Paleo-Metagenomics of Late Quaternary Packrat Middens

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Smith College
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AMNH
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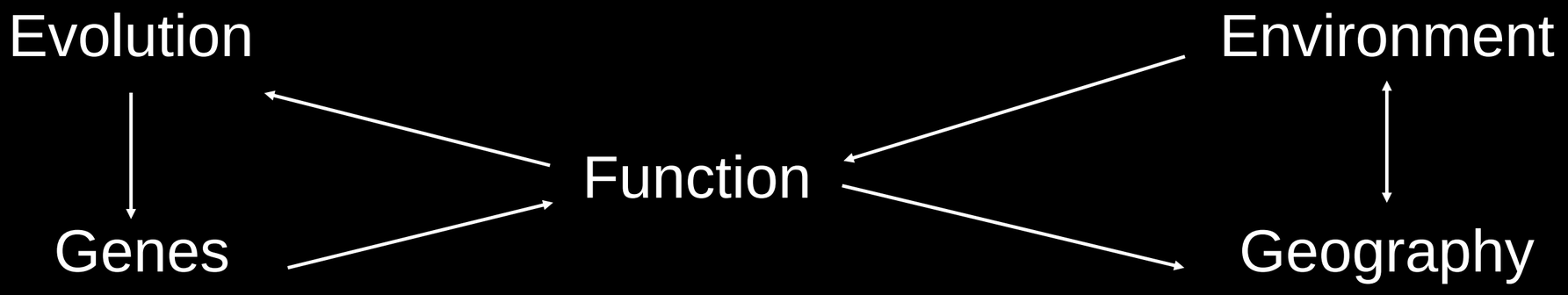
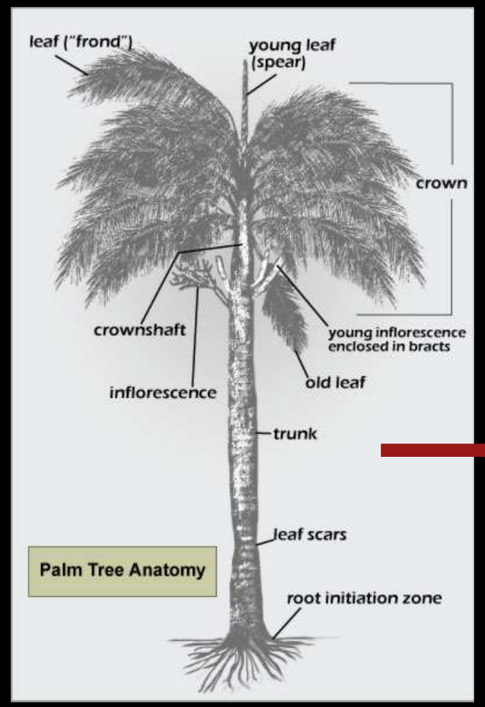
Topics

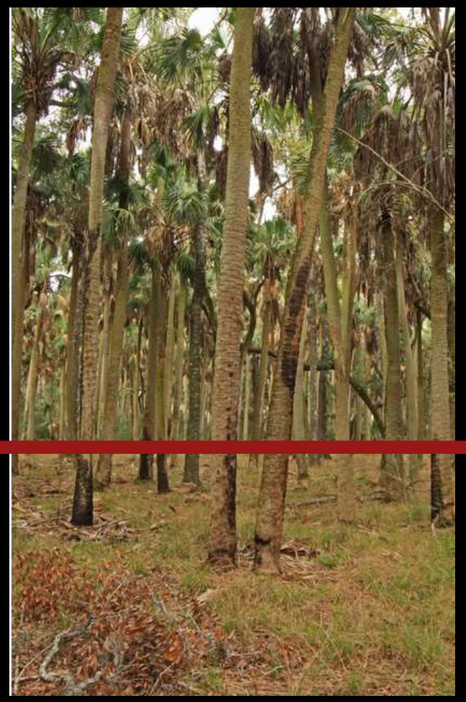
- 1) Packrat middens as paleoecological and paleoclimatological record
- 2) Ancient DNA profiling of fossil packrat middens
- 3) Current teaching/research topics

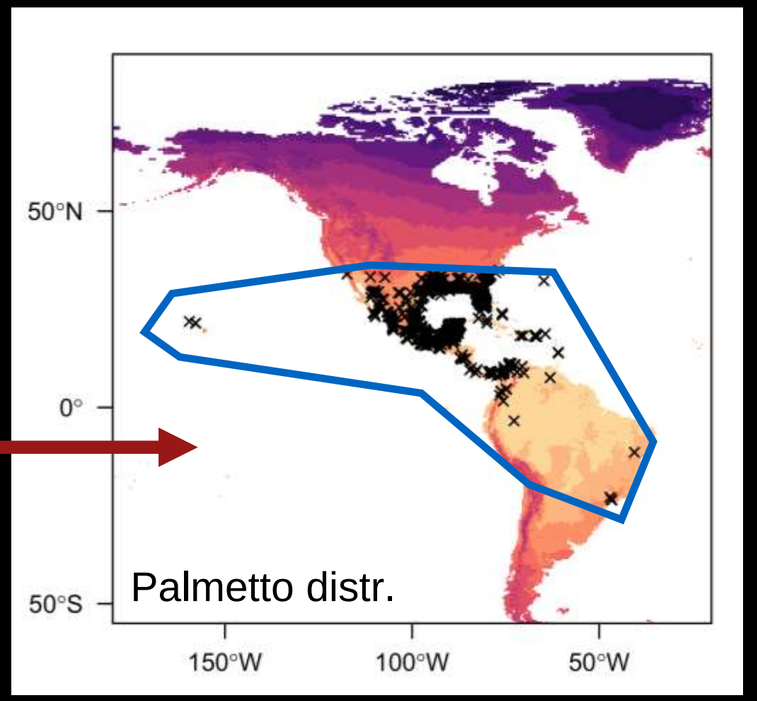
What can plant communities tell us about climate?

Ecological Feedback:

