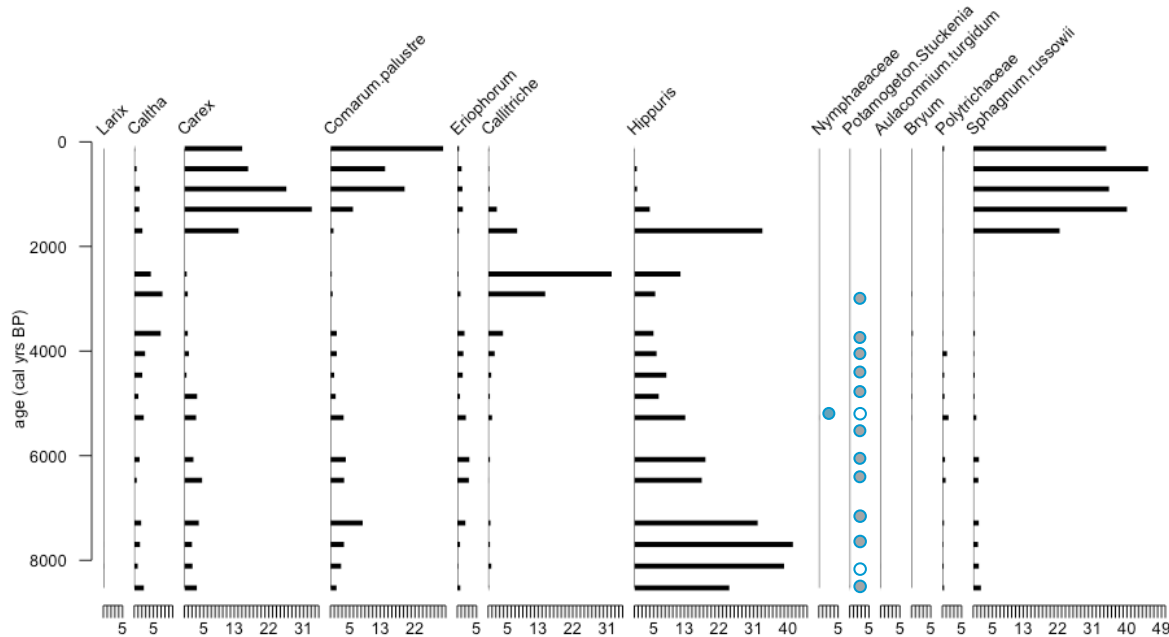
GGTCCGGCTGGCACGATAAGGAACCCACGAAGCA



TTTGGGCCTAATACGATAAGGTACGAATTCTAGCA



Courtesy of Illumina, Inc.

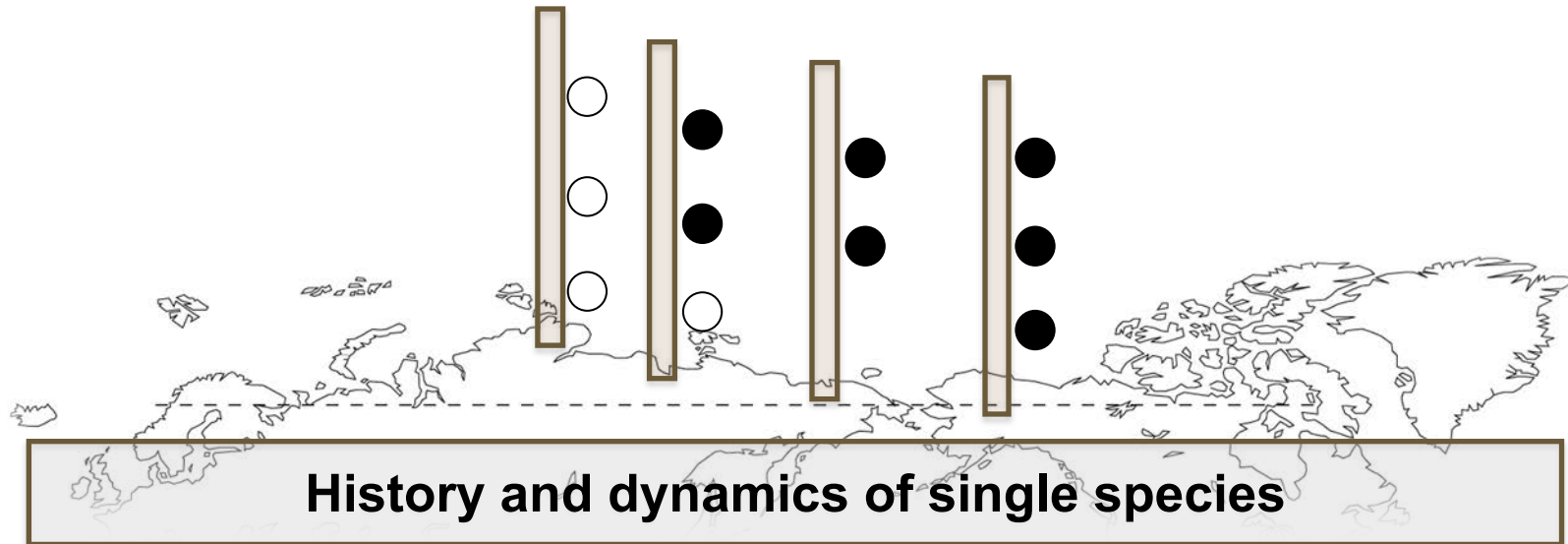


Analyses of genomic variation - cryptic changes

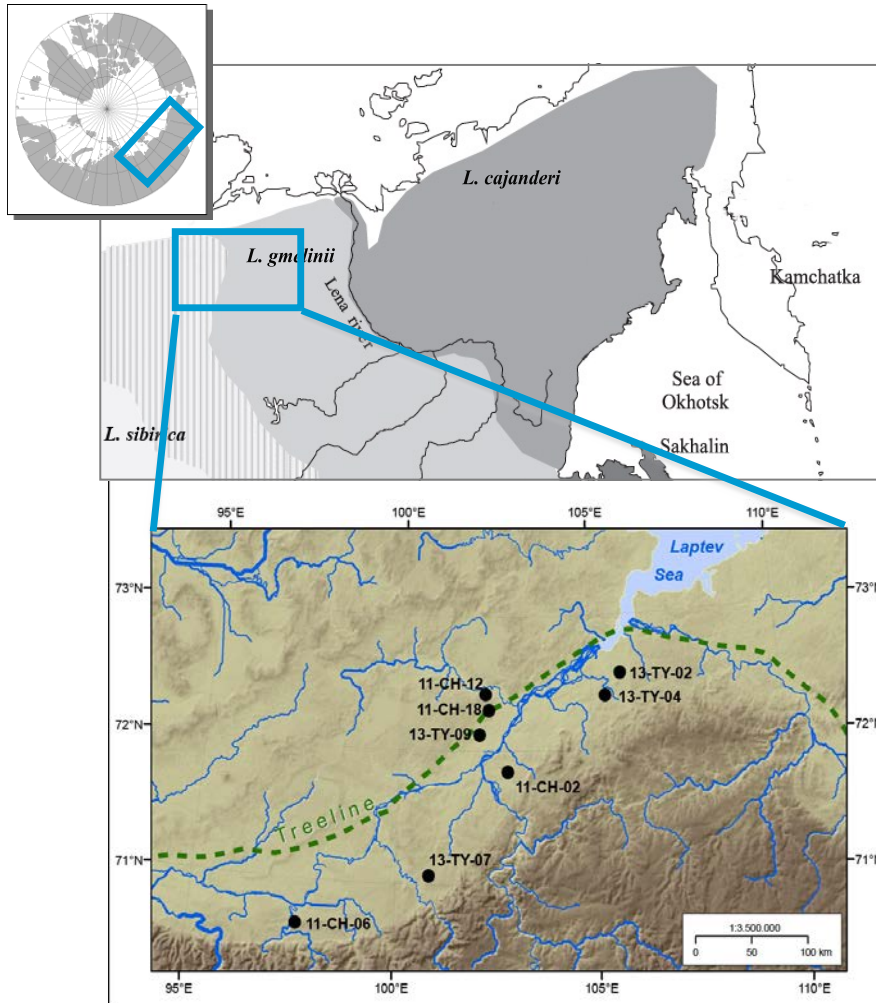
CTACTGCCT ●

CTACTGCCT ●

CCGCTGCCT ○



History and dynamics of single species



Expeditions across the tree line

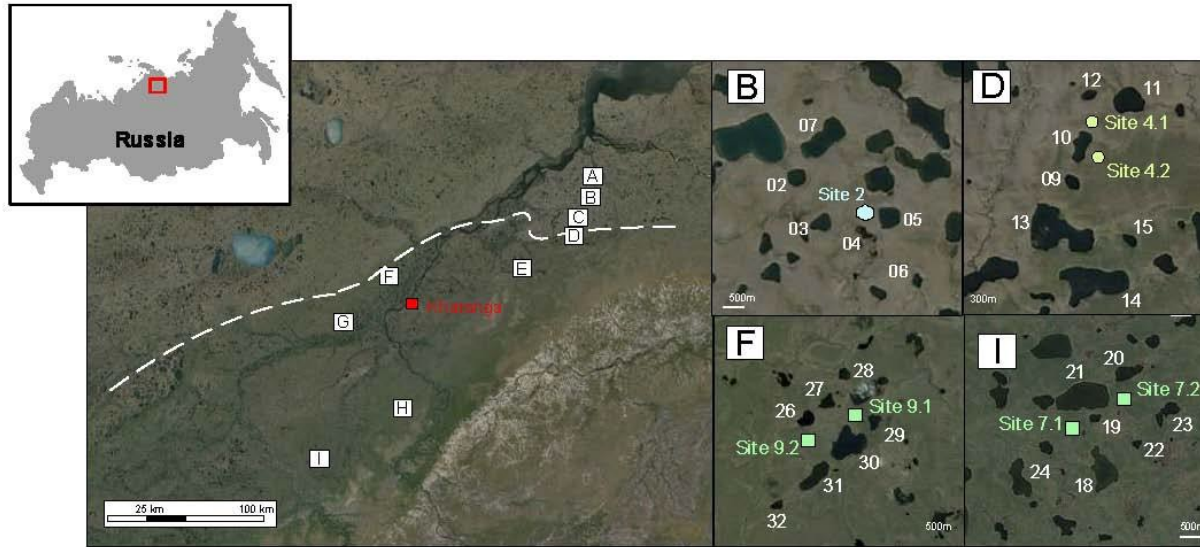
How well are communities represented?

