Assembling specimen-based trait knowledgebases to test broad-scale drivers of life-history variation

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Biodiversity @gurlab

Jabberwocky Ecology

Trait Databases: What is the End Goal?

"Currently, many trait databases focus on a species-level value… This is a logical place to start building a database if many of the questions are focused on comparing central tendencies across species….Having any info is still better than no info, but often we need info on variability across individuals within a species or we want to know how the trait might vary with changes in the environment."

The critical need for trait and life history compilations that extend past the trait-by-species approach is being recognized

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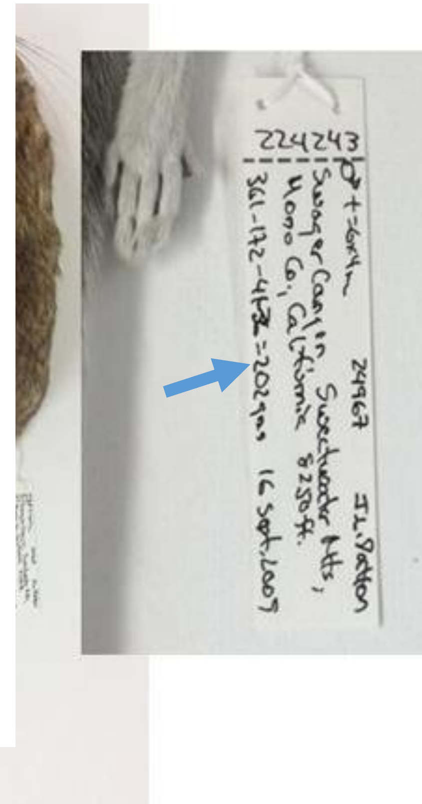
MVZ Mammal specimens 224243 Neotoma cinerea acraia

Submit data issue

Record detail | Data set | Index

Record-level Term	Value
InstitutionCode	MVZ
CollectionCode	Mammal specimens
References	http://arctos.database.museum/guid/MVZ:Mamm:224243
Record Citation	Museum of Vertebrate Zoology, UC Berkeley. MVZ Mammal Collection (Arctos). Record ID: http://arctos.database.museum/guid/MVZ:Mamm:224243?seid=647889. Source: http://ipt.vertnet.org:8080/ipt/resource.do?r=mvz_mammal (source published on 2016-06-24)
BasisOfRecord	PreservedSpecimen
VNType	specimen
DCType	PhysicalObject
License	http://creativecommons.org/publicdomain/zero/1.0/
AccessRights	http://www.vertnet.org/resources/norms.html
InstitutionID	urn:lsid:biocol.org:col:34777
CollectionID	urn:lsid:biocol.org:col:34904
Modified	2017-07-25 20:33:48.0
Language	en



DIGITIZATION OF MUSEUM SPECIMENS HAS MADE SPECIMENS AND SPECIMEN DATA DISCOVERABLE ON THE INTERNET http://arctos.database.museum/guid/UAM:Mamm:114272?seid=1876811

Tamiasciurus hudsonicus

Specific Locality: Goldstream Valley, KK Campbell Residence
Collecting Method: firearm
Collecting Source: wild caught
Event Date: 2012-06-01 to 2012-06-30

Dynamic properties:

age class: young; ear from notch: 23mm; hind foot with claw: 49mm; sex: female; tail length: 121mm; total length: 299mm; weight: 135g