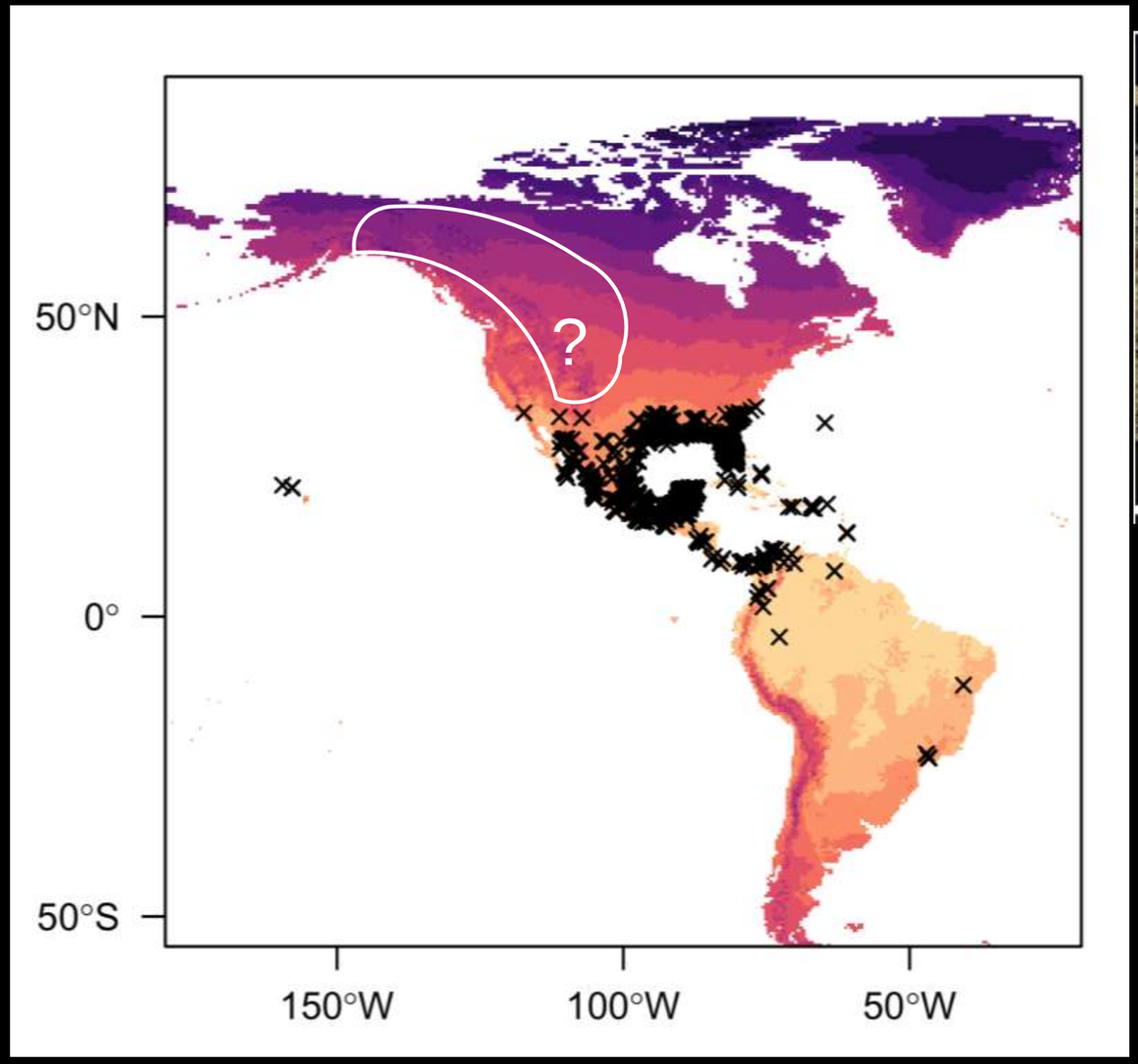








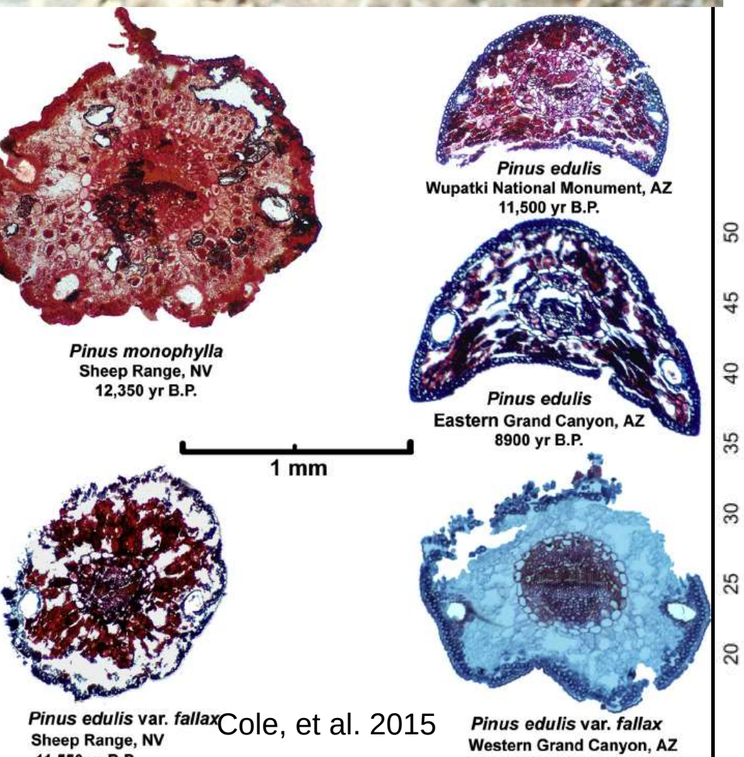
Extrapolation in the Fossil Record



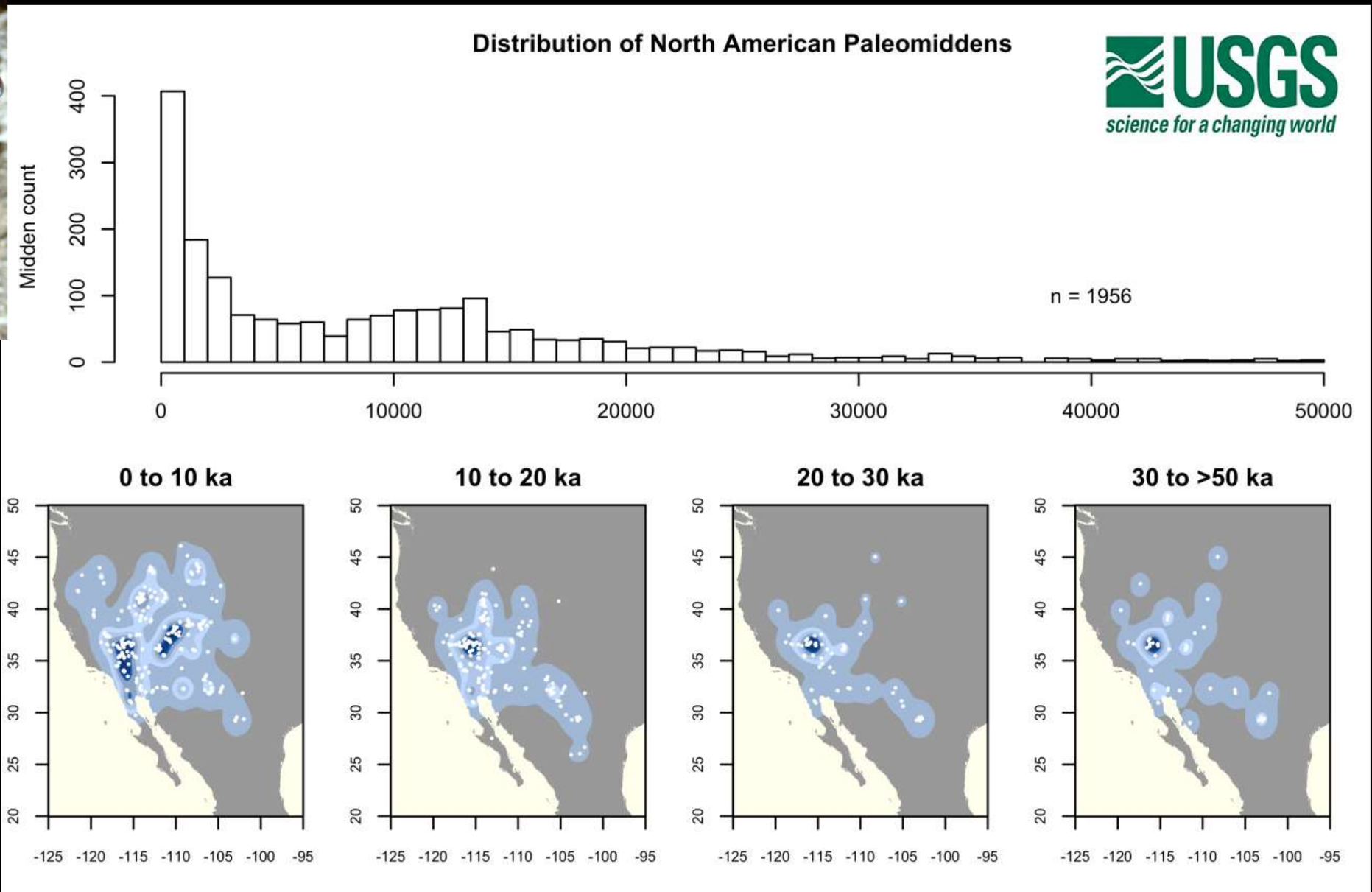
Packrats

Google image search: “packrat nest”

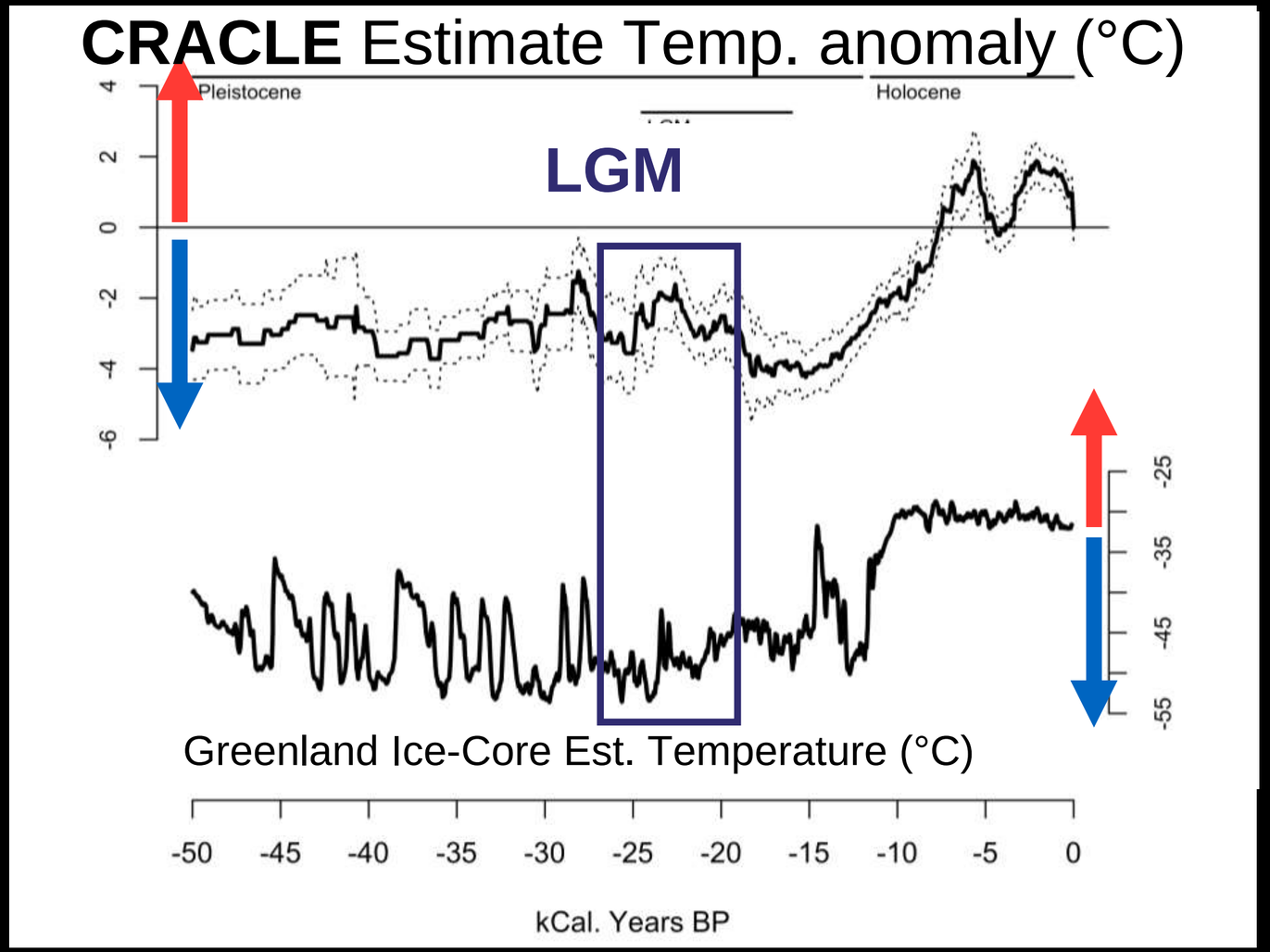
Late Quaternary Packrat (*Neotoma* spp.) midden macrofossils



Cole, et al. 2015



Harbert & Nixon. 2018. **Quantitative Late Quaternary Climate Reconstruction from Plant Macrofossil Communities in Western North America**



