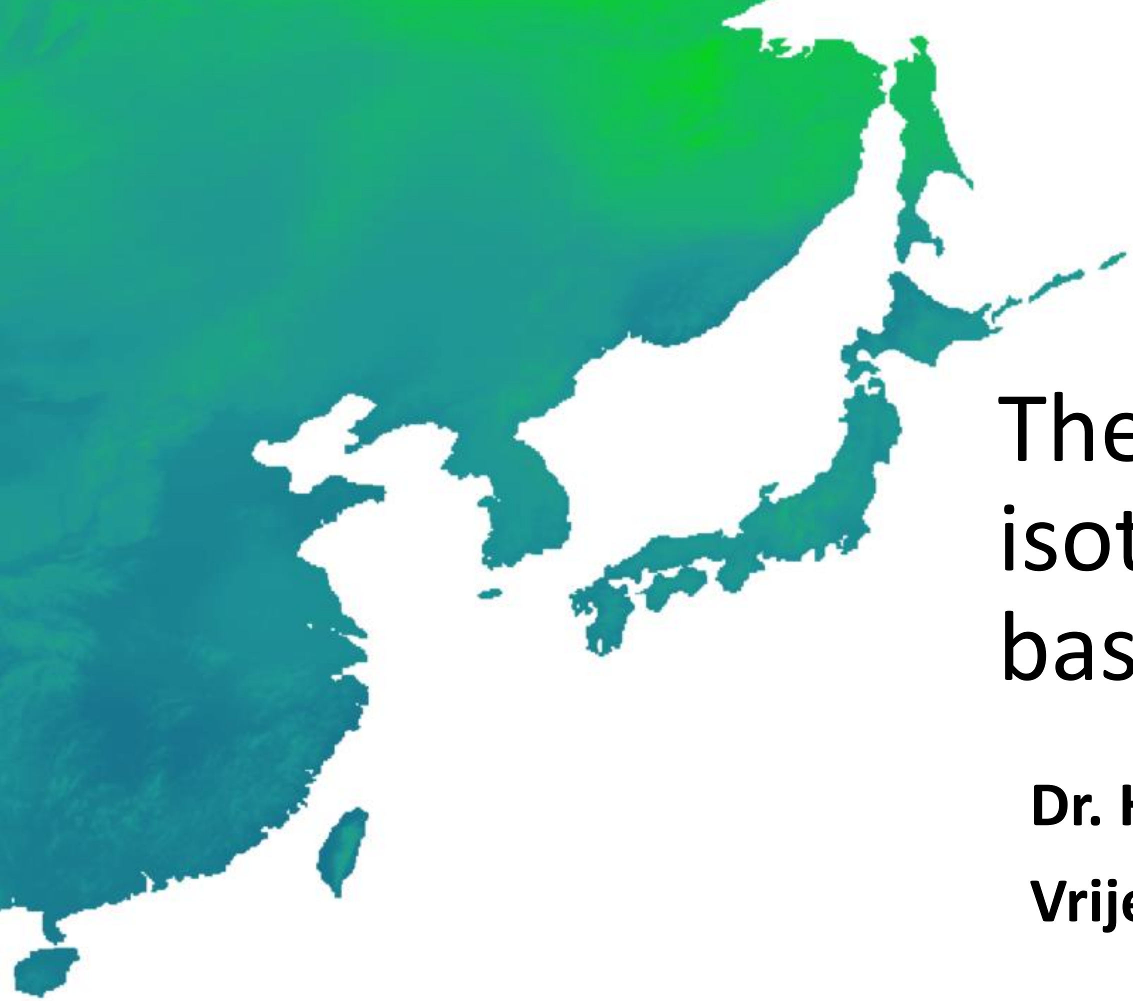
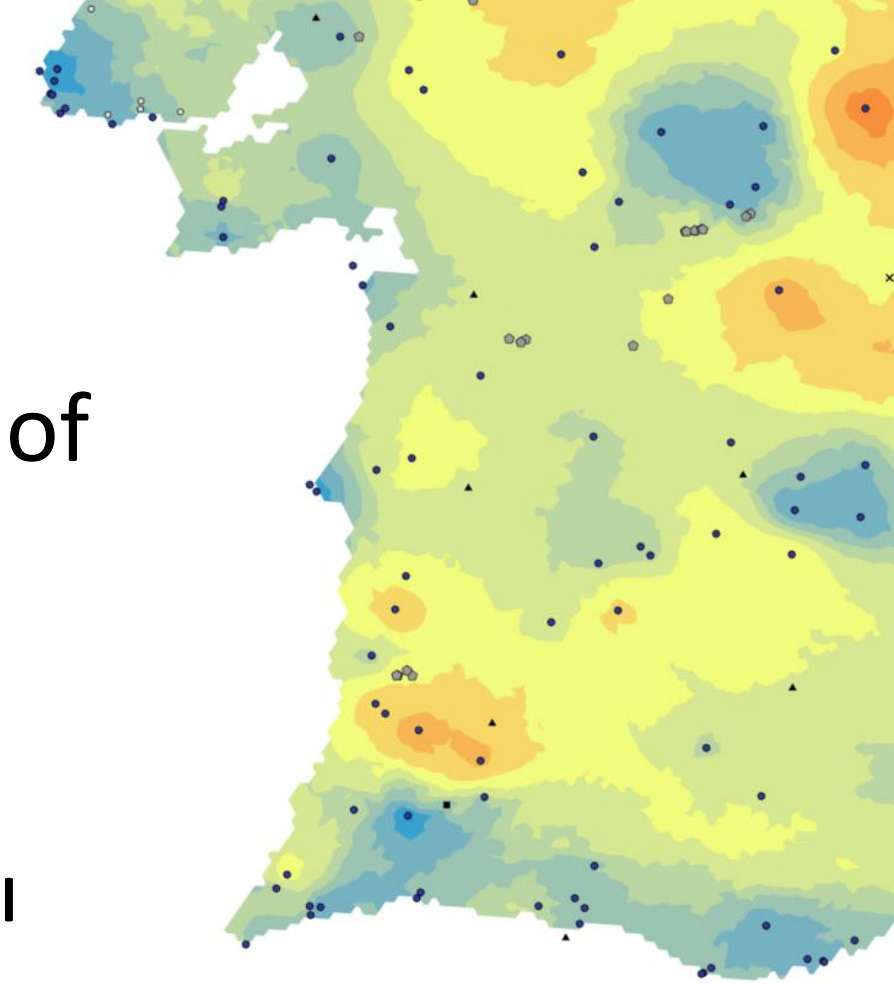


The importance of isotopic spatial baselines



Dr. Hannah James

Vrije Universiteit Brussel

BRUSSELS BIOARCHAEOLOGY LAB

BB-LAB

@ToothDetective
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AMGC

MARI

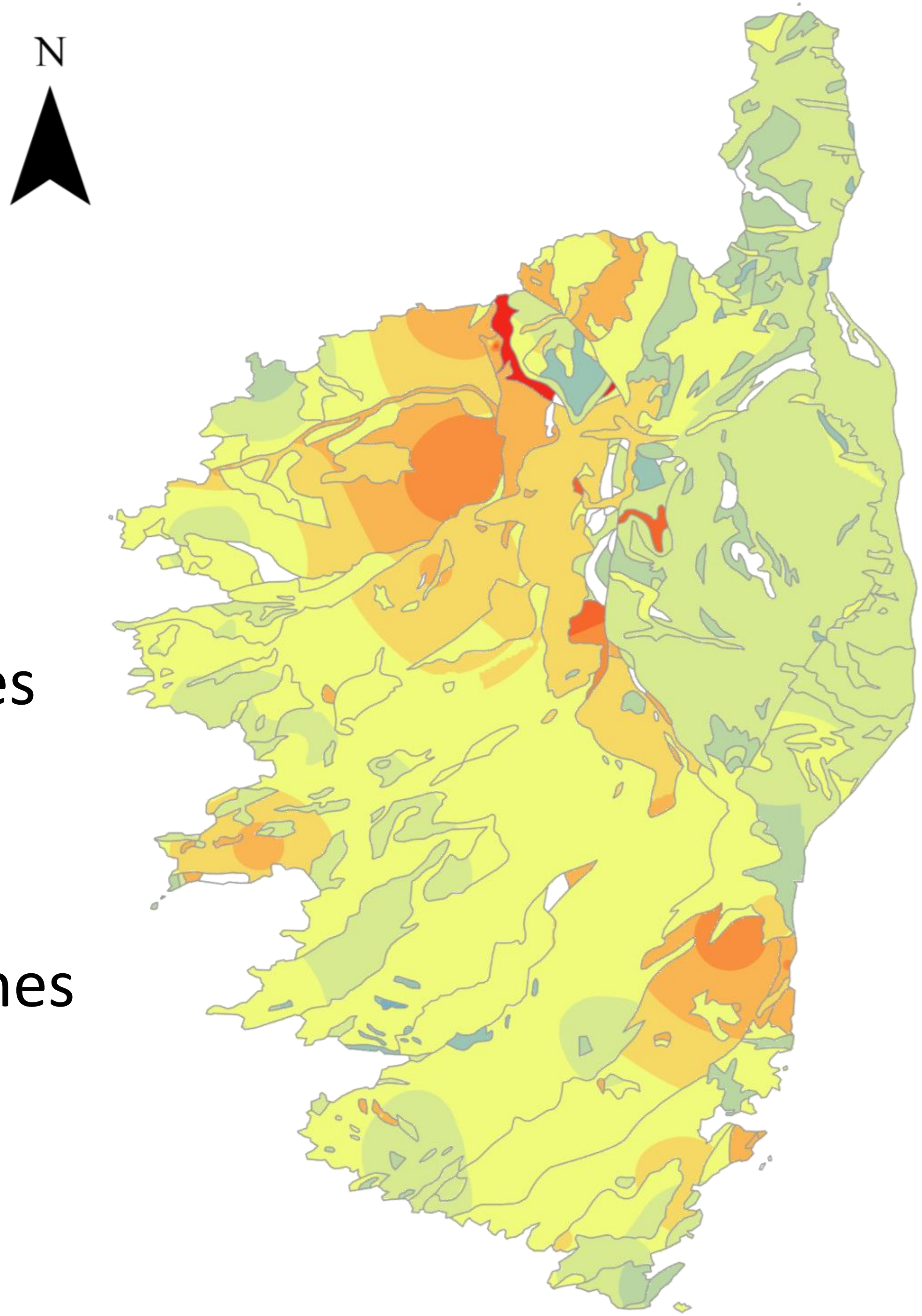
LUMIERE

European Research Council
Established by the European Commission

This project has received funding from the European Union's Horizon 2020 research & innovation programme under grant agreement nº 948913

Overview

- Which isotopes require baselines?
  - Strontium
  - Oxygen
  - Sulphur
- What archives can we sample for baselines
- How we sample for baseline?
- Which archives are best?
- Debates in archive and mapping approaches
- Creating baseline maps



Why do we need an isotopic baseline?

So we have something to compare our measured value to

Strontium

- Alkali earth metal
- Expressed as $^{87}Sr/^{86}Sr$ ratio in a sample

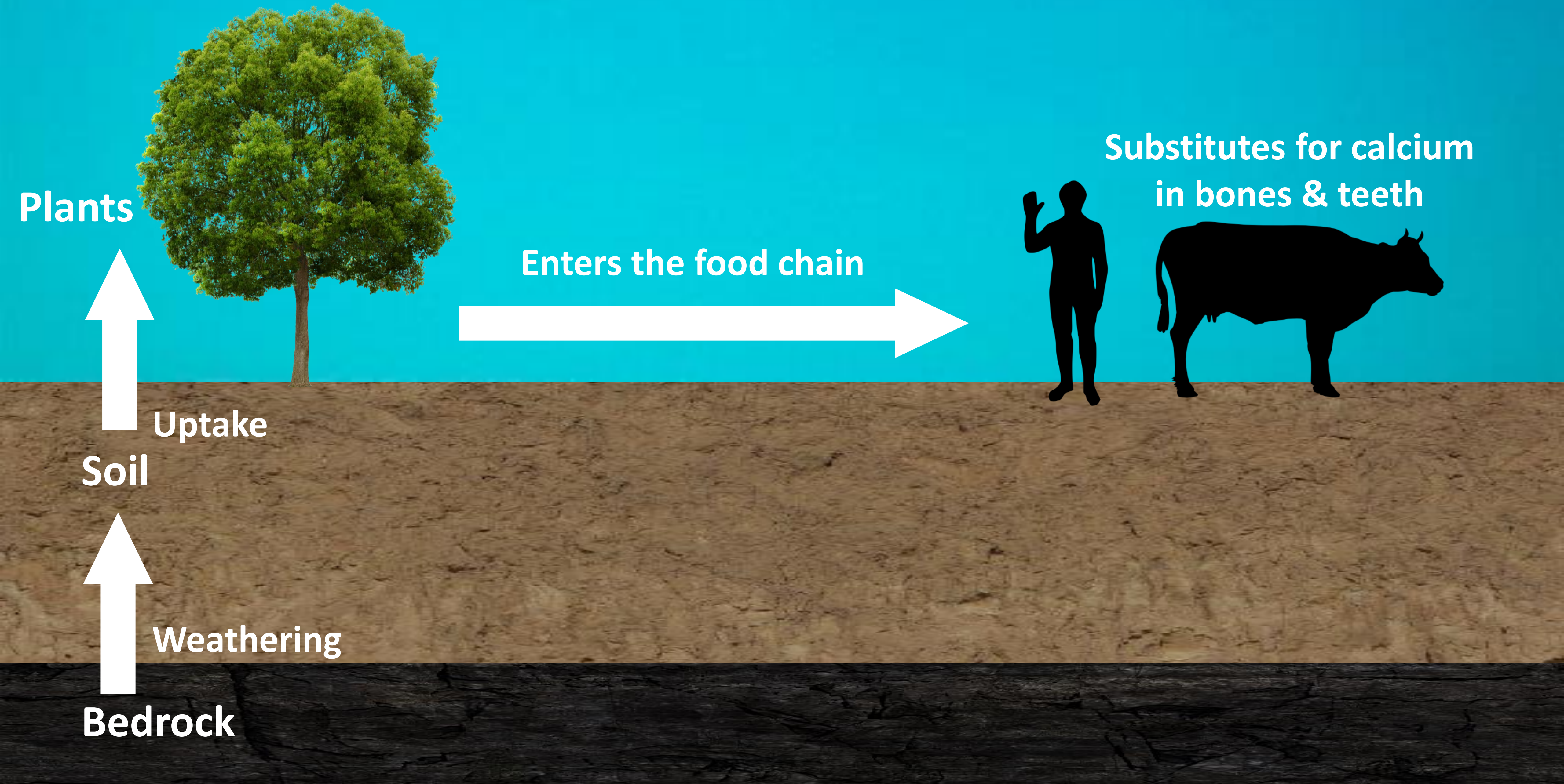
Indicator of mobility in archaeological contexts

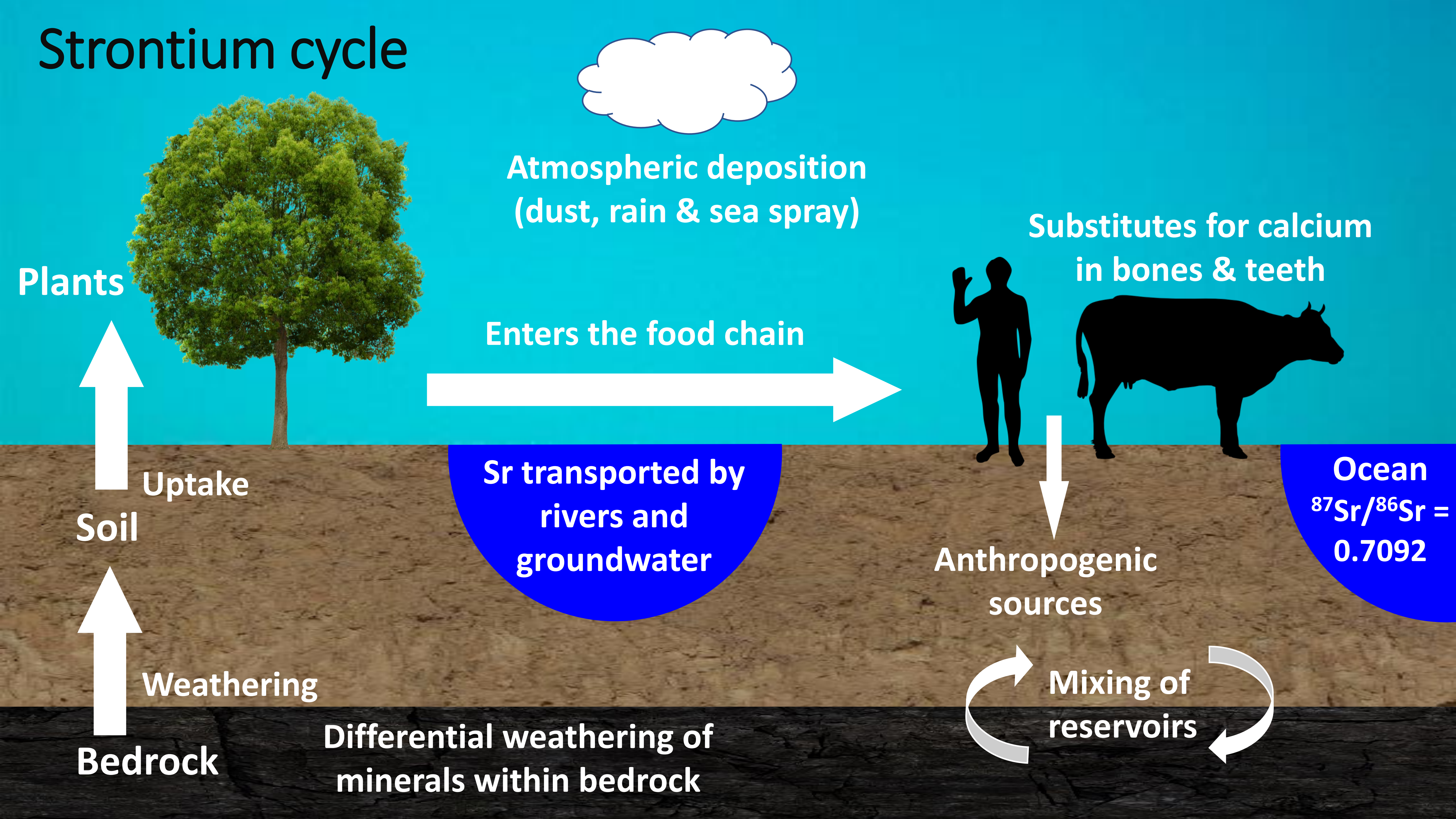
- ^{86}Sr is stable whereas ^{87}Sr is formed by the decay of ^{87}Rb
  - Half life of 48.8 billion years
- Rock $^{87}Sr/^{86}Sr$ ratio depends on:
  - how much ^{87}Rb is in the sample,
  - how long the ^{87}Rb has been decaying (i.e. how old the sample is)
- $^{87}Sr/^{86}Sr$ ratios in archaeology typically range ~0.702-0.750, with the number of decimal places reported according the standards
- Sr substitutes for Ca in bones and teeth

What influences strontium in an environment?

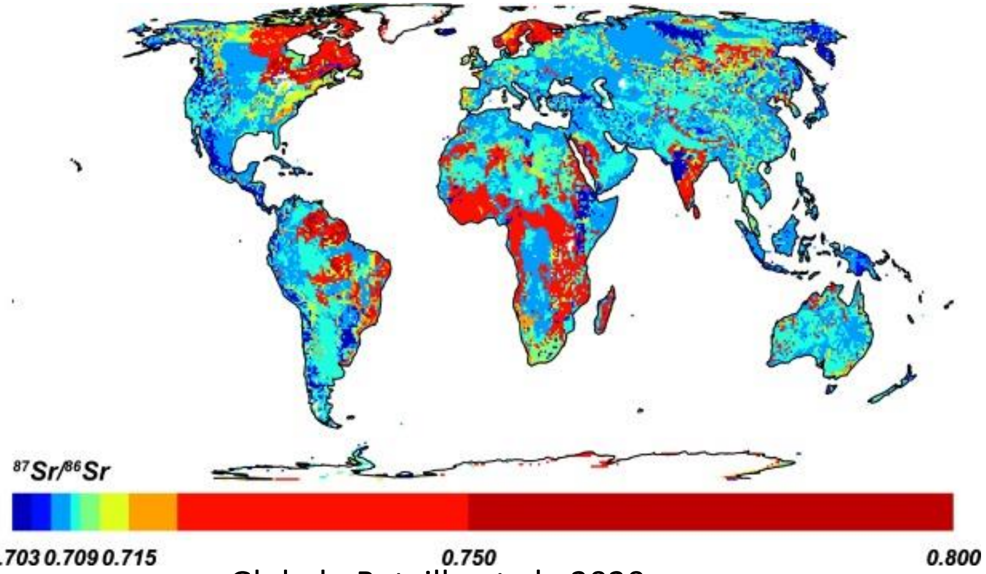
- Geology
- Atmospheric depositions
  - Sea spray
  - Dust
  - Rain
- Glacial transport of soils
- Fluvial transport of soils
- Groundwater
- Differential weathering of minerals within a rock
- Volcanic tephra
- Erosion
- Mixing of sources
- Anthropogenic influences
  - Fertilisers

Strontium cycle

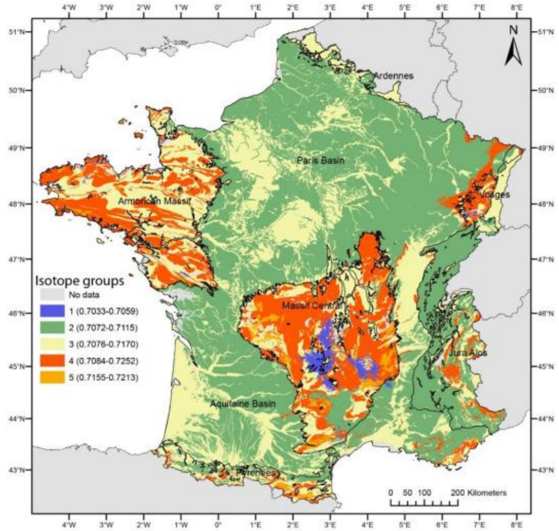



Strontium cycle
Atmospheric deposition (dust, rain & sea spray)
Substitutes for calcium in bones & teeth
Plants
Enters the food chain
Uptake
Soil
Sr transported by rivers and groundwater
Ocean
$^{87}Sr/^{86}Sr$ = 0.7092
Anthropogenic sources
Weathering
Mixing of reservoirs
Bedrock
Differential weathering of minerals within bedrock

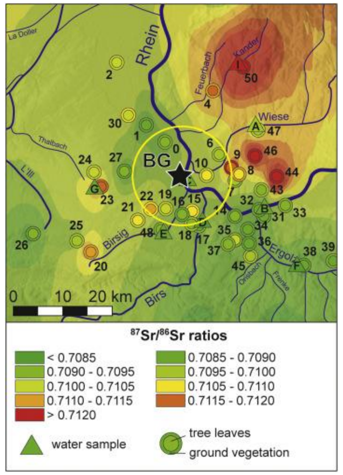
Bioavailable Sr baselines



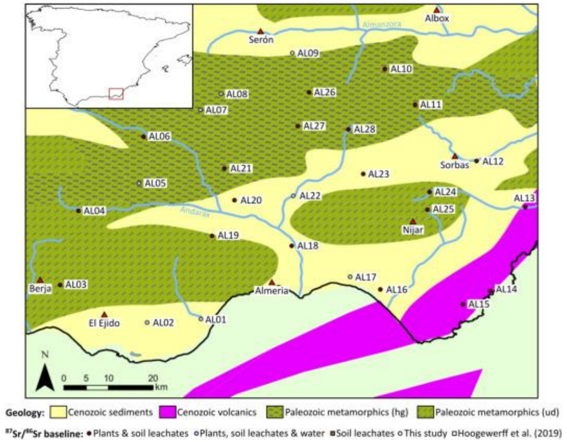
Global - Bataille et al., 2020



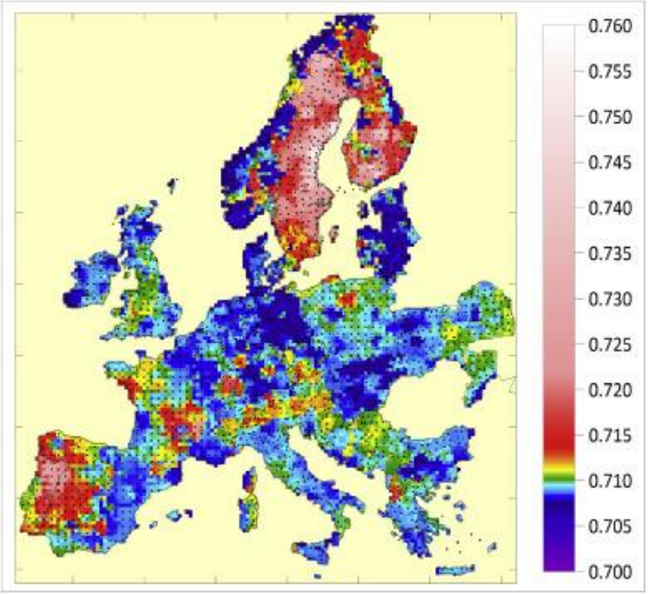
France - Willmes et al., 2018



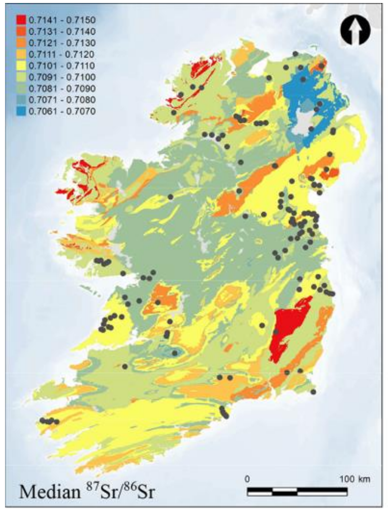
Basel Switzerland – Brönnimann et al., 2018



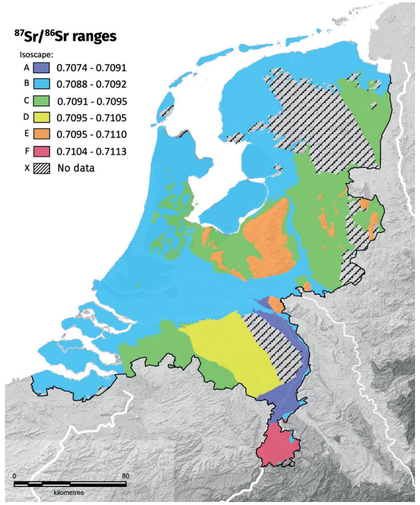
Southern Almería - Frank et al., 2022



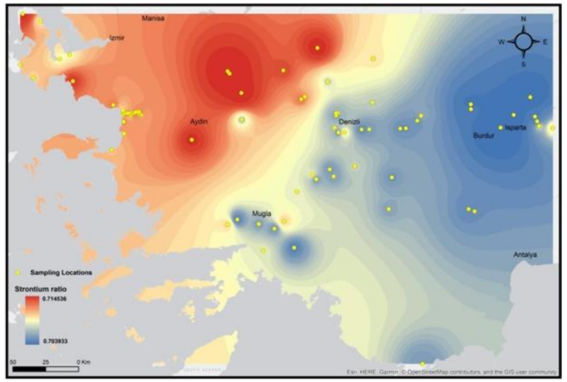
Europe - Hoogewerff et al., 2019



Ireland - Snoeck et al., 2020



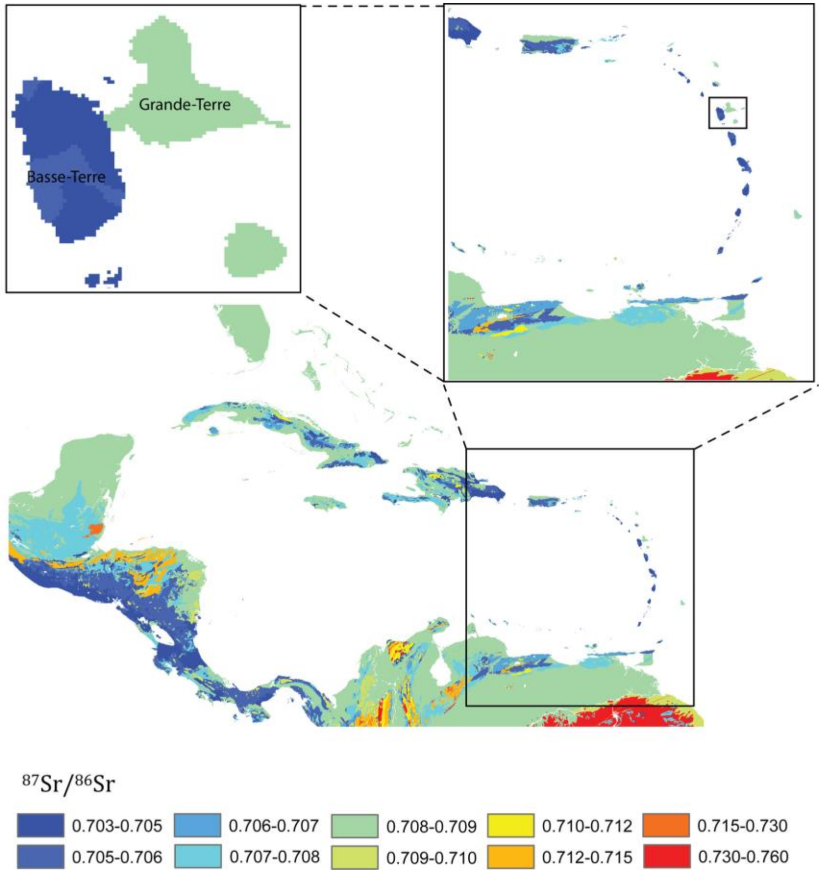
The Netherlands - Kootker et al., 2016



Southwestern Turkey - Wong et al., 2021

What can we sample for Sr baselines?

- **Geology**
- Plants
- Soil leachates
- Surface water
- Archaeological fauna
- Invertebrates
- Modern fauna



Caribbean region - Bataille et al., 2012

What can we sample for Sr baselines?