DNA metabarcoding – Pollen – Vegetation assessments

114 Taxa gesamt

43 Taxa

31 Taxa



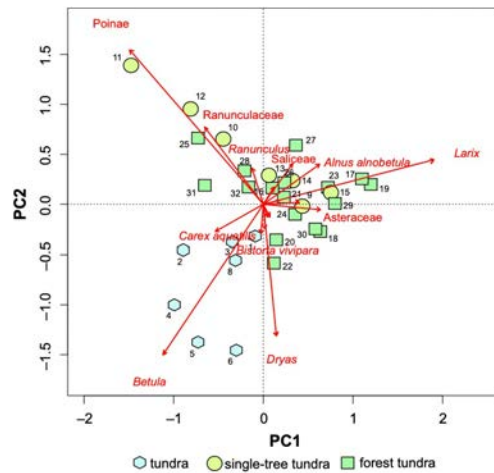
Surface sediments from lakes of the southern Taymyr Peninsula

Niemeyer *et al.* Mol Ecol Res 2017

How well are communities represented?

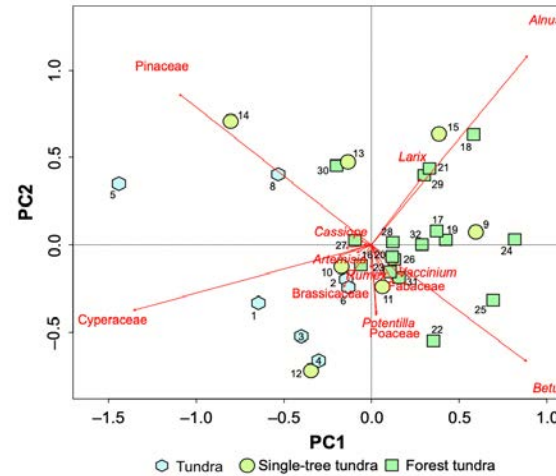
DNA metabarcoding

114 Taxa gesamt



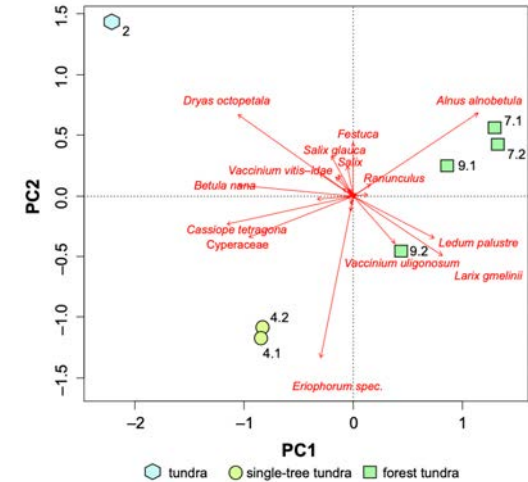
Pollen

43 Taxa



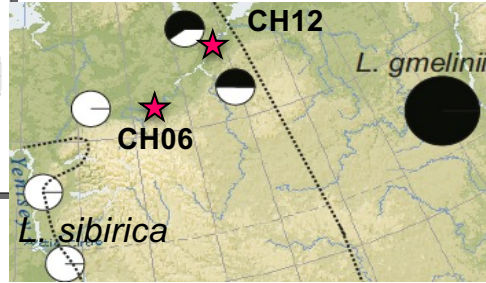
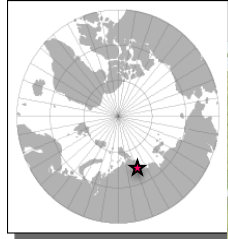
Vegetation assessments

31 Taxa



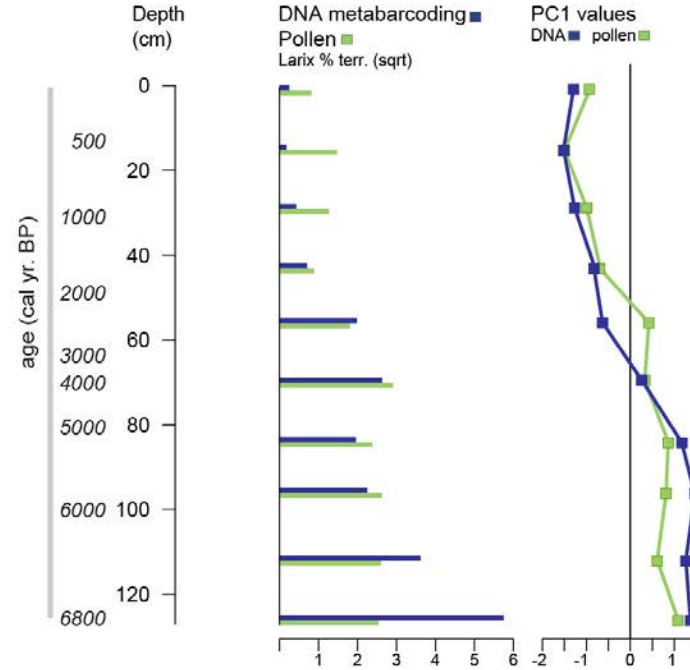
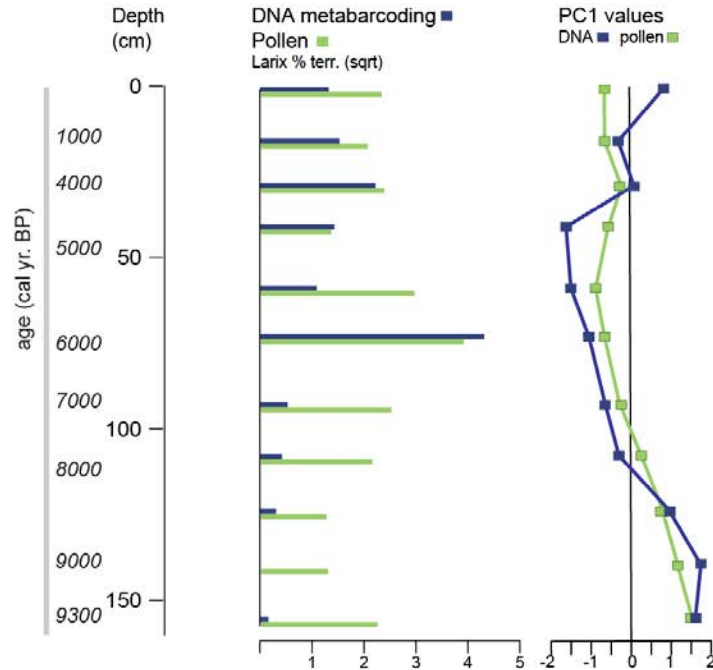
Good agreement of all methods
DNA provides most taxa
Local signal

Niemeyer *et al.* Mol Ecol Res 2017

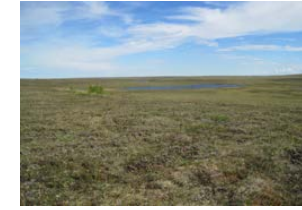
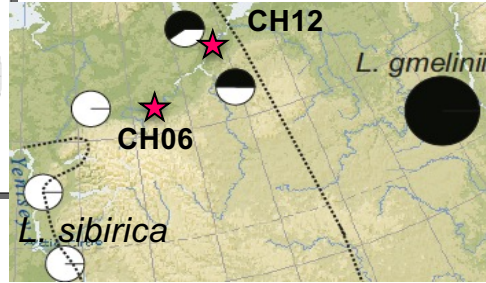
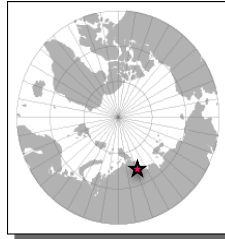


Lake CH06

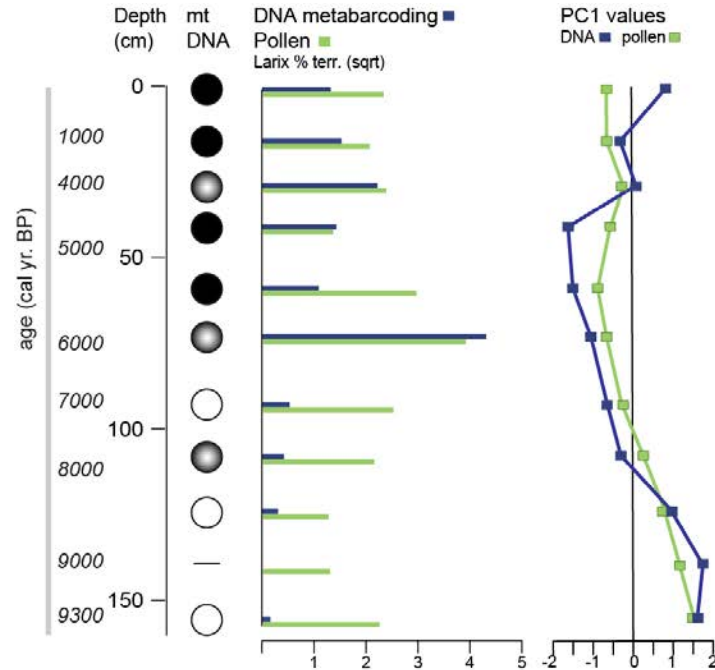
Lake CH12



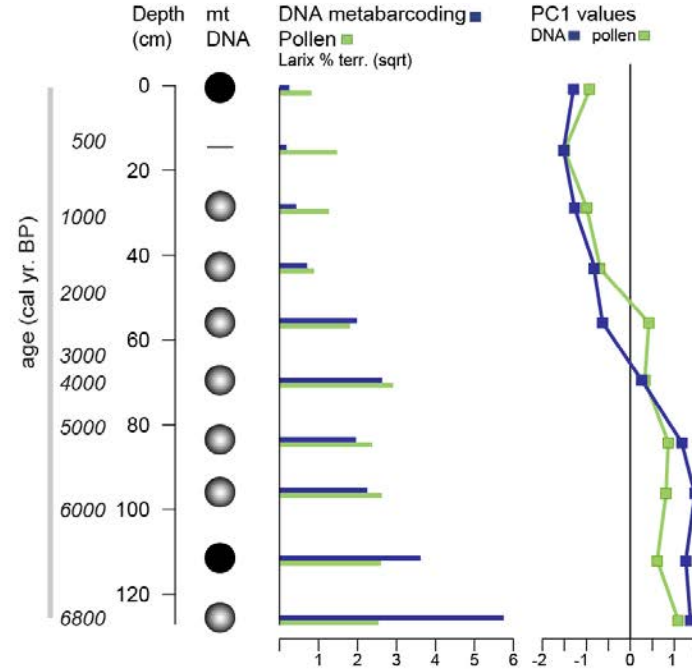
Epp et al. 2018, SciRep

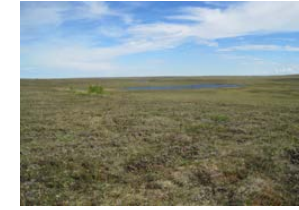
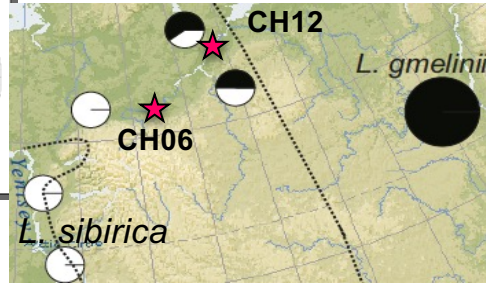
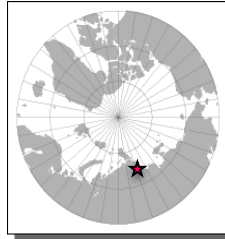