Thousand years before present

https://www.openquaternary.com/articles/10.5334/oq.46/

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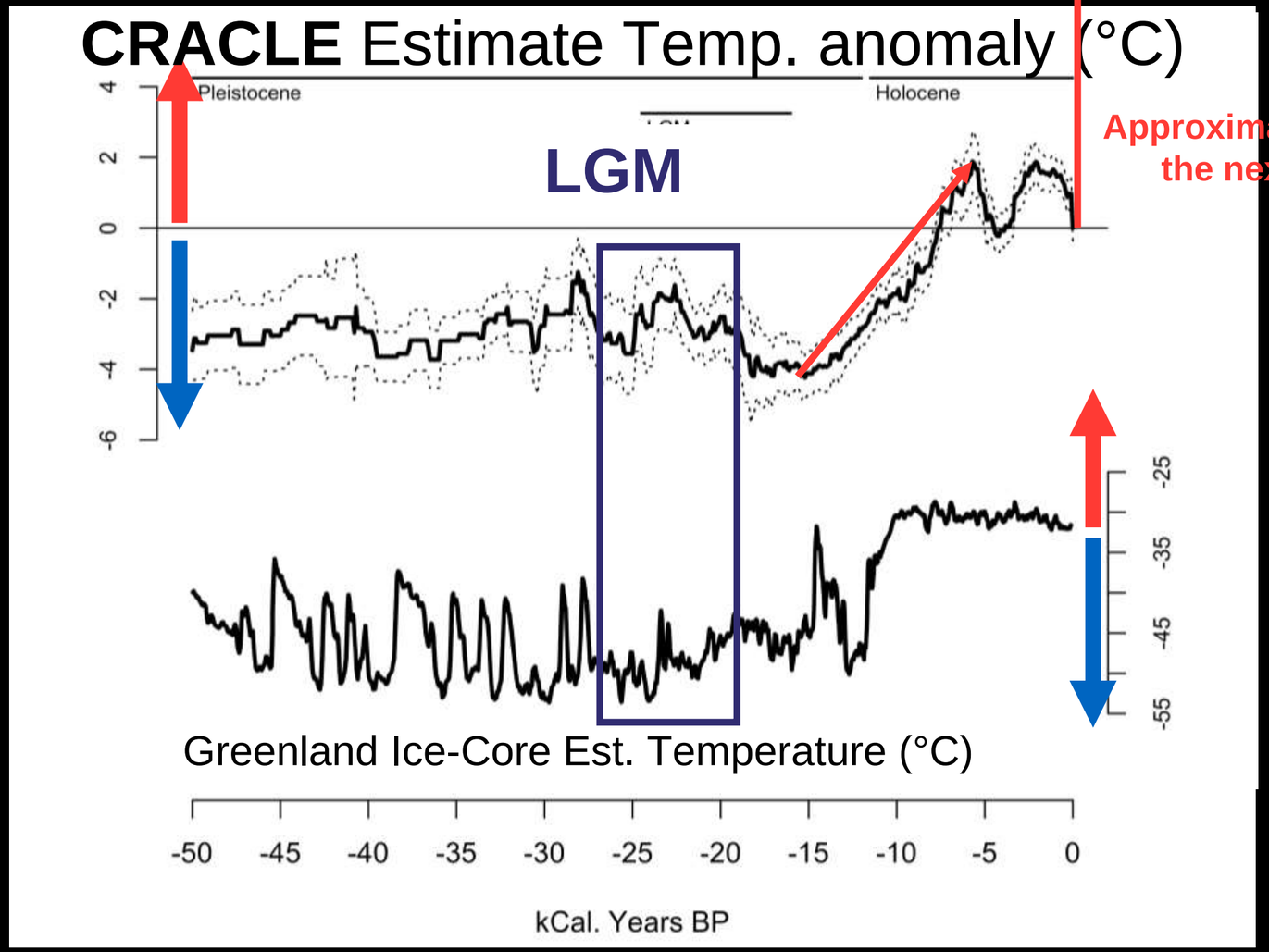


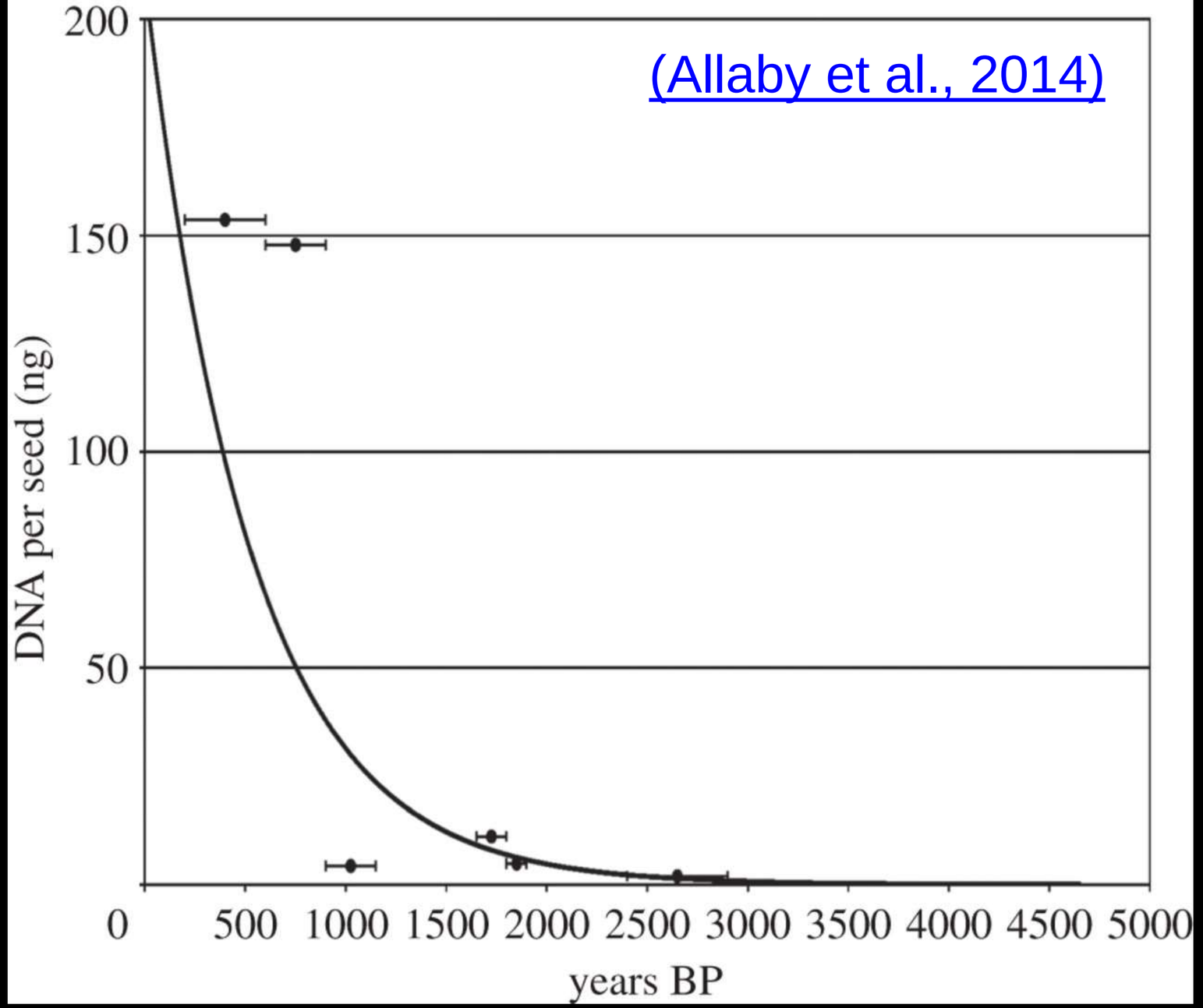
Thousand years before present

https://www.openquaternary.com/articles/10.5334/oq.46/

Coming Soon:

- CRACLE R package:
  - cRacle (https://github.com/rsh249/cRacle.git)
  - R implementation of the CRACLE paleoclimate estimation algorithm and associated functions for data access and visualization.

Ancient DNA



DNA content of desiccated barley seeds over time in Qasr Ibrim, North Africa.

- DNA from plants and insects dating to >500,000 years ago!

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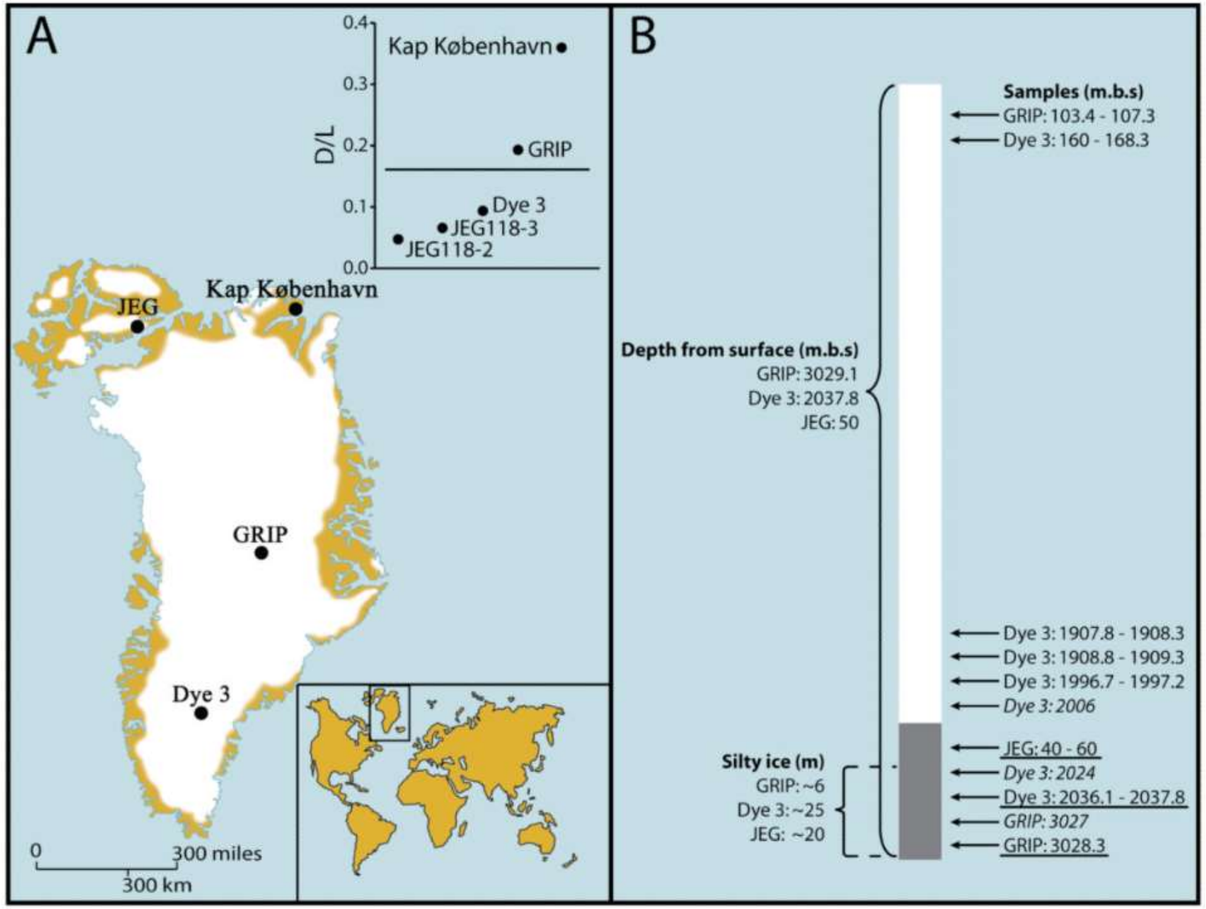
Ancient Biomolecules from Deep Ice Cores Reveal a Forested Southern Greenland

Eske Willerslev[1,*], Enrico Cappellini[2], Wouter Boomsma[3], Rasmus Nielsen[4], Martin B. Hebsgaard[1], Tina B. Brand[1], Michael Hofreiter[5], Michael Bunce[6,7], Hendrik N. Poinar[7], Dorthe Dahl-Jensen[8], Sigfus Johnsen[8], Jørgen Peder Steffensen[8], Ole Bennike[9], Jean-Luc Schwenninger[10], Roger Nathan[10], Simon Armitage[11], Cees-Jan de Hoog[12], Vasily Alfimov[13], Marcus Christl[13], Juerg Beer[14], Raimund Muscheler[15], Joel Barker[16], Martin Sharp[16], Kirsty E.H. Penkman[2], James Haile[17], Pierre Taberlet[18], M. Thomas P. Gilbert[1], Antonella Casoli[19], Elisa Campani[19], and Matthew J. Collins[2]