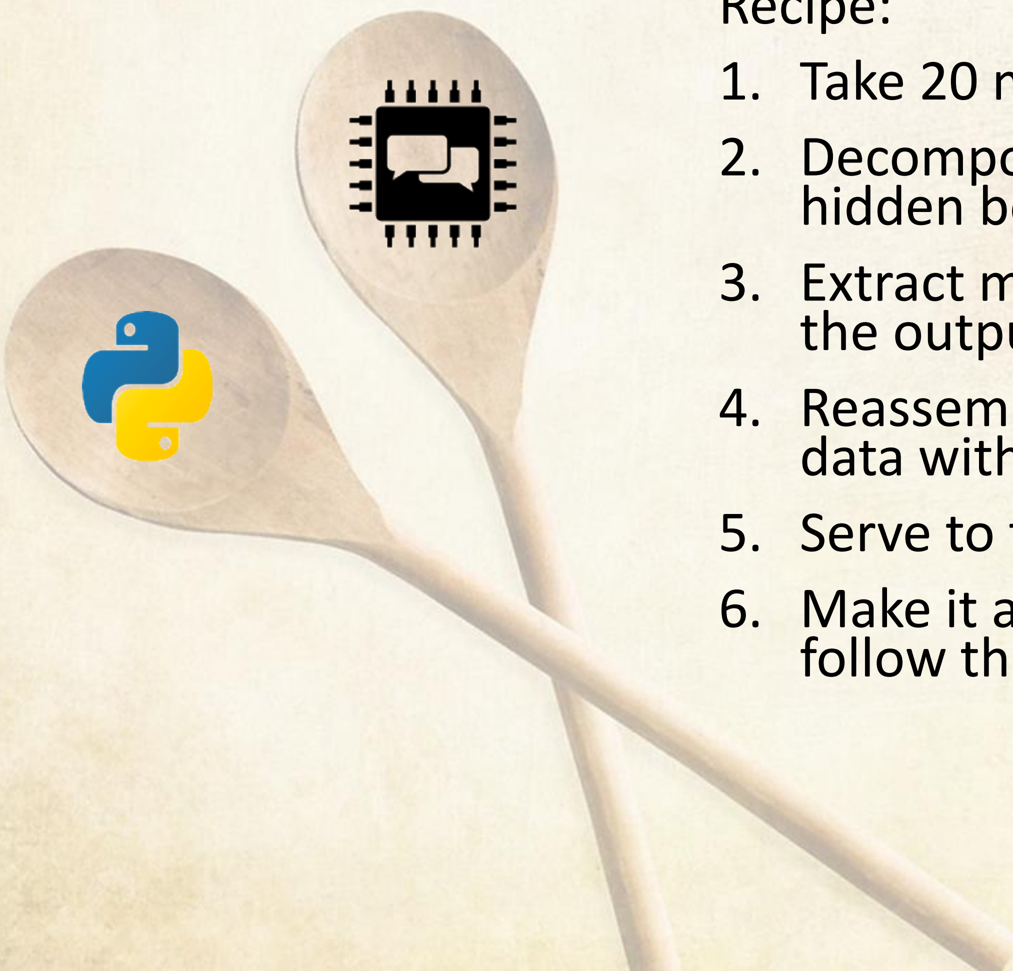
Occurrence Remarks:

Appeared to be first year

Normalized results: **Body mass: 135 grams**, **Total body length: 299mm**

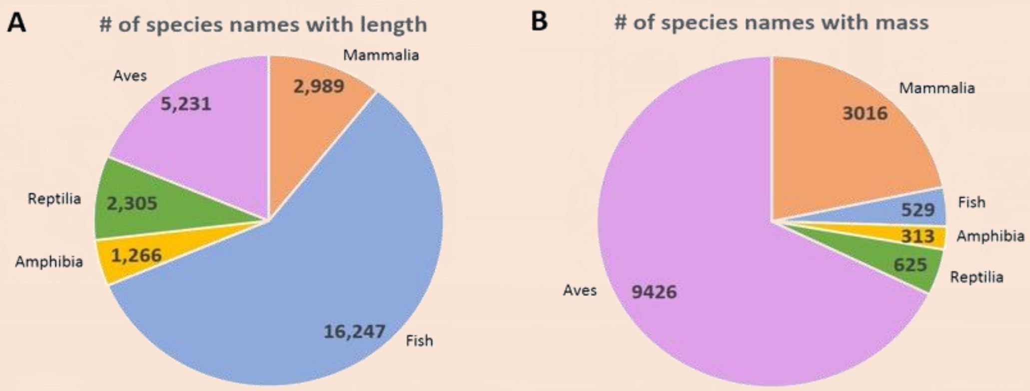
Standardization doesn't assure that ***all*** the data about specimens is mobilized.
In fact, standardization can mean some critical data is hidden in digitized specimen data

How to build the largest knowledge-base of vertebrate body masses ever assembled



Recipe:

1. Take 20 million digitized vertebrate records
2. Decompose the records and look for hidden body size information
3. Extract matching records and harmonize the outputs to same units and format
4. Reassemble into a neat form the extracted data with the original records
5. Serve to the community
6. Make it all reproducible so others can follow the recipe