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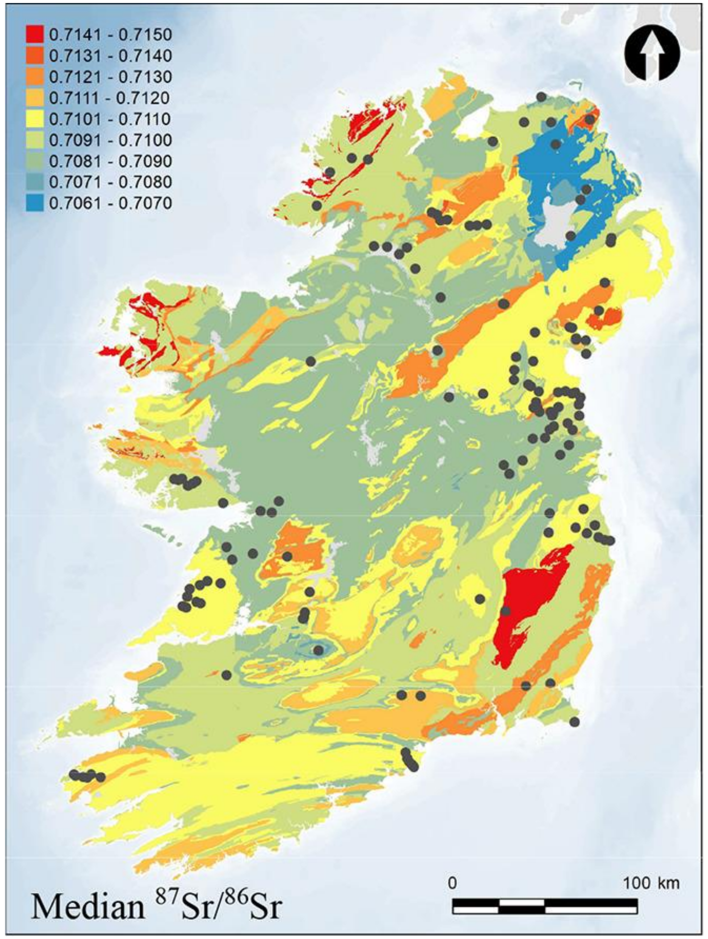
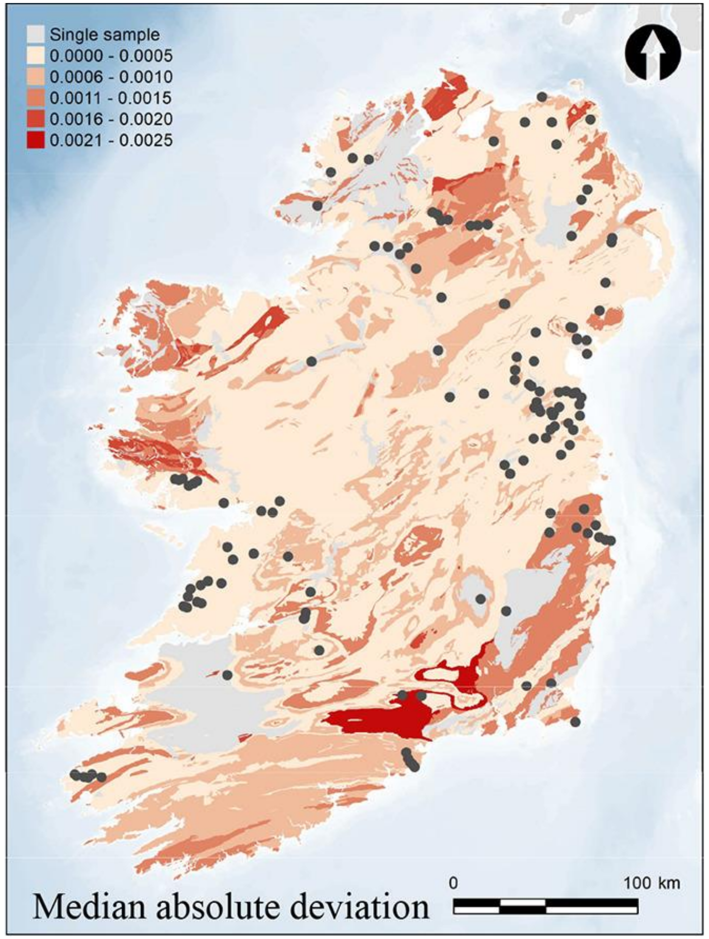
- Invertebrates
- Modern fauna





Ireland - Snoeck et al., 2020

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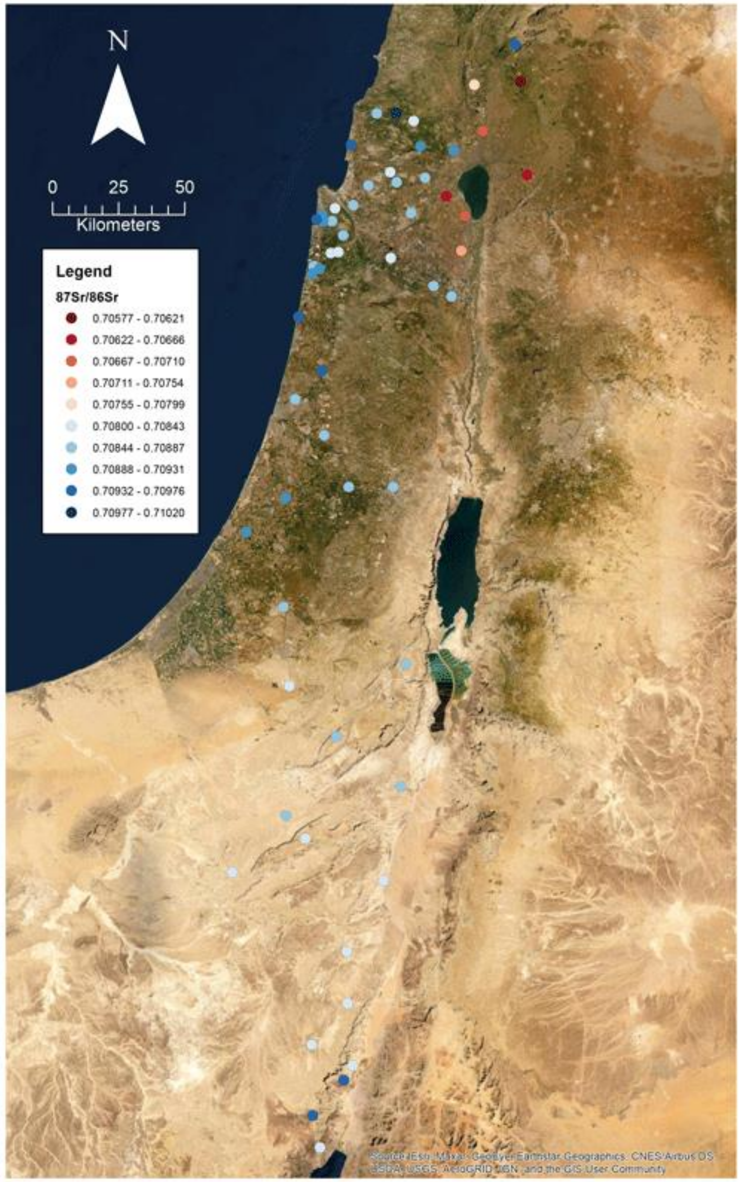
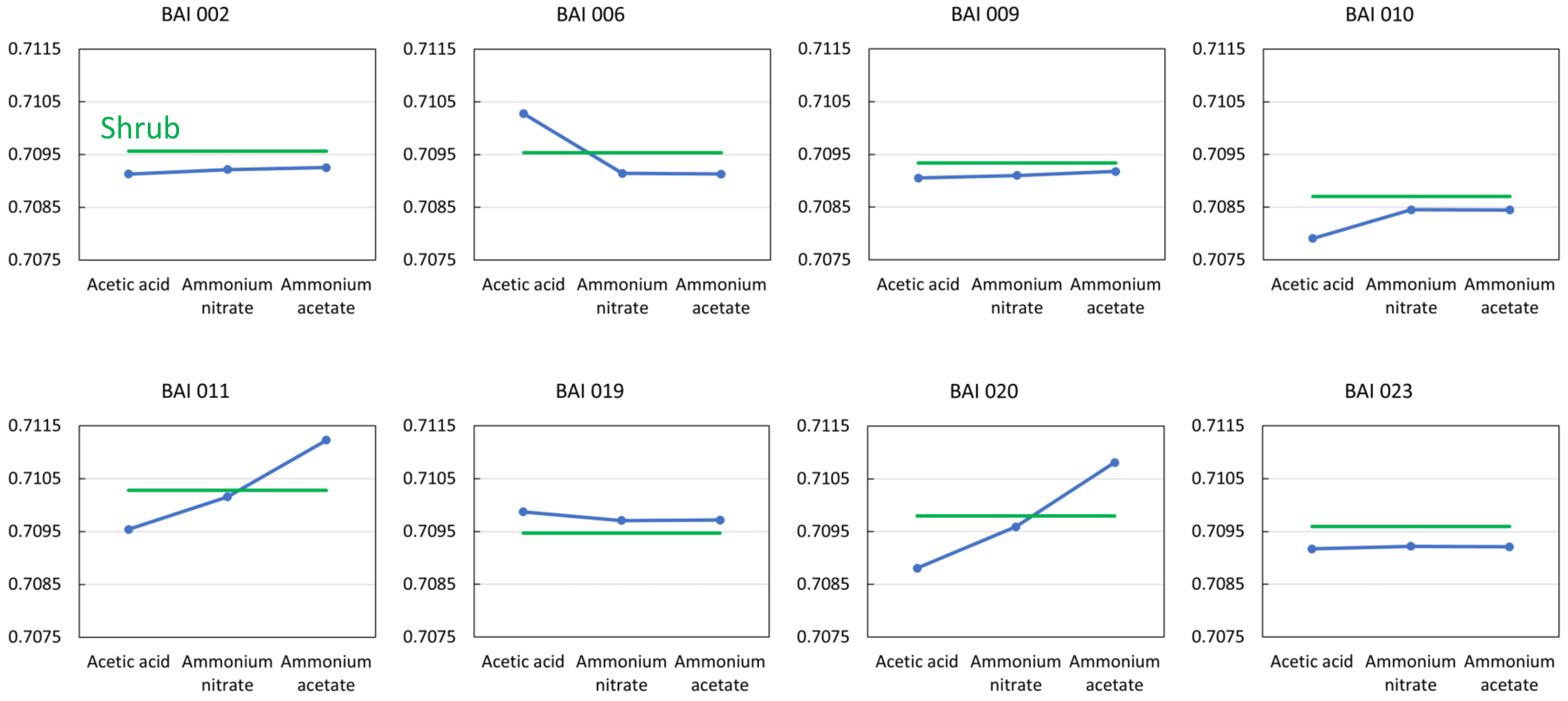


Israel - Moffat et al., 2020

Testing strontium soil leaching methods



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- Geology
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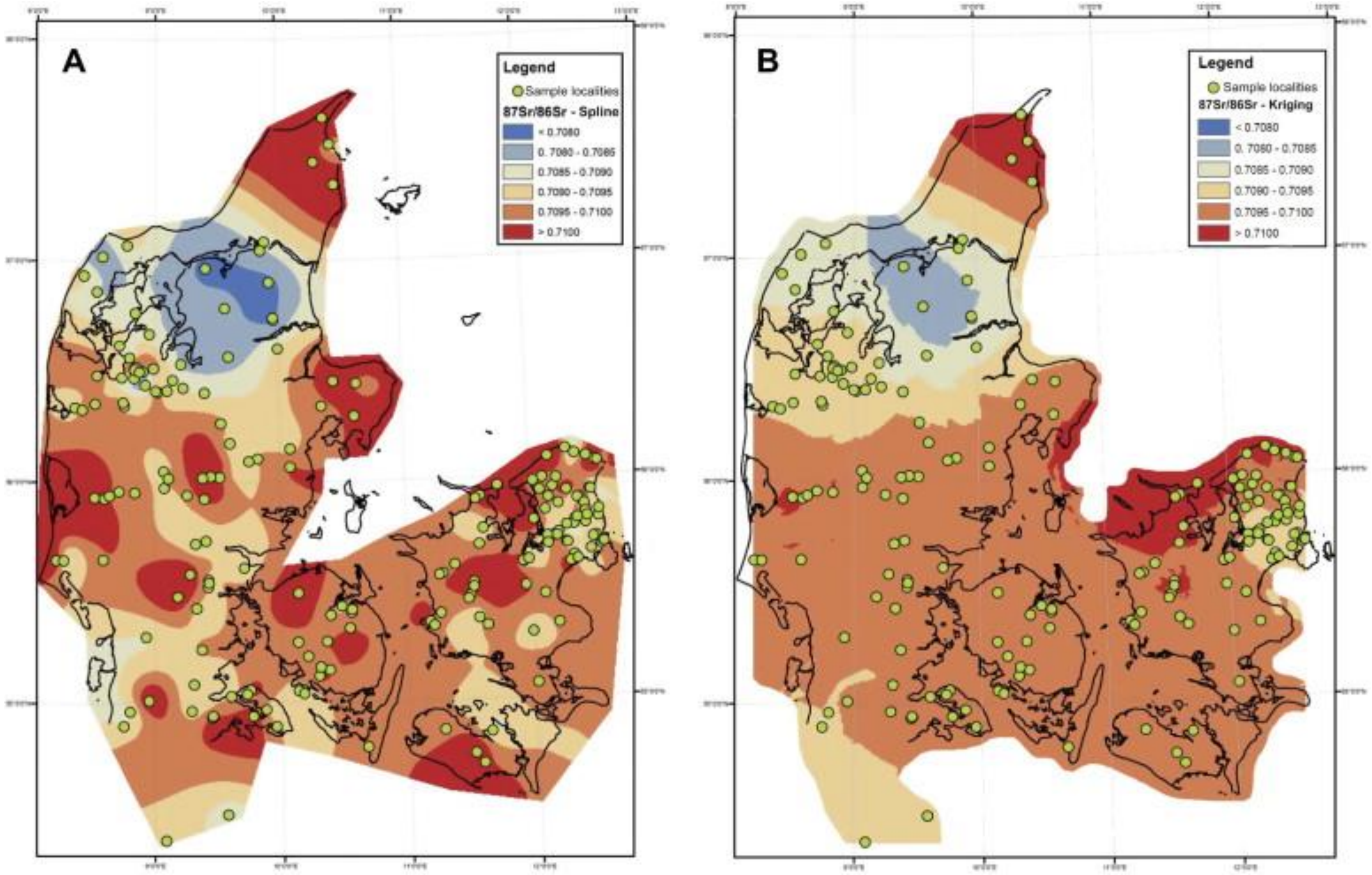
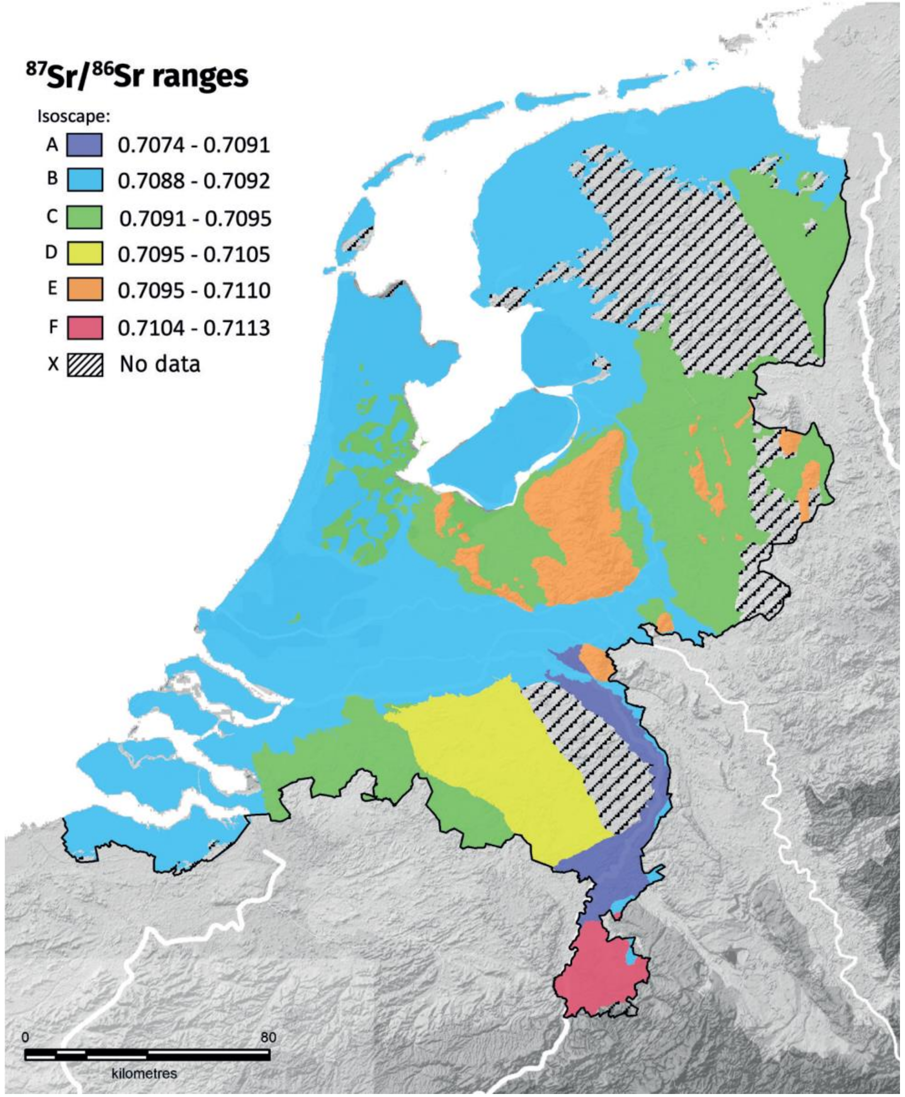


Denmark - Frei and Frei, 2011

What can we sample for Sr baselines?

- Geology
- Plants
- Soil leachates
- Surface water
- **Archaeological fauna**
- Invertebrates
- Modern fauna



The Netherlands - Kootker et al., 2016

What can we sample for Sr baselines?

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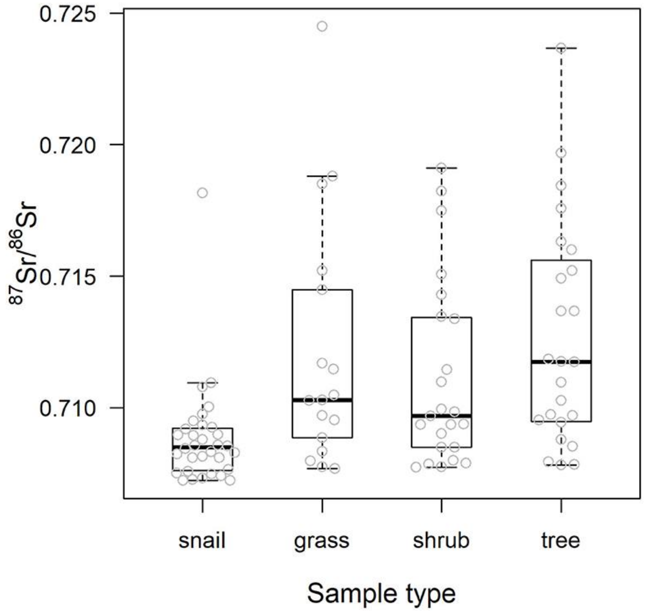
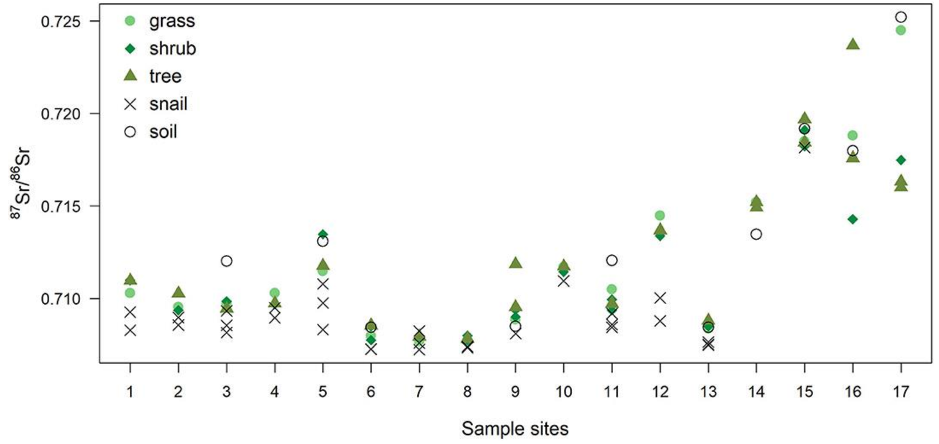
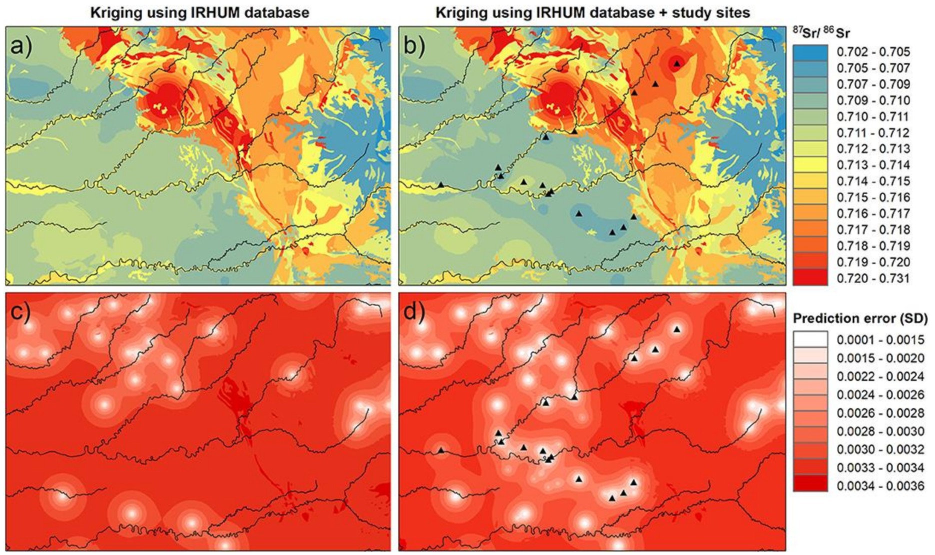
- **Invertebrates**
- Modern fauna







France- Britton et al., 2020

What can we sample

- Geology
- Plants
- Soil leachates
- Surface water
- Archaeological fauna
- Invertebrates
- **Modern fauna**

Cape York Australia
Adams et al., 2019

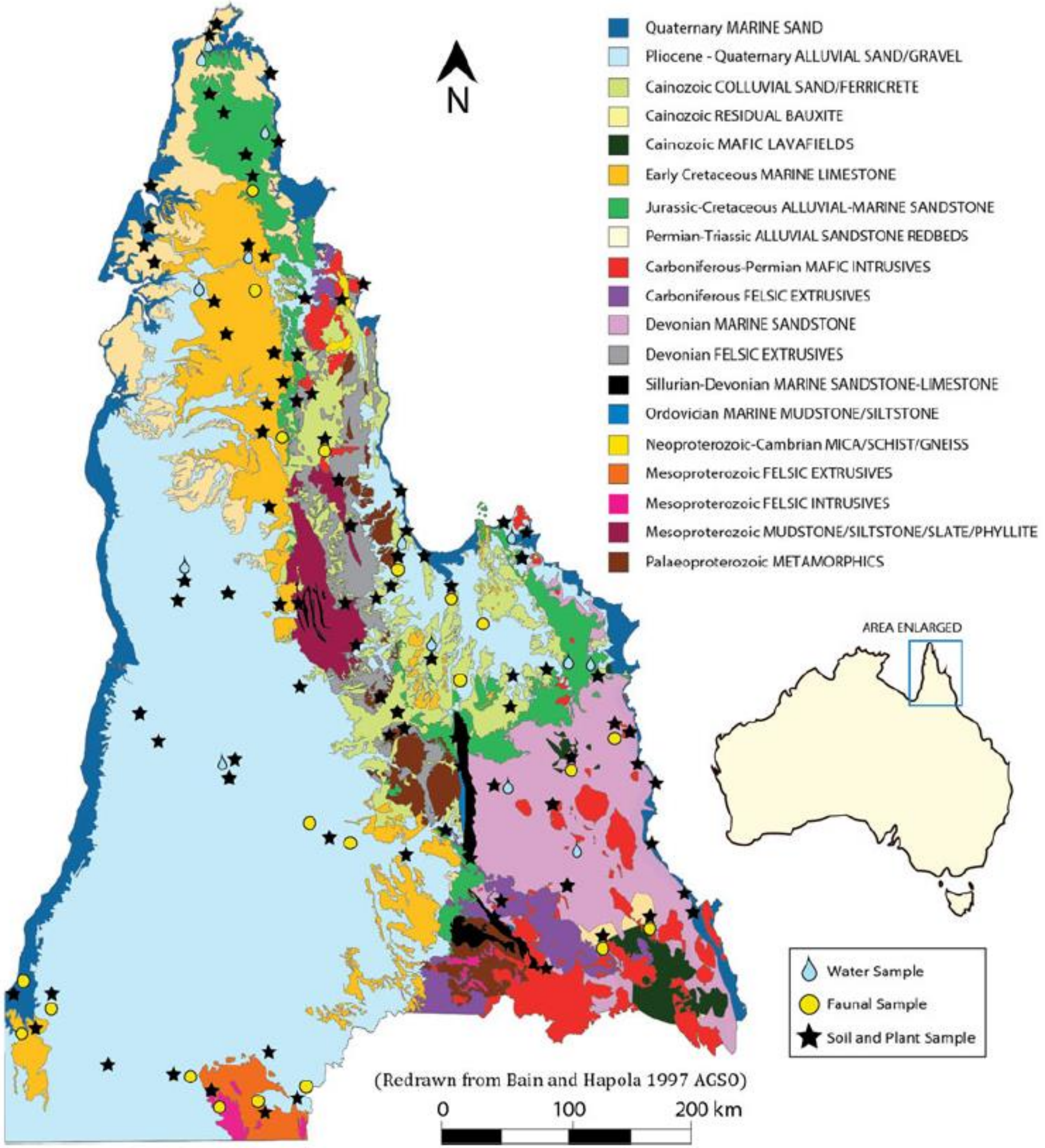


FIGURE 1 Cape York bedrock geology (Bain & Haipola, 1997b) with sample sites [Color figure can be viewed at wileyonlinelibrary.com]

What can we sample for Sr baselines?

- Geology
- Plants
- Soil leachates
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- Archaeological fauna
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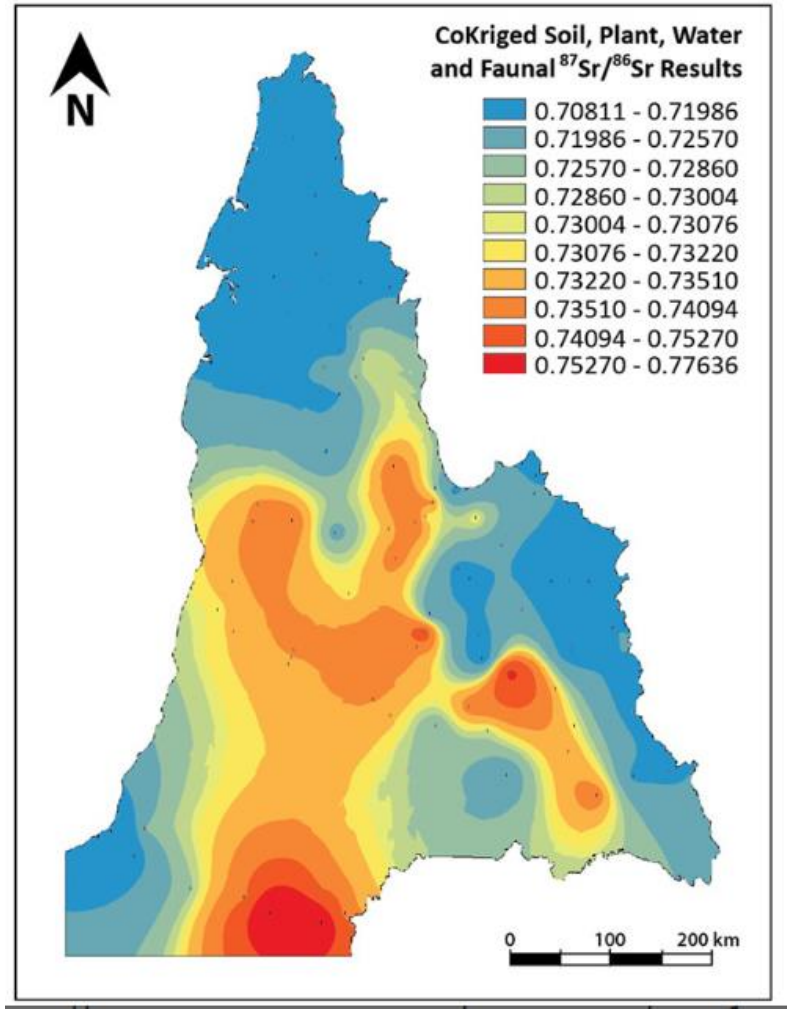
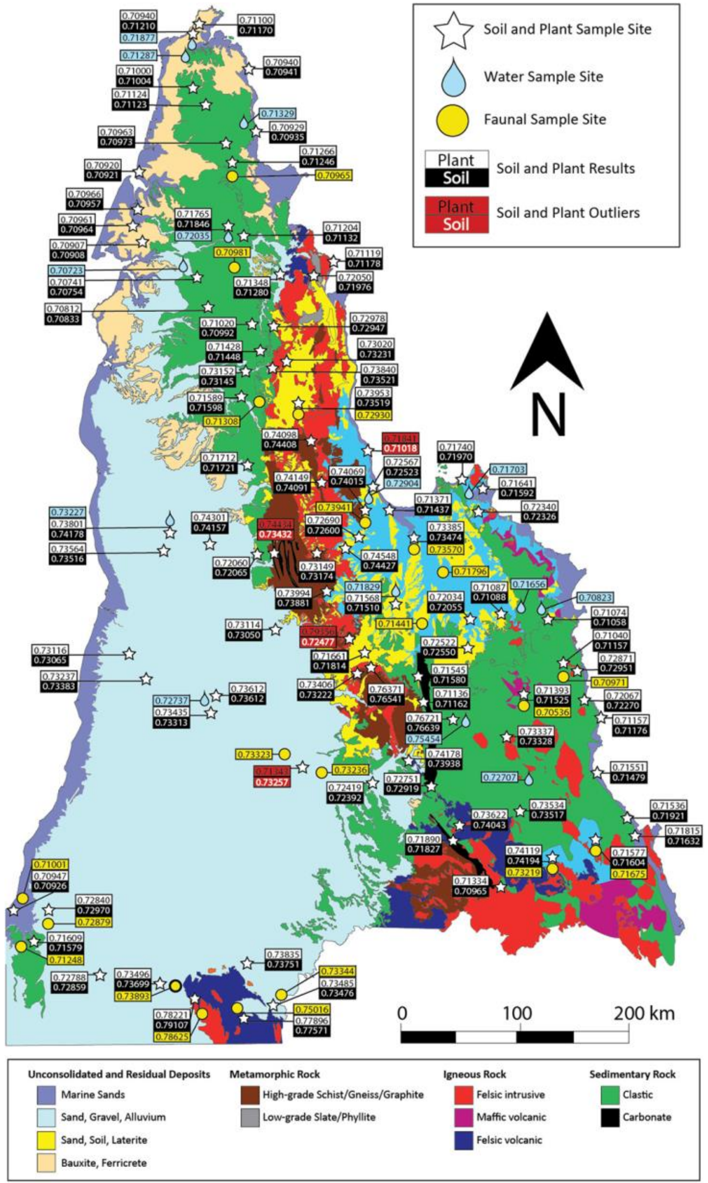
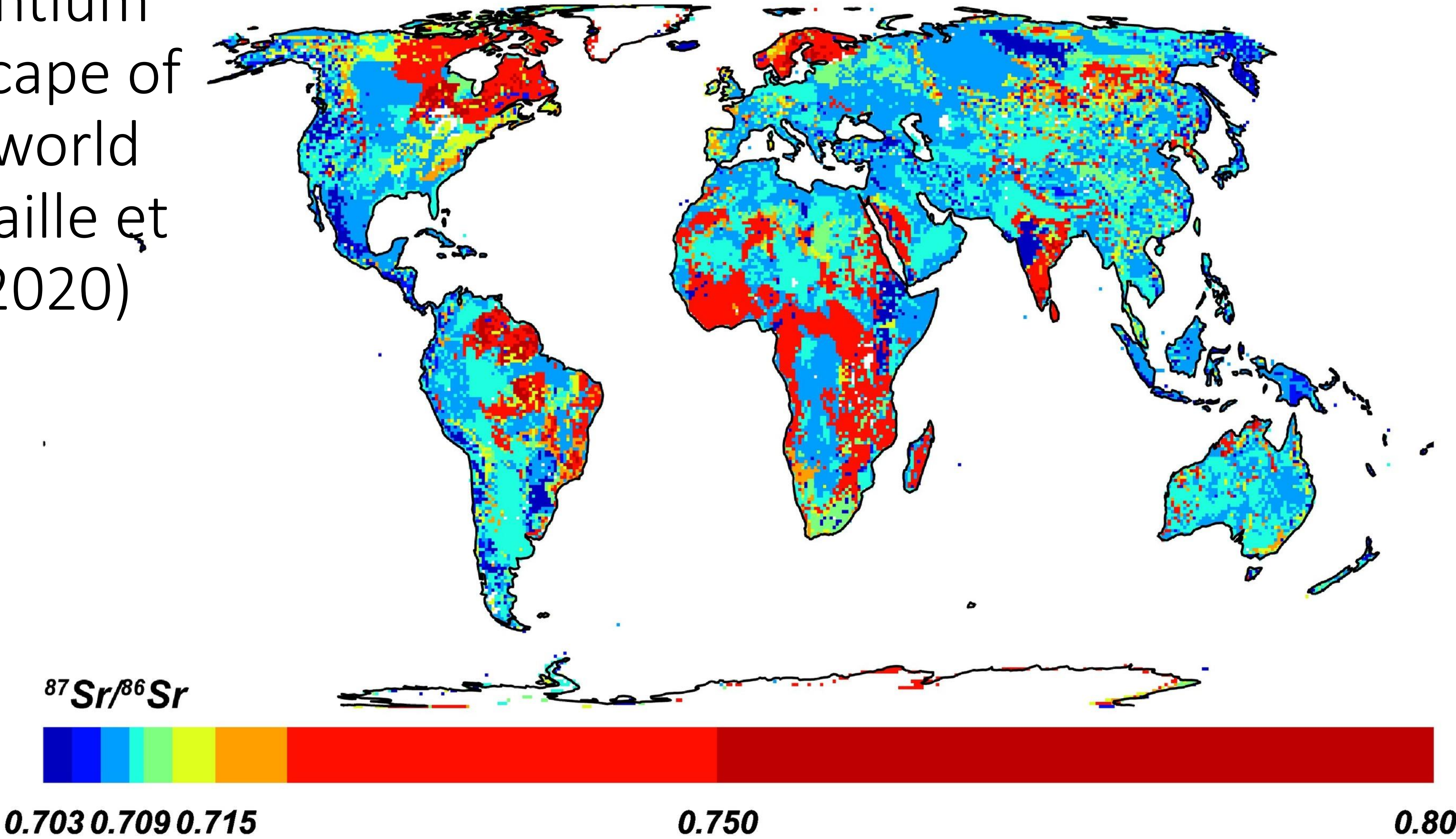
- **Modern fauna**



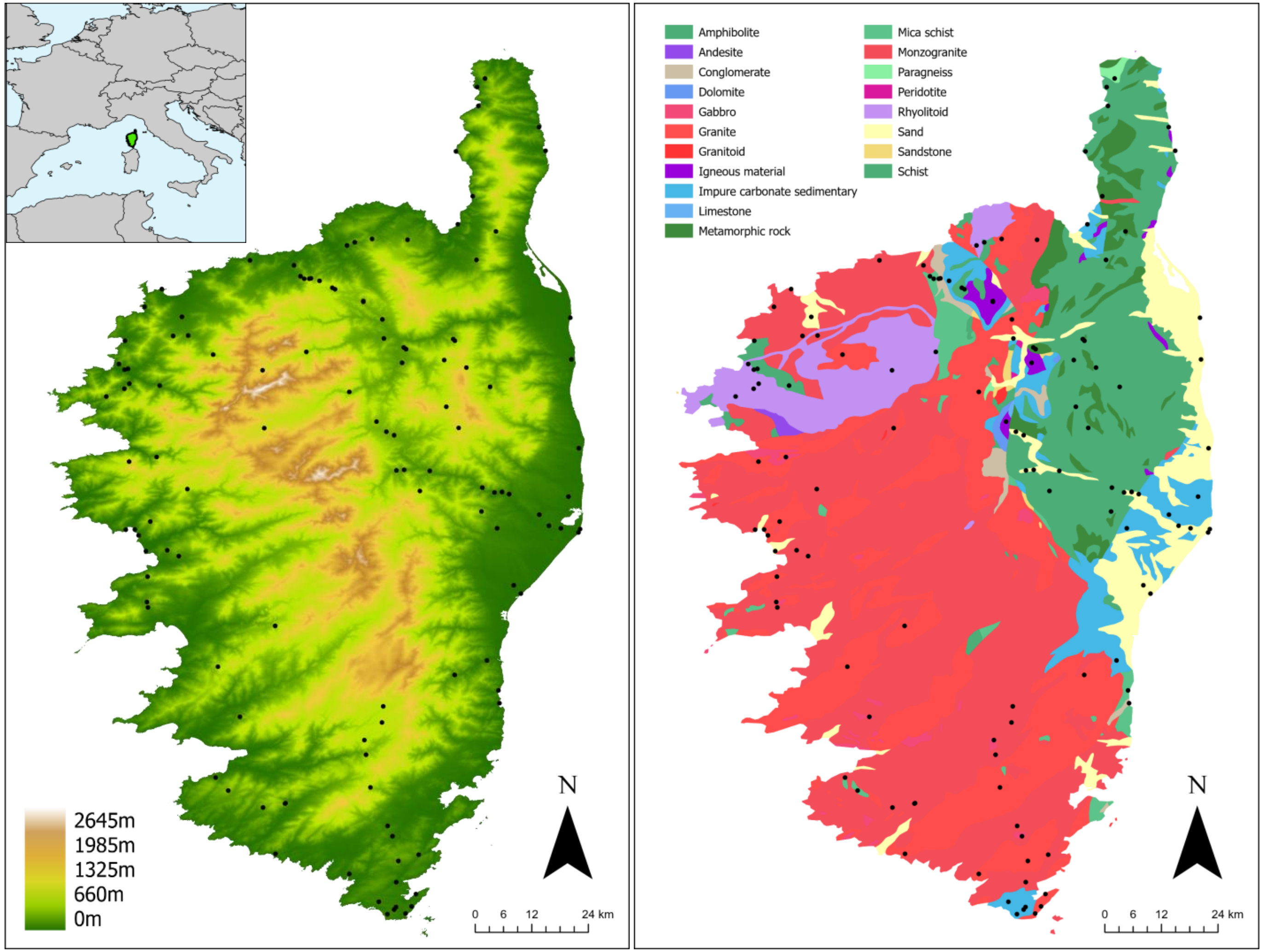


Cape York Australia
Adams et al., 2019

Strontium isoscape of the world (Bataille et al., 2020)



Do we need high-density sampling?