[1]Centre for Ancient Genetics, University of Copenhagen, Denmark [2]BioArch, Departments of



Packrat midden aDNA

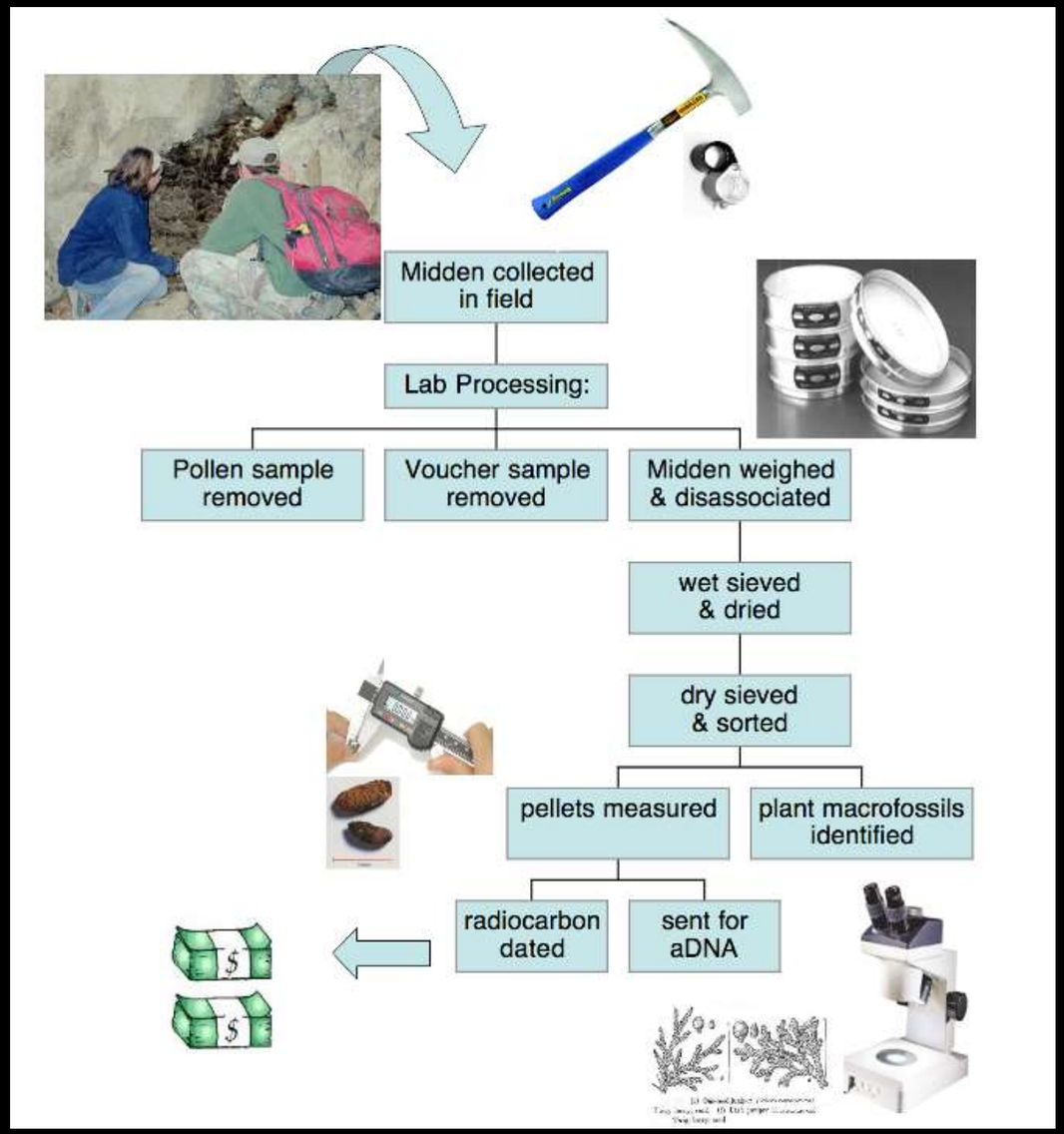


Photo Credit: J. Betancourt, K. Rylander (USGS)

Photo Credit: J. Betancourt, K. Rylander (USGS)

Packrat midden aDNA

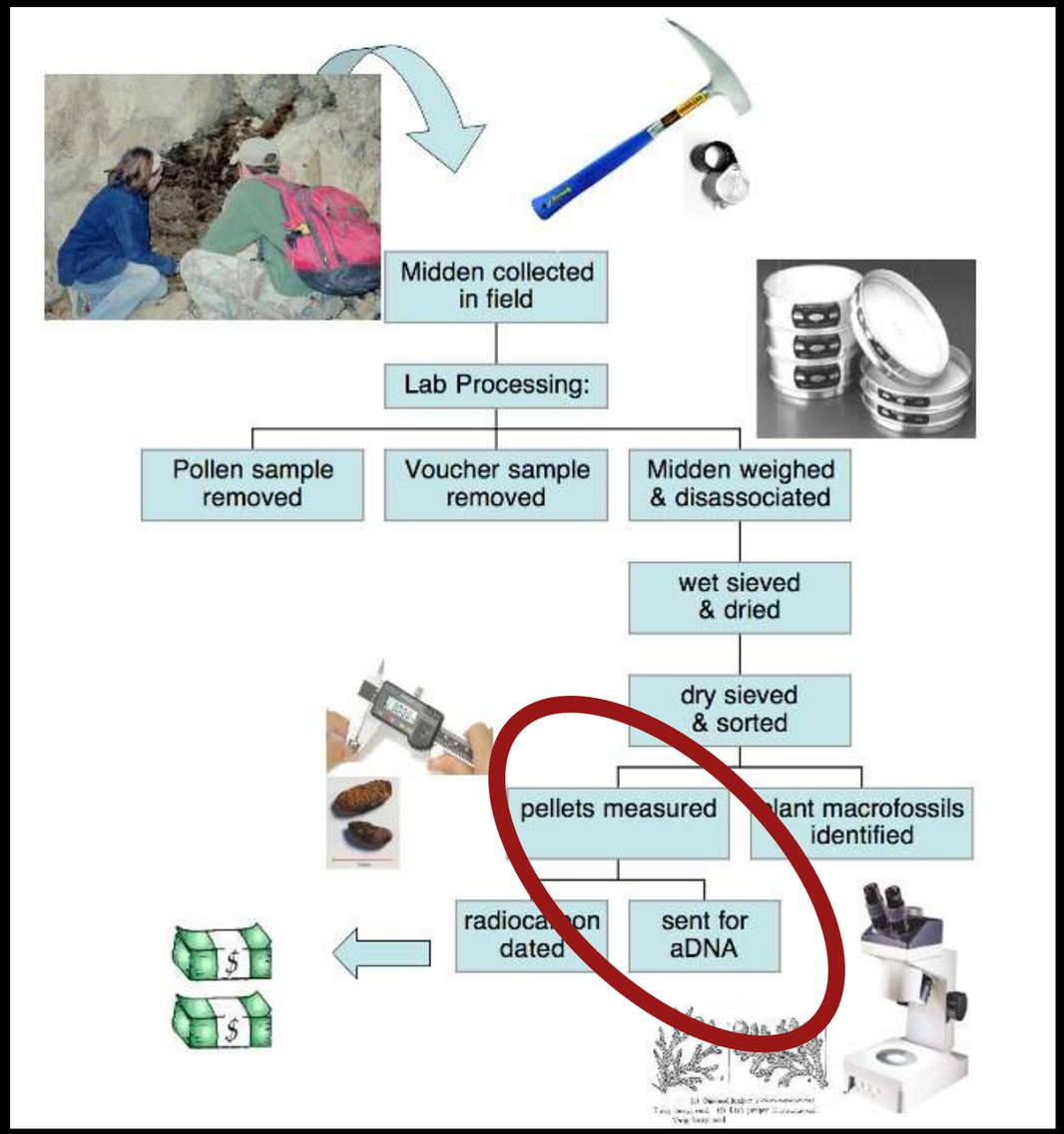
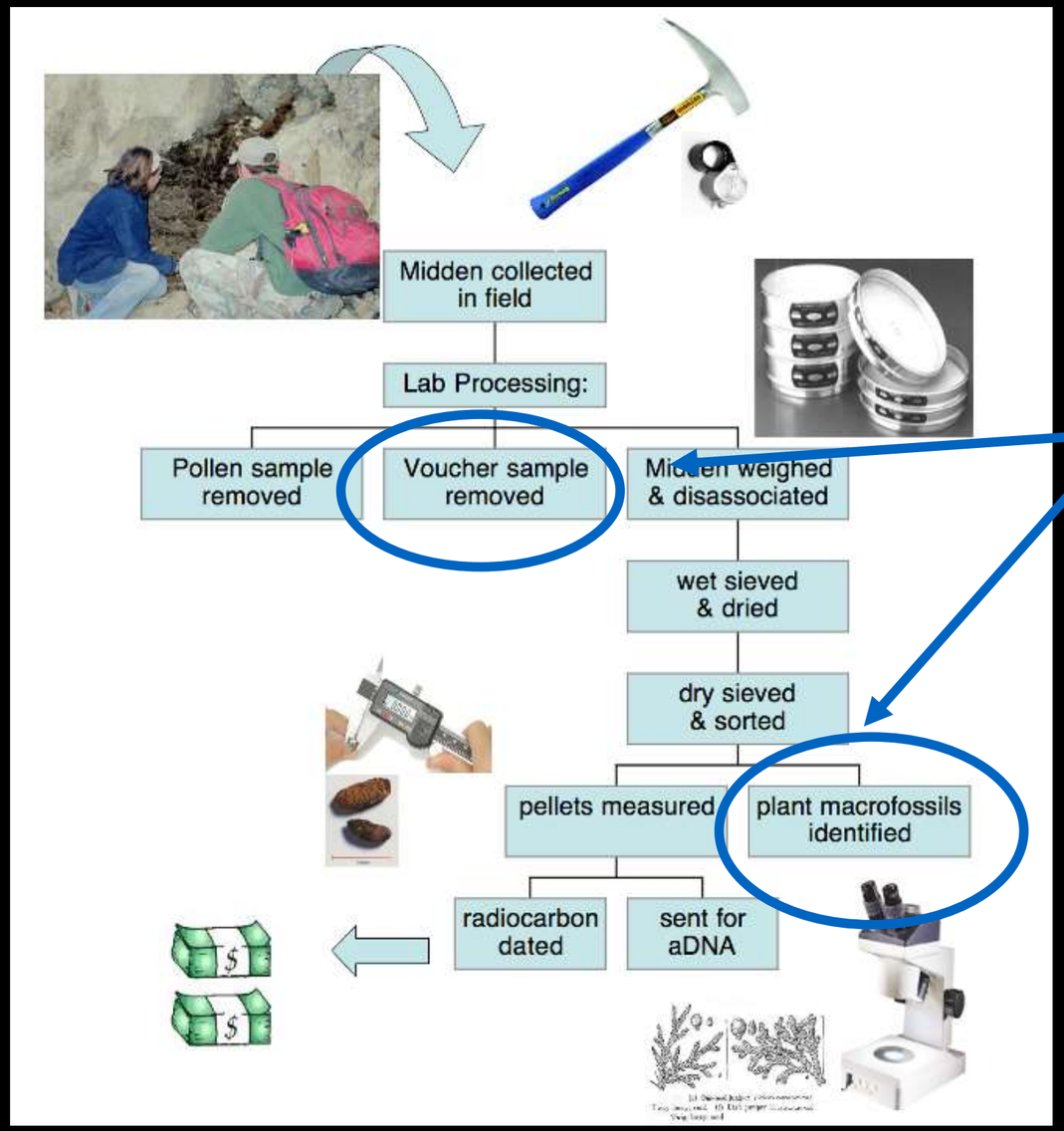