Lake CH06



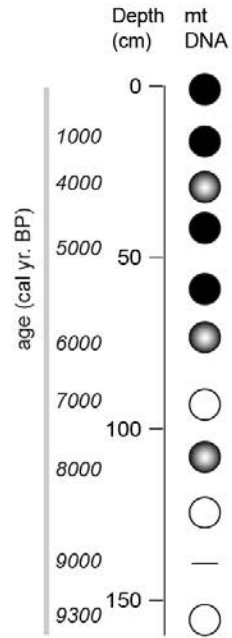
Lake CH12





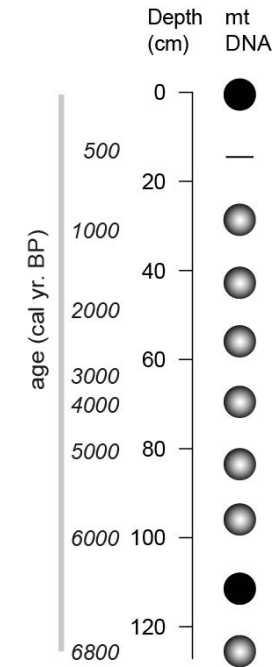
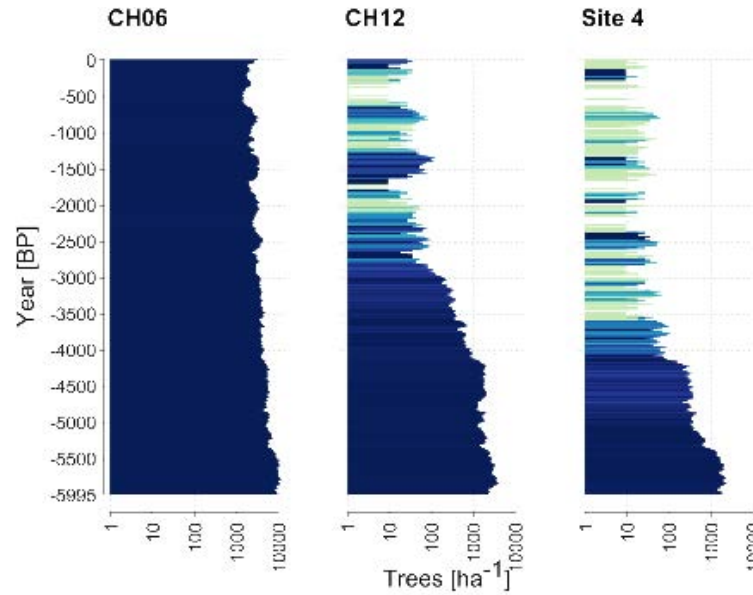
Lake CH06

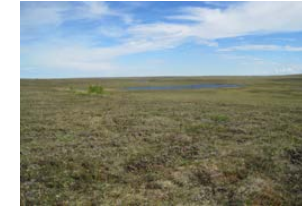
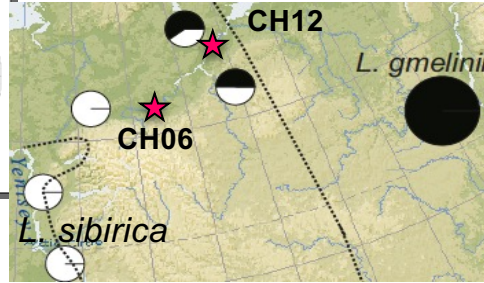
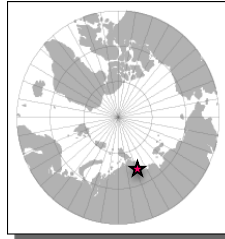
Lake CH12



Model LAVESI

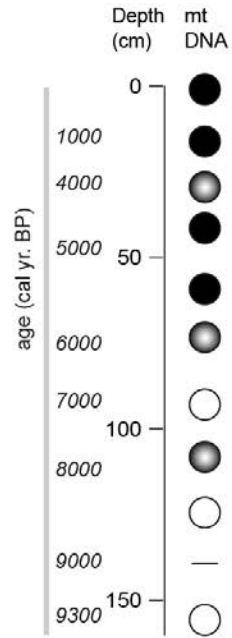
Kruse *et al.* 2016



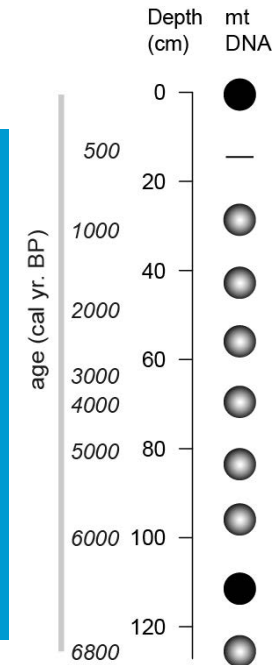


Lake CH06

Lake CH12



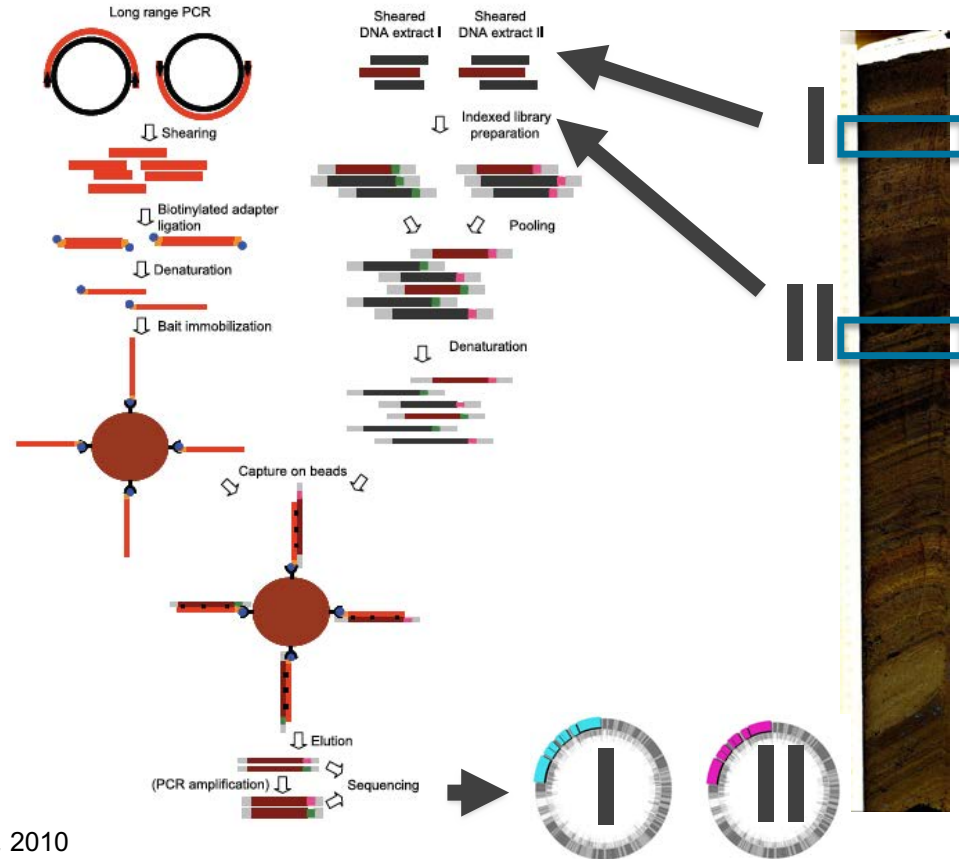
- Effect of glacial refugia in early Holocene
- Higher population density -> *L. gmelinii*
- Direct climate effect -> change in population size.