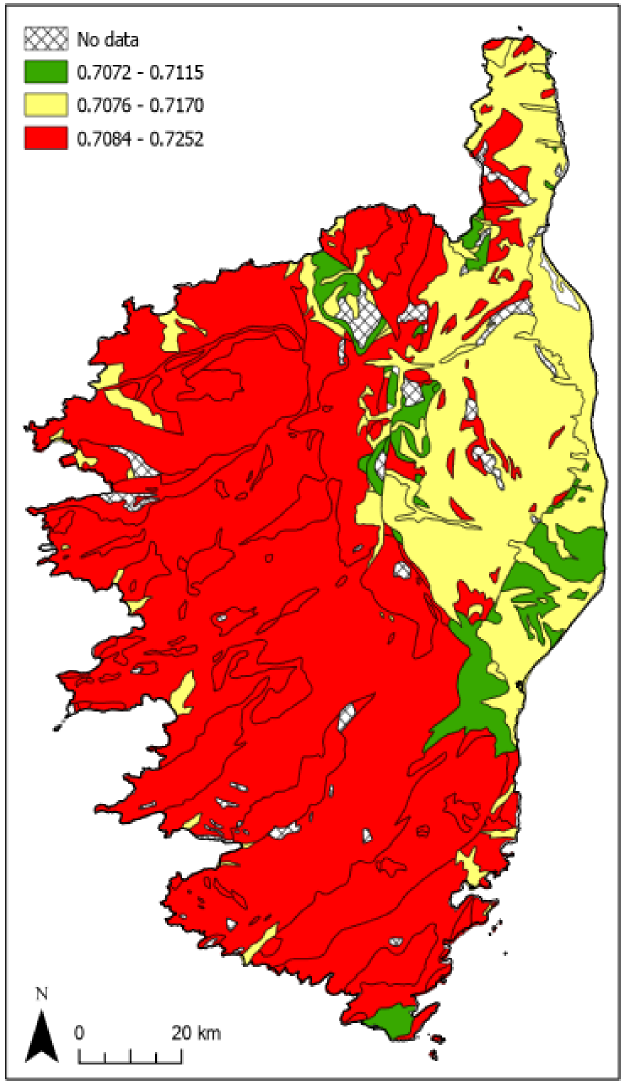


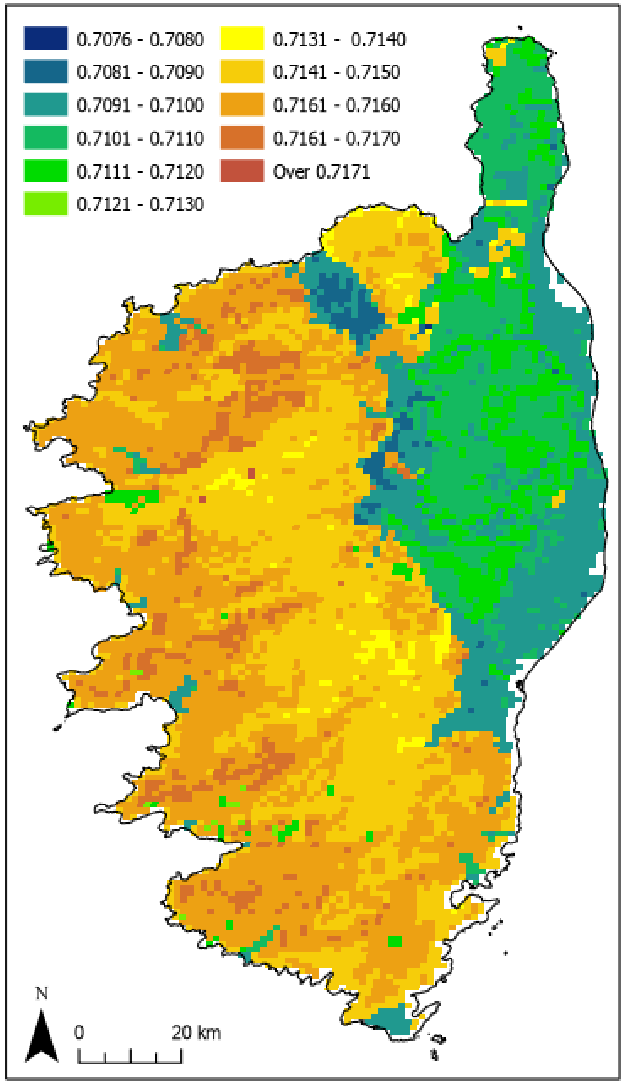
Sr predictions for Corsica

Applied Geochemistry
Volume 90, March 2018, Pages 75-86

Mapping of bioavailable strontium isotope ratios in France for archaeological provenance studies

Malte Willmes [a, b], Clement P. Bataille [c], Hannah F. James [a], Ian Moffat [a, d], Linda McMorrow [a], Leslie Kinsley [a], Richard A. Armstrong [a], Stephen Eggins [a], Rainer Grün [a, e]





Palaeogeography, Palaeoclimatology, Palaeoecology
Volume 555, 1 October 2020, 109849

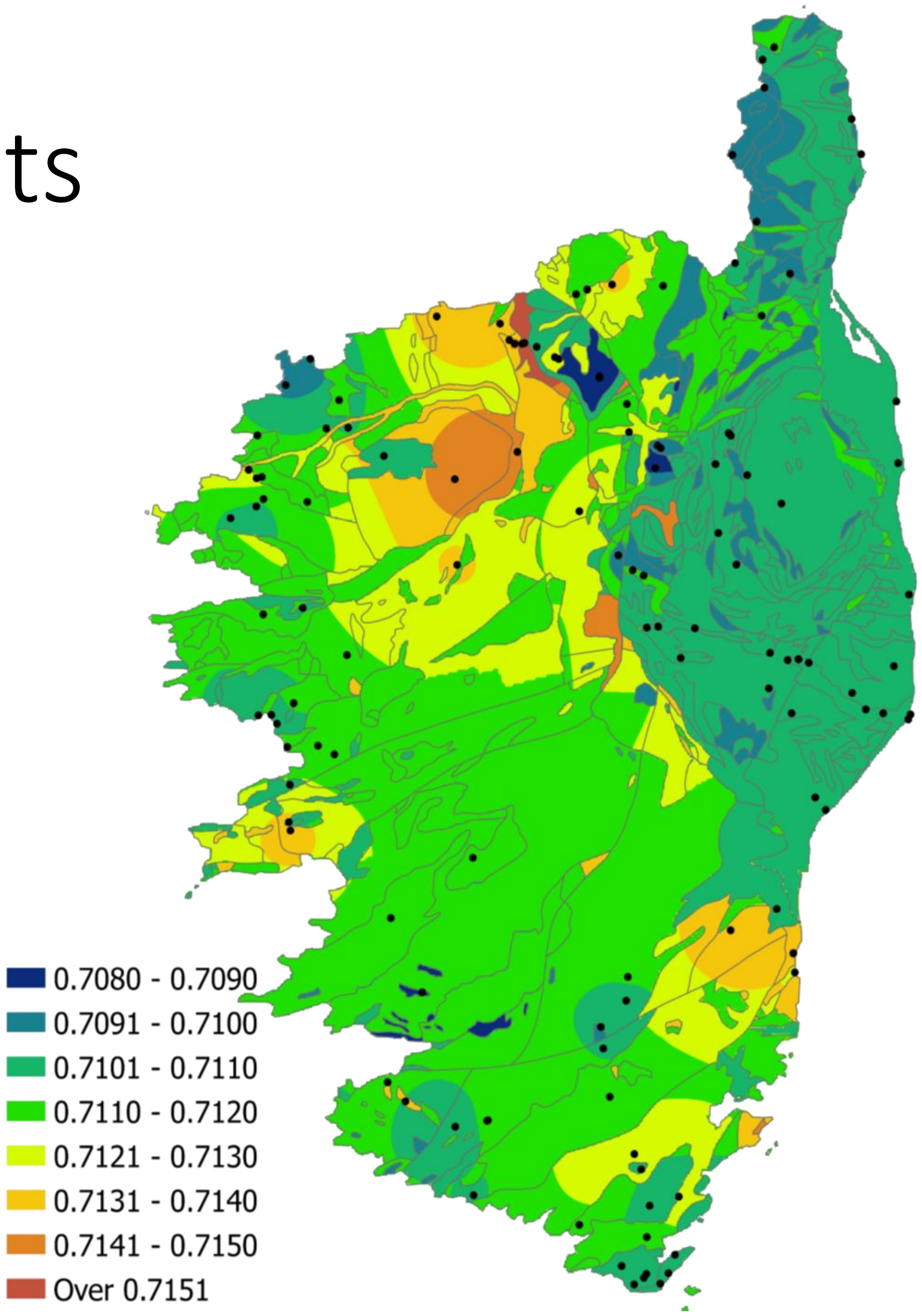
Invited review article

Advances in global bioavailable strontium isoscapes

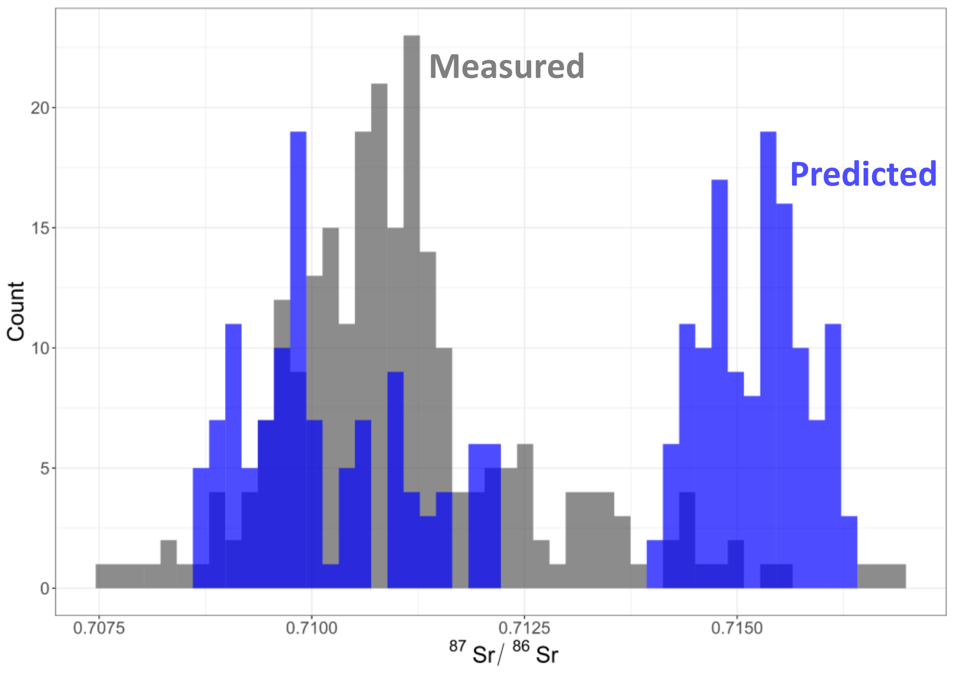
Clement P. Bataille [a], Brooke E. Crowley [b, c], Matthew J. Wooller [d, e], Gabriel J. Bowen [f]

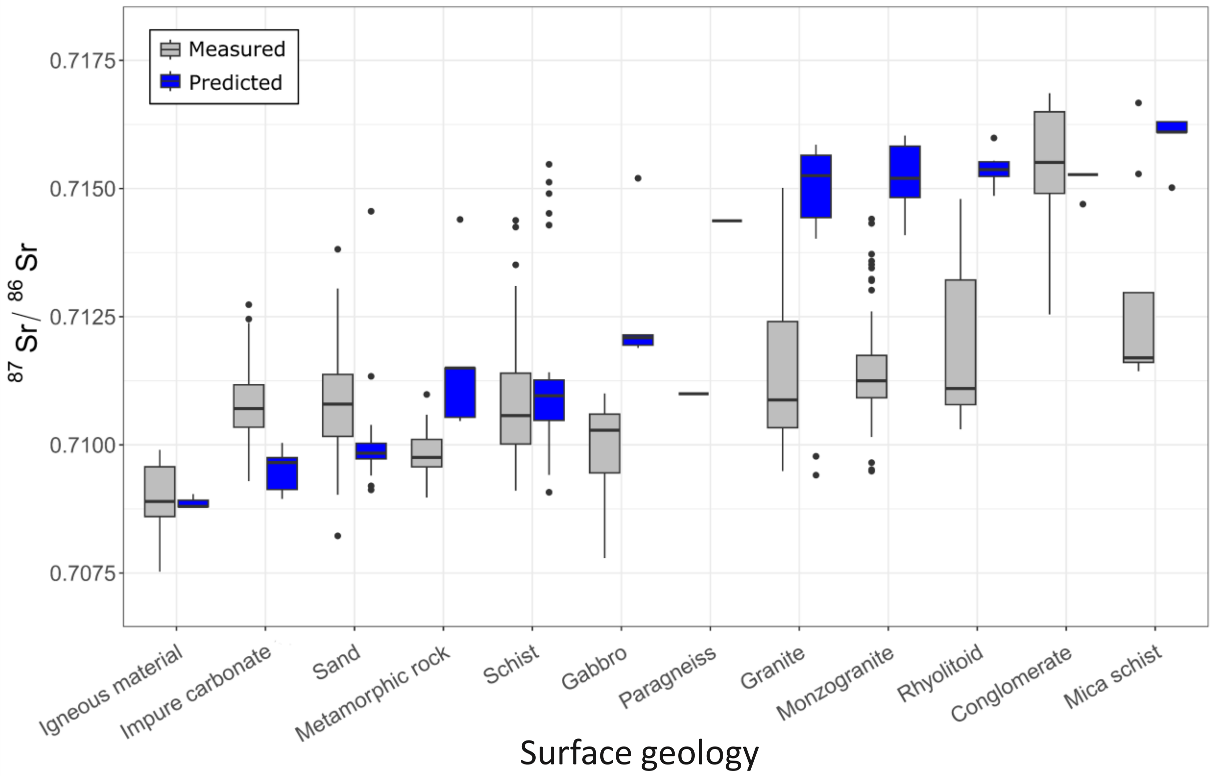
Bioavailable Sr measurements

- Two datasets
  - Triple plant sampling
  - Paired plant and soils
- 245 plant samples
- 83 soil leachate samples
- Overall $^{87}Sr/^{86}Sr$ range of 0.7075 to 0.7169



How does the prediction compare to the measured values?

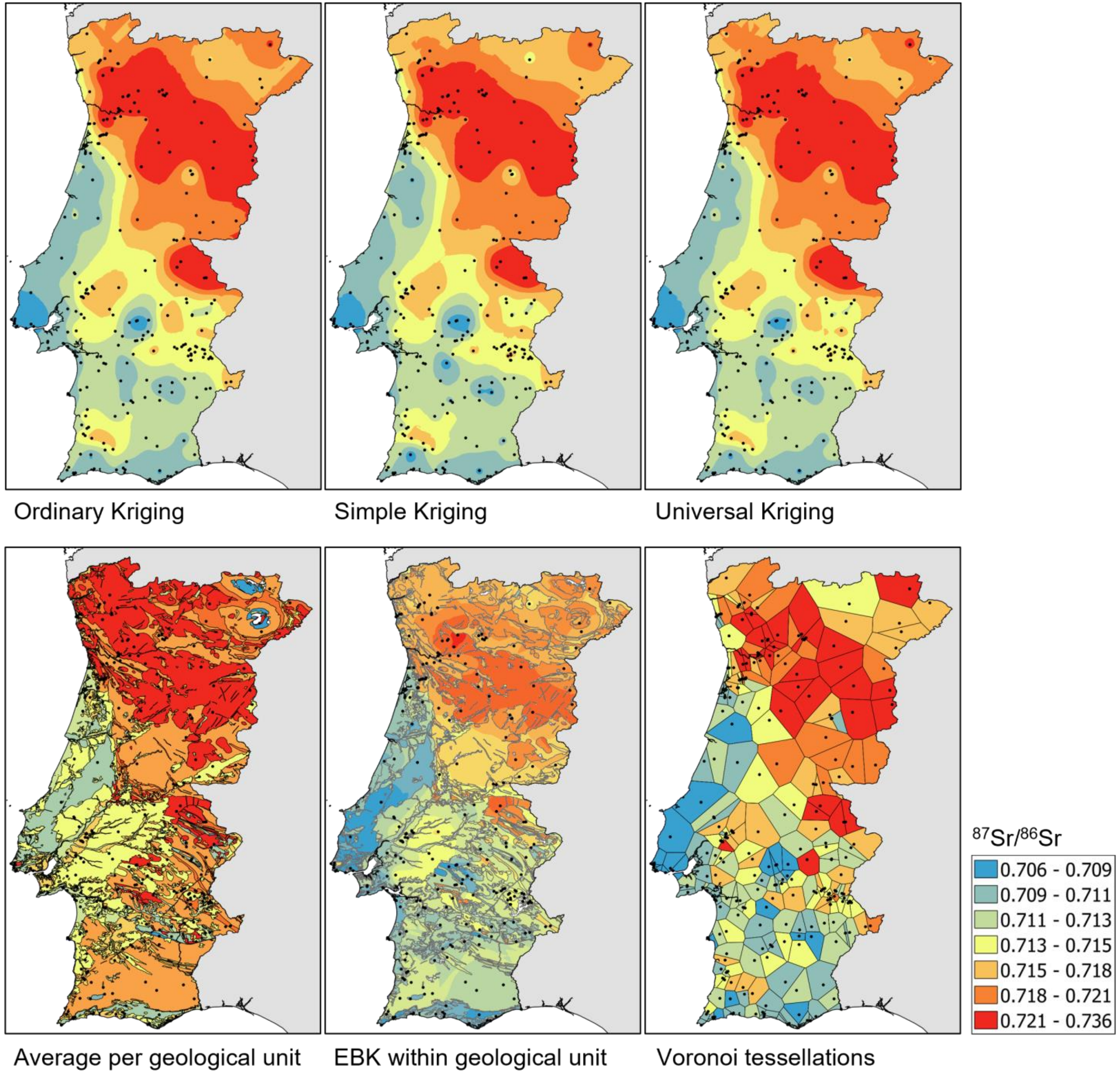




What methods do we use for making a map?

- Domain
- Contour
- Machine learning

Review paper Holt et al., 2021



Mapping Portugal

New paired measurements of plants and soils from 151 sites across Portugal, plus:

- 33 soil sites (Hoogewerff et al., 2019, STOTEN)
- 20 plants from Perdigões (Žalaitė et al., 2018 JASR; Valera et al., 2020 JASR)

Range of $^{87}Sr/^{86}Sr$ = 0.7058 to 0.7349

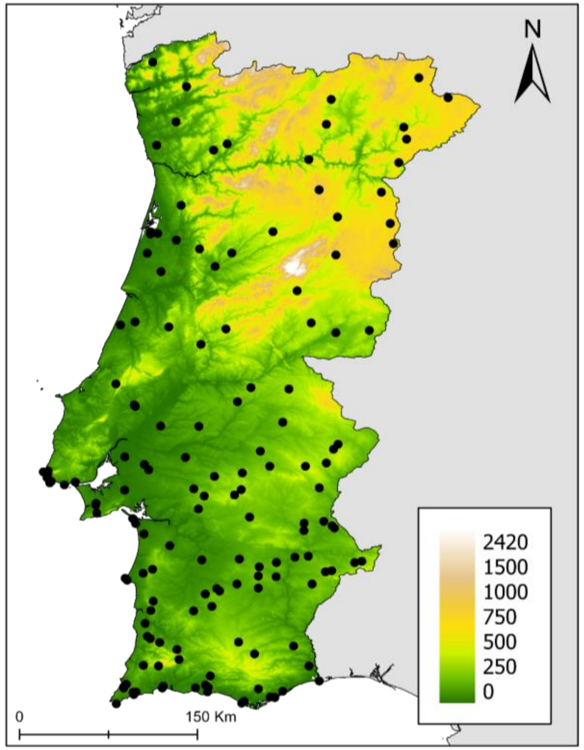
ELSEVIER

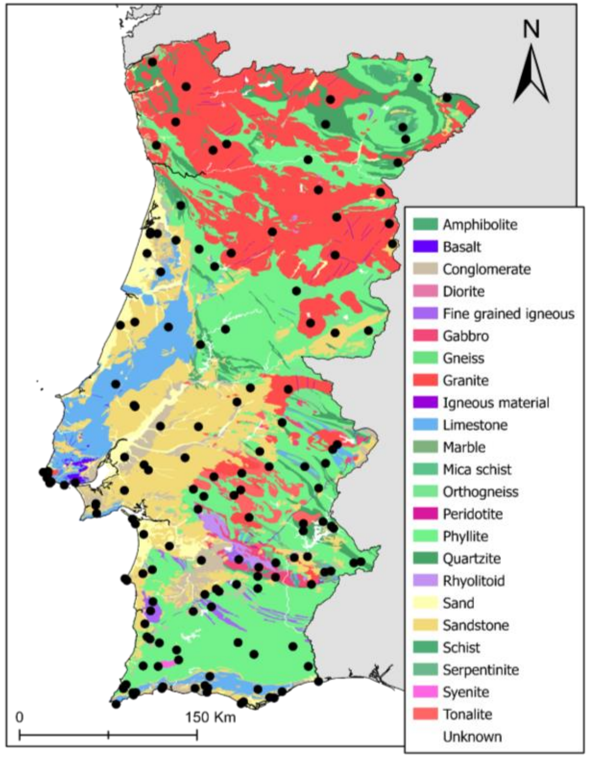
Journal of Archaeological Science

Volume 142, June 2022, 105595

A large-scale environmental strontium isotope baseline map of Portugal for archaeological and paleoecological provenance studies

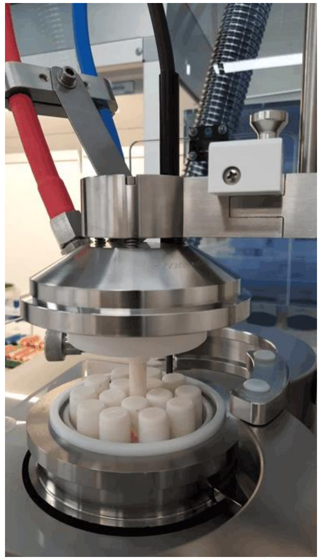
Hannah F. James [a, b, c], Shaun Adams [d, e], Malte Willmes [f, g], Kate Mathison [d], Andrea Ulrichsen [a], Rachel Wood [a, h], Antonio C. Valera [i, j], Catherine J. Frieman [a], Rainer Grün [d, h]

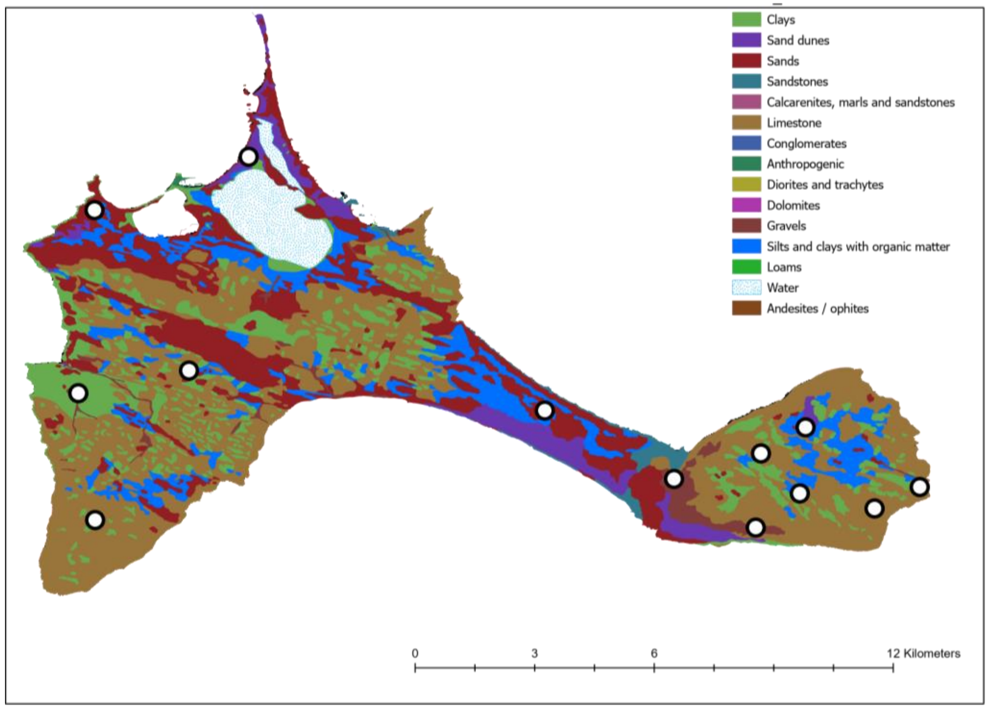




Sampling

Lab work

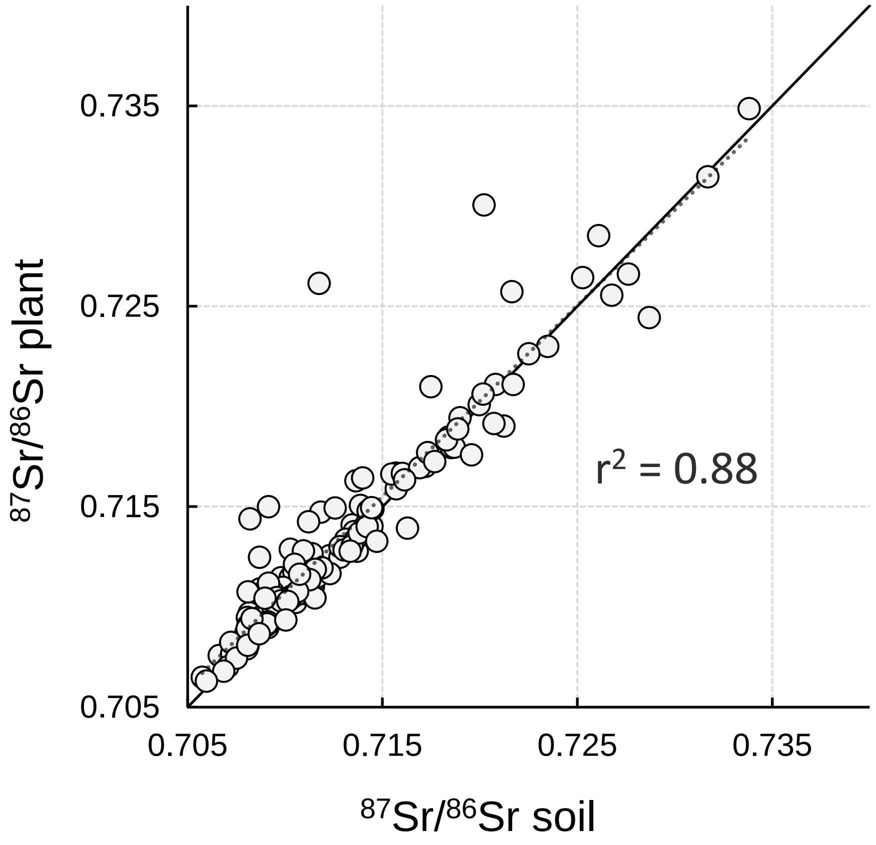




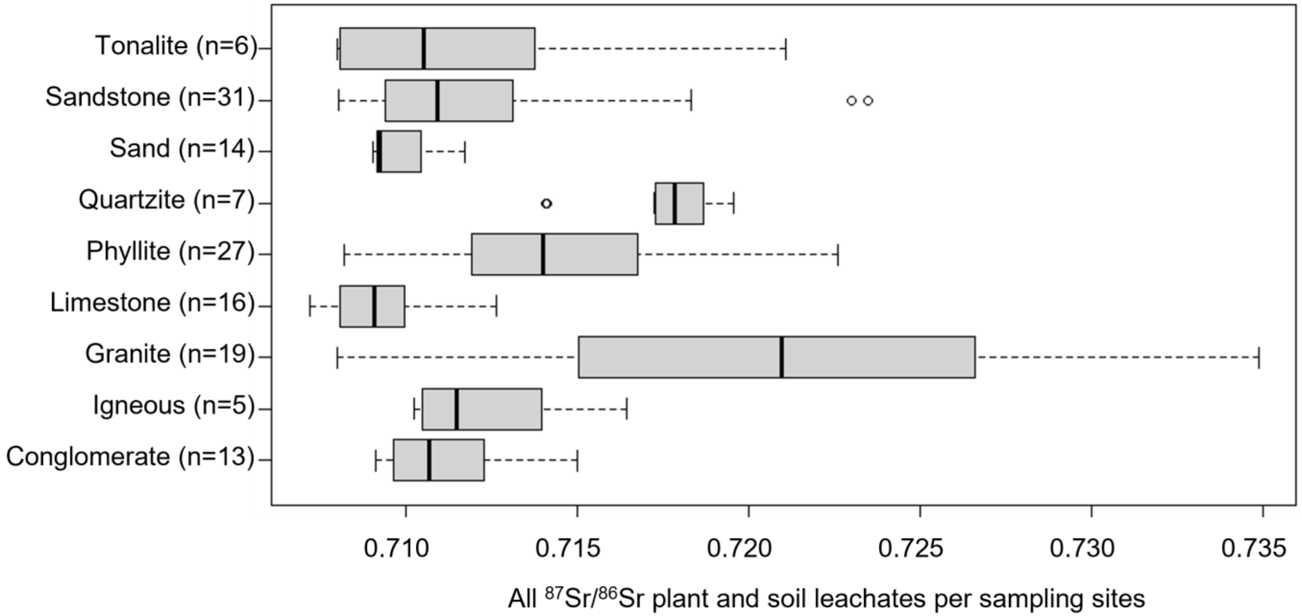
Analysis

Mapping Portugal

Close correlation between soil and plant $^{87}Sr/^{86}Sr$

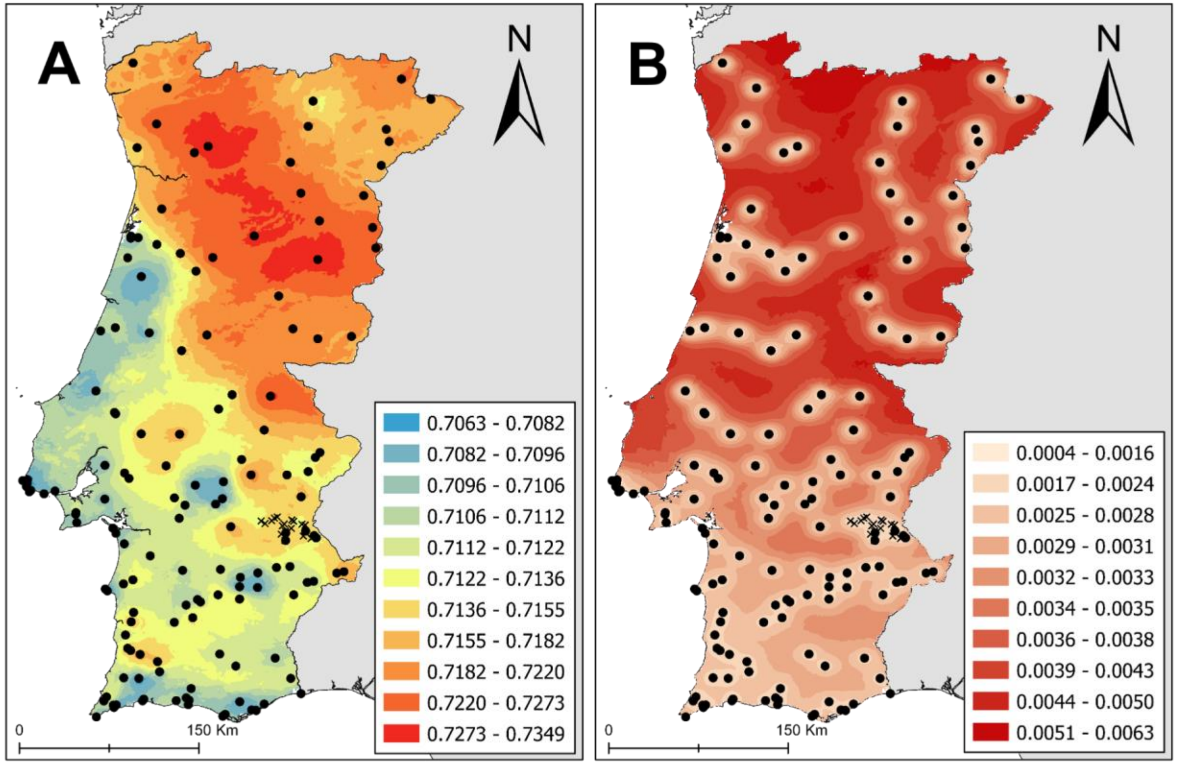


Range of $^{87}Sr/^{86}Sr$ in surface geologies

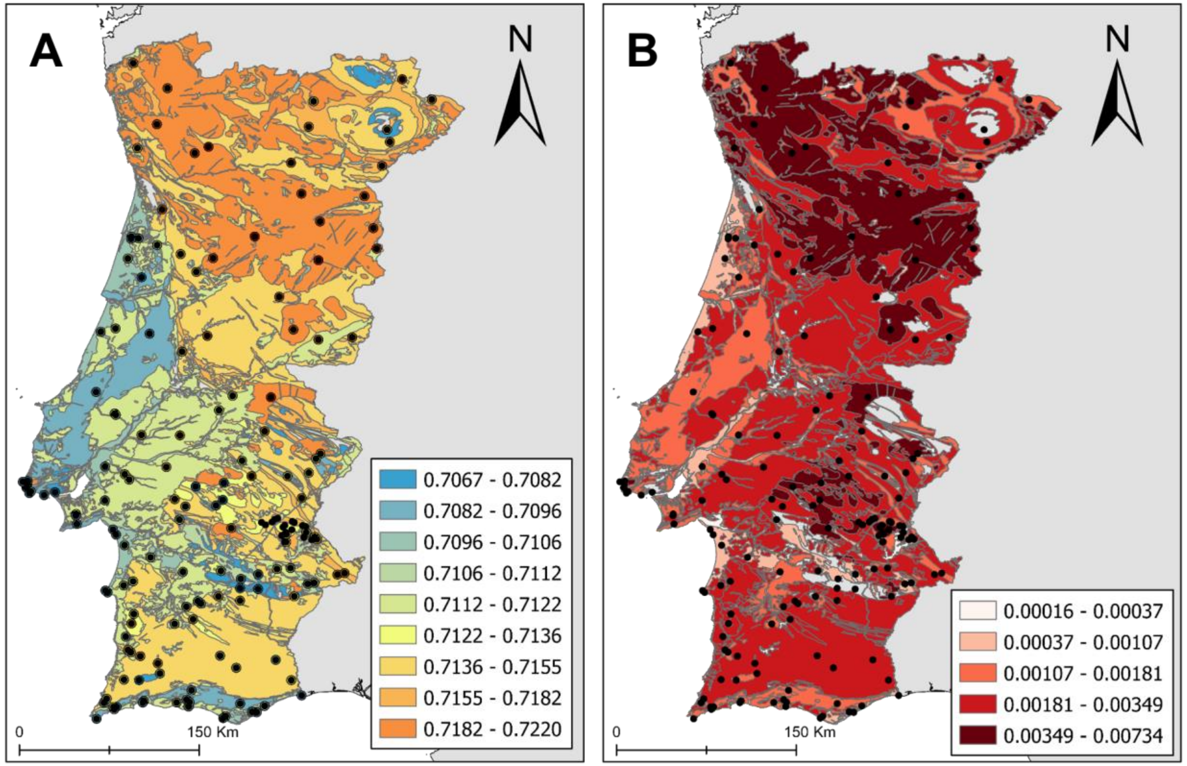


James et al., 2022, JAS

Portugal plant isoscapes



Empirical Bayesian Kriging Regression
using surface geology and elevation
as explanatory variables