Photo Credit: J. Betancourt, K. Rylander (USGS)

Packrat midden aDNA



Need to optimize methods for extraction and analysis of aDNA from plant material

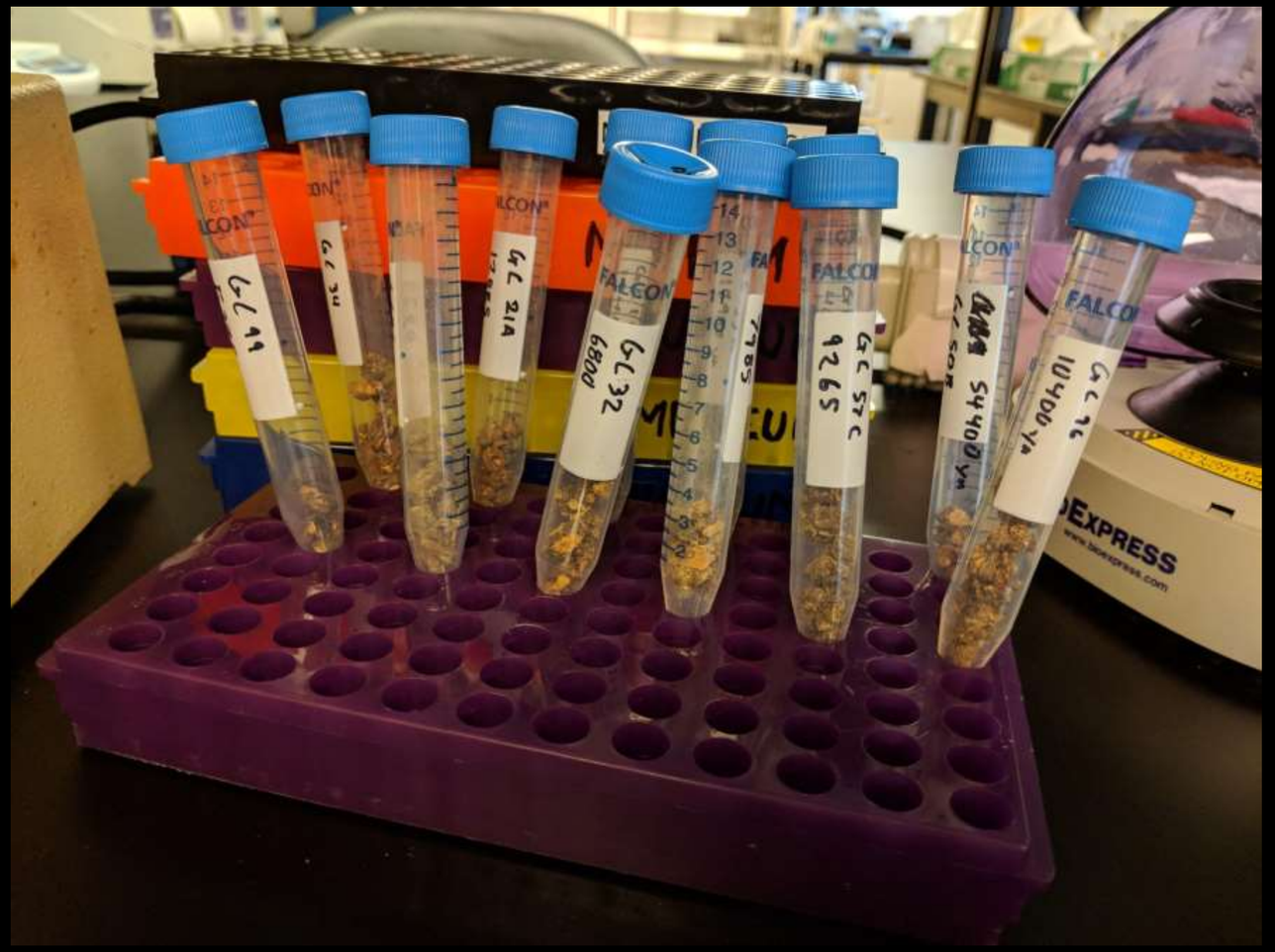
Photo Credit: J. Betancourt, K. Rylander (USGS)

City of Rocks
(COR)

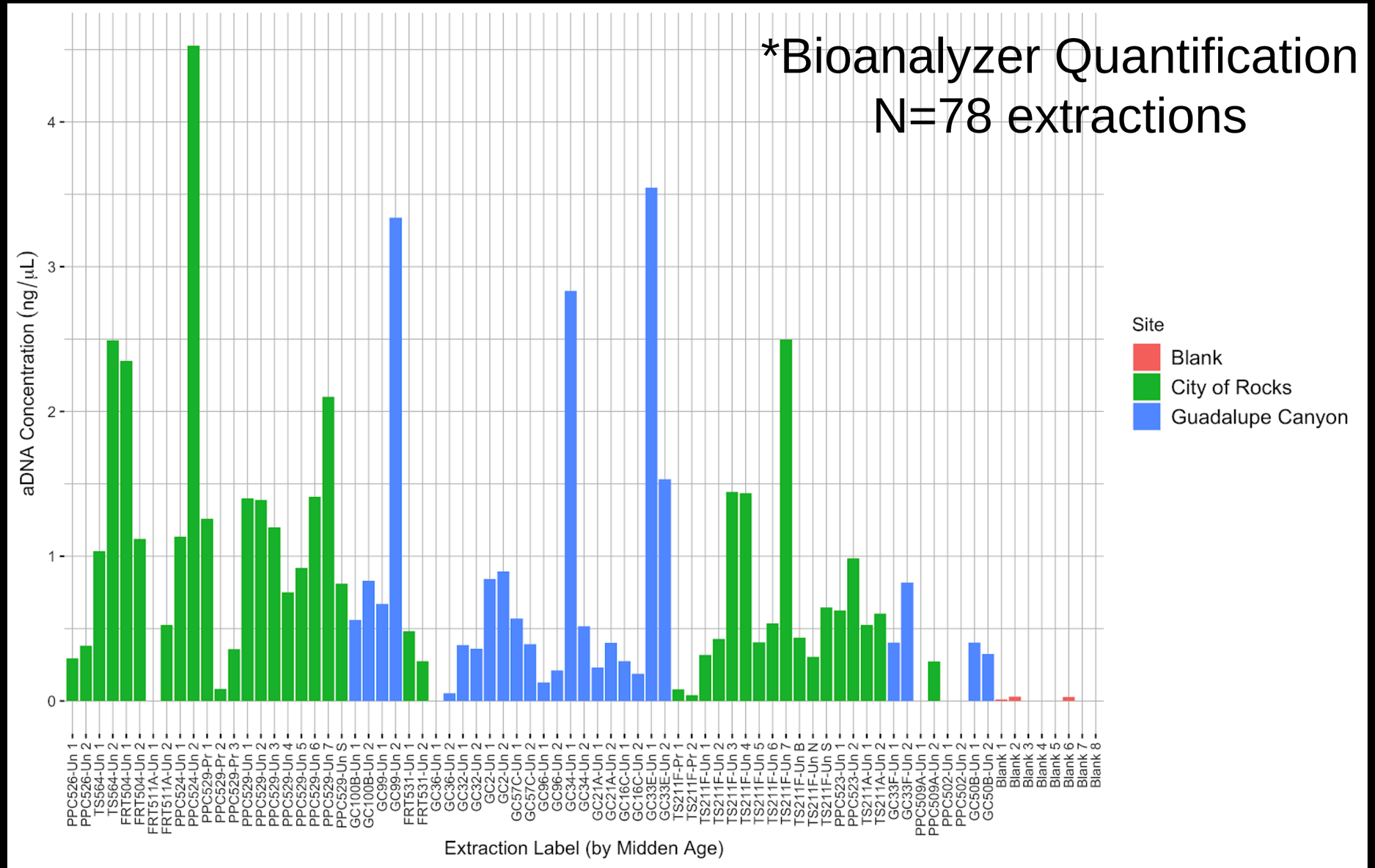
Guadalupe
Canyon
(GC)

aDNA Extraction Methods

- DNeasy PowerSoil® Kit protocol
- Measured resulting DNA concentration
  - Qubit® 2.0
  - Agilent 2100 Bioanalyzer