**Chloroplast Genome: single circular molecule.
In *Larix* size of ~120 kb, paternally inherited.**



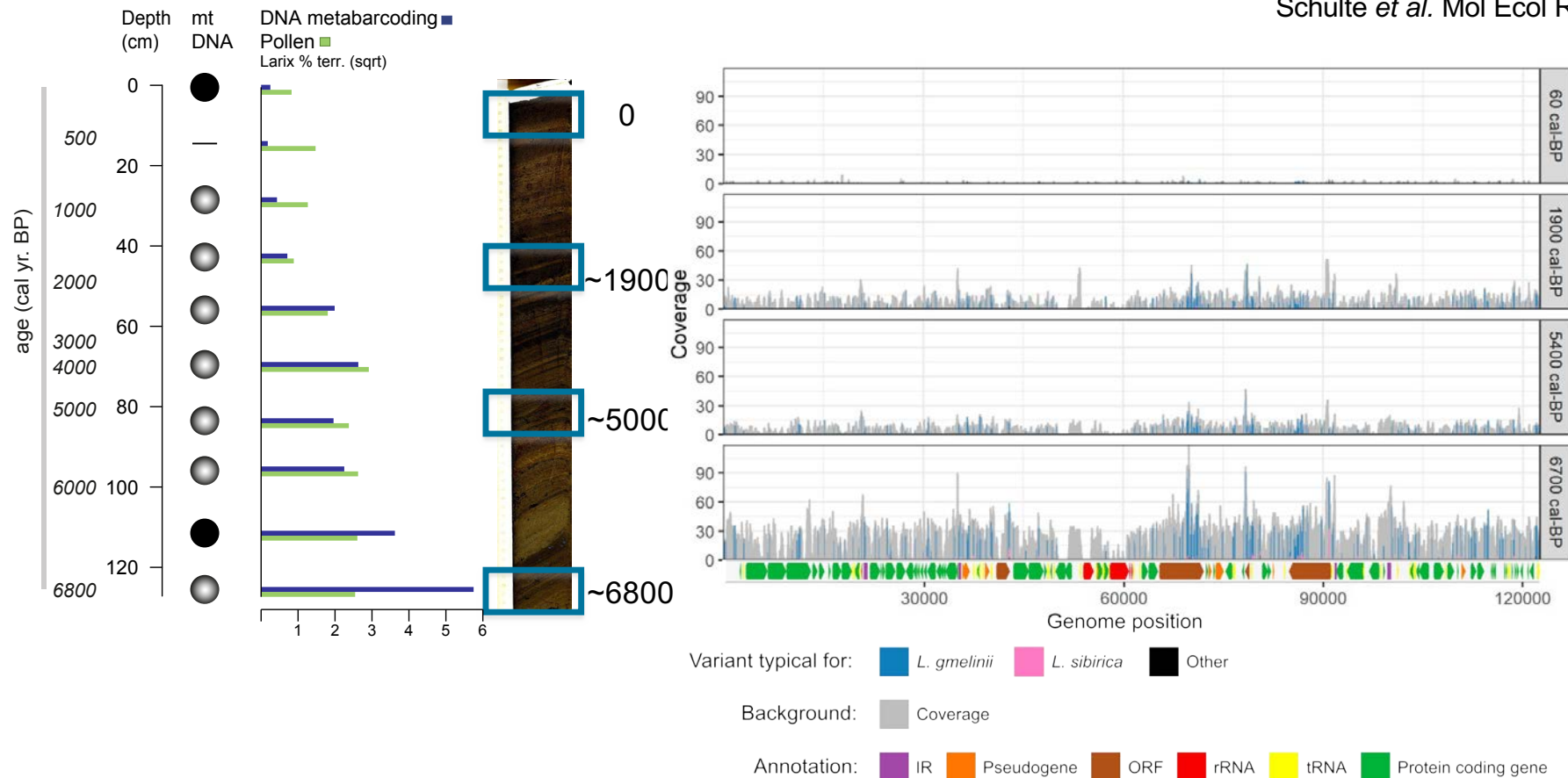
Larch plant



Maricic *et al.* 2010

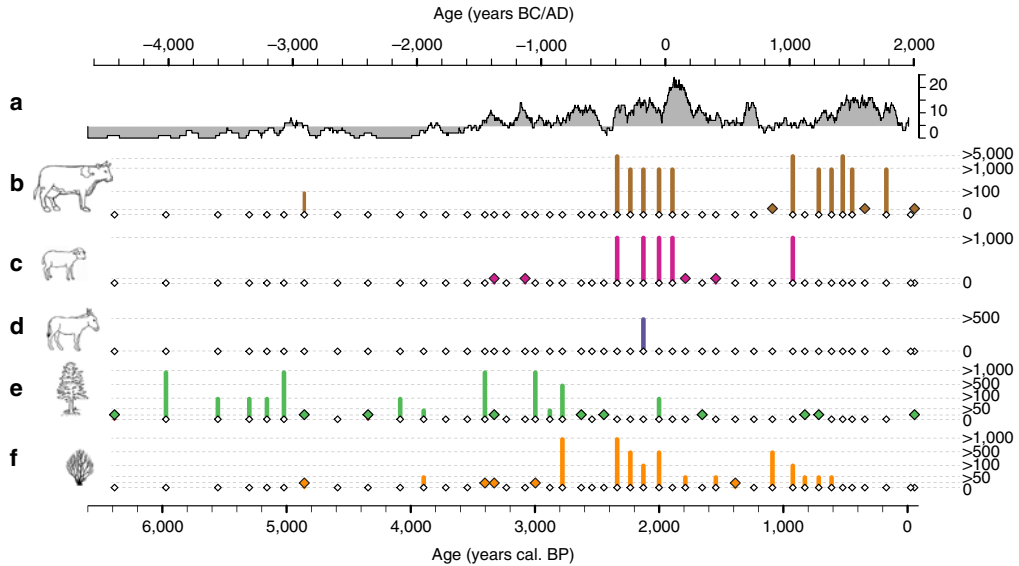
Lake CH12 - *Larix* Chloroplast Genomes – Hybridisation-Capture

Schulte *et al.* Mol Ecol Resources 2021



Amplicon sequencing employing a primer designed for mammals

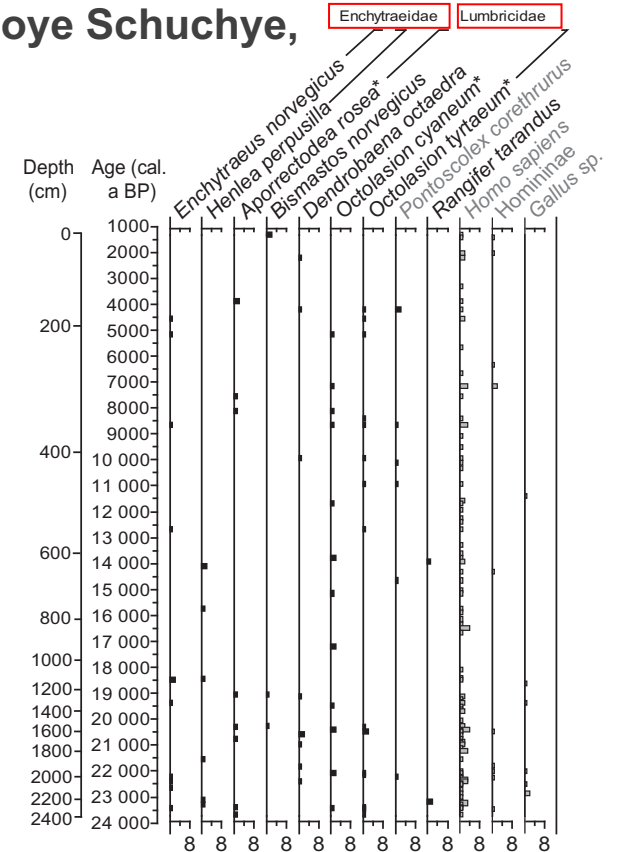
Lake Anterne, France



Giguët-Covex *et al.* 2014

ideal dataset vs. common results

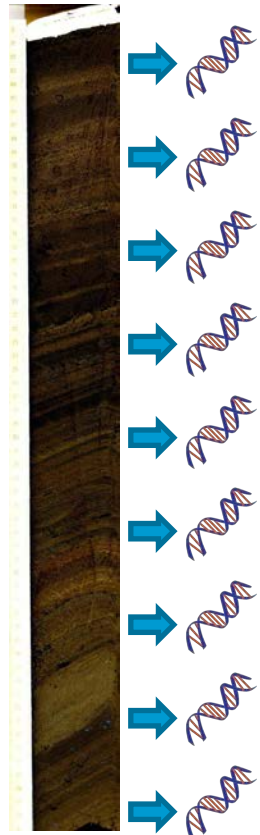
Lake Bolshoye Schuchye, Russia



Lammers *et al.* 2018



Peter Seeber
PostDoc
*Environmental Genomics
Limnological Institute
University of Konstanz*



Biodiversity change through time

➤ Relative impacts of climate and herbivory on vegetation

Plants

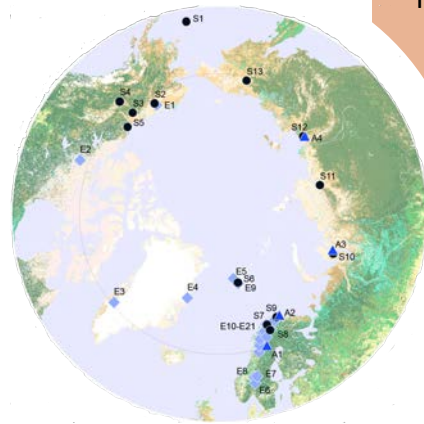
- DNA metabarcoding
U Tromsø,
I. Alsos & A. Poliakova

Mammals

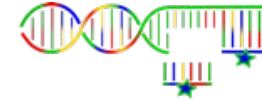
- DNA metabarcoding,
shotgun, hybridisation
capture
UCSC, B. Shapiro
McMaster U, H. Poinar

Mammal proxies

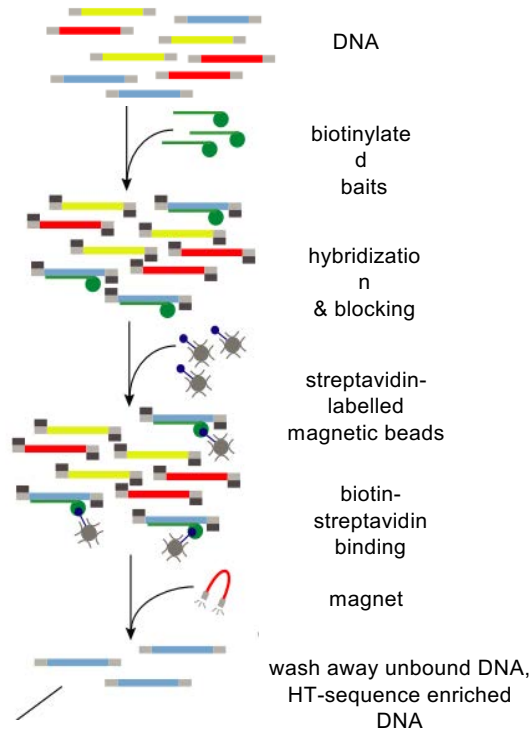
- Coprophilous fungi
- Endoparasites
(Nematodes)
- Ectoparasites (Mites,
Insects)
U Konstanz,



hybridization capture enrichment



= immobilization of target DNA by hybridization with "anchored" complementary oligonucleotides ("baits")



baits designed from reference sequences of target organisms:



Fungi

894 species



Nematodes

49 species



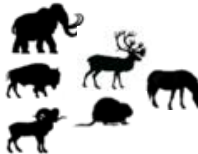
Mites

12 species



Insects

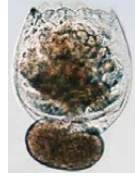
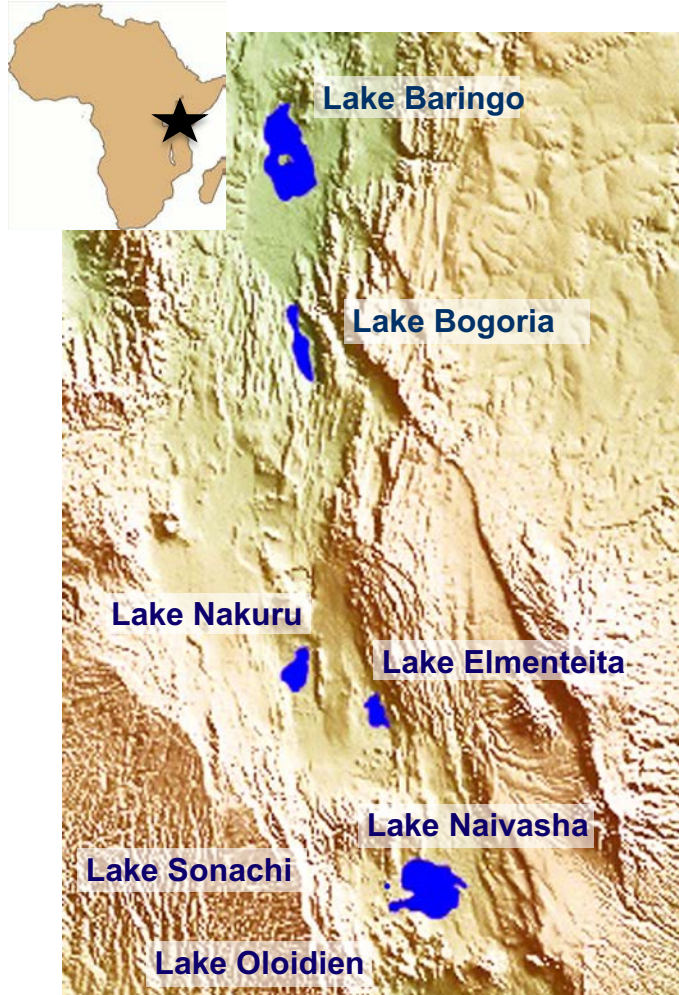
25 species