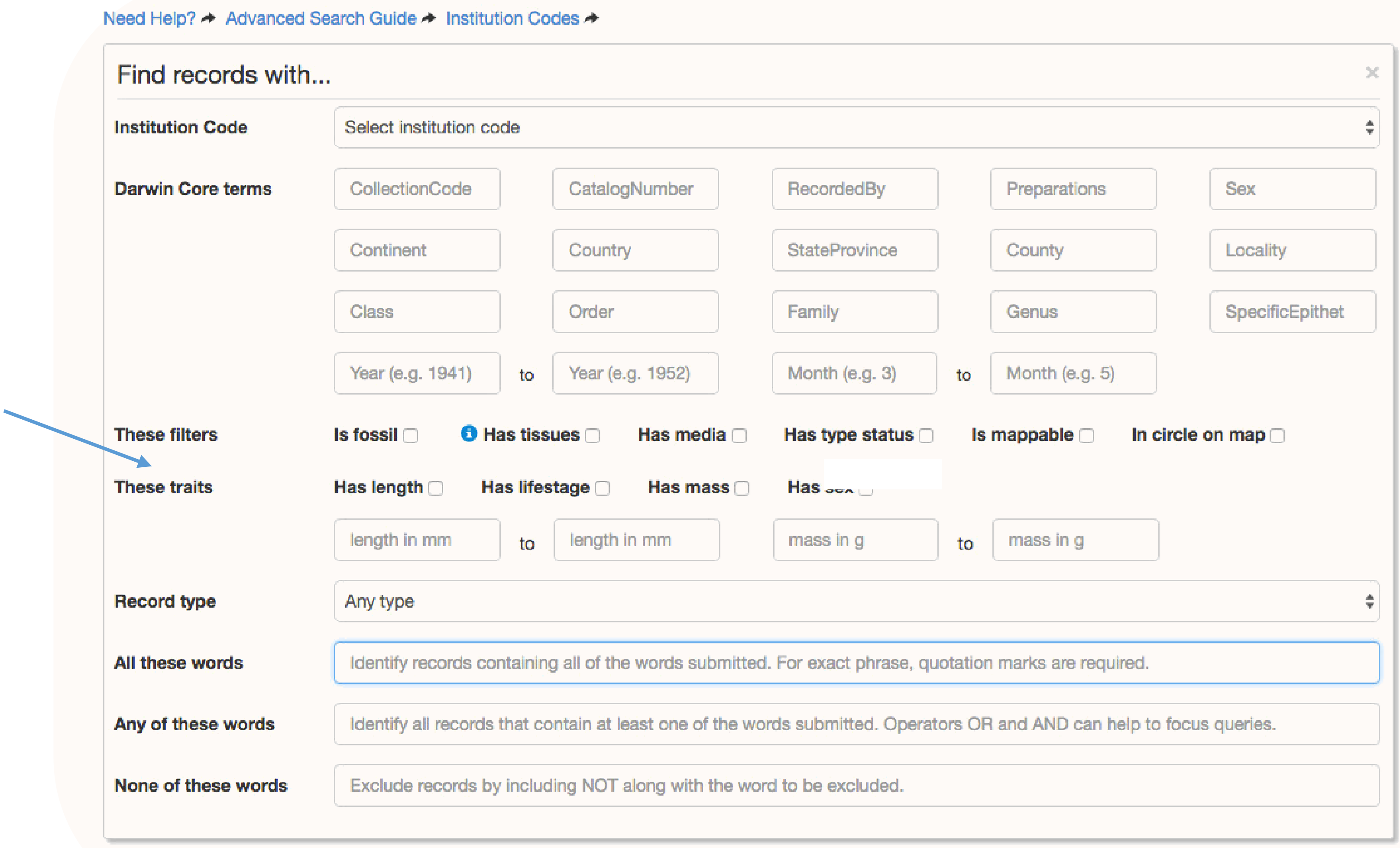


# records / sp name		Length			Body mass		
		> 100	> 10	at least 1	> 100	> 10	at least 1
Class	Fish [1]	380	3214	16247	3	14	529
	Amphibia	48	332	1266	21	87	313
	Reptilia	62	507	2305	24	167	625
	Aves	234	1364	5231	706	4050	9426
	Mammalia	417	1161	2989	331	1045	3016
Non_vertebrates		0	0	44	0	0	4
Unknown		0	4	31	0	2	4
Total		1141	6582	28113	1085	5365	13917

Trait or attribute

Our efforts unlocked an enormous number of body mass and length measurements

Bringing It back to VertNet –
Adapting the portal to make the trait data discoverable



Enabling New Research

ECOLOGY

No general relationship between mass and temperature in endothermic species

https://doi.org/10.1111/j.1600-0706.2013.00463.x
Google Scholar

26 **Carnegie Museum of Natural History**
CM Birds Collection (2015)
Accessed 2017.