Ancient midden DNA quantification

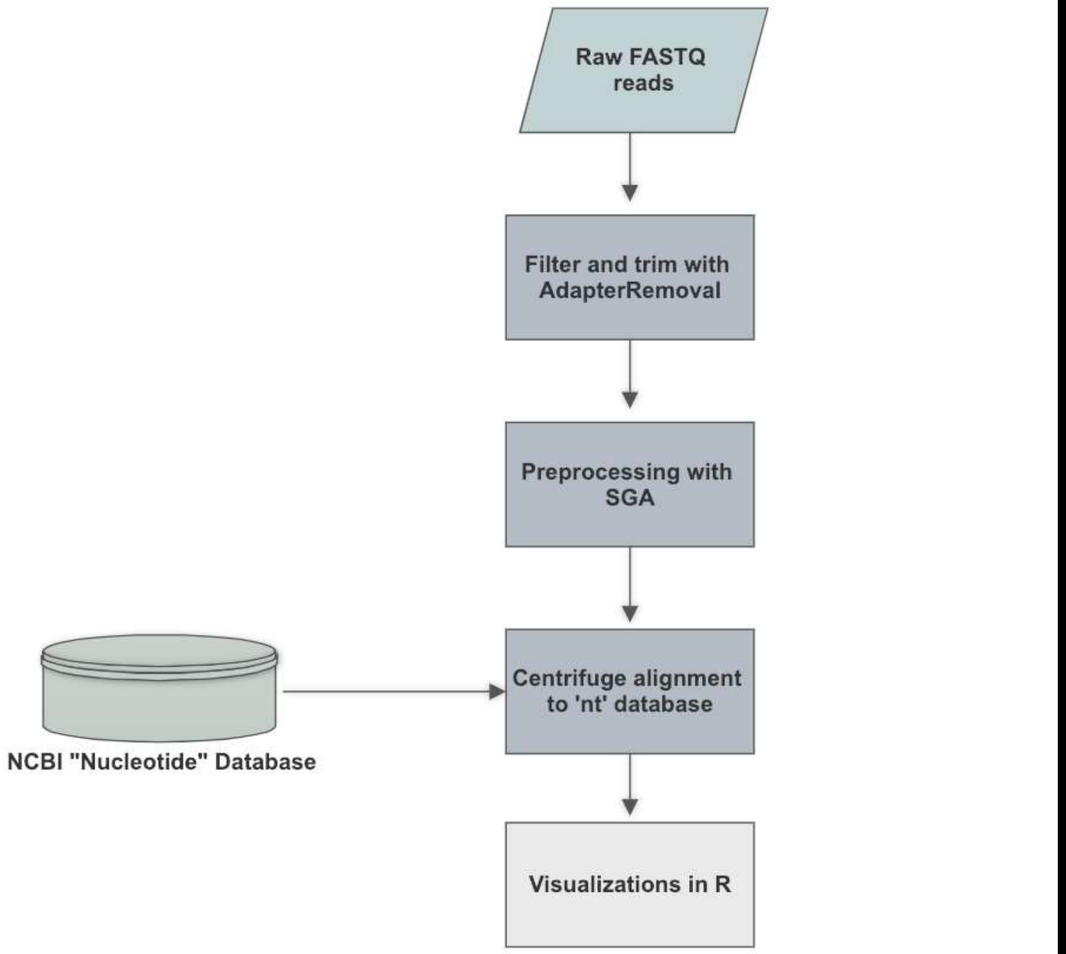


Sequencing

- Shotgun/Whole Genome
- Illumina HiSeq 2500, 2x125bp reads
- 22 samples submitted → 11 successful libraries
- ~30 – 60 million reads per sample

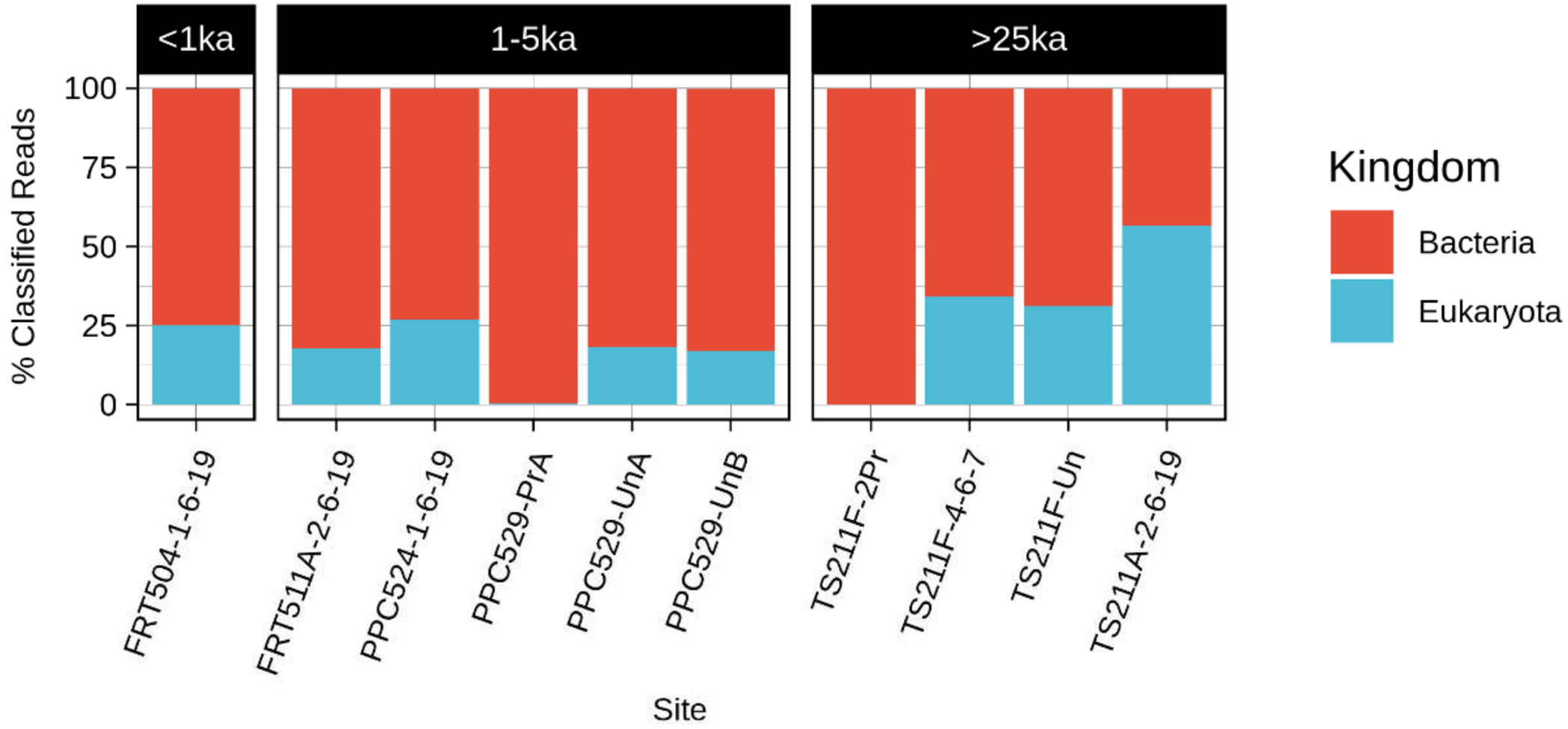
Metagenomics

Pipeline

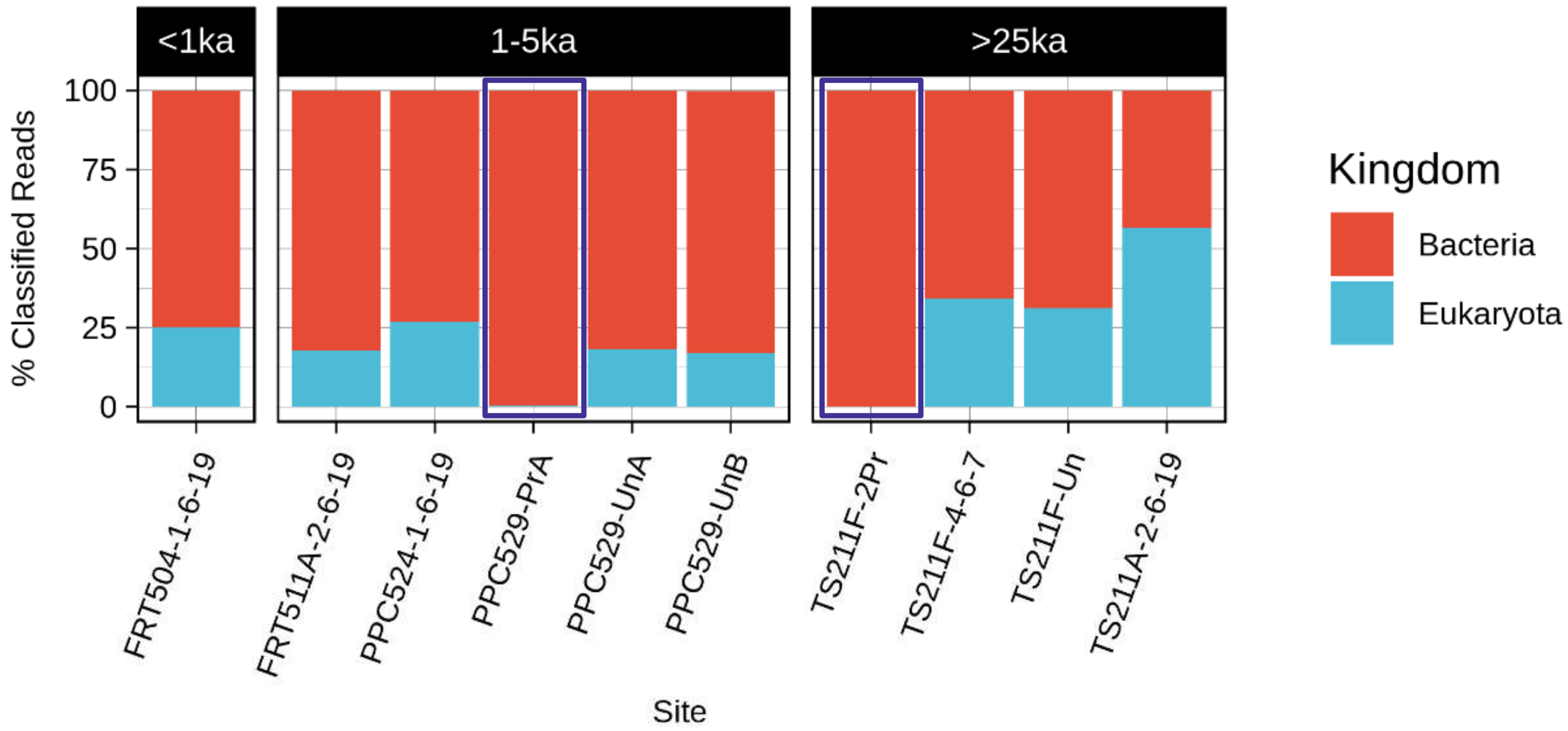


- Input: Raw Illumina ‘fastq’ files
- Data: HiSeq 2500, 2x125bp
- Output: Taxonomic classification of reads