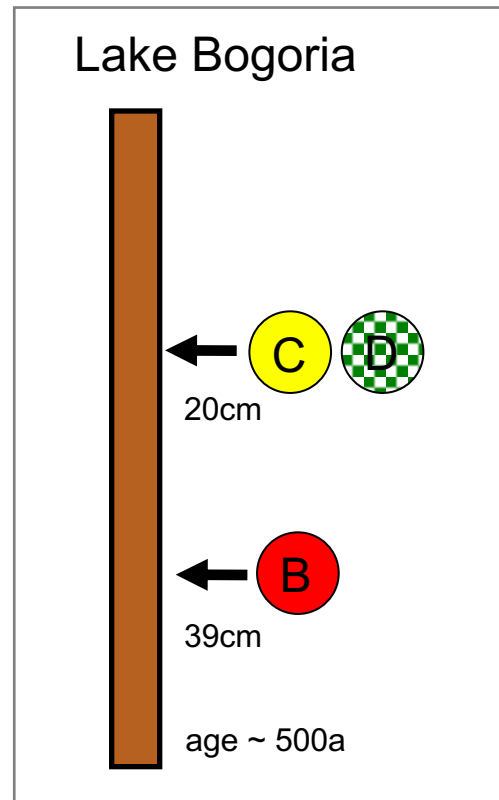
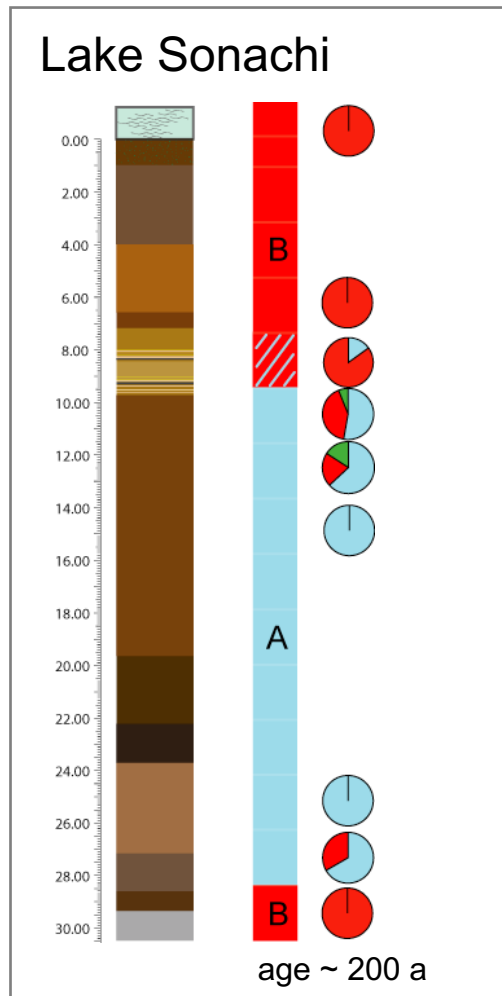
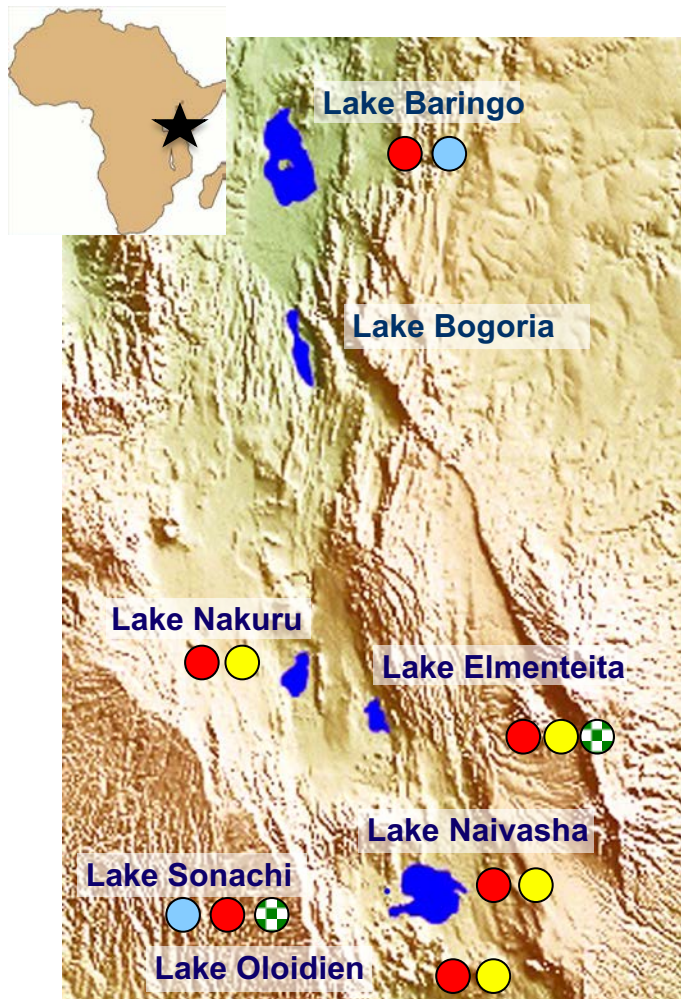


Mammals

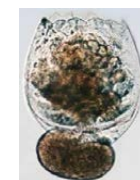
11 species

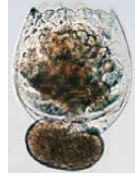
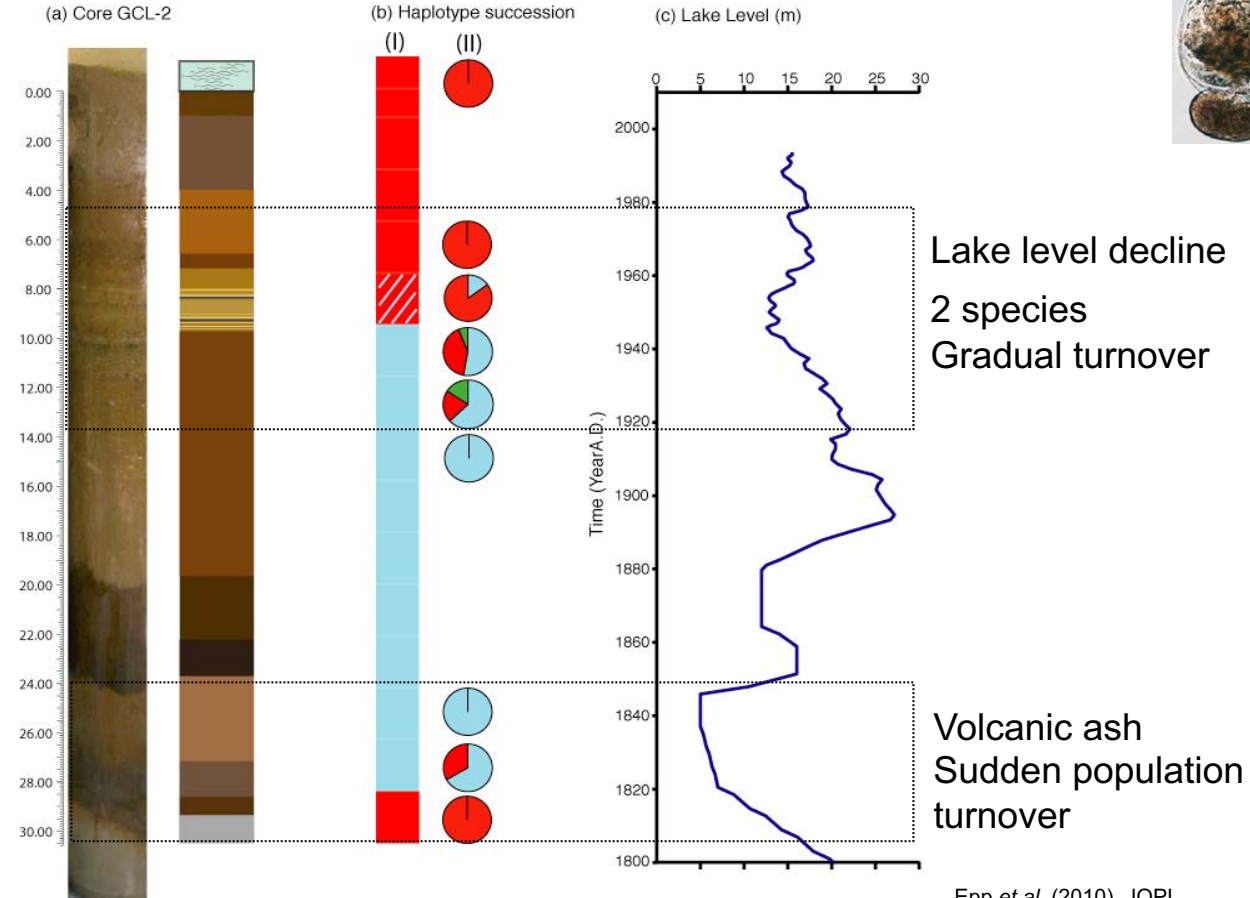
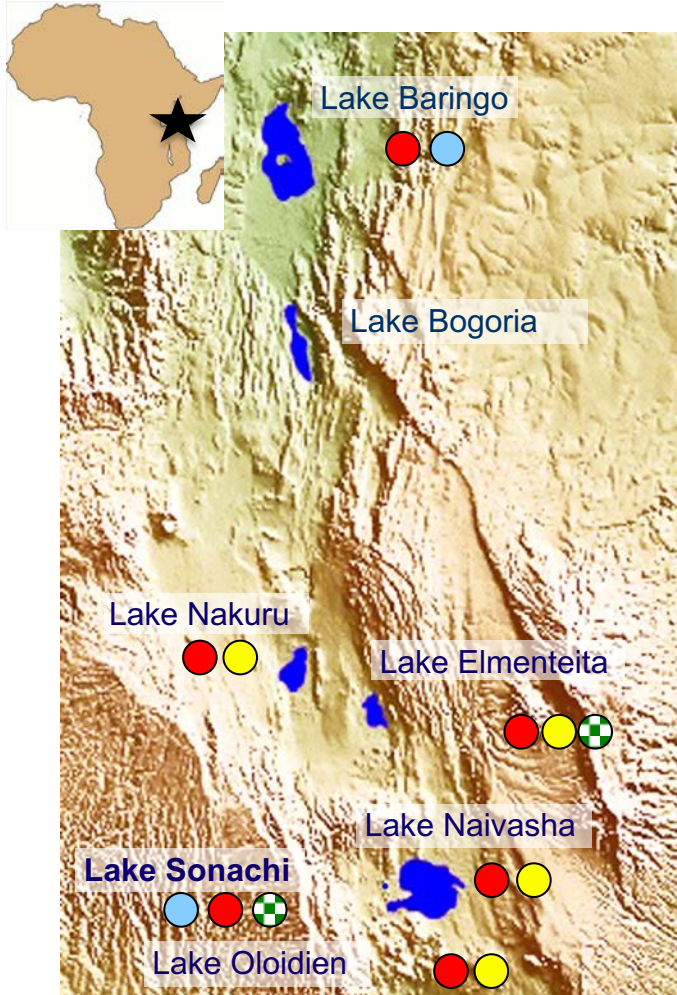
18.000 unique baits