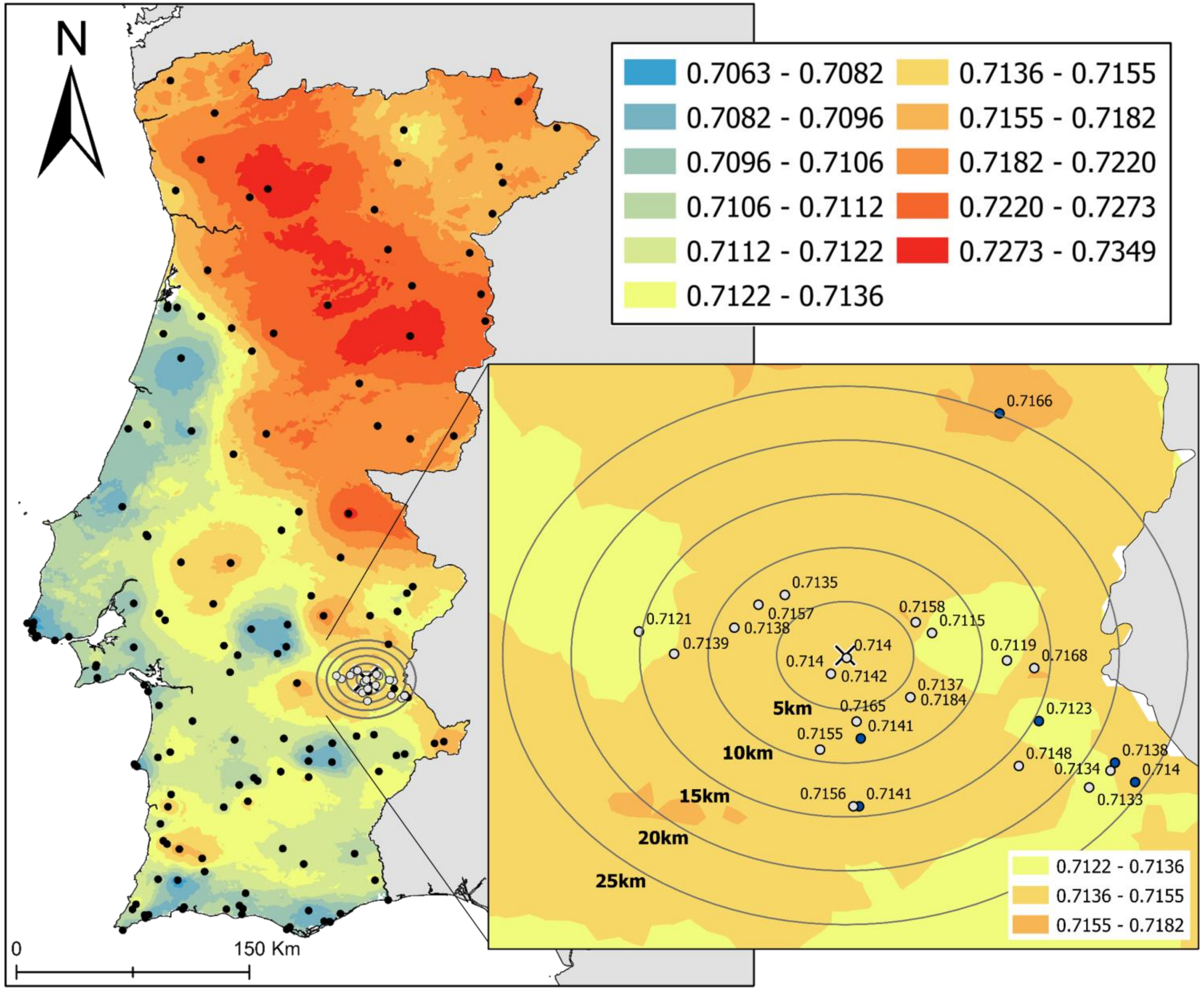
Median per surface geology unit (1:1million OneGeology)

James et al., 2022, JAS

Importance of mapping at archaeological sites

Country baseline predicts local region is $^{87}Sr/^{86}Sr$ = 0.7136-0.7155

Measured plants extend this range to $^{87}Sr/^{86}Sr$ = 0.7115 to 0.7184



Site data from Žalaite et al., 2018 JASR; Valera et al., 2020 JASR

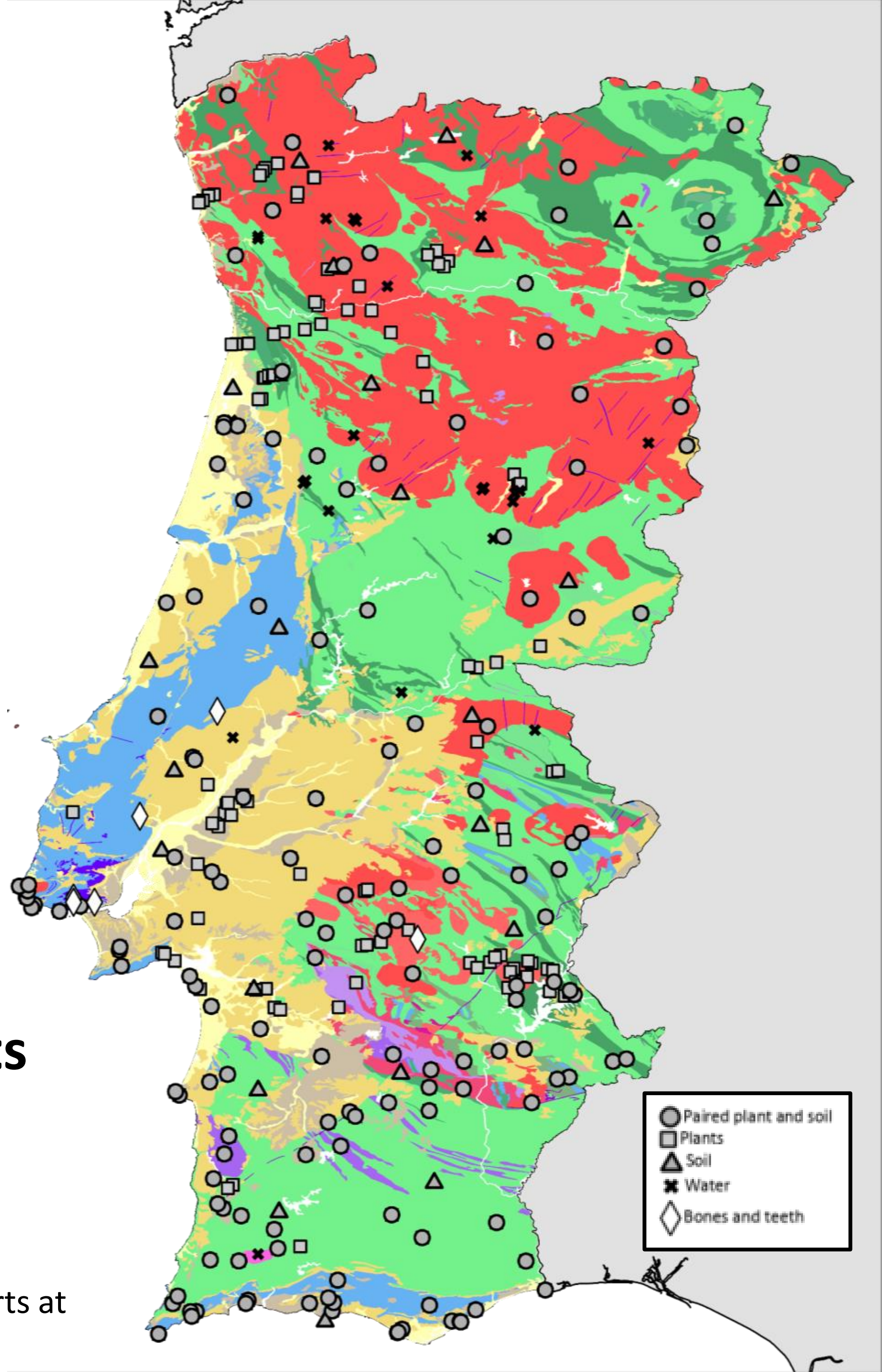
James et al., 2022, JAS

More BASr for Portugal

More data:

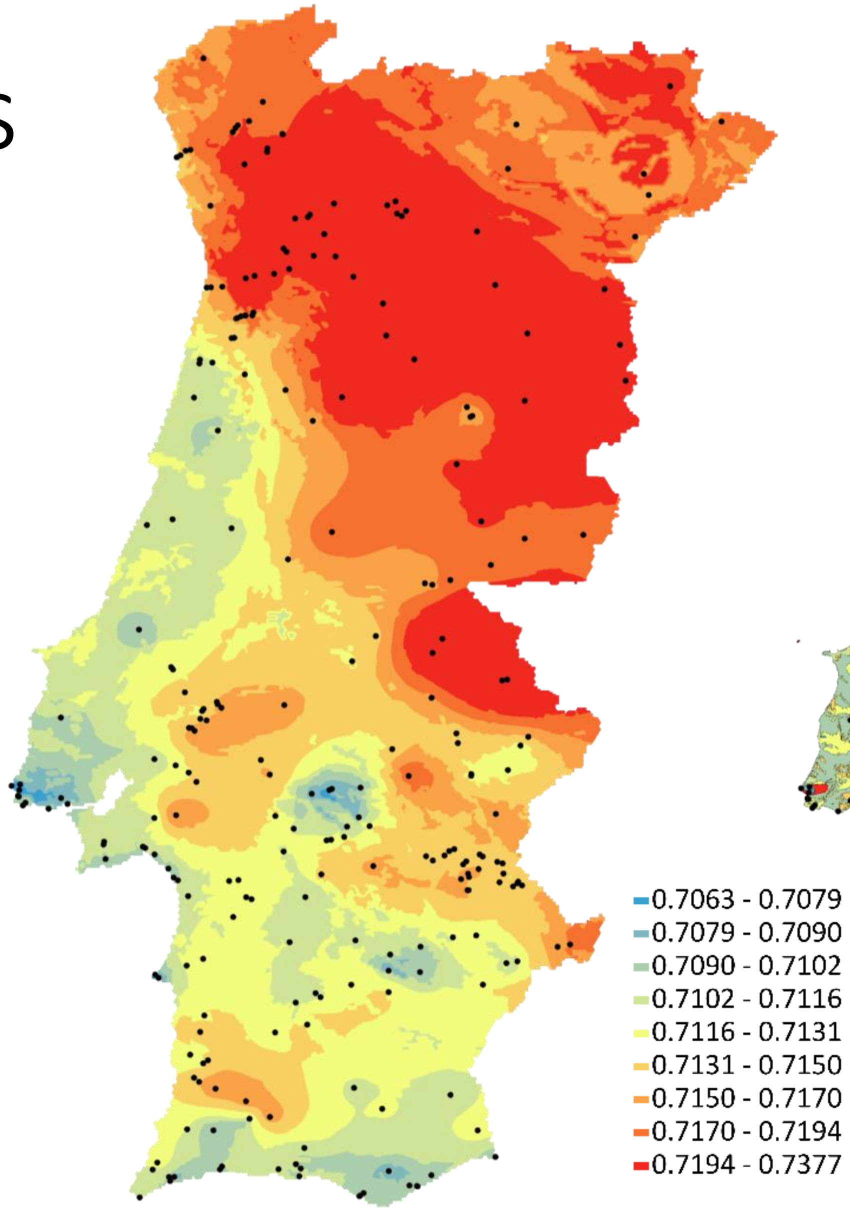
- **2** unpublished regional datasets on grass, shrubs, and trees at **93** sampling sites, **279** $^{87}Sr/^{86}Sr$ values
- **4** additional plants from archaeological sites
- **39** archaeological samples
- **34** natural mineral waters, surface waters and snow

In total **334 sampling sites** with **706 $^{87}Sr/^{86}Sr$ measurements**

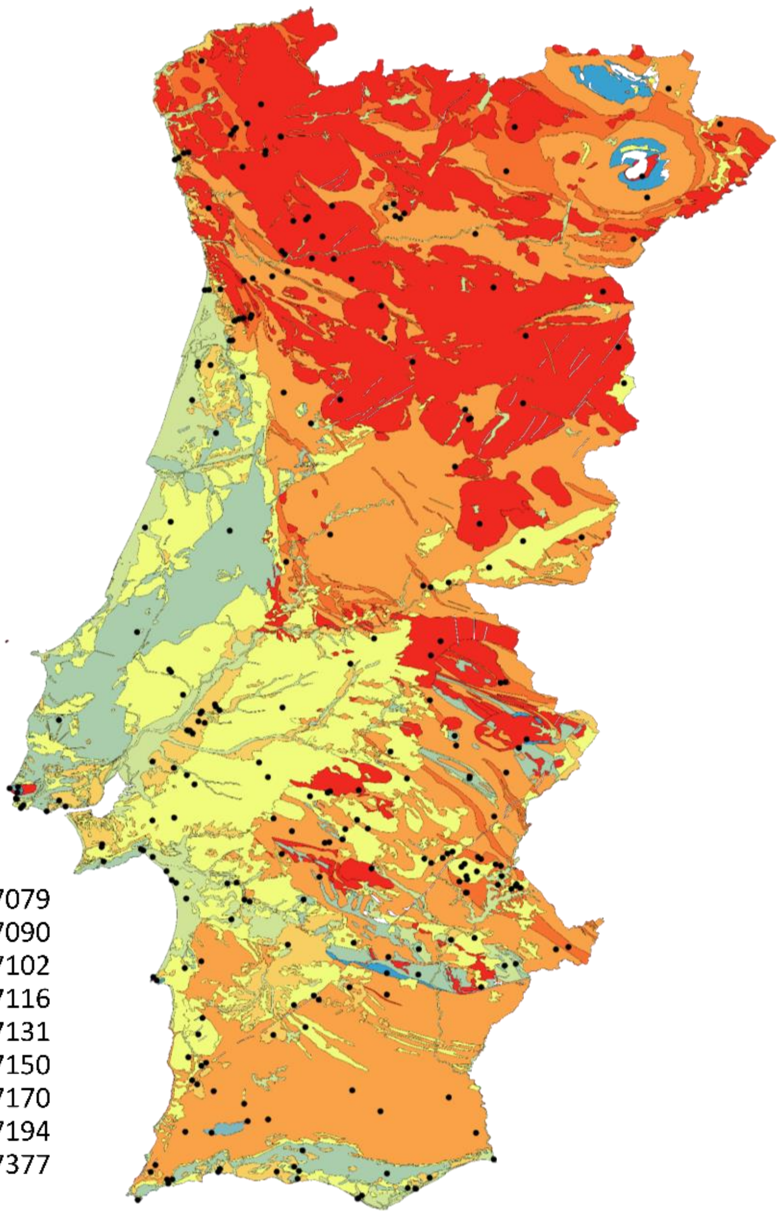


Wright et al., 2019 JASR; Price et al., 2014; Carvalho et al., 2019 AAS; Waterman et al., 2010 JAS; MacRoberts at al., 2020 JASR; Voerkelius et al., 2010 Food Chem. ; Ribeiro et al., 2014 Comunicações Geológicas

Combining datasets in Portugal

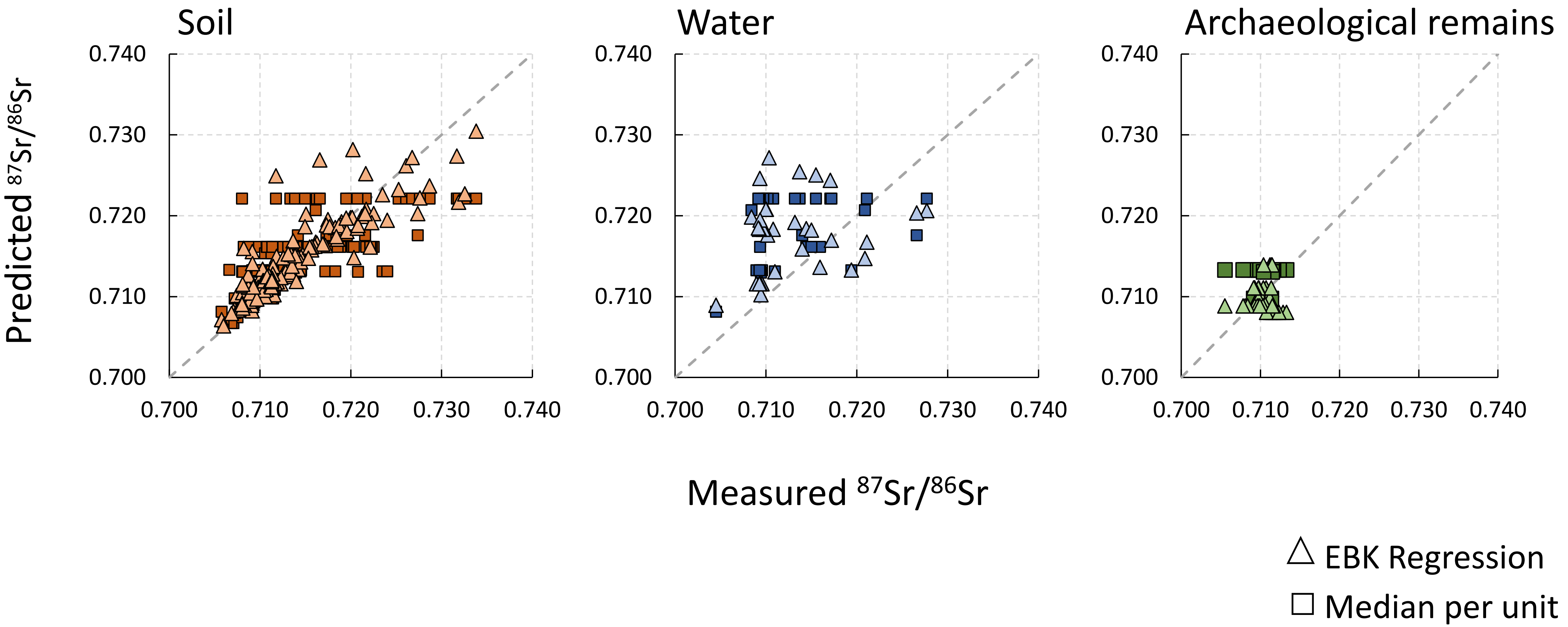


Empirical Bayesian Kriging Regression using surface geology and elevation as explanatory variables



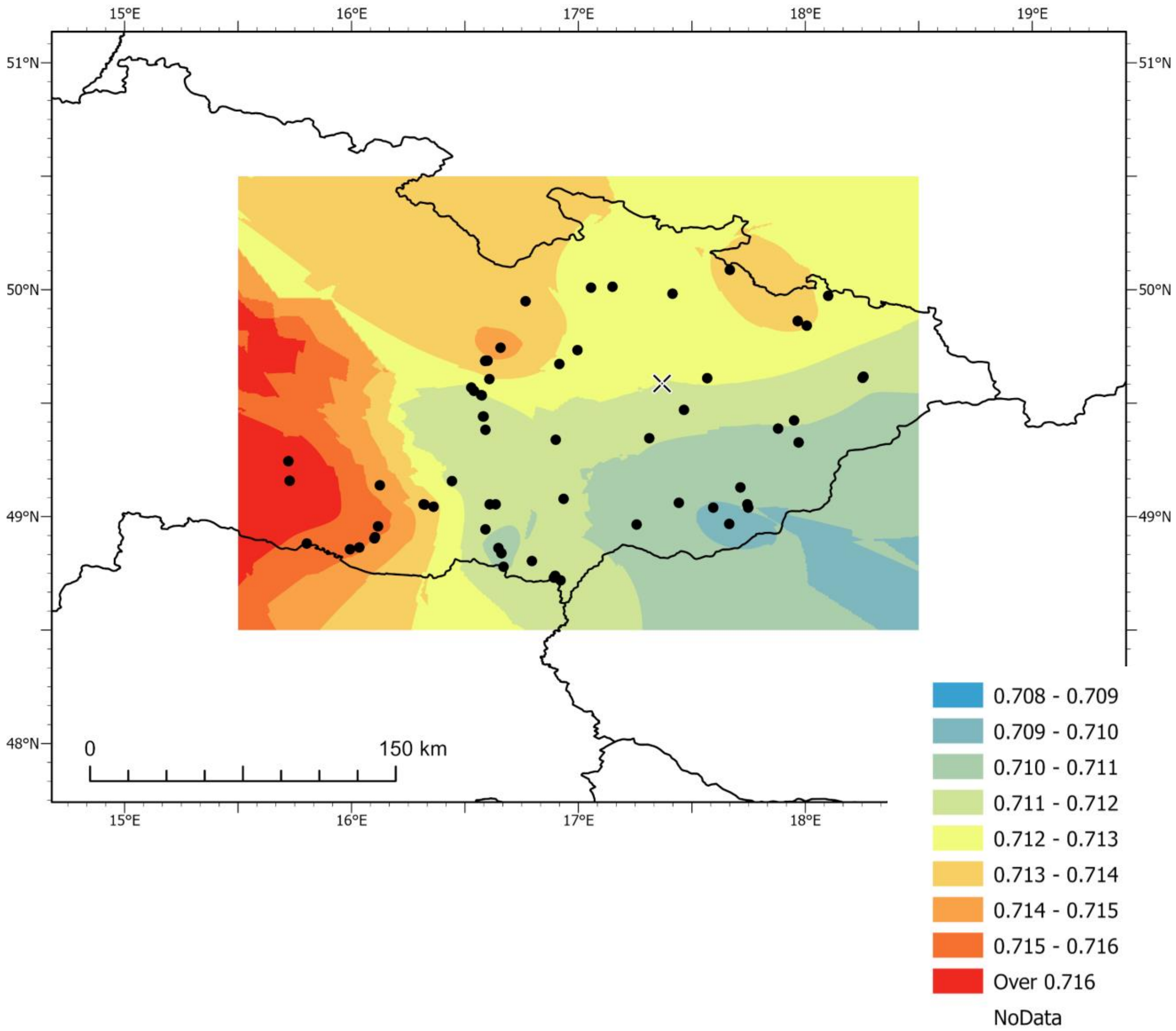
Median per surface geology unit (1:1million OneGeology)

How well can plant baselines predict other sample types?



Mapping Czechia

- Plant samples from 65 sampling sites
- Site medians range from $^{87}Sr/^{86}Sr = 0.7084 – 0.7208$



Using the Sr baseline in Ireland

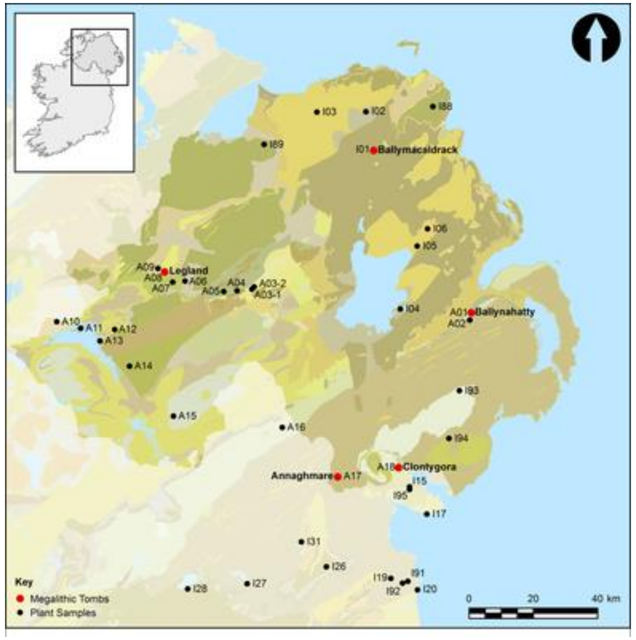
AMERICAN JOURNAL OF
BIOLOGICAL ANTHROPOLOGY
The Official Journal of the American Association of Biological Anthropologists

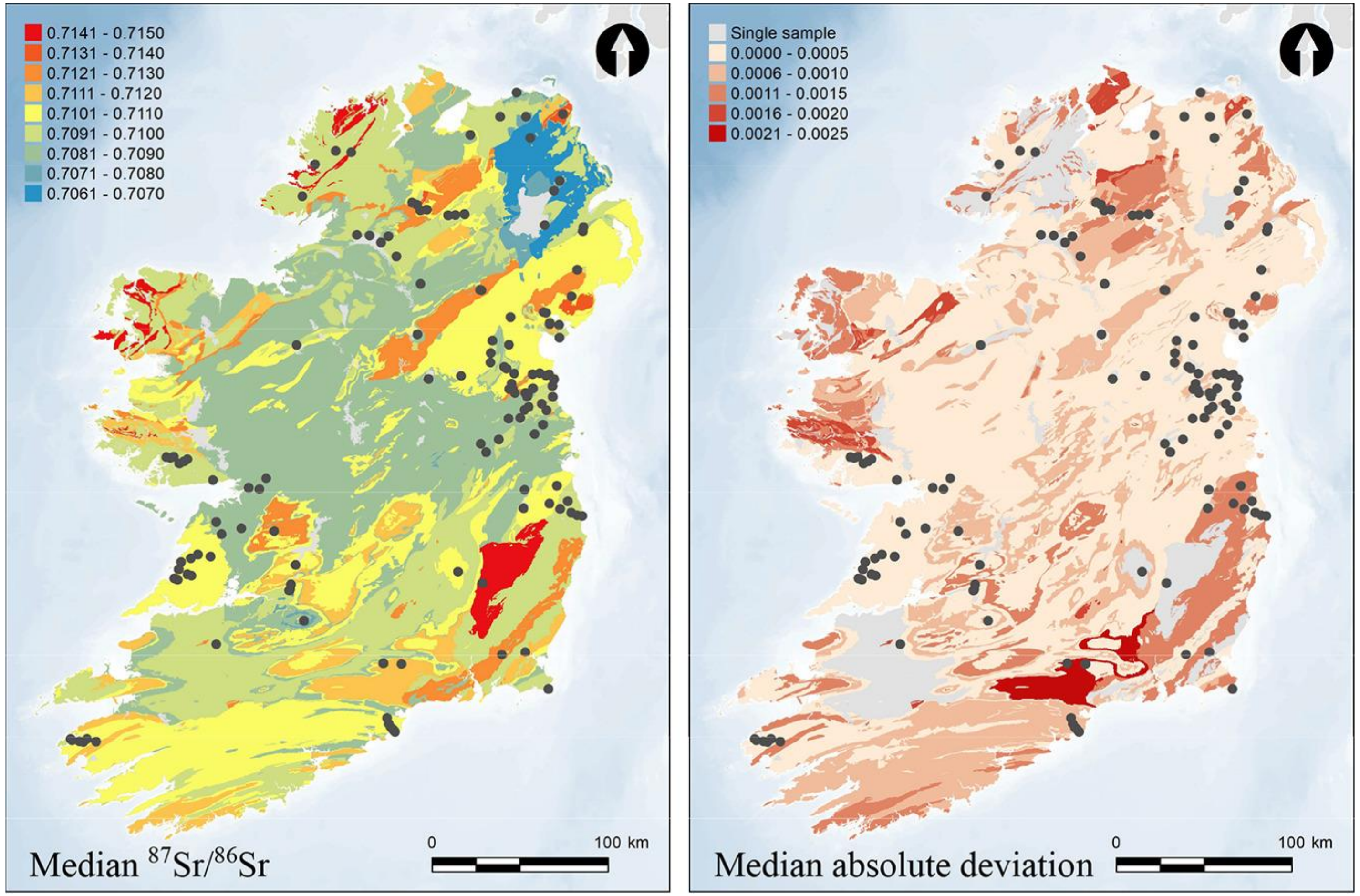
Research Article | Full Access

Mobility during the neolithic and bronze age in northern ireland explored using strontium isotope analysis of cremated human bone

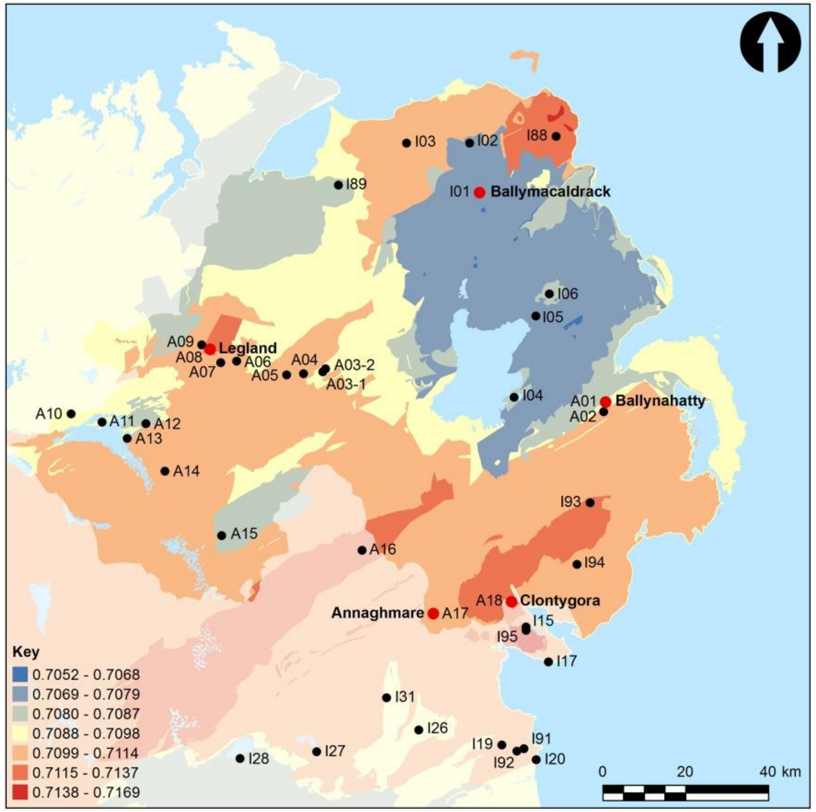
Christophe Snoeck, John Pouncett, Greer Ramsey, Ian G. Meighan, Nadine Mattielli, Steven Goderis, Julia A. Lee-Thorp, Rick J. Schulting