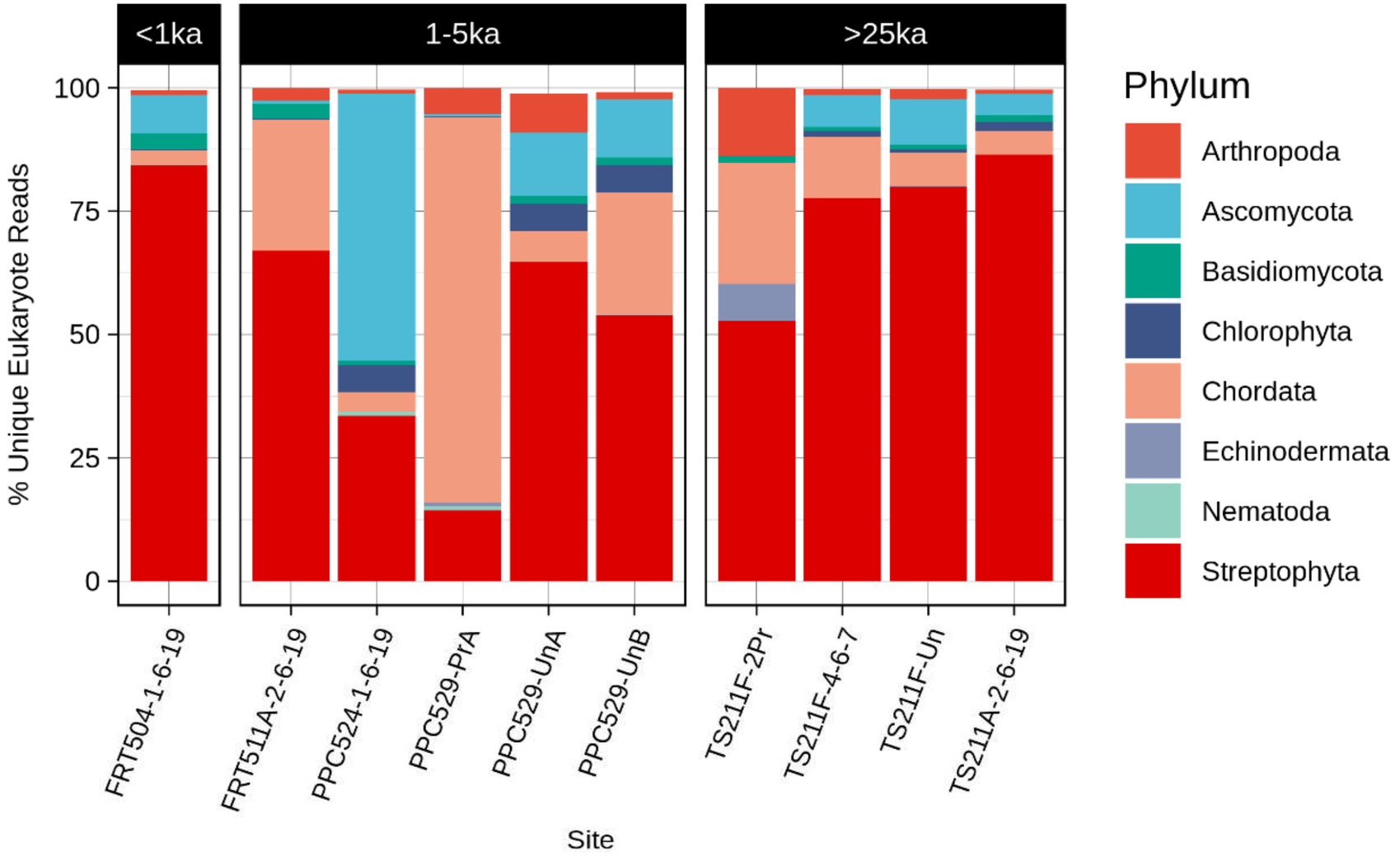
Taxonomic Classification



Taxonomic Classification



Eukaryotes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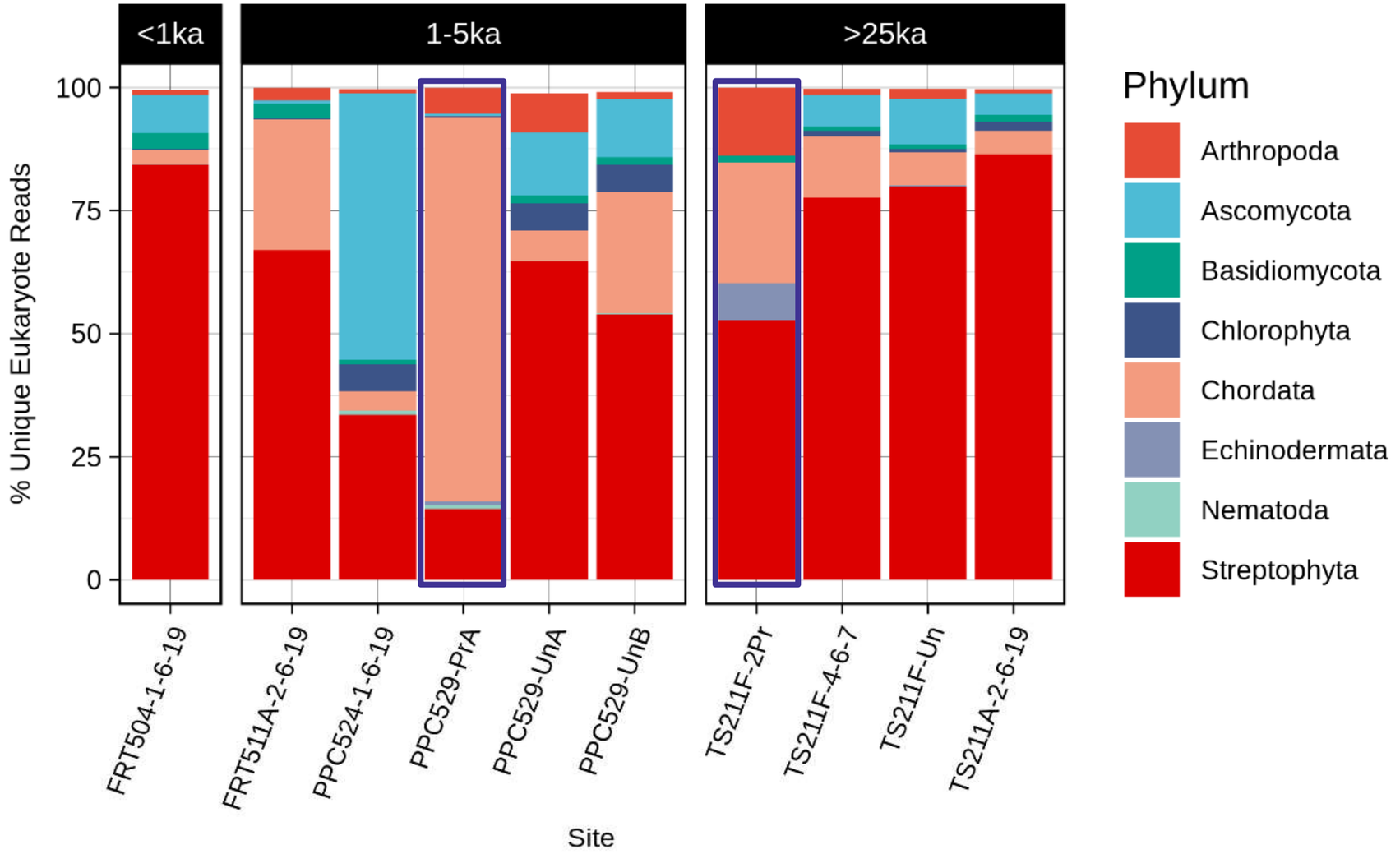
>25ka
% Unique Eukaryote Reads
100
75
50
25
0
FRT504-1-6-19
FRT511A-2-6-19
PPC524-1-6-19
PPC529-PrA
PPC529-UnA
PPC529-UnB
TS211F-2Pr
TS211F-4-6-7
TS211F-Un
TS211A-2-6-19
Site
Phylum
Arthropoda
Ascomycota
Basidiomycota
Chlorophyta
Chordata
Echinodermata
Nematoda
Streptophyta

Eukaryotes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1-5ka
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% Unique Eukaryote Reads
100
75
50
25
0
FRT504-1-6-19
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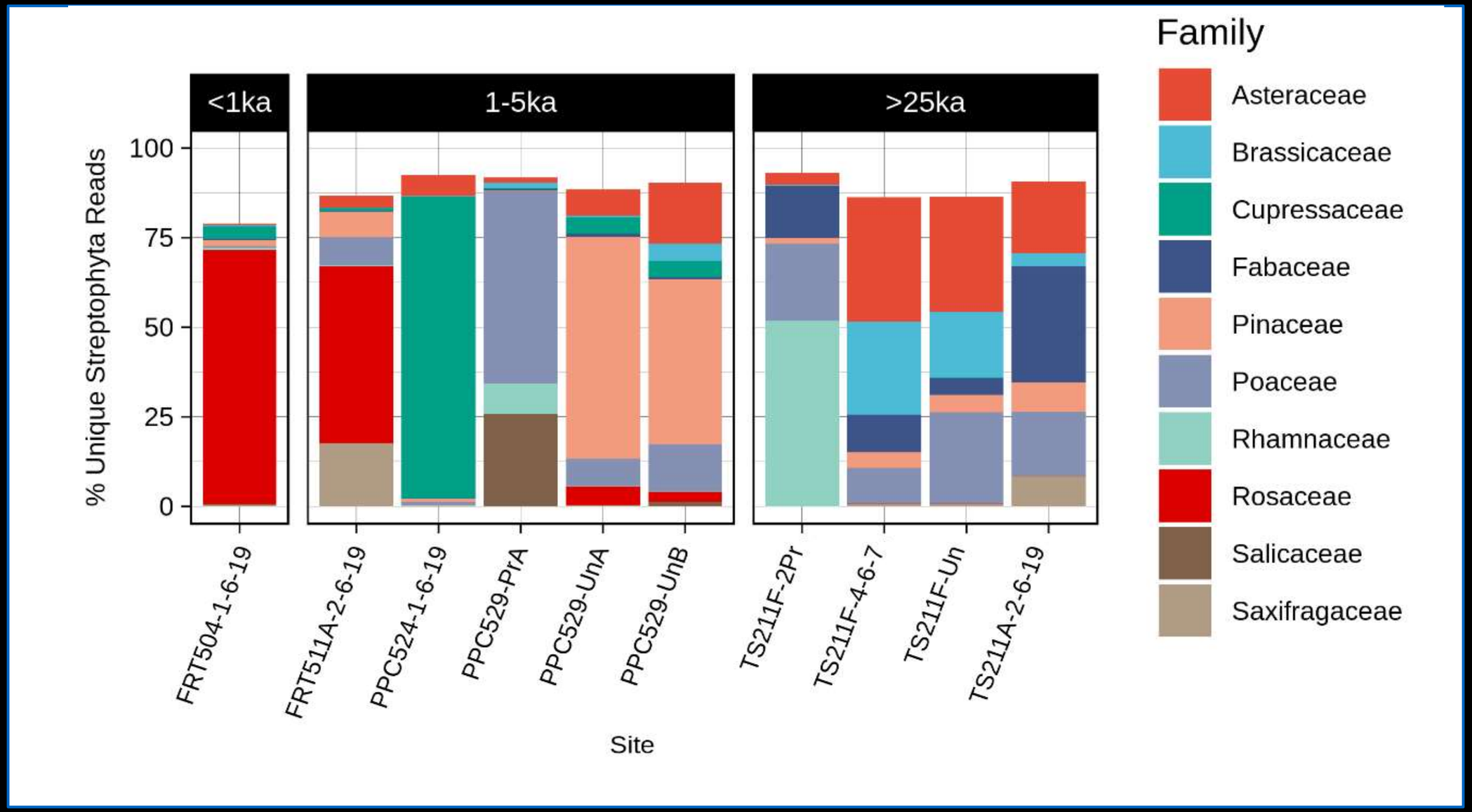
PPC524-1-6-19
PPC529-PrA
PPC529-UnA
PPC529-UnB
TS211F-2Pr
TS211F-4-6-7
TS211F-Un
TS211A-2-6-19
Site
Phylum
Arthropoda
Ascomycota
Basidiomycota
Chlorophyta
Chordata
Echinodermata
Nematoda
Streptophyta