mt DNA haplotypes in distinct layers





Epp *et al.* (2010), JOPL

Lake Constance



Limnological Institute,
University of Konstanz

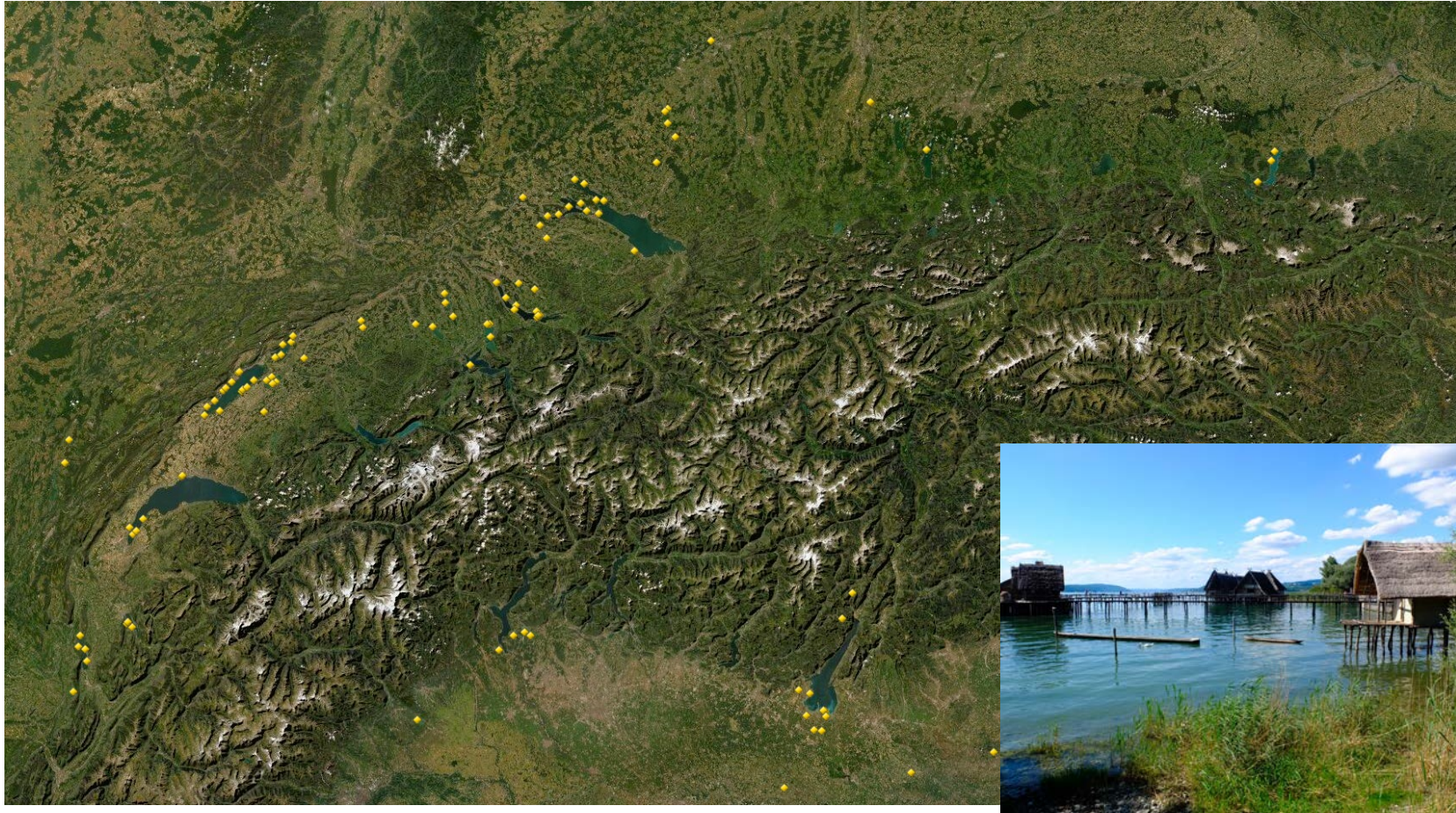


(C) Alexander Böhm

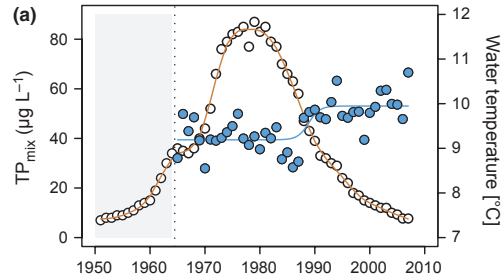
Dynamic postglacial history



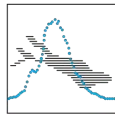
Pile dwellings ~ 7000 – 2500 yrs BP



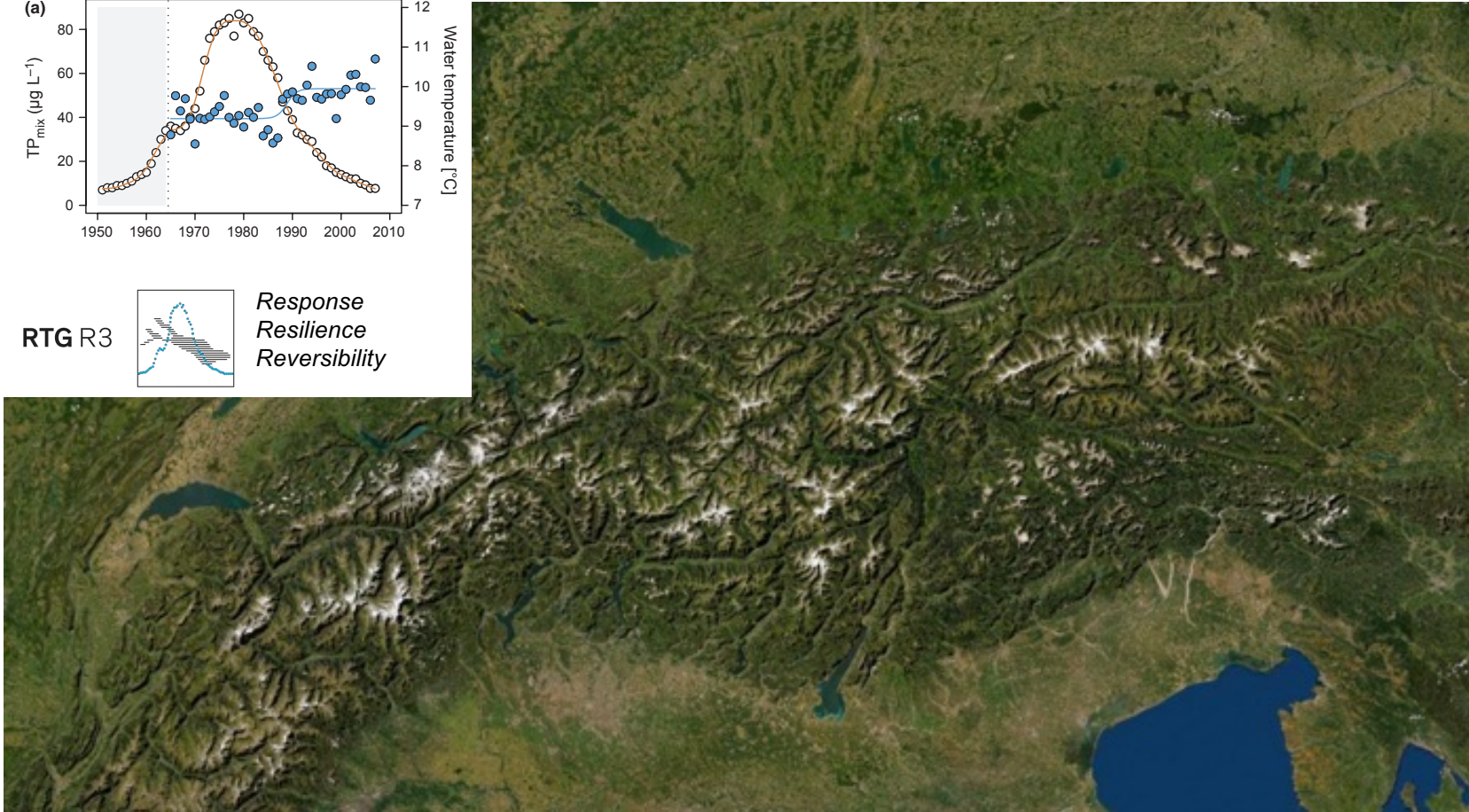
20th century eutrophication



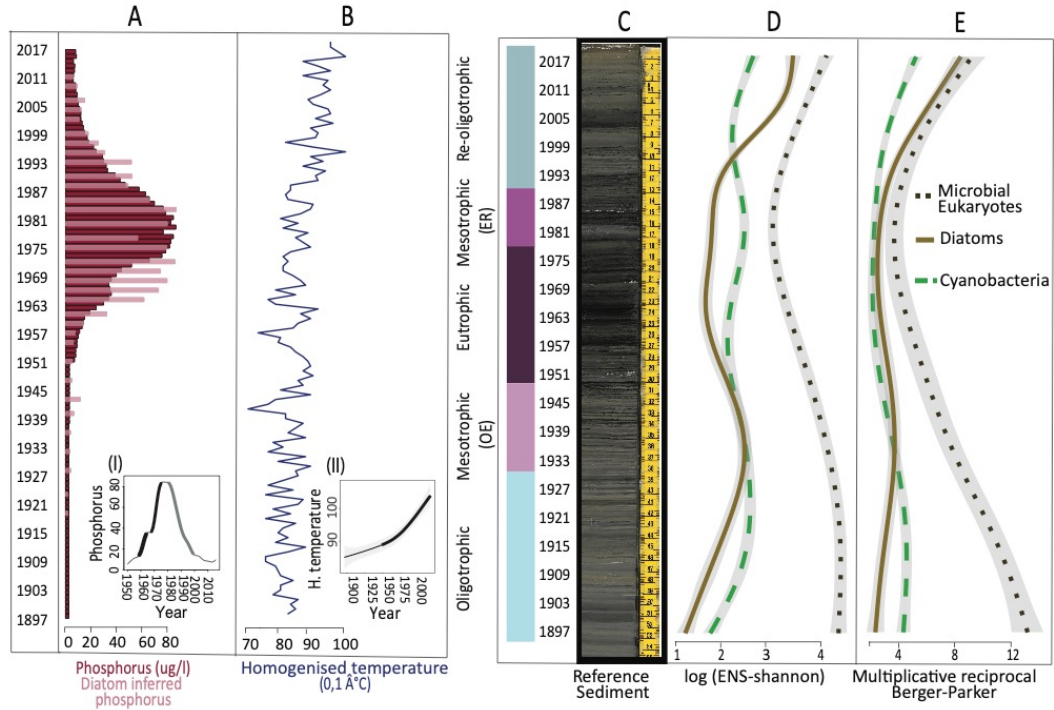
RTG R3



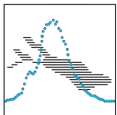
Response
Resilience
Reversibility



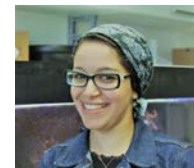
20th century eutrophication



RTG R3

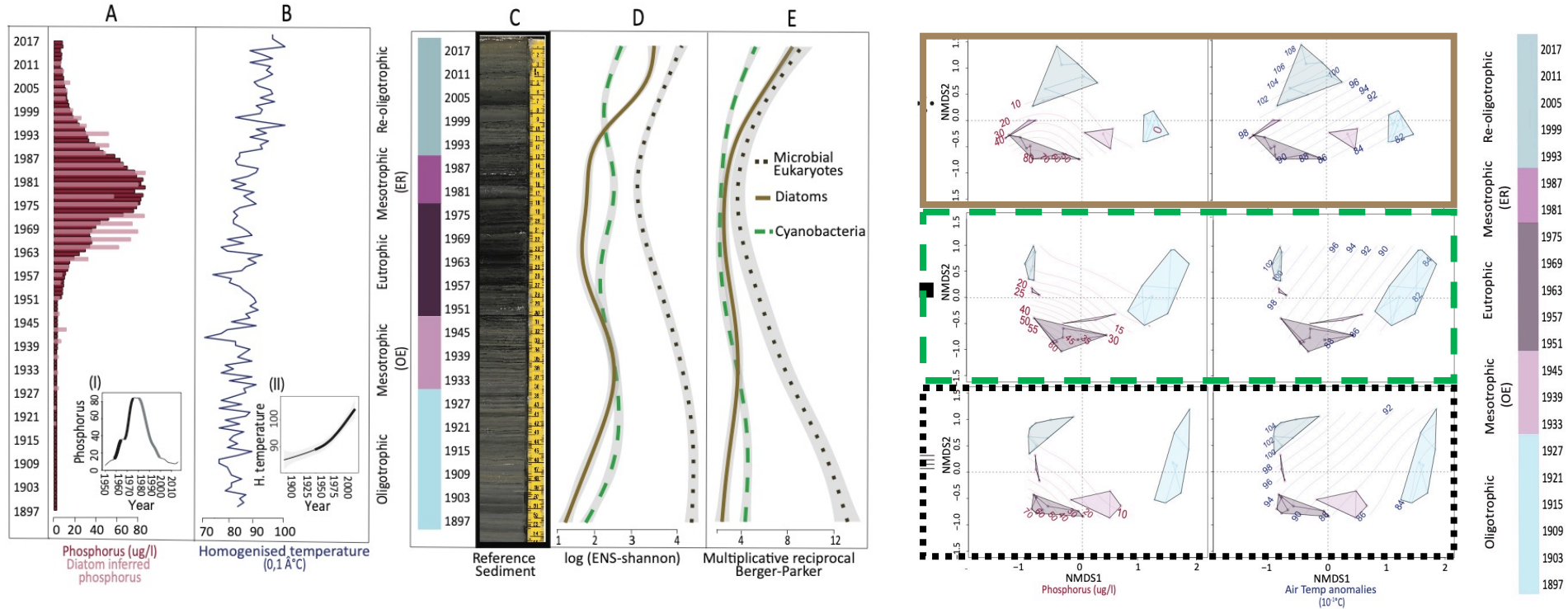