First published: 09 April 2016 | https://doi.org/10.1002/ajpa.22977 | Citations: 32

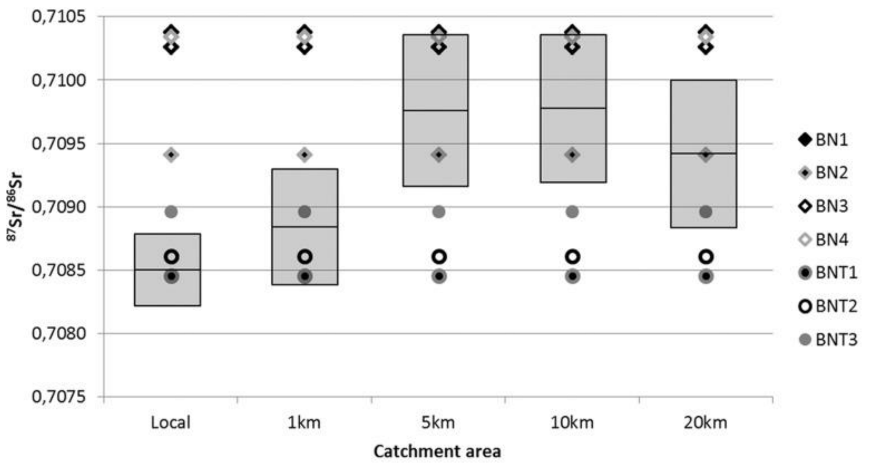


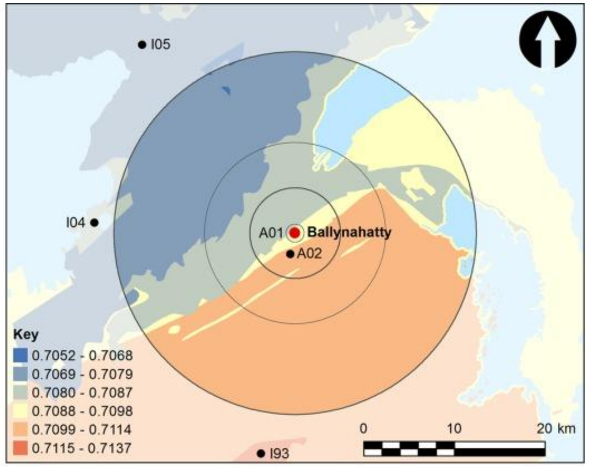


Using the Sr baseline in Ireland

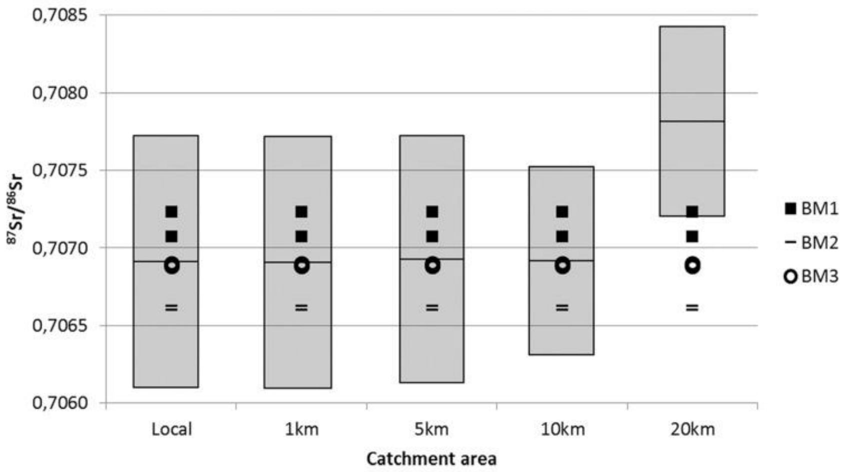


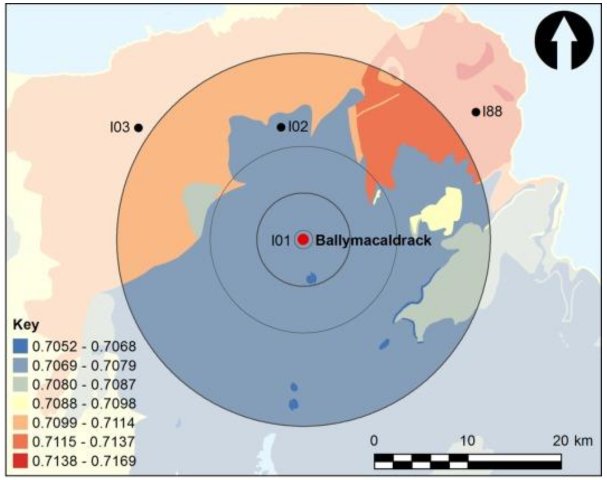
Ballynahatty





Ballymacaldrack

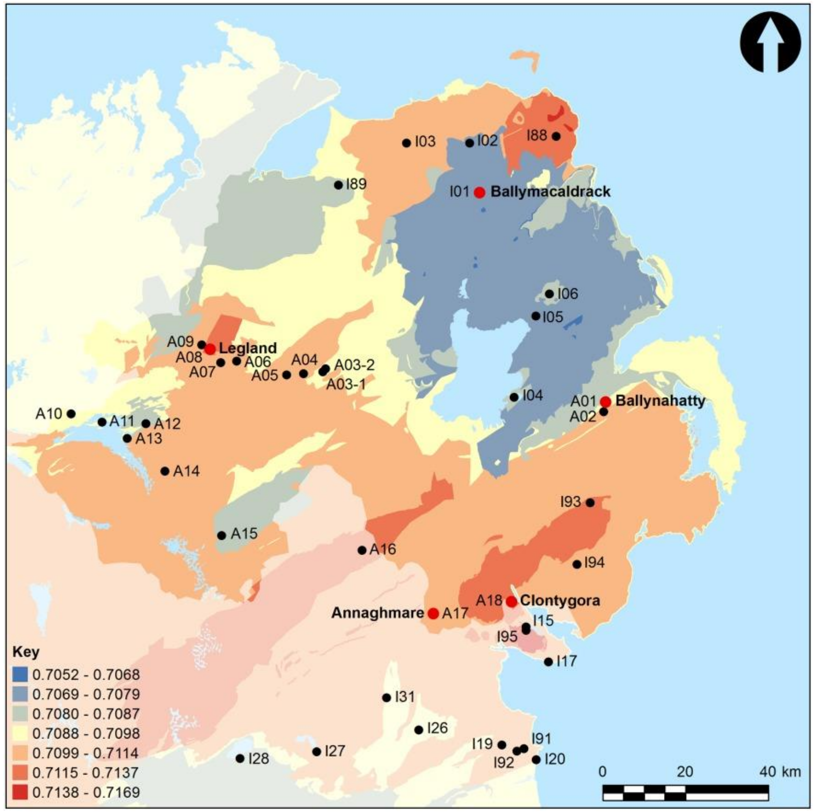




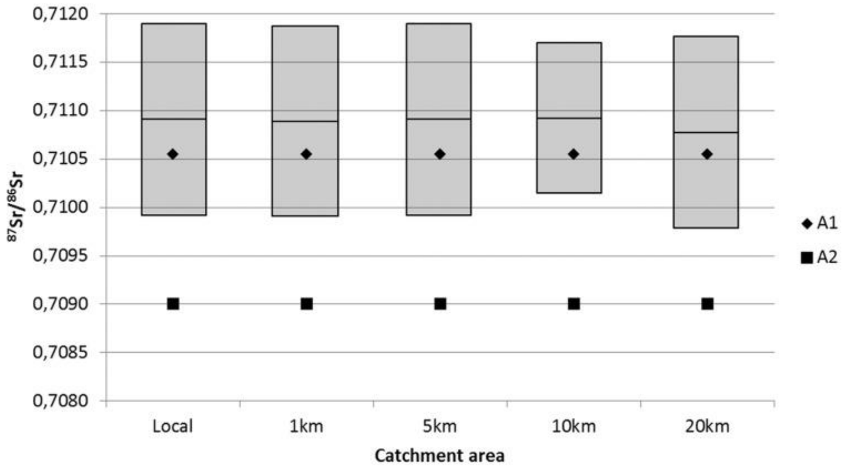
(a)

(b)

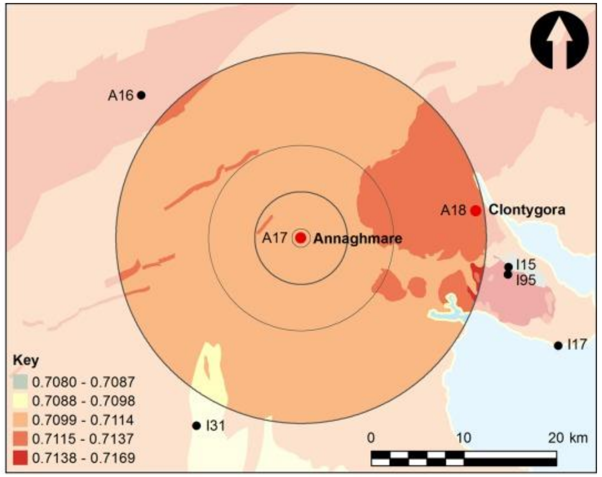
Using the Sr baseline in Ireland



Annaghmare

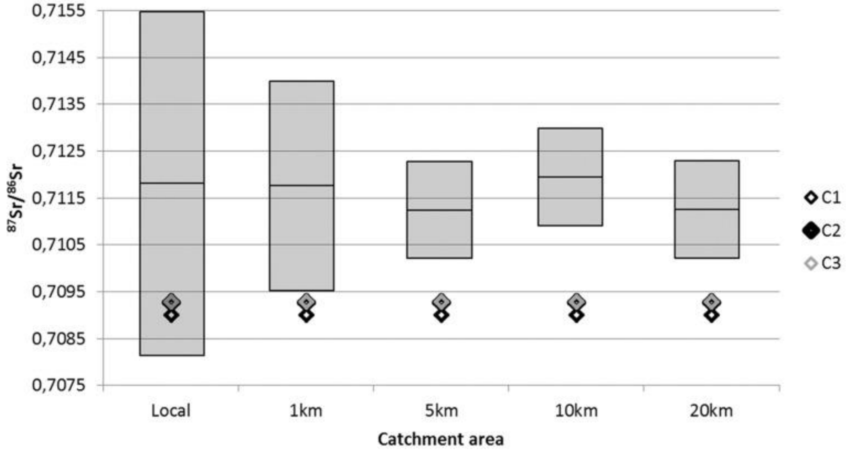


(a)

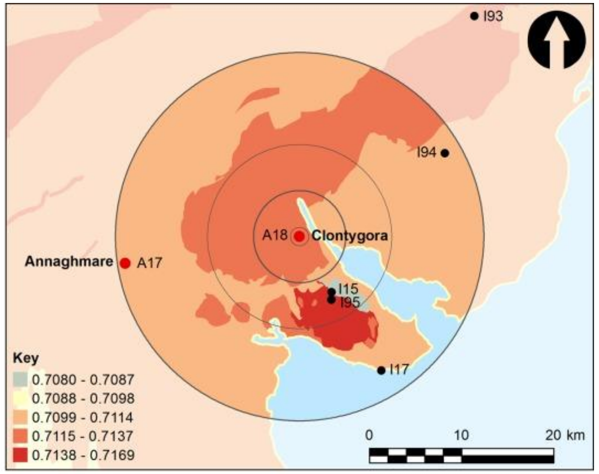


(b)

Clontygora



(a)



(b)

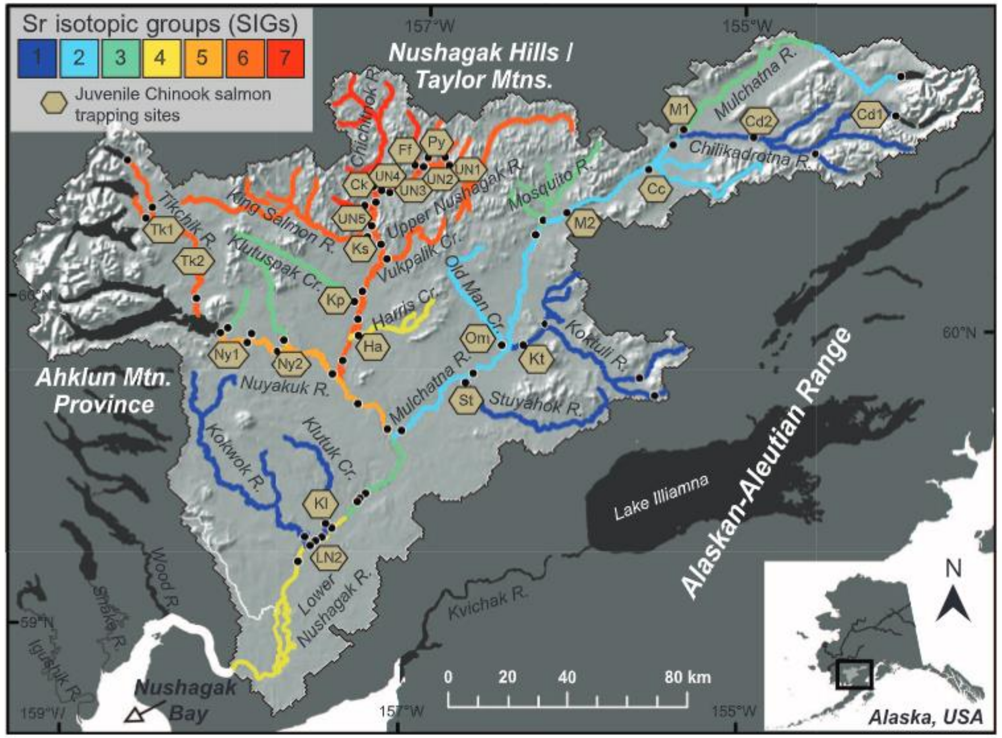
Sr baselines in ecology

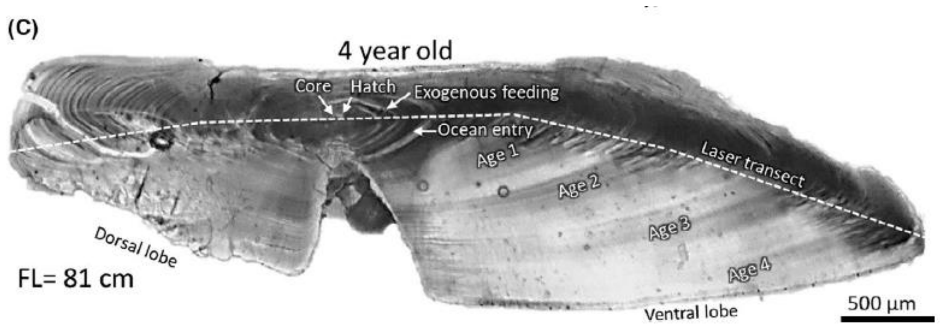
RESEARCH ARTICLE

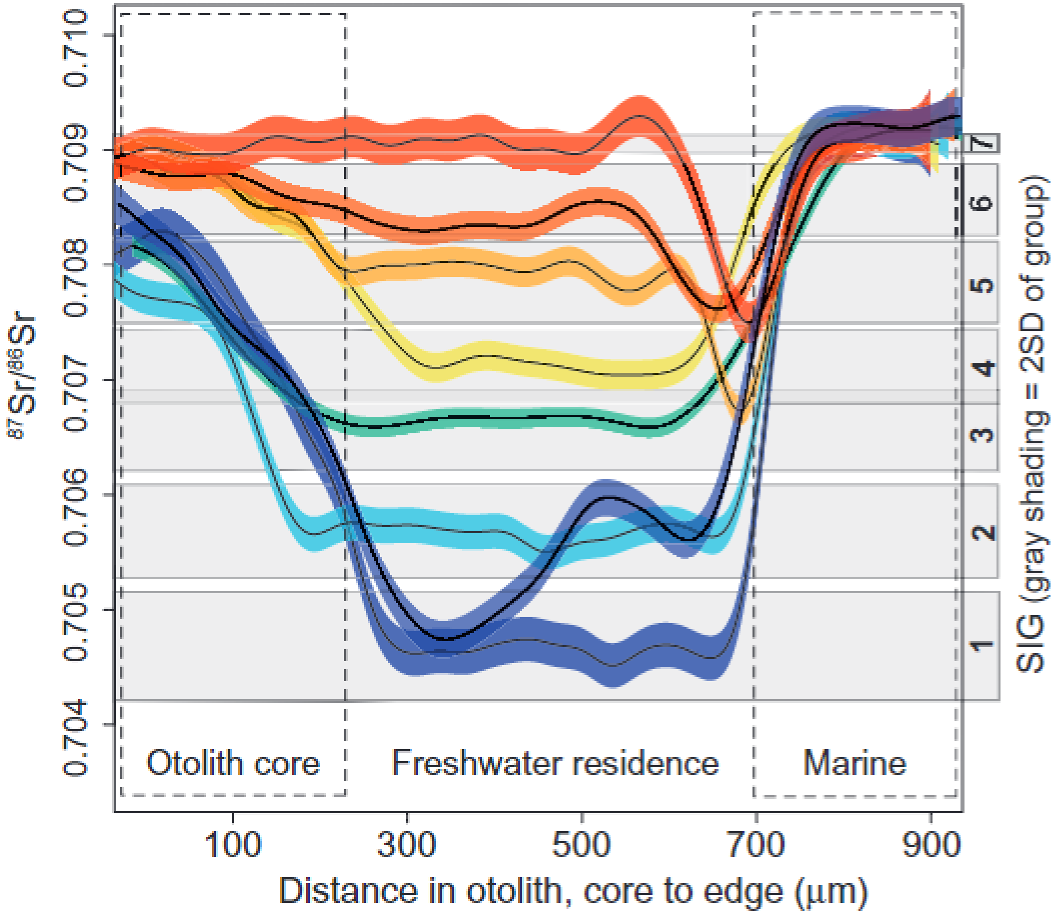
CONSERVATION ECOLOGY

Strontium isotopes delineate fine-scale natal origins and migration histories of Pacific salmon

Sean R. Brennan,[1,2*†] Christian E. Zimmerman,[3,4] Diego P. Fernandez,[5] Thure E. Cerling,[5] Megan V. McPhee,[1,6] Matthew J. Wooller[1,2]



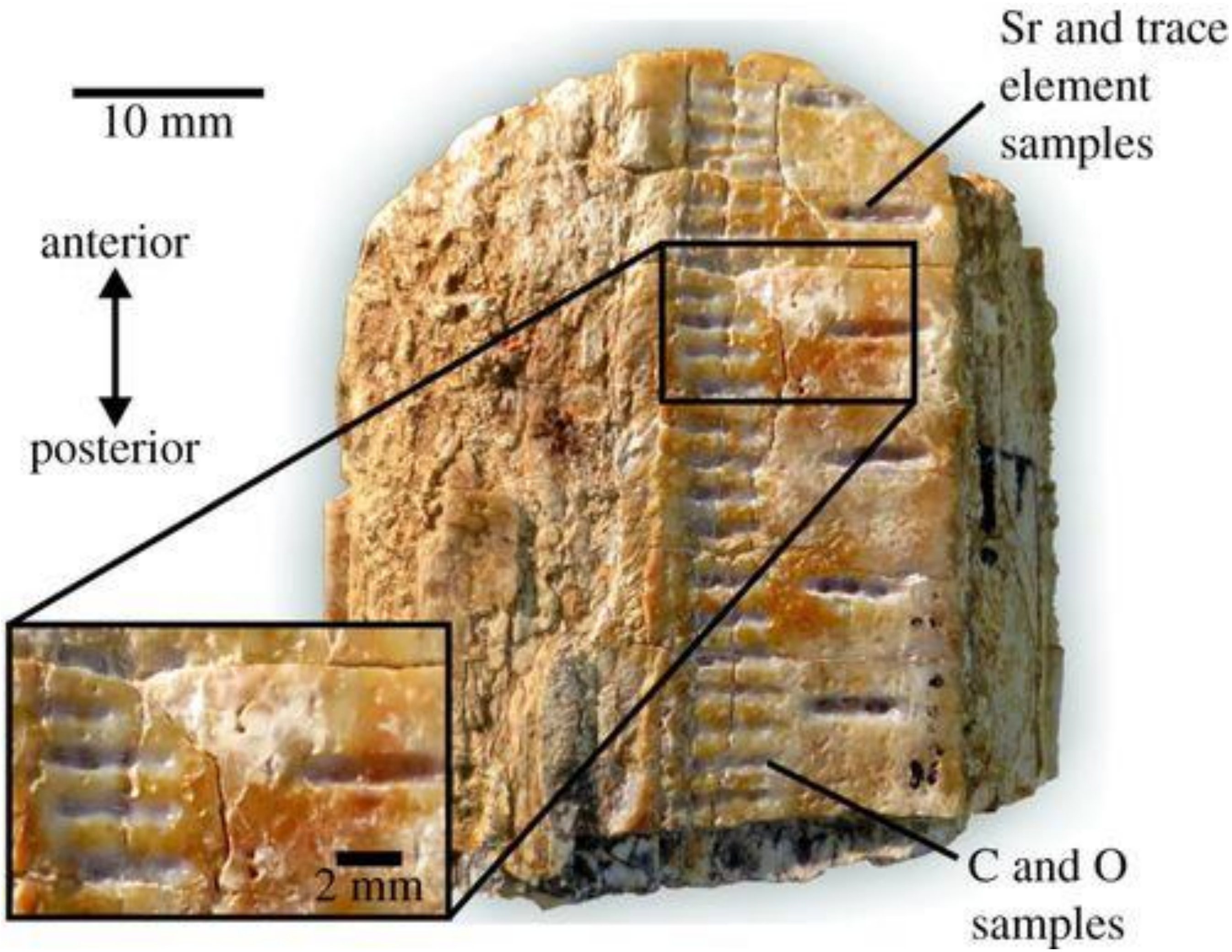




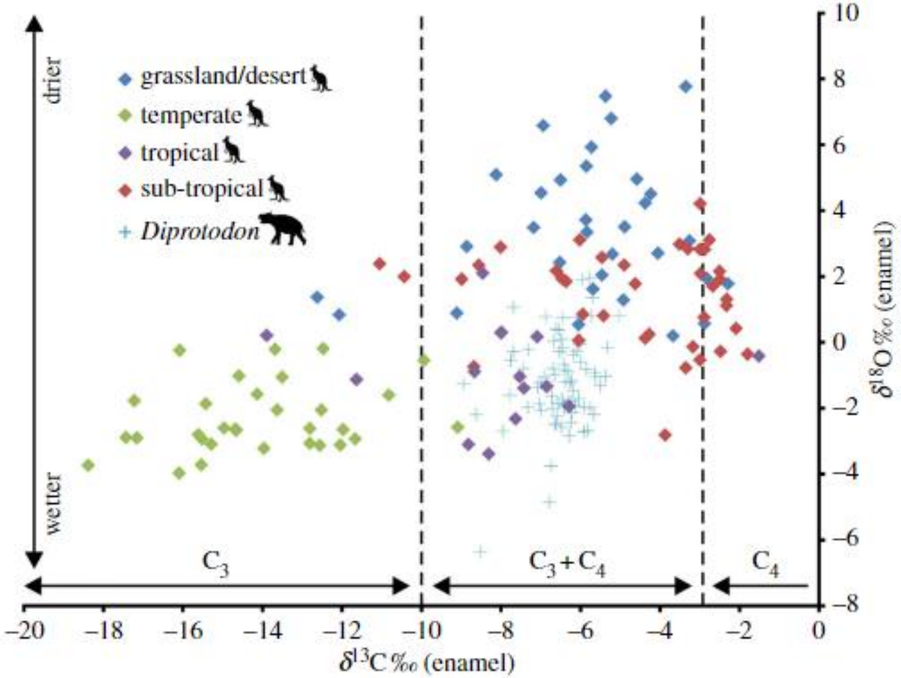
Palaeontology

Seasonal migration of marsupial megafauna in Pleistocene Sahul (Australia – New Guinea)

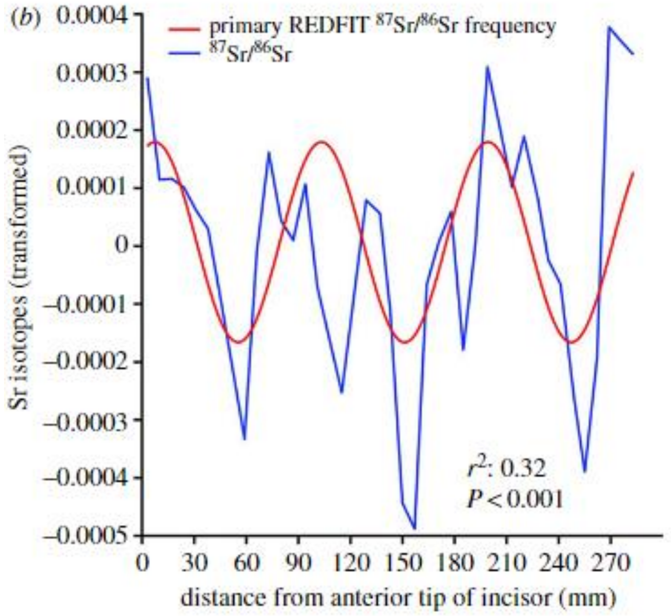
Gilbert J. Price[1], Kyle J. Ferguson[1], Gregory E. Webb[1], Yue-xing Feng[1], Pennilyn Higgins[2], Ai Duc Nguyen[1], Jian-xin Zhao[1], Renaud Joannes-Boyau[3] and Julien Louys[4]

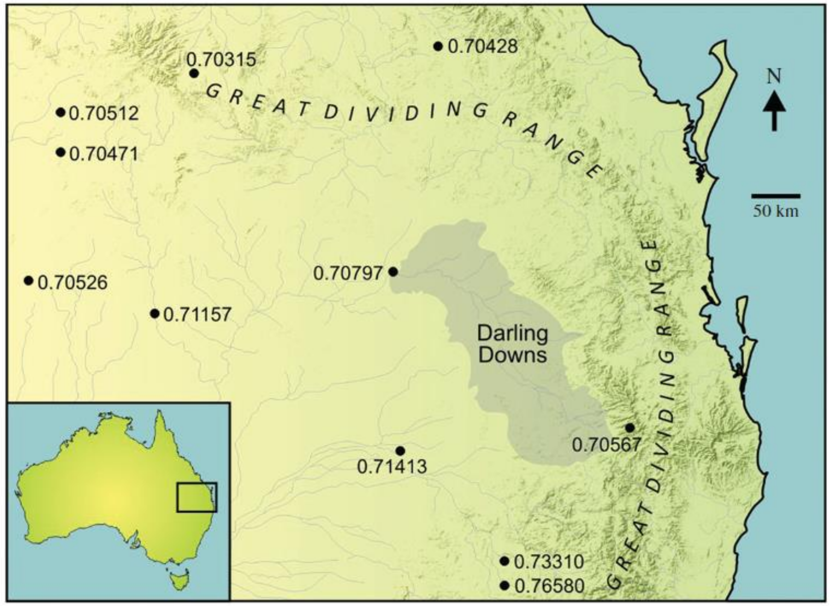


Palaeontology



Strontium





The $^{87}Sr/^{86}Sr$ ratios (n = 37) fluctuate between 0.706333 and 0.707396 along the tooth

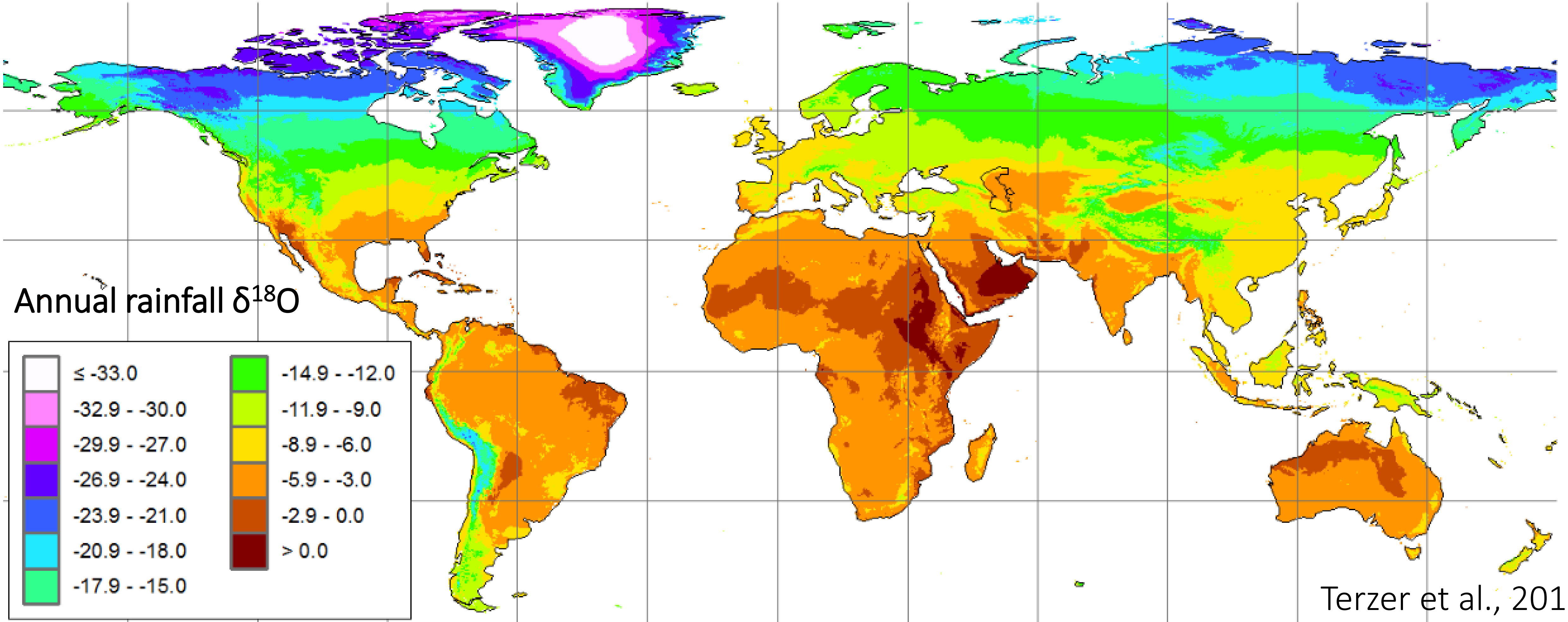
Oxygen isotopes ($\delta^{18}O$)

→ Rain $\delta^{18}O$ changes with amount of rain and temperature

→ Oxygen in human tissues mainly from drinking water

→ Assuming that water is sourced locally from rainwater

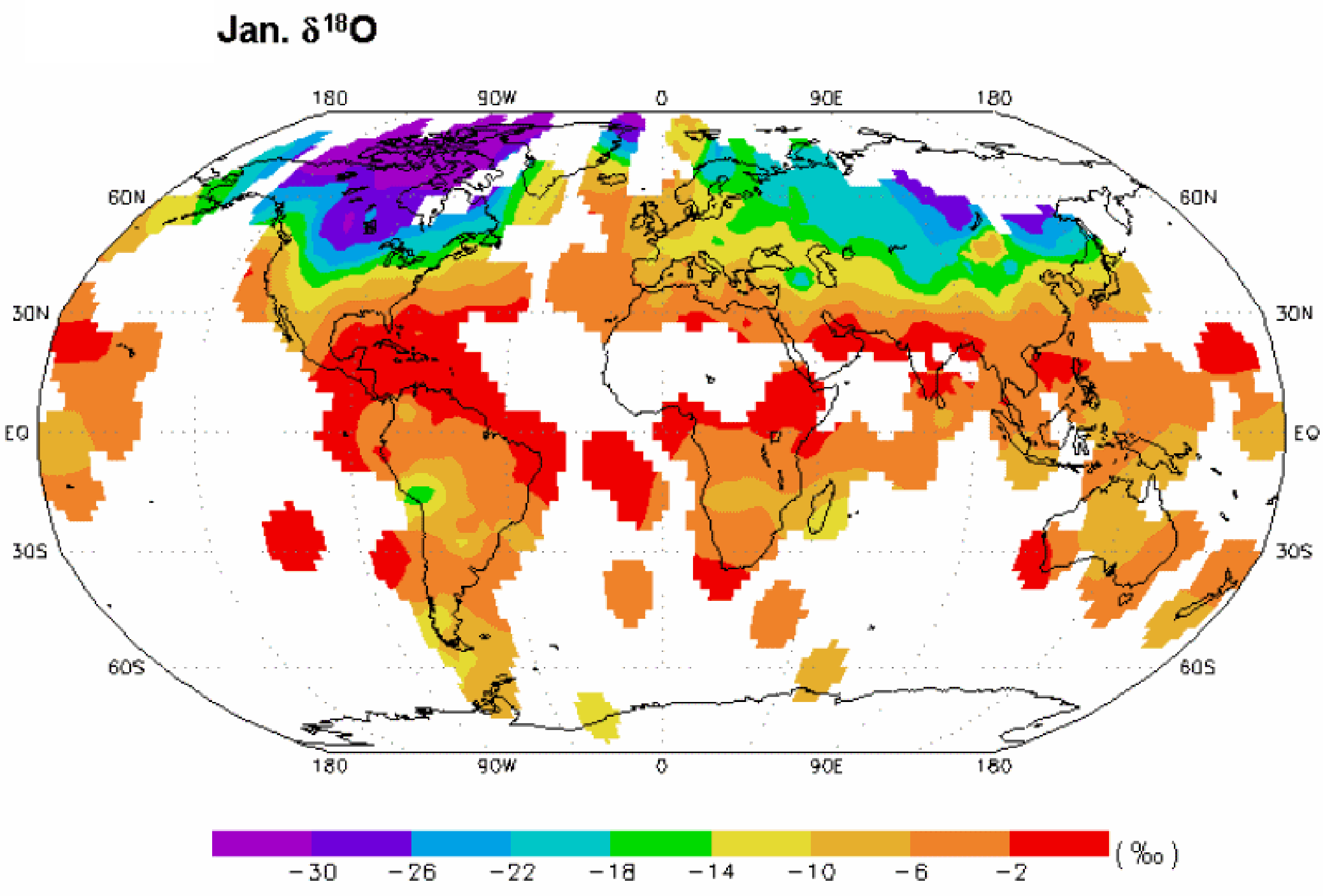
→ $\delta^{18}O$ reflects rain during the time the tissue was forming.