Plants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1-5ka
>25ka
% Unique Streptophyta Reads
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75
50
25
0
FRT504-1-6-19
FRT511A-2-6-19
PPC524-1-6-19
PPC529-PrA
PPC529-UnA
PPC529-UnB
TS211F-2Pr
TS211F-4-6-7
TS211F-Un
TS211A-2-6-19
Site
Family
Asteraceae
Brassicaceae
Cupressaceae
Fabaceae
Pinaceae
Poaceae
Rhamnaceae
Rosaceae
Salicaceae
Saxifragaceae

Hints of A Changing Ecosystem

3,260 year-old midden

Top Plant Genera
Based on aDNA
Abundance

Pinus

Triticum

Diplostephium

Juniperus

Cercocarpus

28,460 year old midden

Top Plant Genera
Based on aDNA
Abundance

Triticum

Diplostephium

Lupinus

Poa

Artemisia

Images: nps.gov, en.wikipedia.org

Still working on:

- Amplicon Sequencing comparison
- Analysis of DNA damage patterns → Attempt to confirm ancient origins
- Evaluation of non-plant data

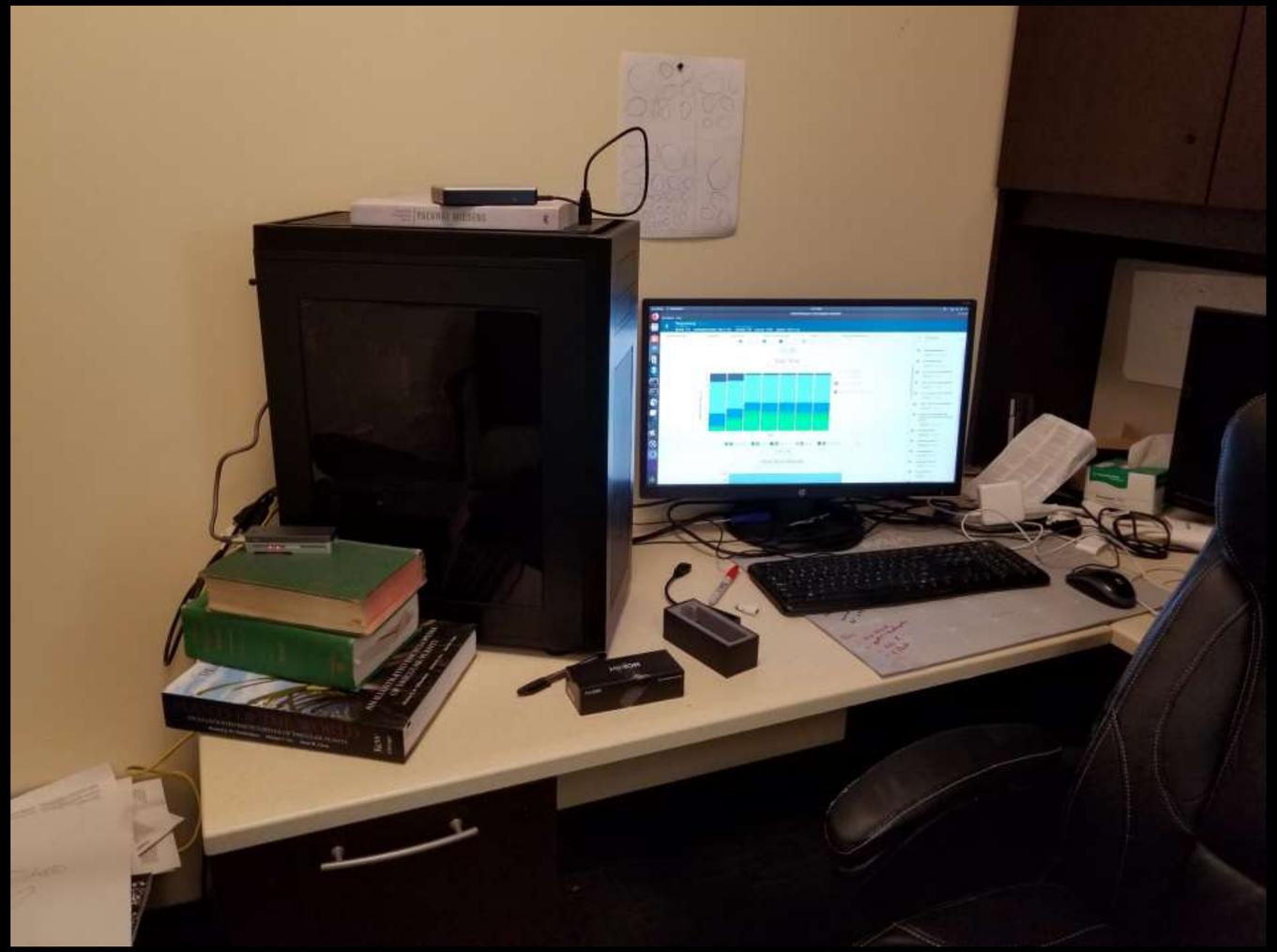
Current teaching/research topics

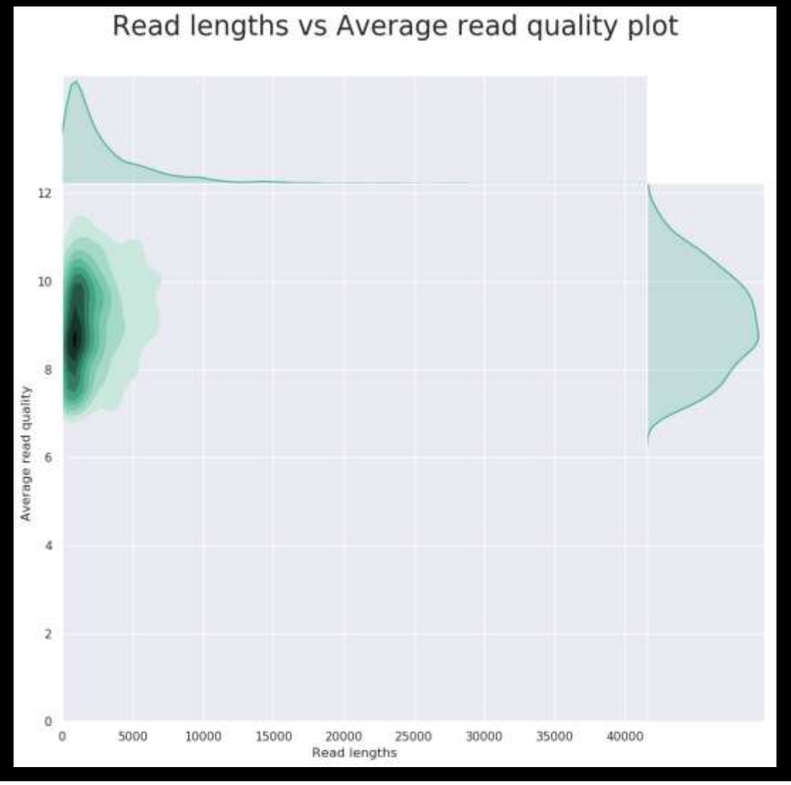
Teaching & Research

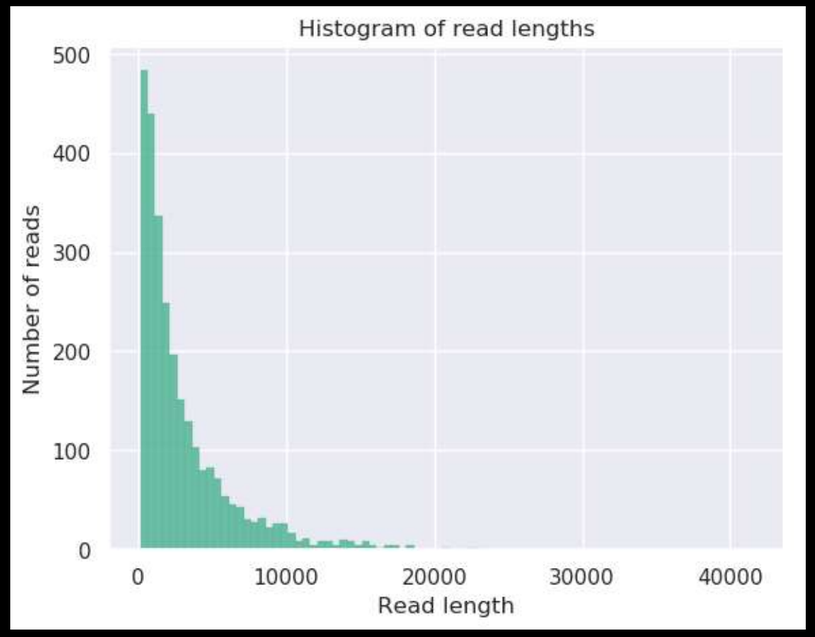
- Developing UG Bioinformatics courses
  - https://rsh249.github.io/bioinformatics
  - https://rsh249.github.io/applied_bioinformatics
- Oxford Nanopore MinION
- eDNA – Detecting plant communities from aquatic environmental DNA

https://pubs.usgs.gov/tm/02/a13/tm2a13.pdf

MinION: *E. coli*







Acknowledgements

Stonehill College

Alex Baryiames, Jordan Callahan, Caroline Pitten, Andrew Williams, Patrick O'Shea

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Cornell University
Kevin Nixon, Bill Crepet, Jeffrey Doyle, Thereis Choo, Daniella Allevato, Avery Hill

USGS — Packrat middens
Julio Betancourt
Packrat Midden Futures Working Group

Links

- Papers:
  - CRACLE https://bsapubs.onlinelibrary.wiley.com/doi/full/10.3732/ajb.1400500
  - Packrat Paleoclimate https://www.openquaternary.com/articles/10.5334/oq.46
  - Packrat aDNA **Coming soon to bioRxiv!**
- Courses:
  - Introduction to Bioinformatics – https://rsh249.github.io/bioinformatics
  - Applied Bioinformatics (Nanopore) – https://rsh249.github.io/applied_bioinformatics