Decline of diversity during eutrophication - reversible

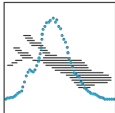


Ibrahim *et al.* 2020
Molecular Ecology

20th century eutrophication



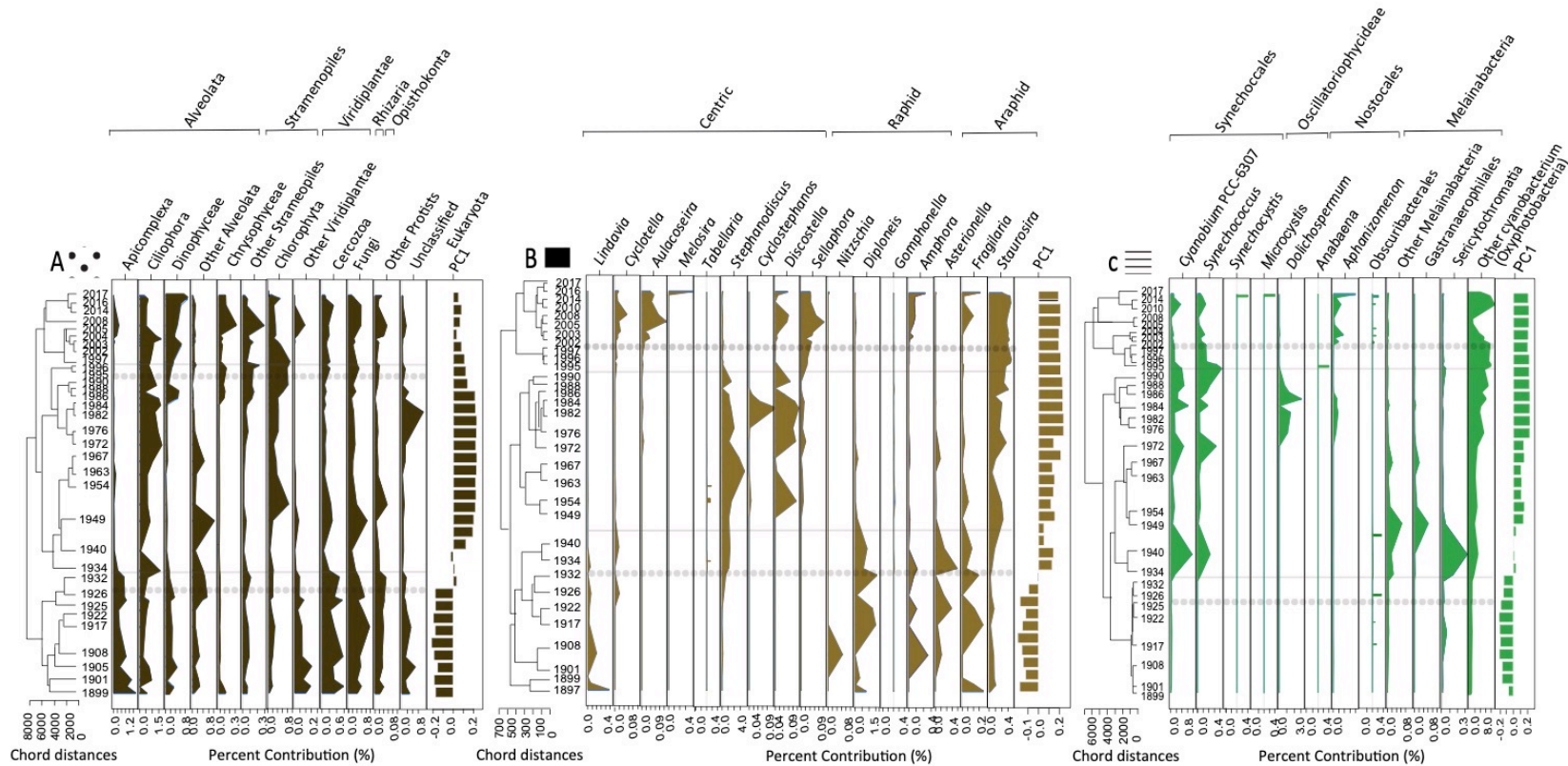
RTG R3



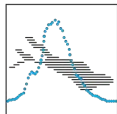
Decline of diversity during eutrophication - reversible
Change of communities on molecular level – not reversible



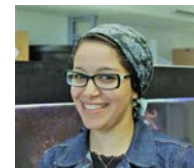
Ibrahim *et al.* 2020
Molecular Ecology



RTG R3



Breakpoint of community change already 1930s/40s
Diatoms seem to be latest – new molecular indicators possible?



Ibrahim et al. 2020
Molecular Ecology

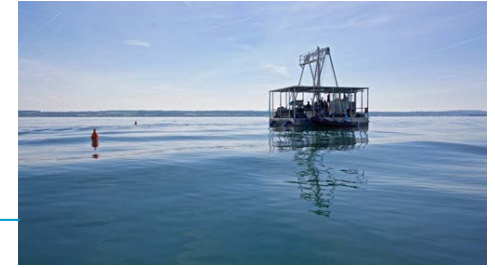
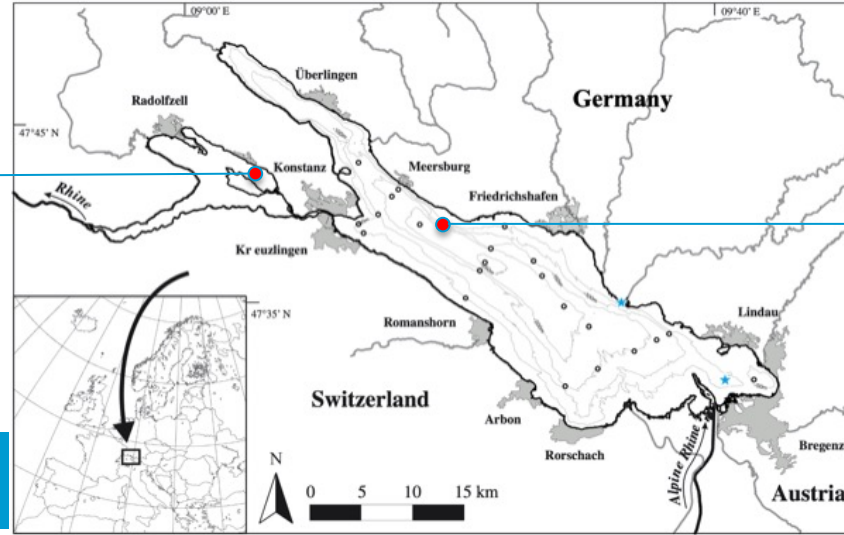