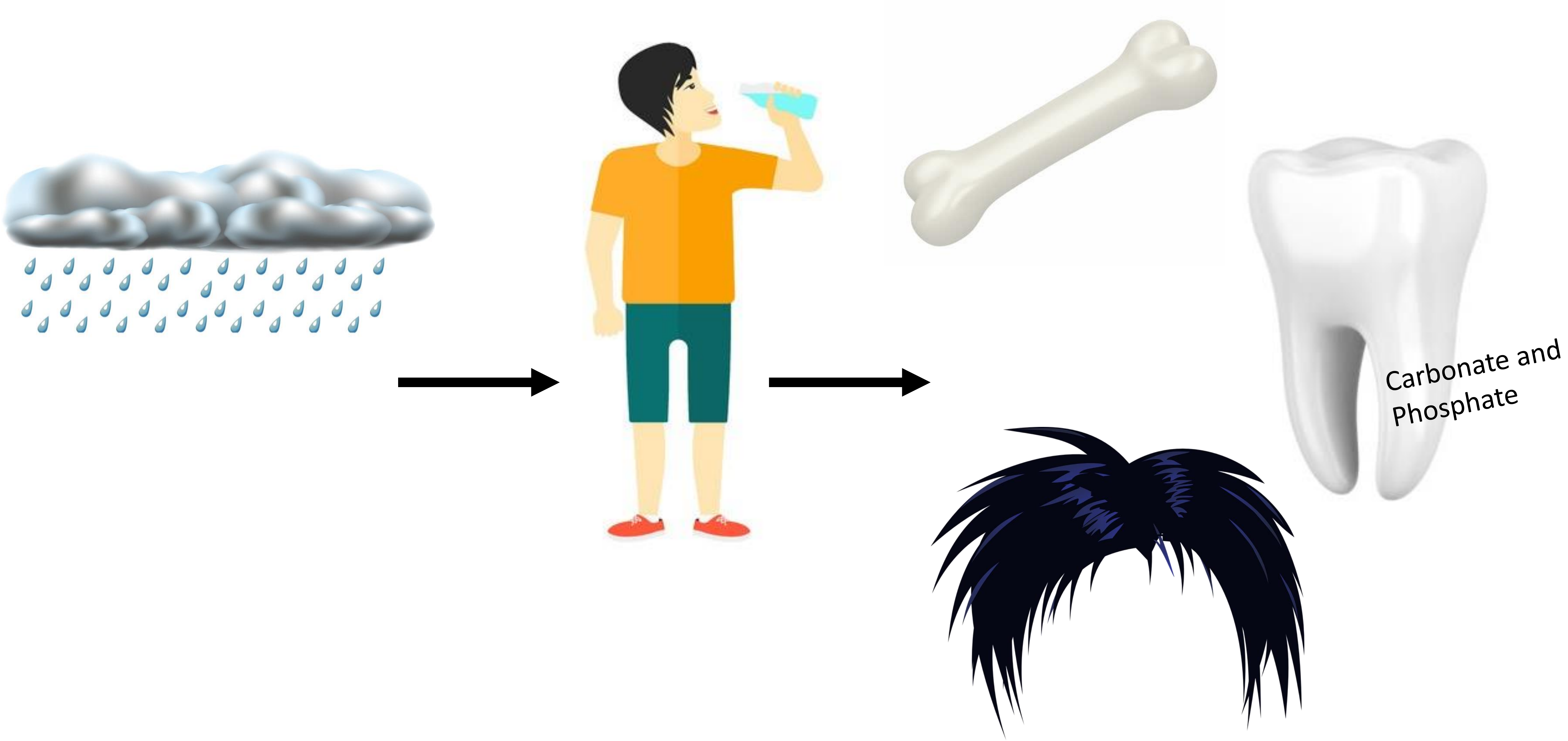
Terzer et al., 2013

Not just mobility influencing δ¹⁸O

- Seasonal changes in rain
  - ~3‰ between summer and winter
- Breastfeeding
  - Breastmilk is more enriched in ^{18}O,
- Water sources
- Humans doing stuff to liquids
  - Storing
  - Boiling
  - Stewing
  - Brewing
  - Slow cooking



What can you measured $\delta^{18}O$ in?



Fractionation

The incorporation of O isotopes into skeletal tissues involves a fractionation

Offset between structural carbonates ($\delta^{18}O_C$) and body water is ~ 27‰; the phosphate ($\delta^{18}O_P$) to body water offset is smaller ~ 18‰

Difference between carbonate and phosphate oxygen in human tooth enamel explained by the equation:

$\delta^{18}O_P = 1.0322\ (\pm 0.008)\ x\ \delta^{18}O_C - 9.6849\ (\pm 0.187)$ - (Chenery et al., 2012)

Converting $\delta^{18}O$ values into water values

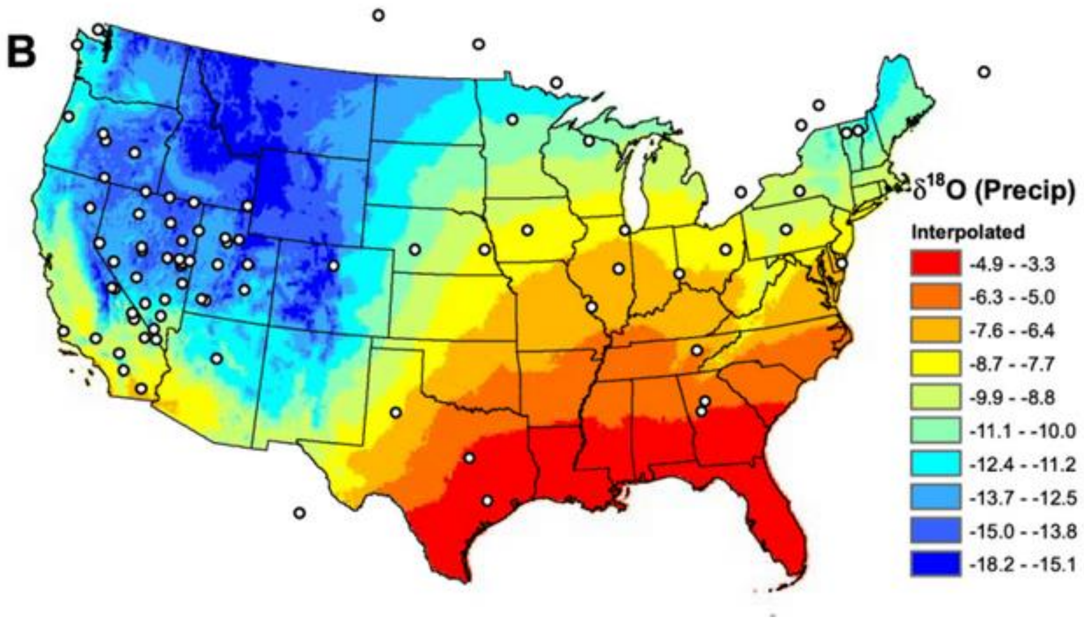
$\delta^{18}O_w = 1.54 \times \delta^{18}O_p - 33.72$ (Daux et al., 2008)

$\delta^{18}O_w = 1.590 \times \delta^{18}O_C - 48.634$ (Chenery et al., 2012)

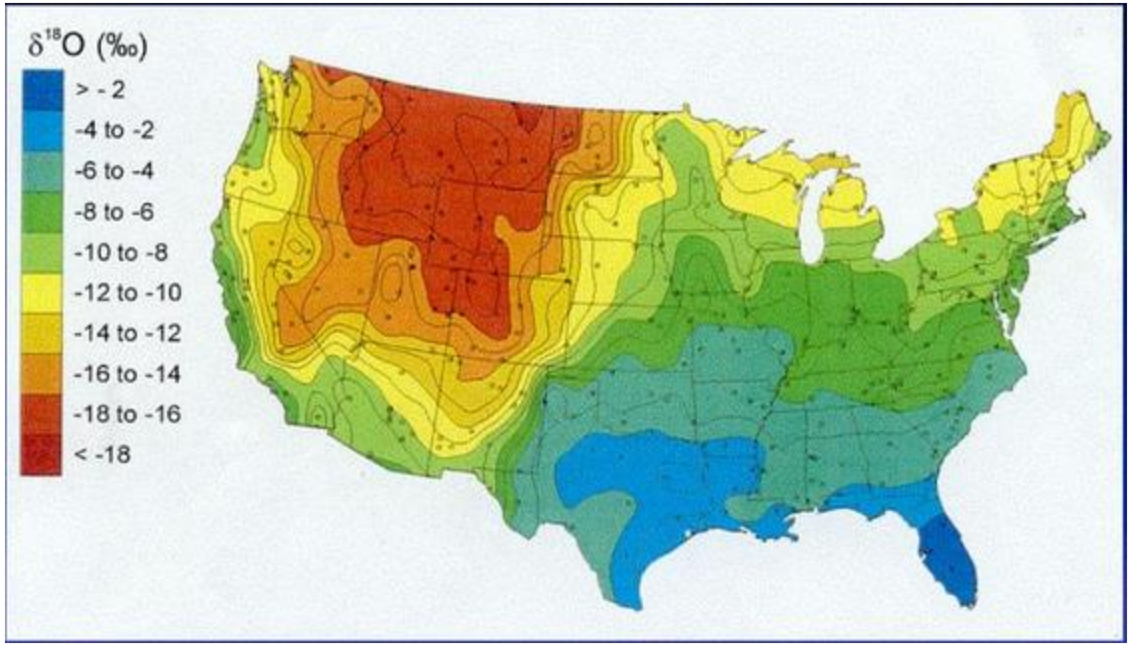
Equations are species specific

USA

Rainfall

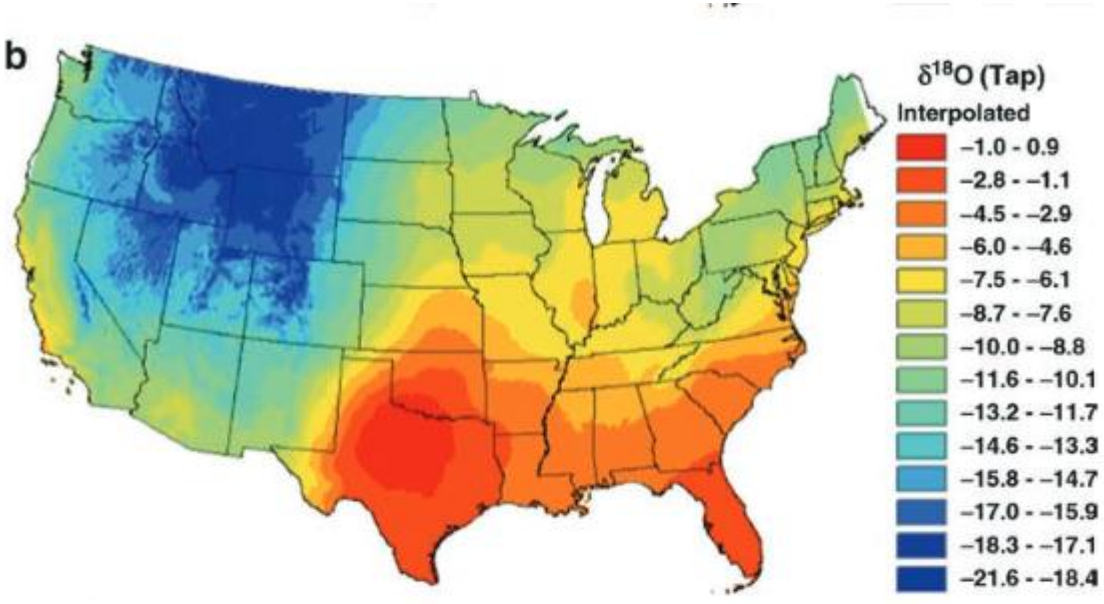


Surface water

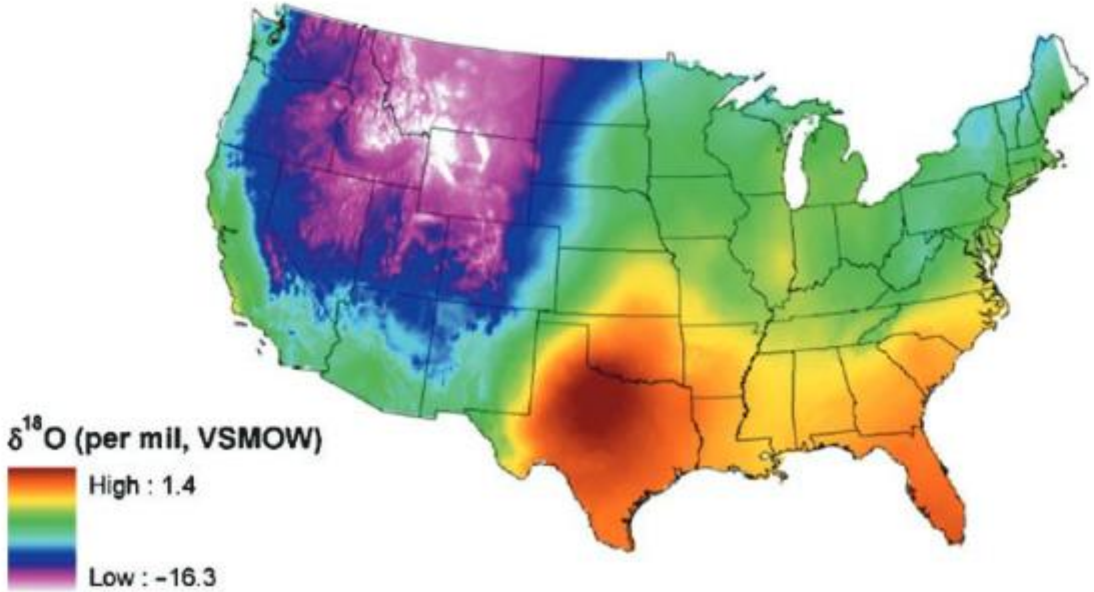


Ehleringer., 2016; Kendall and Coplen 2001

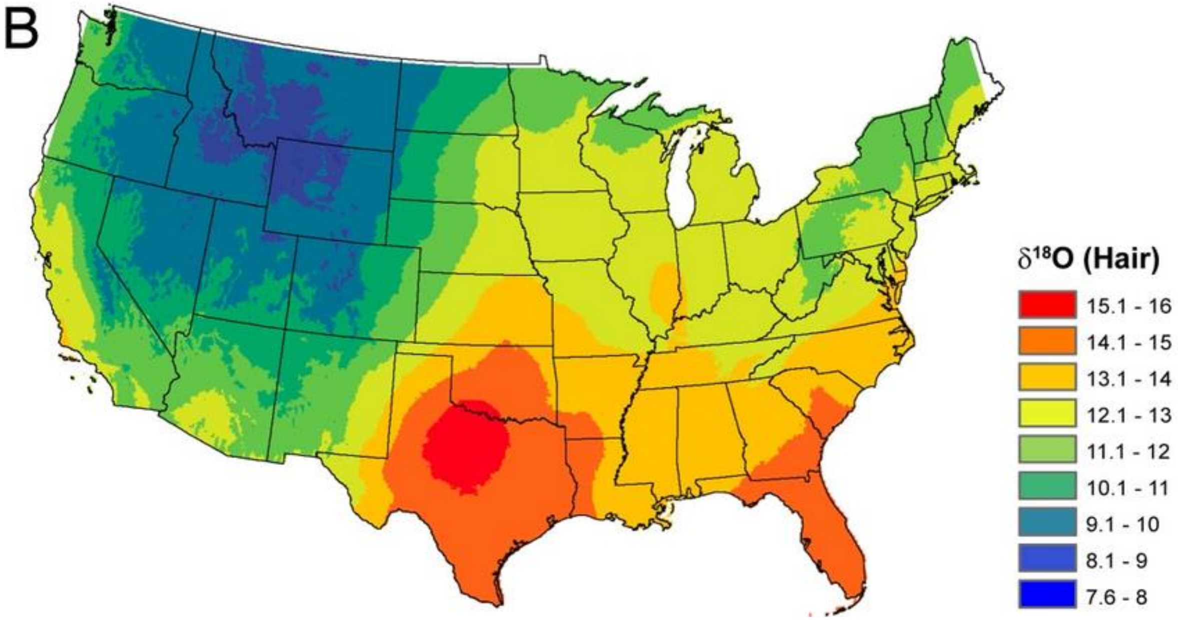
Tap water

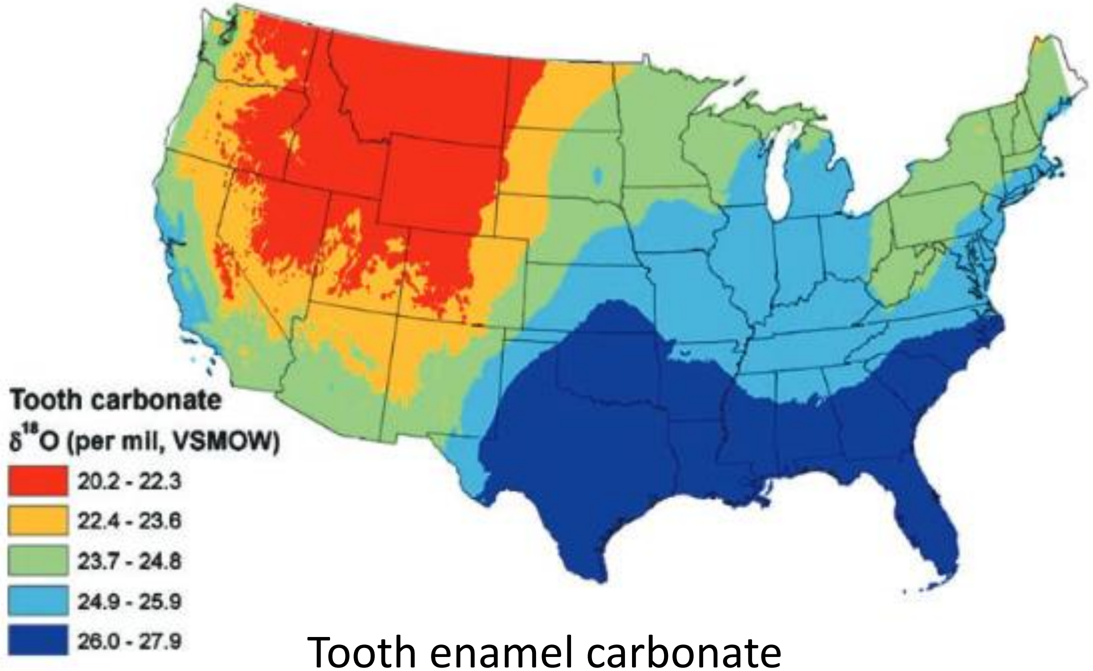


Body water



Hair

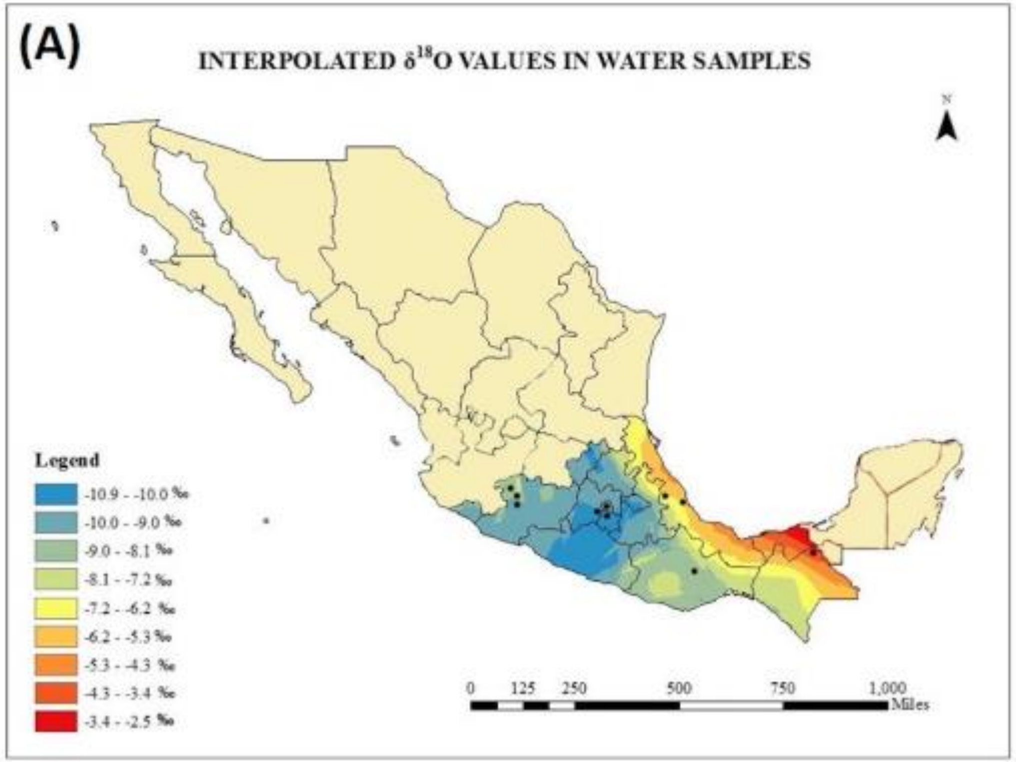


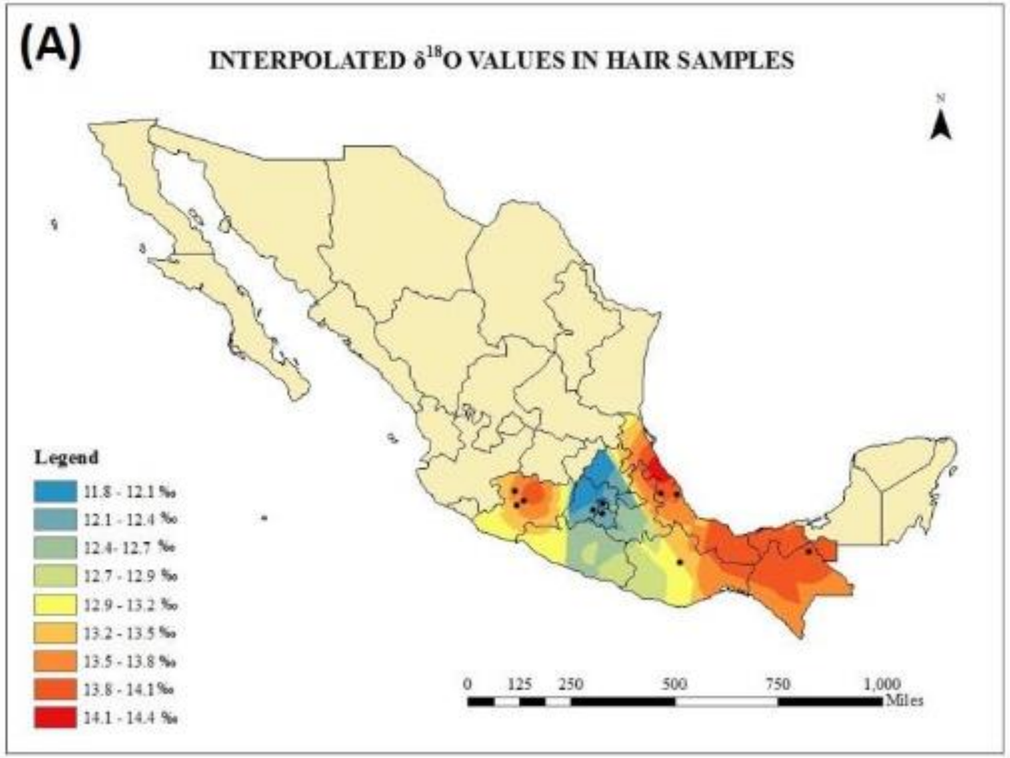


Tooth enamel carbonate

Ehleringer., 2016; Kendall and Coplen 2001

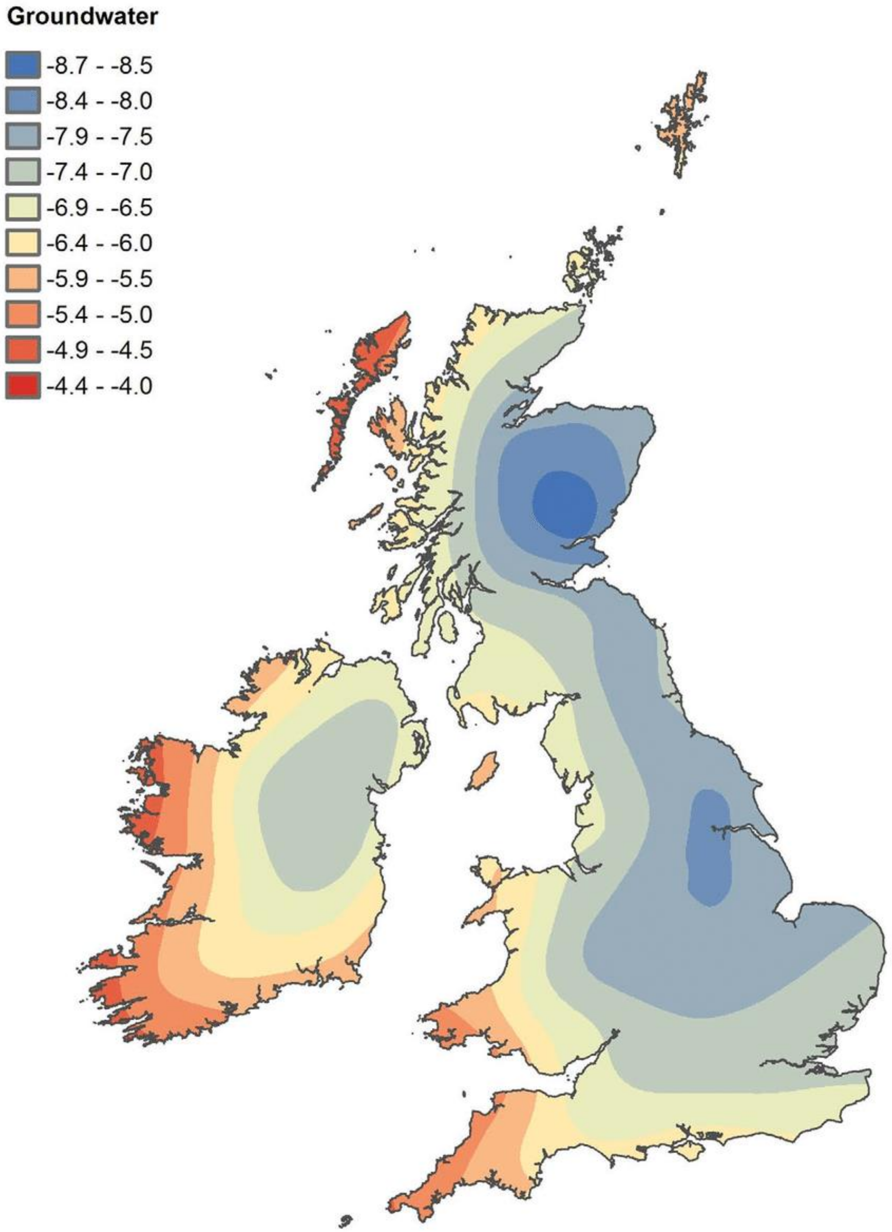
Mexico



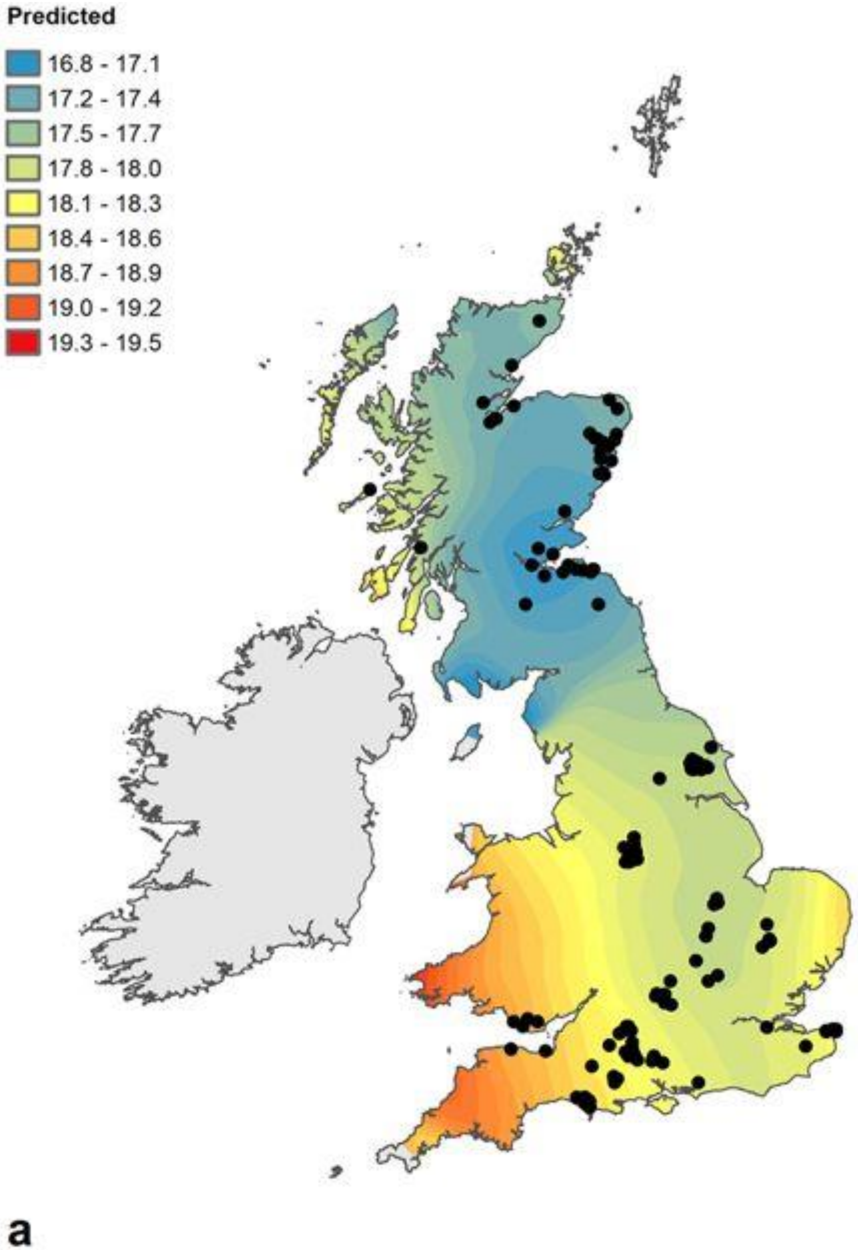


Juarez et al., 2019

UK



Groundwater (Pellegrini et al., 2016)



Tooth enamel carbonate (Pellegrini et al., 2016)

Oxygen isotope analysis is widely used in archaeology

ELSEVIER
Journal of Archaeological Science
Volume 33, Issue 2, February 2006, Pages 265-272

A strontium and oxygen isotope assessment of a possible fourth century immigrant population in a Hampshire cemetery, southern England

Jane Evans [a], Nick Stoodley [b], Carolyn Chenery [a]

ELSEVIER
Journal of Anthropological Archaeology
Volume 36, December 2014, Pages 32-47

New isotope data on Maya mobility and enclaves at Classic Copan, Honduras

T. Douglas Price [a], Seiichi Nakamura [b], Shintaro Suzuki [c], James H. Burton [d], Vera Tiesler [e]

ELSEVIER
Journal of Archaeological Science: Reports
Volume 8, August 2016, Pages 416-425

Stable oxygen isotope evidence for mobility in medieval and post-medieval Trondheim, Norway

Stian Suppersberger Hamre [a], Valérie Daux [b]

archaeometry
Original Article | Full Access

OXYGEN AND CARBON ISOTOPE ANALYSIS OF HUMAN DENTAL ENAMEL FROM THE CARIBBEAN: IMPLICATIONS FOR INVESTIGATING INDIVIDUAL ORIGINS

J. E. LAFFOON, R. VALCÁRCEL ROJAS, C. L. HOFMAN

First published: 19 July 2012 | https://doi.org/10.1111/j.1475-4754.2012.00698.x | Cited by: 22

ELSEVIER
Journal of Archaeological Science
Volume 28, Issue 11, November 2001, Pages 1199-1208
Regular Articles

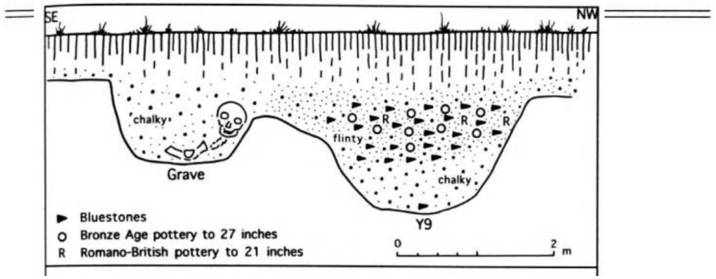
Strangers in a Strange Land: Stable Isotope Evidence for Human Migration in the Dakhleh Oasis, Egypt

Tosha L. Dupras [a, 1], Henry P. Schwarcz [b]
Show more

https://doi.org/10.1006/jasc.2001.0640 Get rights and content

An Anglo-Saxon Decapitation and Burial at Stonehenge

by Mike Pitts[1], Alex Bayliss[2], Jacqueline McKinley[3], Anthea Boylston[4], Paul Budd[5], Jane Evans[6], Carolyn Chenery[6], Andrew Reynolds[7] and Sarah Semple[8]



ELSEVIER
Earth and Planetary Science Letters
Volume 375, 1 August 2013, Pages 92-100

Egyptian mummies record increasing aridity in the Nile valley from 5500 to 1500 yr before present

Alexandra Touzeau [a], Janne Blichert-Toft [a], Romain Amiot [a], François Fourel [a], François Martineau [a], Jenefer Cockitt [b], Keith Hall [c], Jean-Pierre Flandrois [d], Christophe Lécuyer [a, 1]

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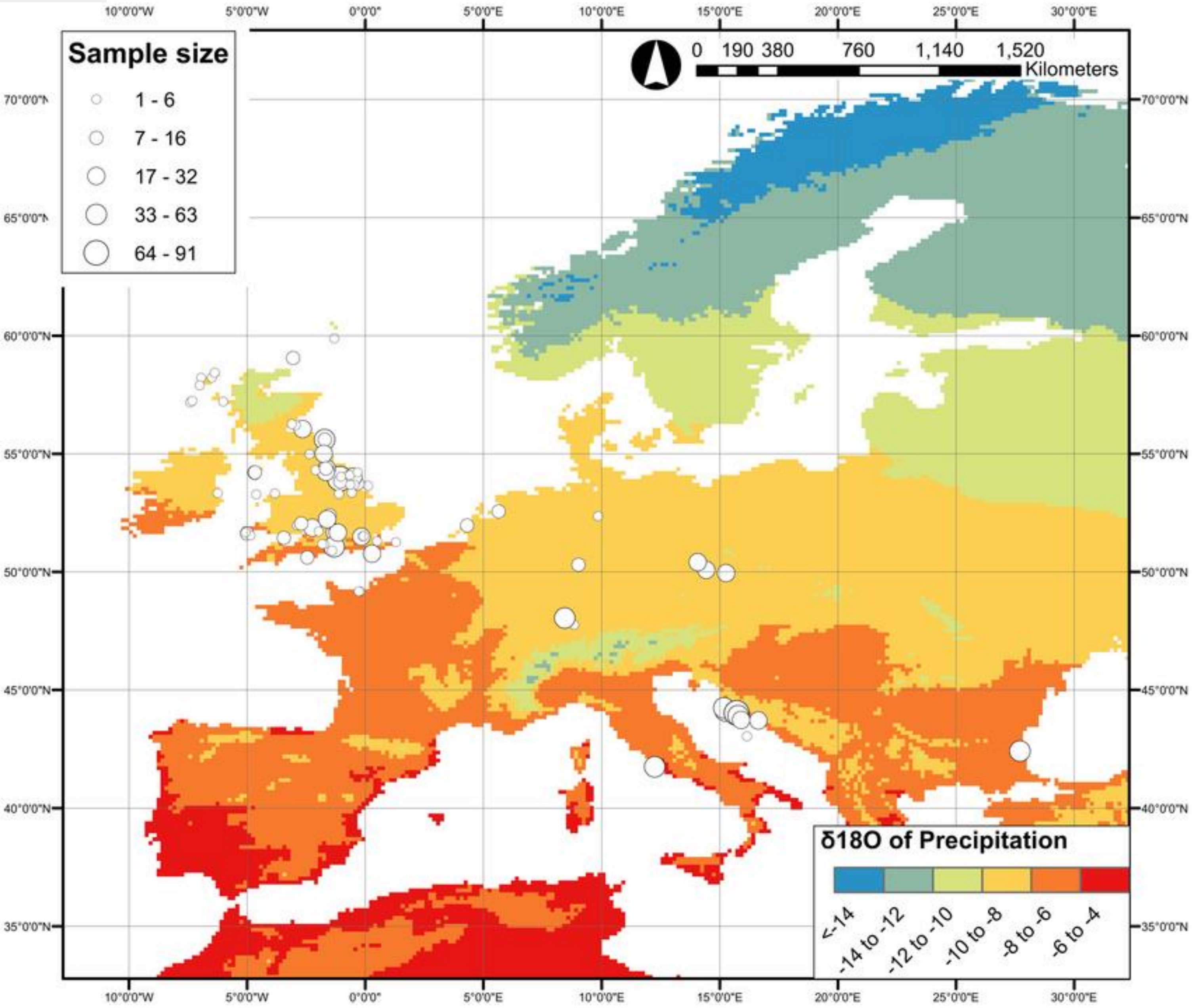
RESEARCH ARTICLE

On the Use of Biomineral Oxygen Isotope Data to Ider Human Migrants in the Archaeological Record: Intra-S Variation, Statistical Methods and Geographical Considerations

Emma Lightfoot, Tamsin C. O'Connell

Published: April 28, 2016 • https://doi.org/10.1371/journal.pone.0153850



Is there enough $\delta^{18}O$ variation to identify homelands

How do we identify outliers?

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RESEARCH ARTICLE

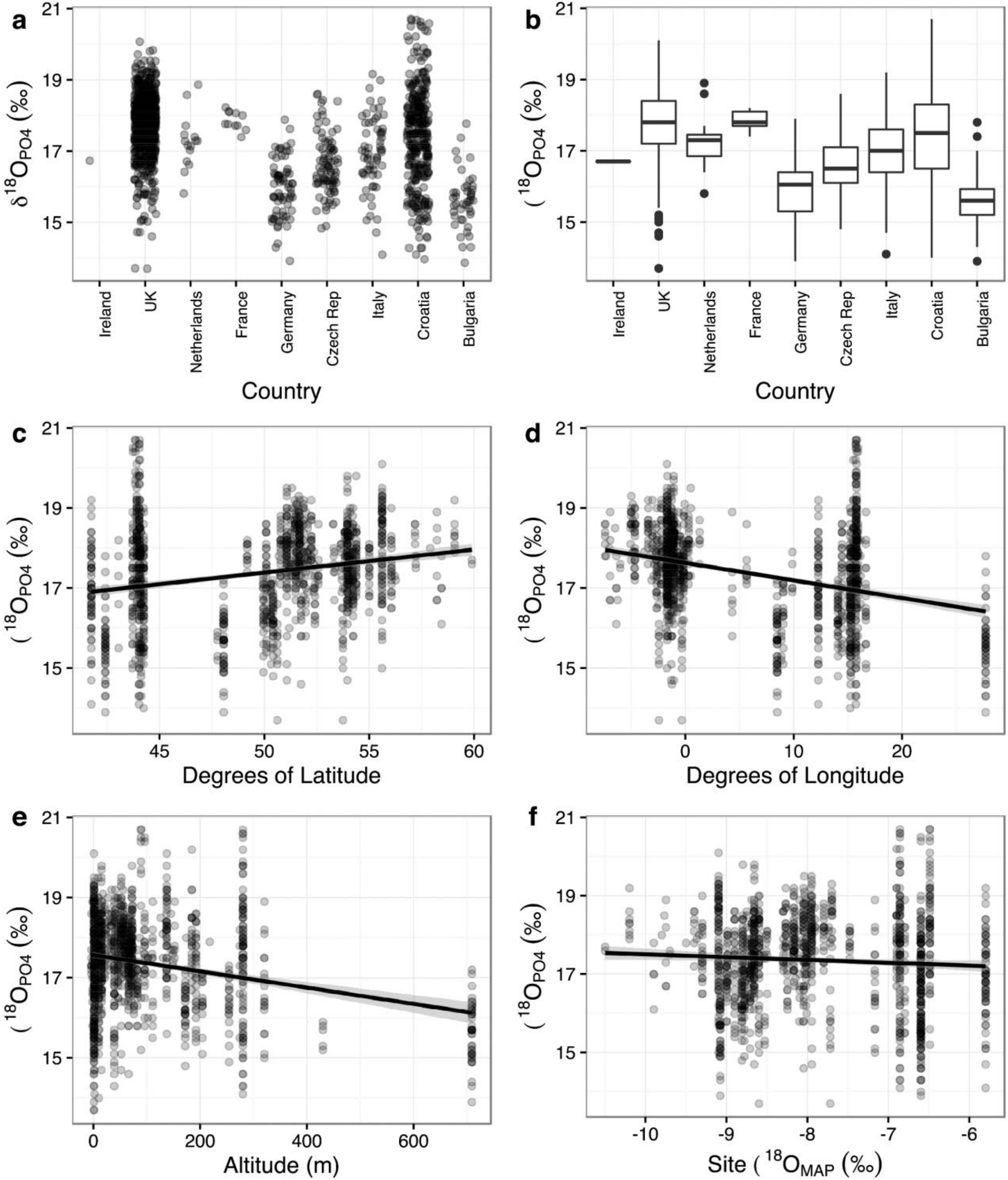
On the Use of Biomineral Oxygen Isotope Data to Identify Human Migrants in the Archaeological Record: Intra-Sample Variation, Statistical Methods and Geographical Considerations

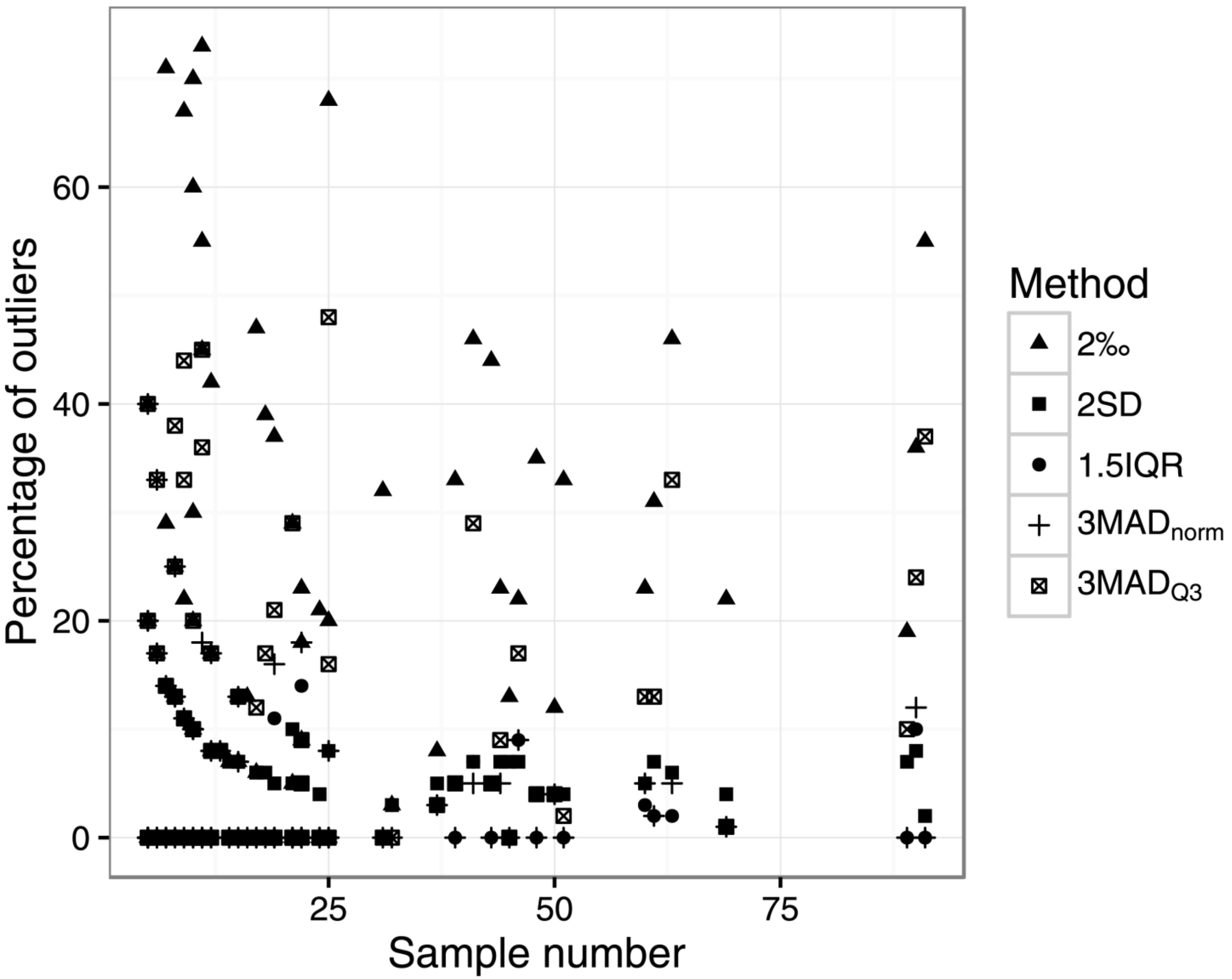
Emma Lightfoot, Tamsin C. O'Connell

Published: April 28, 2016 • https://doi.org/10.1371/journal.pone.0153850

European tooth enamel $\delta^{18}O_P$ fall within 13.7 to 20.7‰ (a total of 1266 individuals from 91 sites).

63 of the 92 analysed European sites fall between $\delta^{18}O$ = -9 and -7‰, and all sites have $\delta^{18}O$ of between -10.5 and -5.8‰

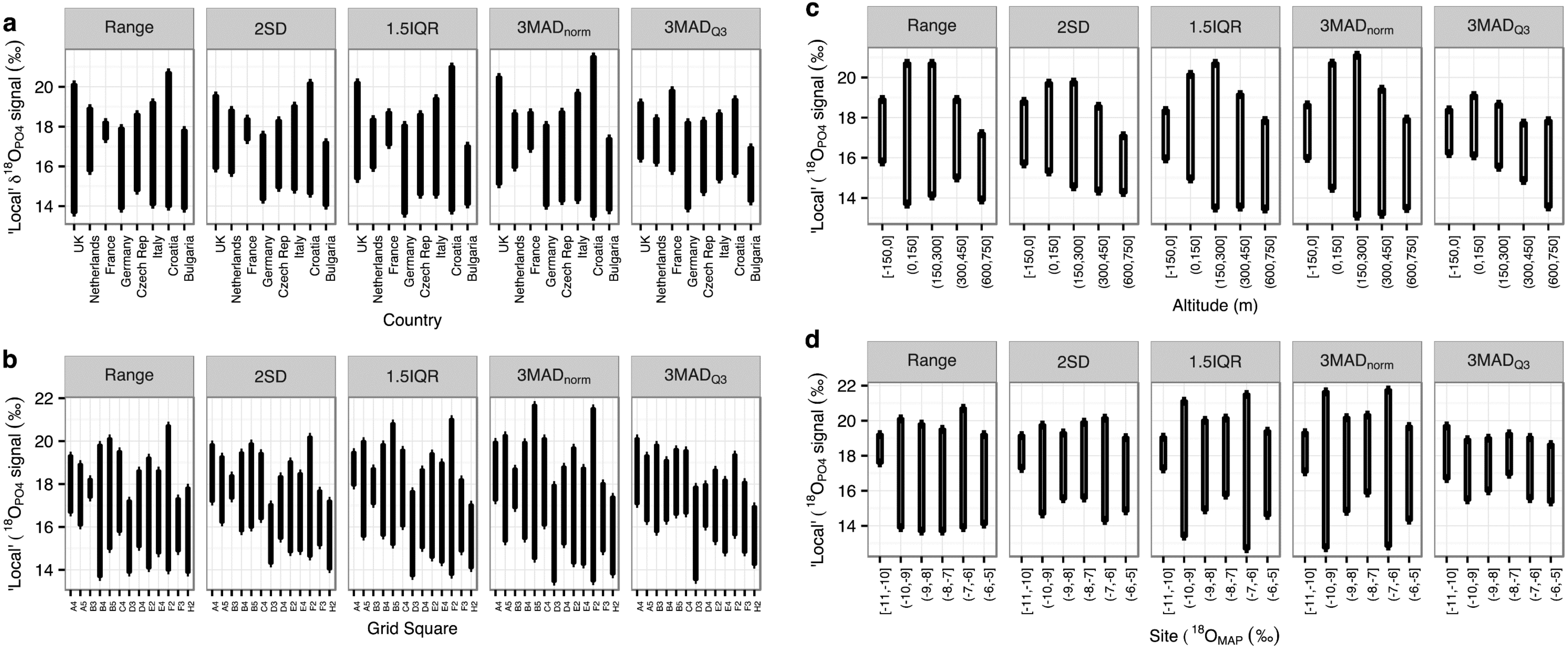




Number of outliers in a population is dependent on the number of samples analysed from that population.

Lightfoot et al., 2016

How do you identify outliers?



Lightfoot et al., 2016

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RESEARCH ARTICLE

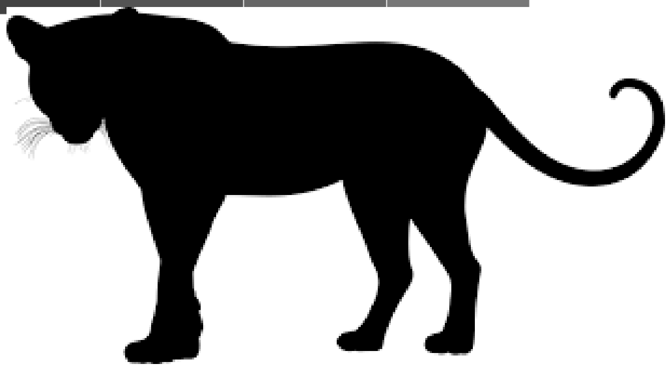
Tracking cats revisited: Placing terrestrial mammalian carnivores on δ^{2}H and δ^{18}O isoscapes

Geoff Koehler, Keith A. Hobson

Published: September 3, 2019 • https://doi.org/10.1371/journal.pone.0221876

Article | Authors | Metrics | Comments | Media Coverage

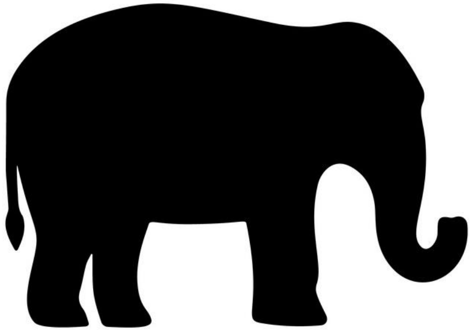
Abstract
Introduction
Experimental
Results and discussion
Conclusions
Supporting information
Acknowledgments
References



Isotopic Tracking of Change in Diet and Habitat Use in African Elephants

Paul L. Koch, Jennifer Heisinger, Cynthia Moss, Richard W. Carlson, Marilyn L. Fogel, Anna K. B
+ See all authors and affiliations

Science 03 Mar 1995:
Vol. 267, Issue 5202, pp. 1340-1343
DOI: 10.1126/science.267.5202.1340



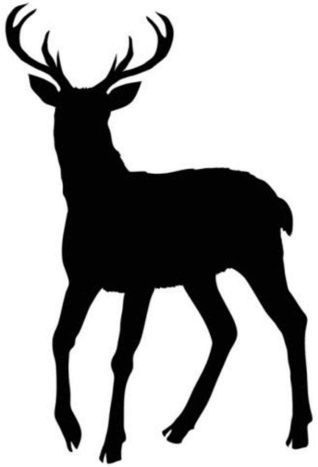
ELSEVIER

Palaeogeography, Palaeoclimatology, Palaeoecology

Volume 301, Issues 1–4, 15 February 2011, Pages 64-74

Intra-tooth oxygen isotope variation in a known population of red deer: Implications for past climate and seasonality reconstructions

Rhiannon E. Stevens [a], Marie Balasse [b], Tamsin C. O'Connell [a, c]



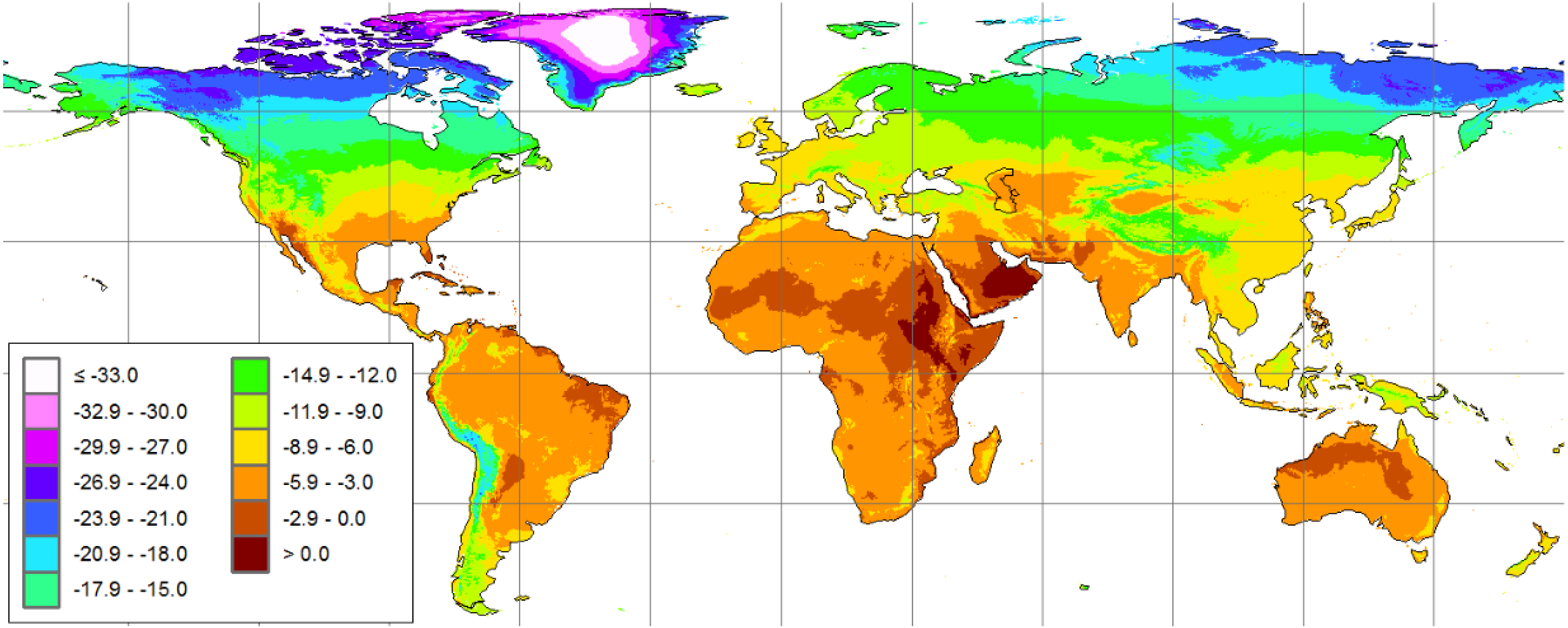
Oecologia (2004) 141: 477–488
DOI 10.1007/s00442-004-1671-7

ECOSYSTEM ECOLOGY

Keith A. Hobson · Gabriel J. Bowen ·
Leonard I. Wassenaar · Yves Ferrand · Hervé Lormee

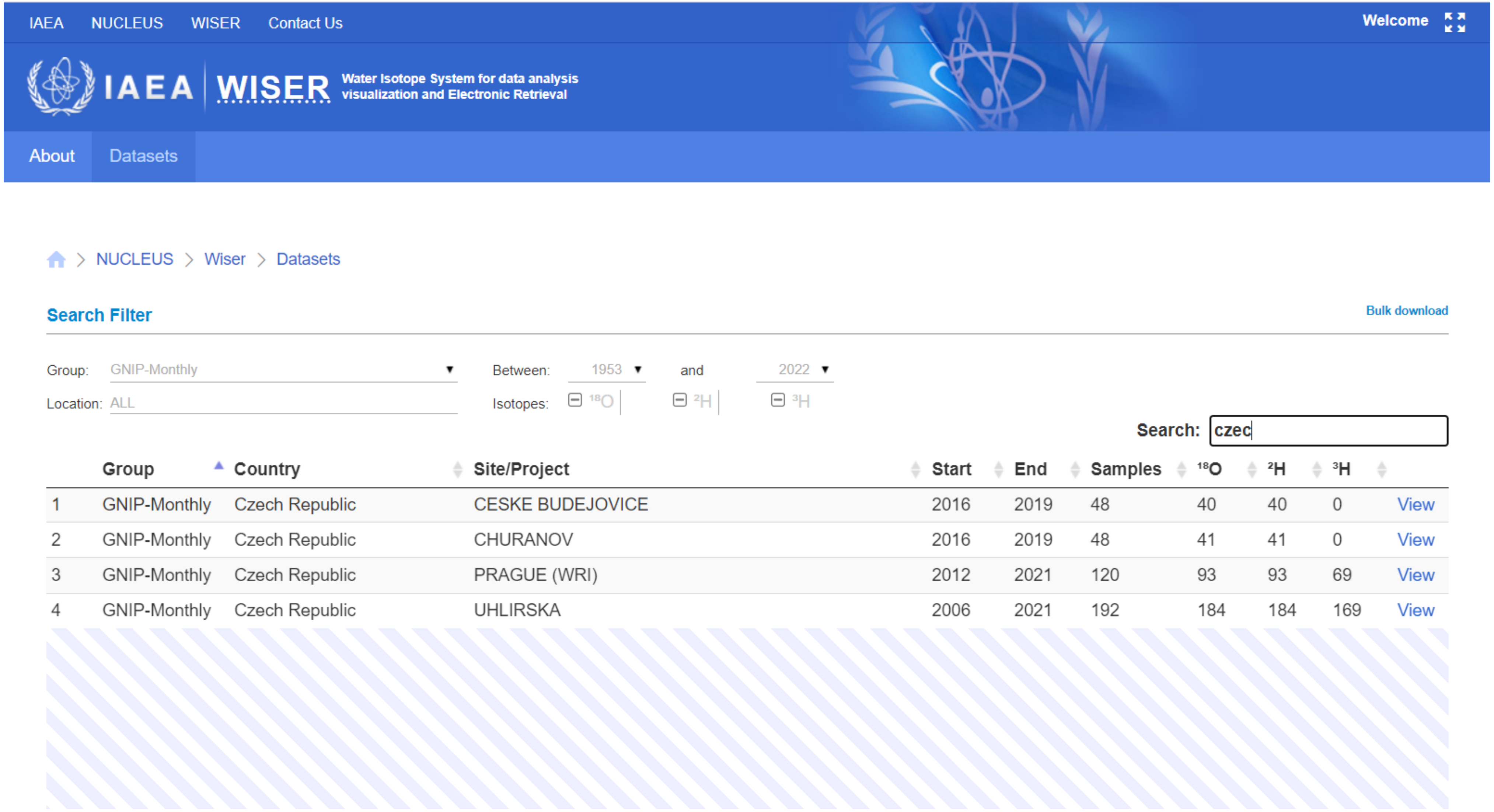
Using stable hydrogen and oxygen isotope measurements of feathers to infer geographical origins of migrating European birds

Annual rainfall $\delta^{18}O$



Terzer et al., 2013

$\delta^{18}O$ databases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IAEA WISER Water Isotope System for data analysis visualization and Electronic Retrieval

About Datasets

NUCLEUS > Wiser > Datasets

Search Filter Bulk download

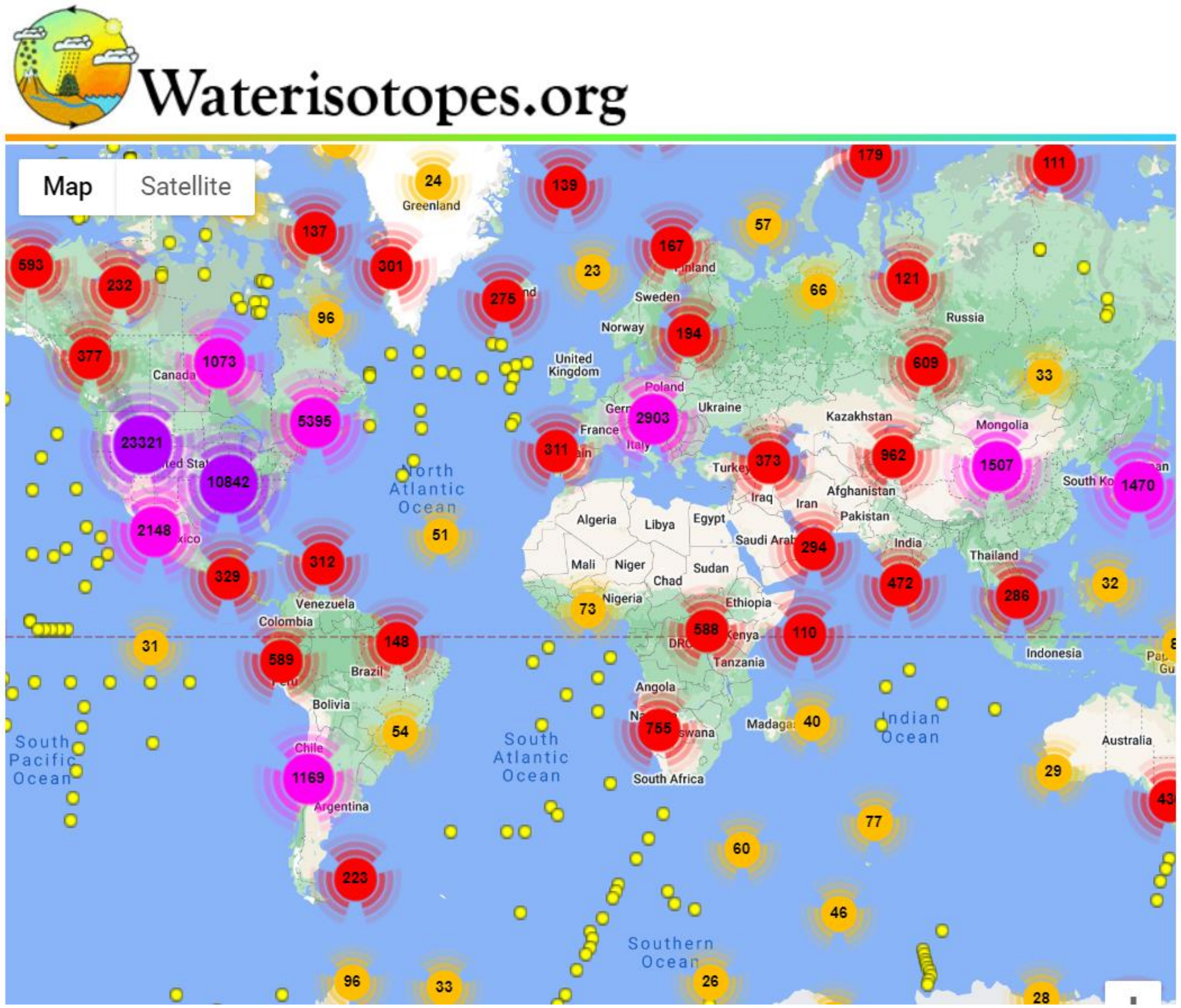
Group: GNIP-Monthly Between: 1953 and 2022

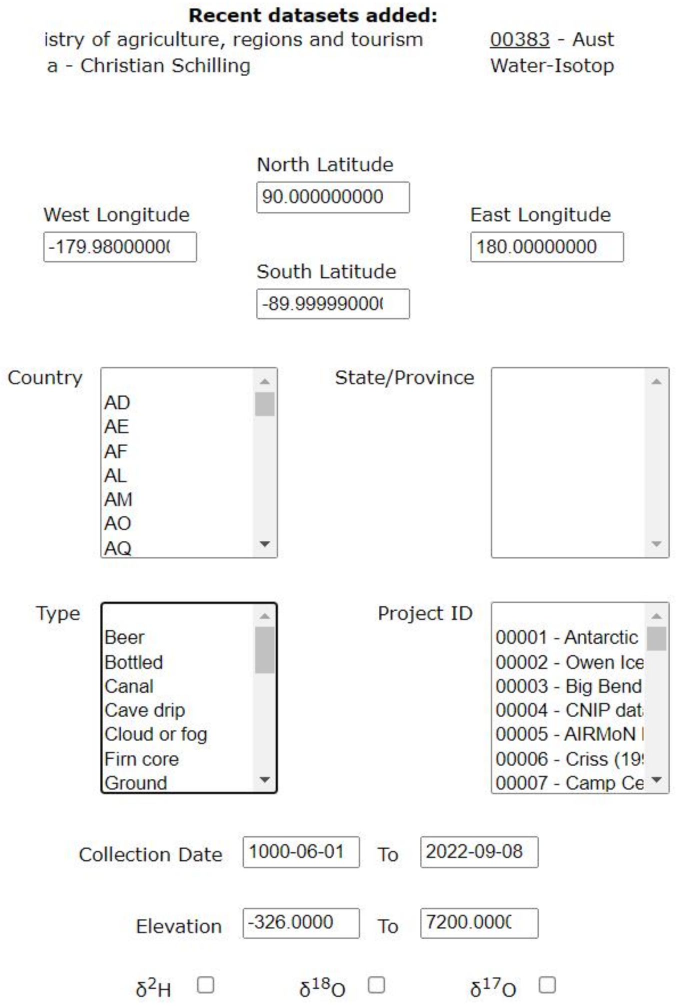
Location: ALL Isotopes: ^{18}O ^{2}H ^{3}H