September 2020
- Landesamt für Denkmalschutz



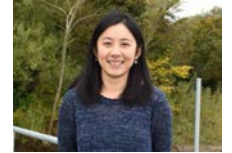
~7 m two sites
~ 11 000 Jahre

Anna Chagas
PhD thesis

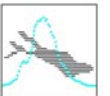


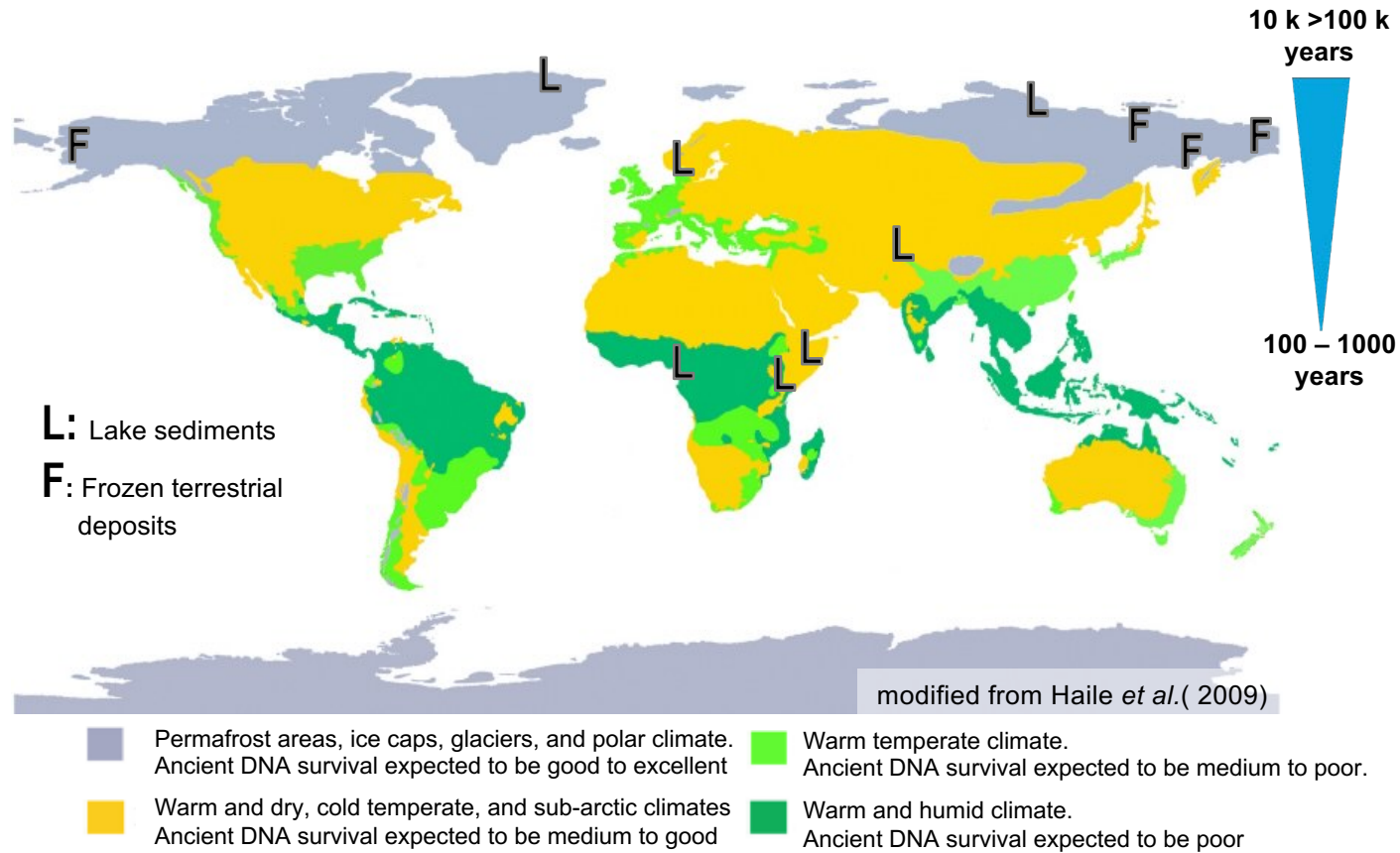
May-June 2019 Hiperorig Coring Campaign
- TU Braunschweig
- Universität Bern
- ISF Langenargen

22 m,
~13 000 Jahre

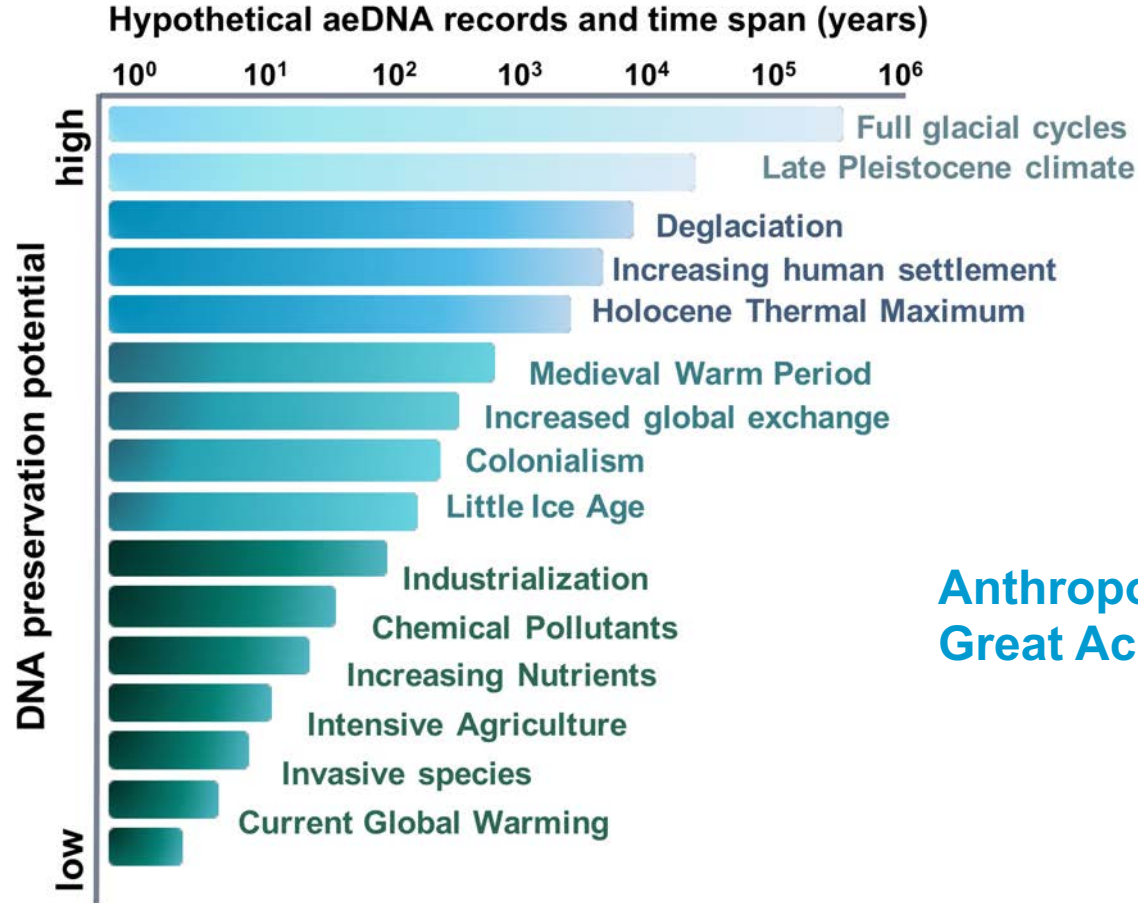


Yi Wang
PhD thesis





Timescales of ,easy‘ analysis vary with climate zones



Natural Baselines

of scientific importance

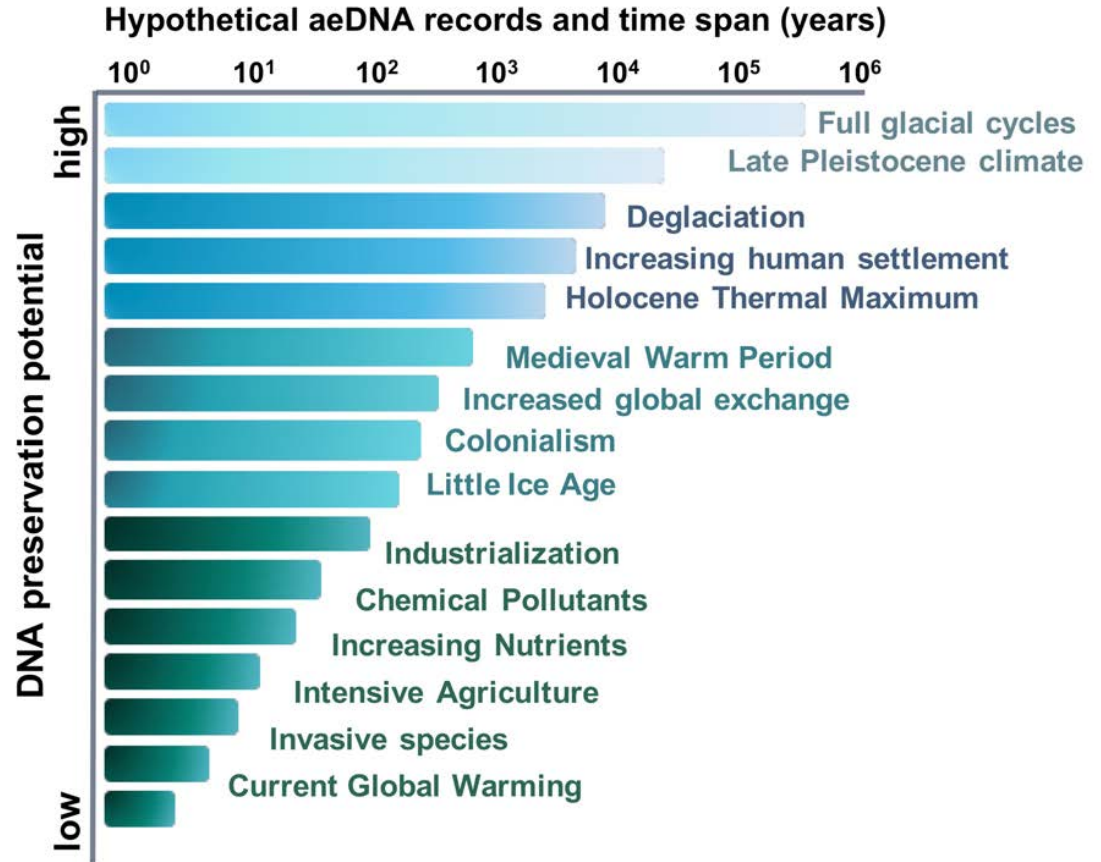
Anthropocene Great Acceleration

*of immediate societal
importance*

Epp 2019, Mol Ecol

Methods are developing

- „Shotgun-Sequencing“, direct sequencing of complete extracts (Pedersen *et al.* 2016, Parducci *et al.* 2019).
- Enrichment techniques besides PCR (Schulte *et al.* 2021, Murchie *et al.* 2021)
- Genomic data (Schulte *et al.* 2021, Lammers *et al.* 2021)
- Reference genomes necessary

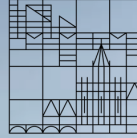


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ALFRED-WEGENER-INSTITUT
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