Search: czec

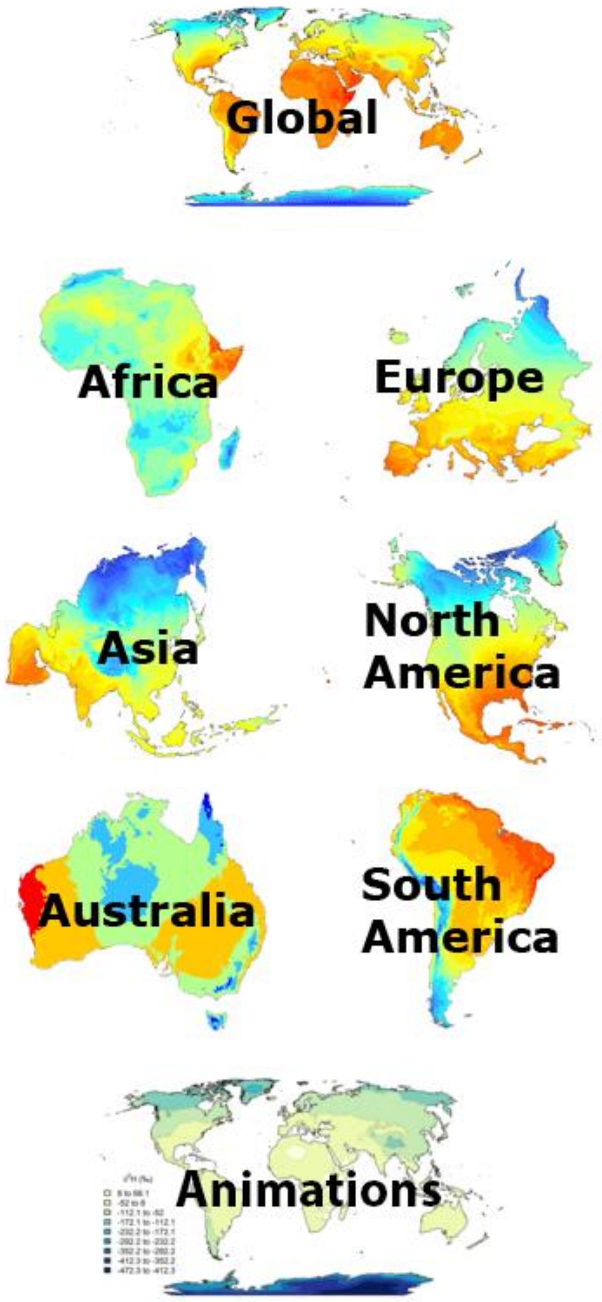
	Group	Country	Site/Project	Start	End	Samples	^{18}O	^{2}H	^{3}H	
1	GNIP-Monthly	Czech Republic	CESKE BUDEJOVICE	2016	2019	48	40	40	0	View
2	GNIP-Monthly	Czech Republic	CHURANOV	2016	2019	48	41	41	0	View
3	GNIP-Monthly	Czech Republic	PRAGUE (WRI)	2012	2021	120	93	93	69	View
4	GNIP-Monthly	Czech Republic	UHLIRSKA	2006	2021	192	184	184	169	View

$\delta^{18}O$ databases



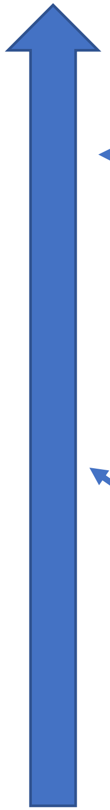


$\delta^{18}O$ databases



Sulphur ($\delta^{34}S$)

+25‰



$\delta^{34}S$ (‰, VCDT)

–25 ‰

+20‰

Oceanic sulfate

– 5 to +5‰

Continental minerals

–15.4 to –7.1‰

+2.8 to +17.1‰

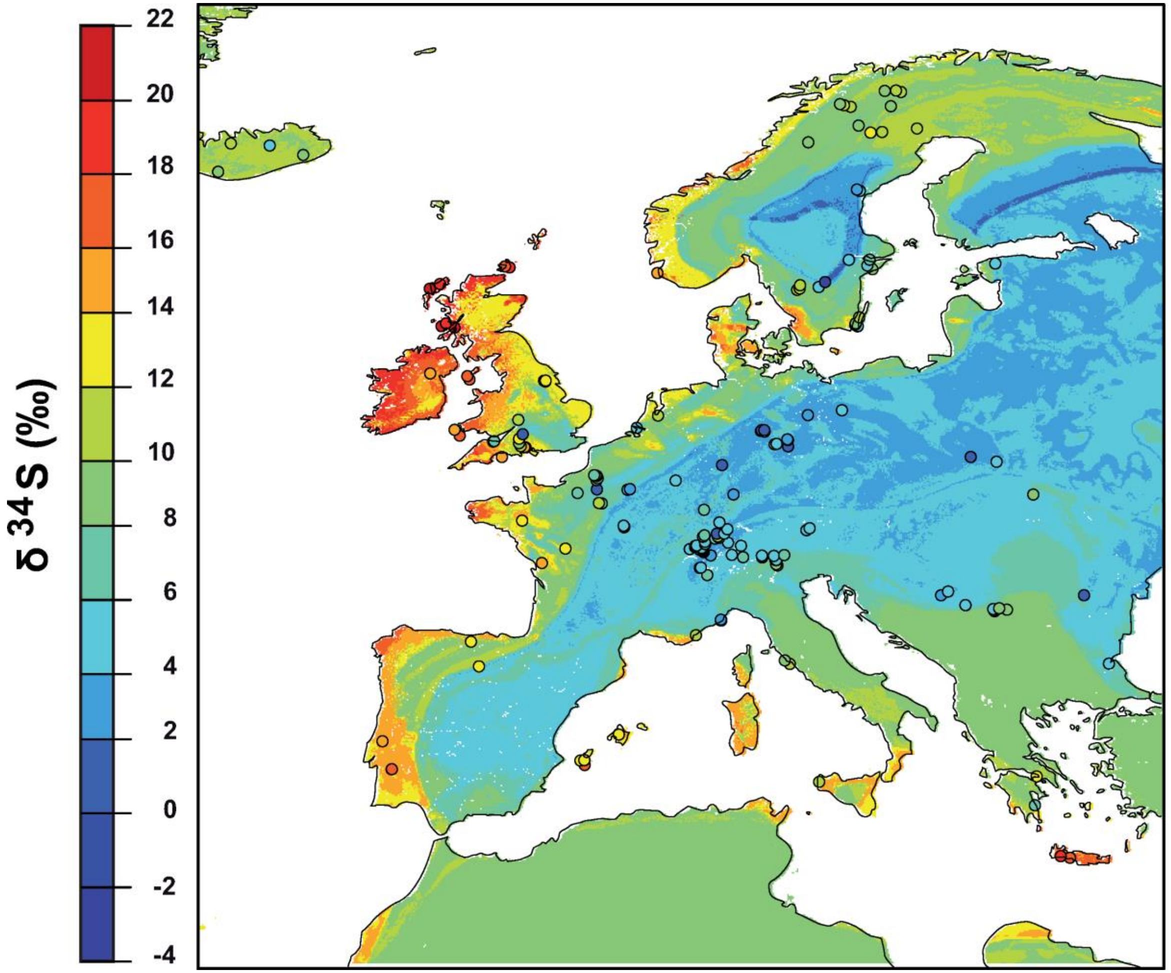
–10.9 to +16.3‰

Sulphur


Triple sulfur-oxygen-strontium isotopes probabilistic geographic assignment of archaeological remains using a novel sulfur isoscape of western Europe

Clément P. Bataille, Klervia Jaouen, Stefania Milano, Manuel Trost, Sven Steinbrenner, Éric Crubézy, Rozenn Colleter

- Using Sr, O and S isotope analysis to determine the origin of teeth with known origins.



Spatial distribution of the sulfur isotope composition ($\delta^{34}S$) across Europe from a compilation of animal and human teeth from post-Mesolithic times

Combining Sr, O and S isoscapes

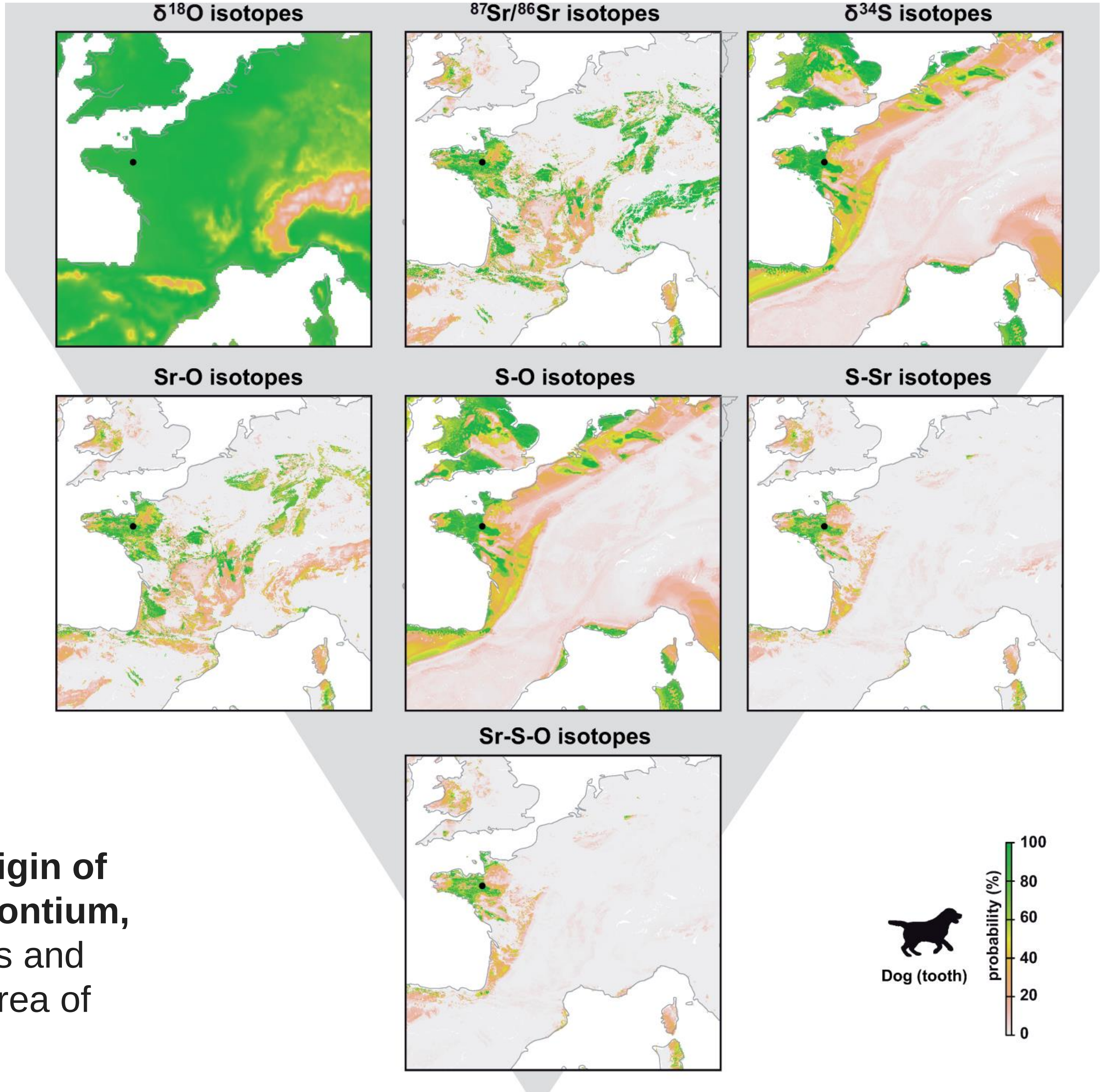


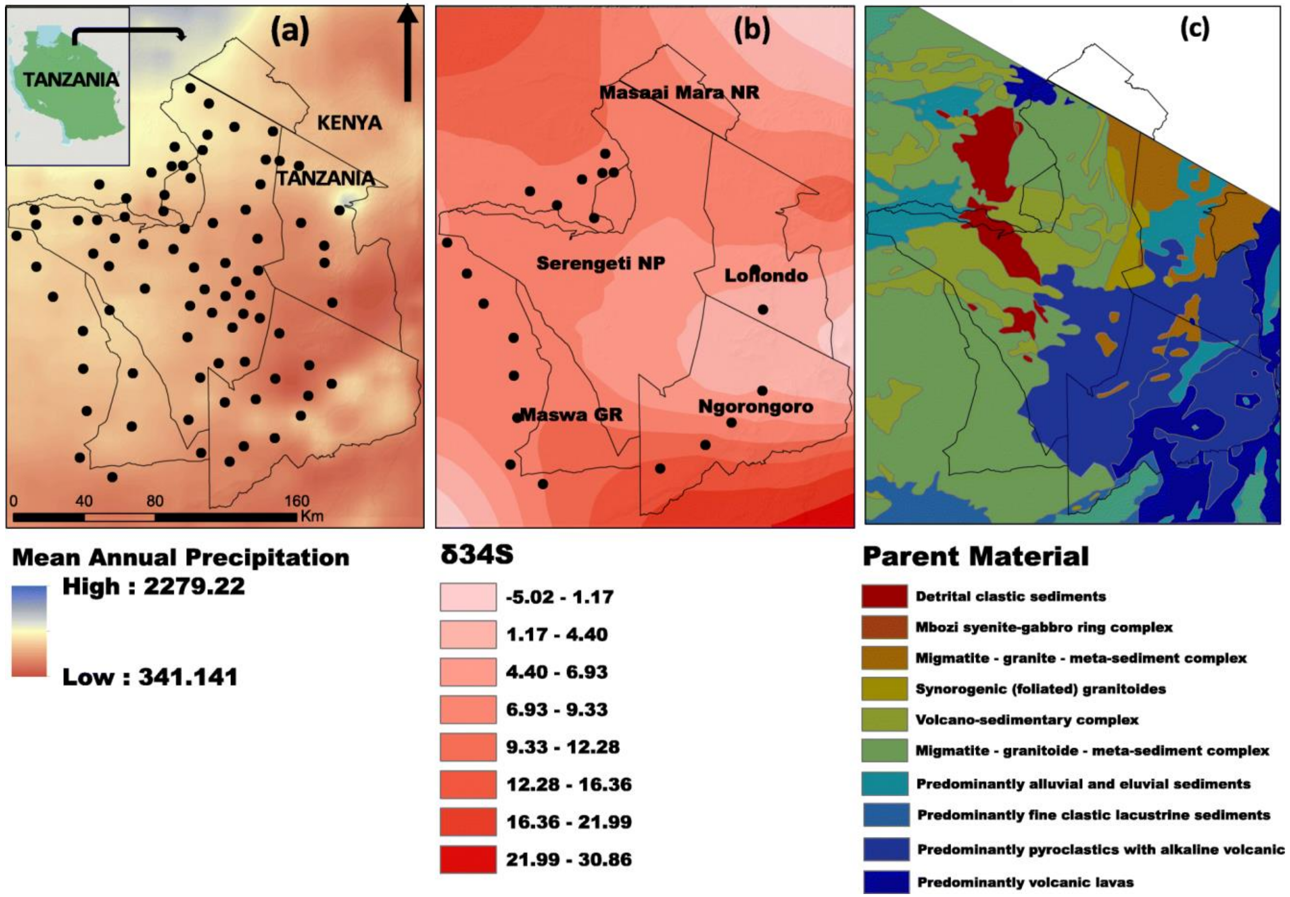
Fig 3. Maps showing the probability of tooth origin of the dog according to the selected isotopes (strontium, sulfur and/or oxygen). Depending on the isotopes and combinations of isotopes used, the geographical area of assignment is increasingly more precise.

Sulphur for animal migrations

Research | Open Access | Published: 18 September 2020

Tracking animal movements using biomarkers in tail hairs: a novel approach for animal geolocating from sulfur isoscapes

Zabibu Kabalika ✉, Thomas A. Morrison, Rona A. R. McGill, Linus K. Munishi, Divine Ekwem, Wilson Leonidas Mahene, Alex L. Lobora, Jason Newton, Juan M. Morales, Daniel T. Haydon & Grant G. J. C. Hopcraft



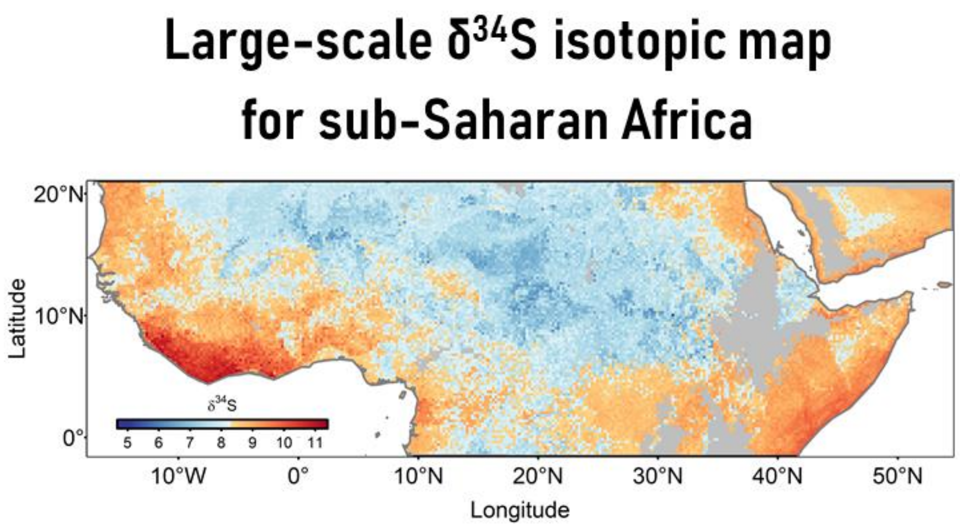
Journal of Animal Ecology | BRITISH ECOLOGICAL SOCIETY

RESEARCH ARTICLE | Full Access

Animal tracing with sulfur isotopes: Spatial segregation and climate variability in Africa likely contribute to population trends of a migratory songbird

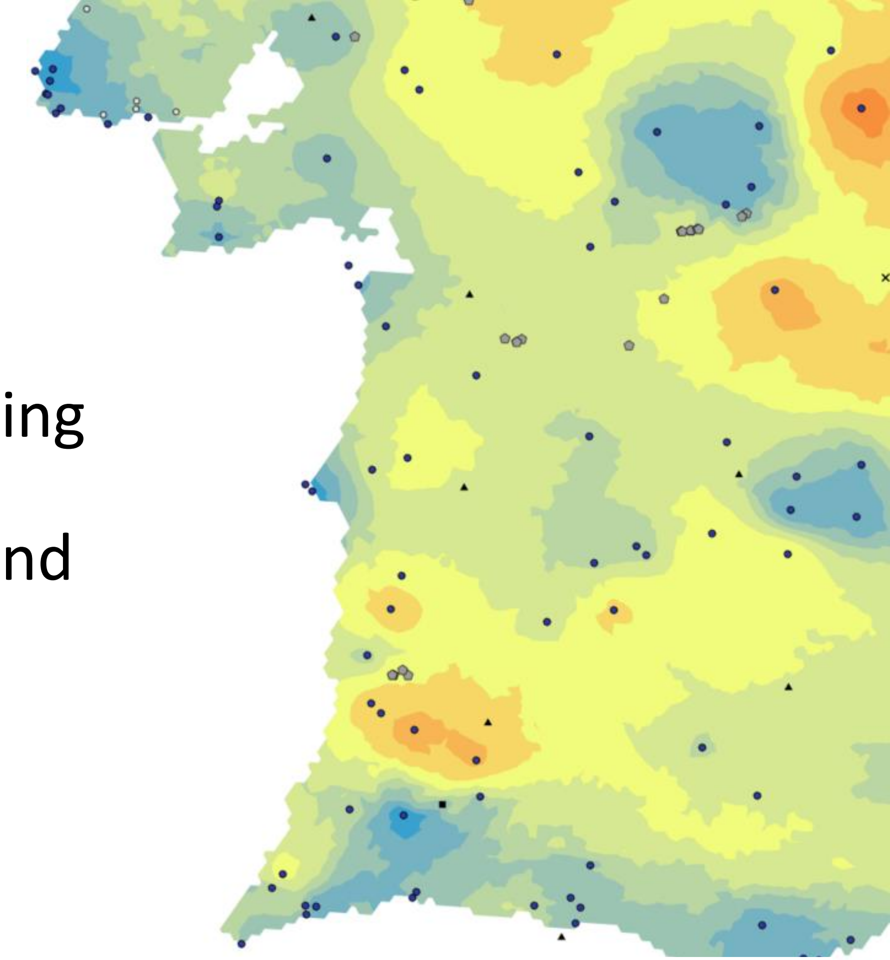
Vojtěch Brlík ✉, Petr Procházka, Bengt Hansson, Craig A. Stricker, Elizabeth Yohannes, Rebecca L. Powell, Michael B. Wunder

First published: 21 November 2022 | https://doi.org/10.1111/1365-2656.13848



Conclusions

- Environmental baselines are crucial for understanding any bioarchaeological analyses
- Baselines need to be appropriate for the samples and the research question



- Any questions, feel free to contact me - Hannah.James@vub.be

BRUSSELS BIOARCHAEOLOGY LAB

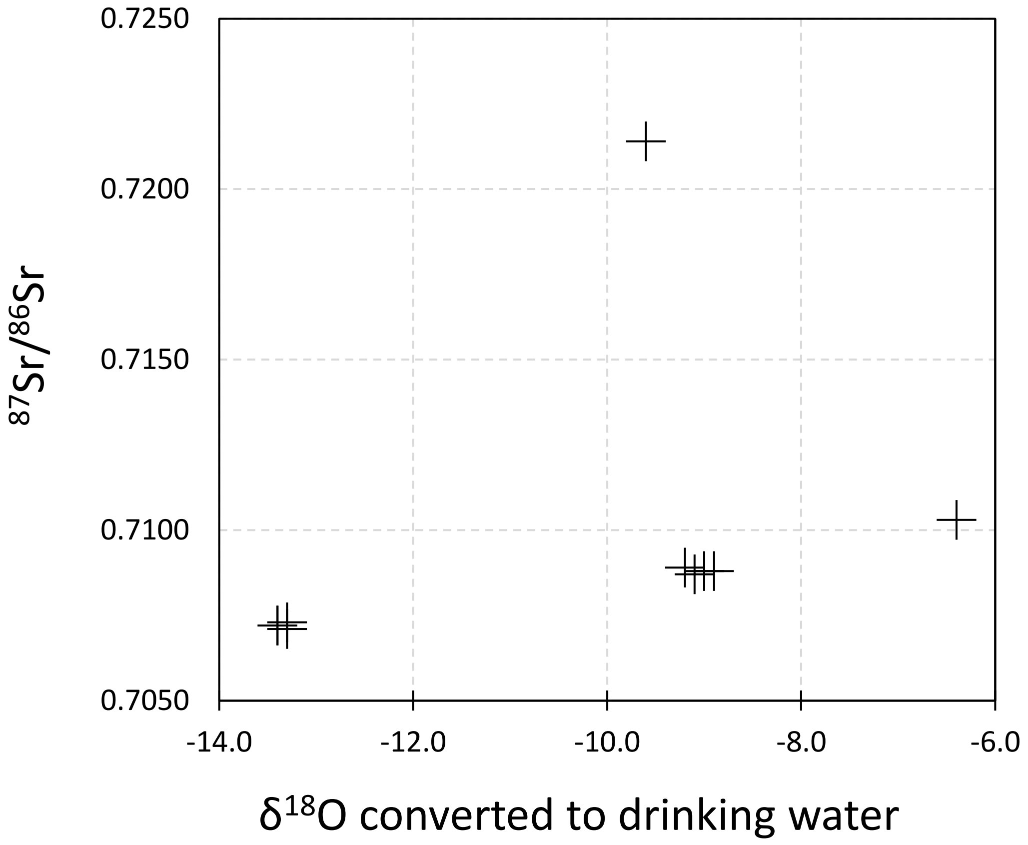
@ToothDetective
@ERCLumiere
@BrusselsBioarch

This project has received funding from the European Union's Horizon 2020 research & innovation programme under grant agreement n° 948913

Interpreting data using an isoscape

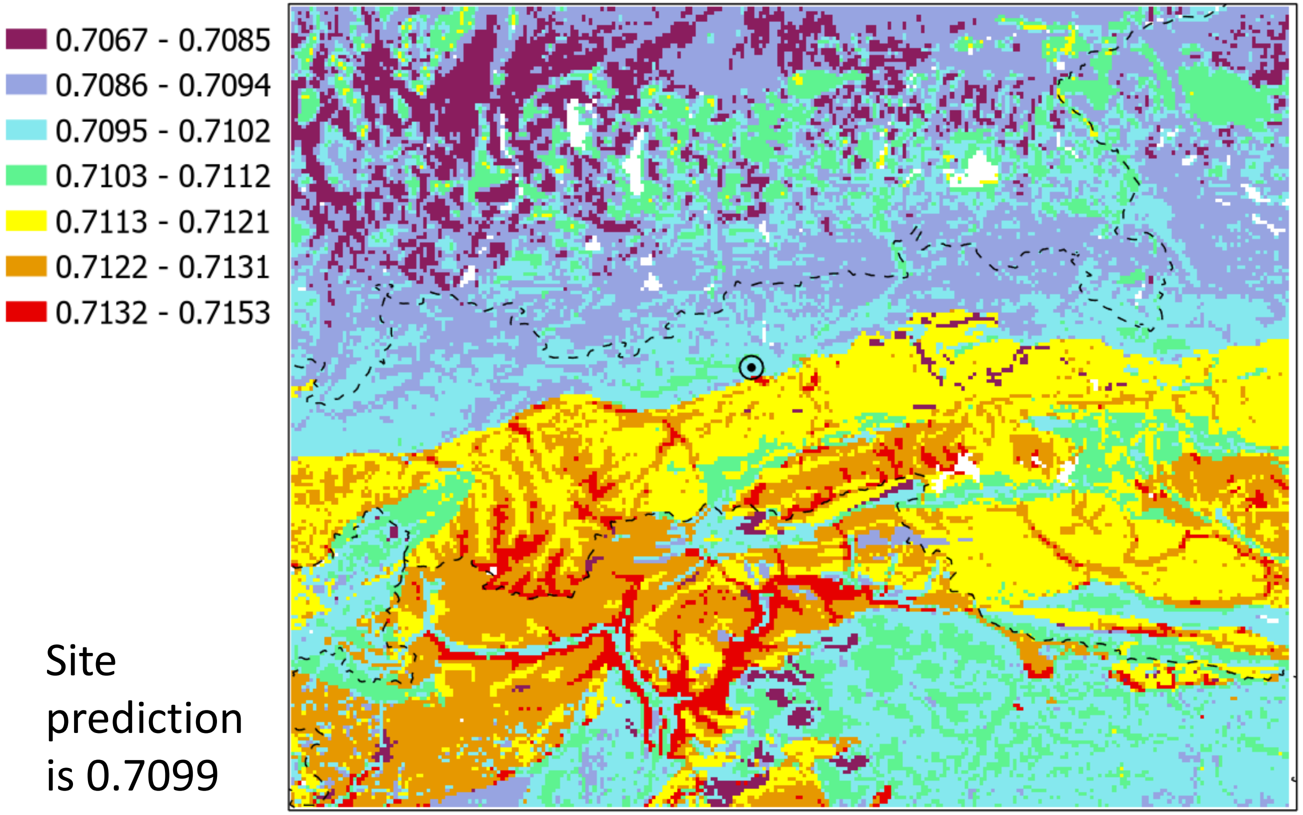
- You have $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ data from 10 tooth enamel samples from a cemetery.
- Samples split into two groups (A and B), with two outliers (C and D).
- All teeth sampled were M3.
- The site is located above a river at the edge of a mountain range.
- There is evidence of a settlement next to the site.

$^{87}Sr/^{86}Sr$ and $\delta^{18}O$ data



	$^{87}Sr/^{86}Sr$	$\delta^{18}O$ (‰)	Group
Ind 1	0.7071	-13.3	A
Ind 2	0.7072	-13.4	A
Ind 3	0.7073	-13.3	A
Ind 4	0.7072	-13.4	A
Ind 5	0.7087	-9.1	B
Ind 6	0.7088	-8.9	B
Ind 7	0.7089	-9.2	B
Ind 8	0.7088	-9.0	B
Ind 9	0.7214	-9.6	C
Ind 10	0.7103	-6.4	D

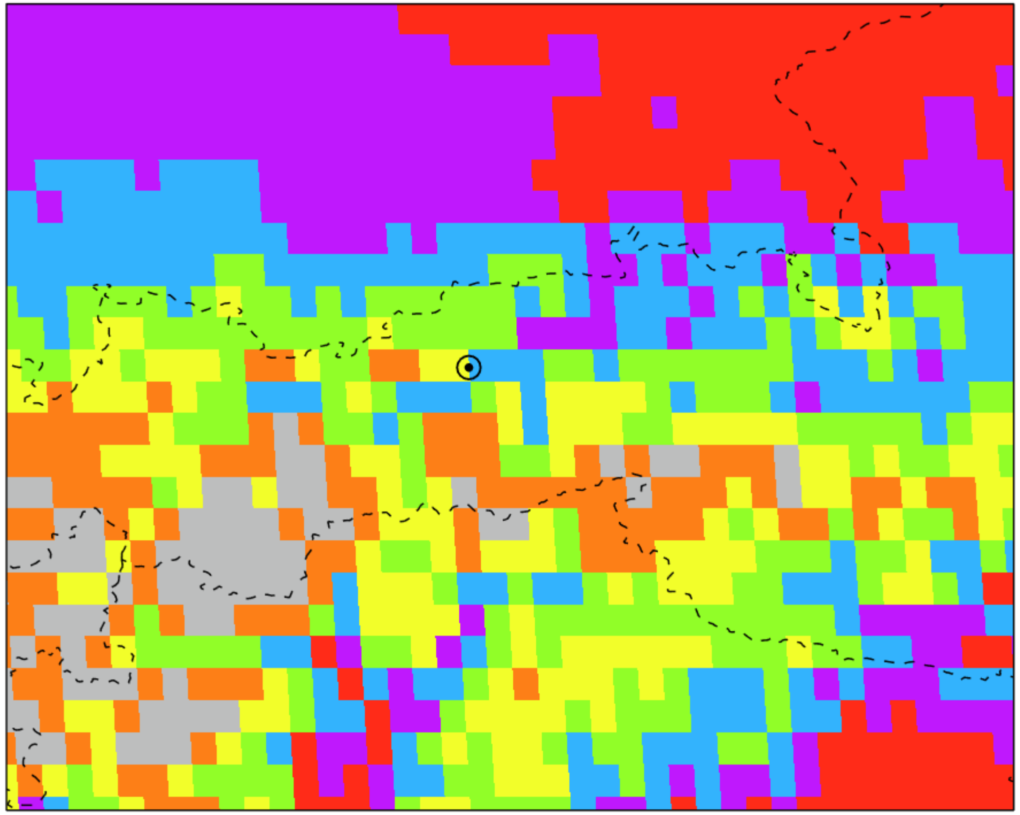
Modelled bioavailable $^{87}Sr/^{86}Sr$ values for the global land surface based on measured rock, soil, plant, water, animal and human data (Bataille et al., 2020)



Site prediction is 0.7099

Annual mean $\delta^{18}O$ for modern rainwater (WaterIsotopes.org)

-14.4 to -13.2
-13.1 to -12.4
-12.3 to -11.6
-11.5 to -10.8
-10.7 to -10.1
-10 to -9.4
-9.3 to -7.6

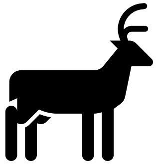


Site prediction is -11.7 ‰

Questions

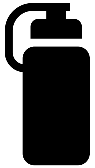
- Do you think these baselines are appropriate for determining past human mobility?
- Based just on the measured individual values and these two isoscapes, do you think all these individuals could be local to the site?
- Are these individuals from the wider region represented by these isoscapes?
- Where might they be from?

Let's think about how archaeological information can help us narrow our predictions



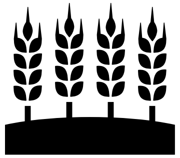
Archaeobotanical evidence indicates large-scale hunting of deer, which are known to live in high altitudes of the mountain range.

- Do you think consuming deer meat would influence the $^{87}Sr/^{86}Sr$ in these individuals?
- If so, which group (if any) might reflect this diet?



The most likely drinking water source at the site are streams which are sourced from higher altitudes. How would that influence the $\delta^{18}O$ value?

- Which group (if any) might reflect this drinking water?



Archaeobotanical evidence from the site shows high consumption of wheat and regions northwest of the site are the ideal region for growing wheat.

- How would the consumption of wheat grown in this region influence the $^{87}Sr/^{86}Sr$?
- If so, which group (if any) might reflect this?

Final thoughts

- If we assume that groups A and B are both local to a region, how would you interpret the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ data?

- How has this changed from your first interpretation?

- Lastly, can you think of any other information that would help you in including or excluding regions of possible origins?