27 **American Museum of Natural History**
AM Collections (2015)
Accessed 2017.

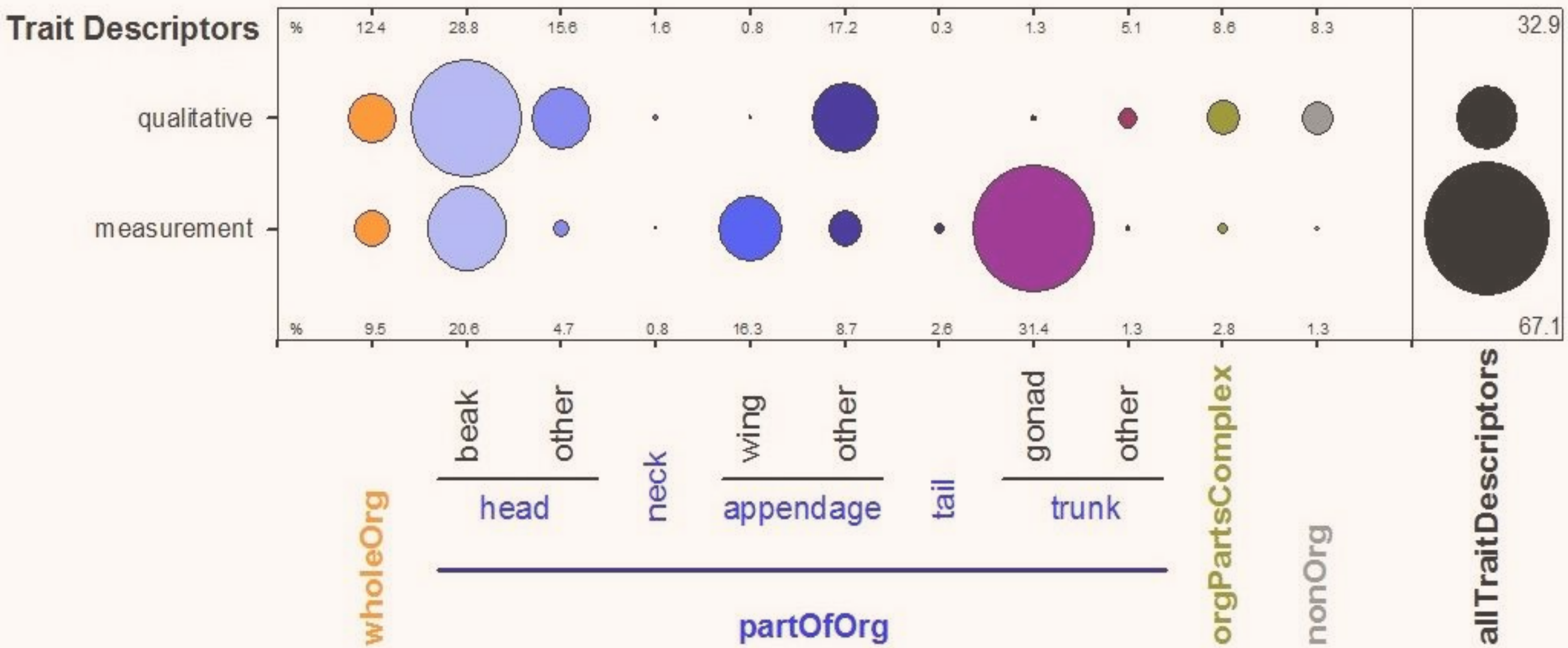
28 **VertNet: a new model for biodiversity data sharing**
H Constable, R Guralnick, J Wieczorek, C Spencer, AT Peterson, VertNet Steering Committee (2010)
PLoS Biology **8**:1–4.
https://doi.org/10.1371/journal.pbio.1000309
PubMed | Google Scholar

29 **University of British Columbia Beaty Biodiversity Museum**
Cowan Tetrapod Collection - Birds (2015)
Accessed 2017.

30 **University of British Columbia Beaty Biodiversity Museum**
Cowan Tetrapod Collection - Mammals (2015)
Accessed 2017.

31 **Cornell University Museum of Vertebrates**
CUMV Bird Collection (Arctos) (2015)

MUCH MORE THAN JUST MASS AND LENGTH

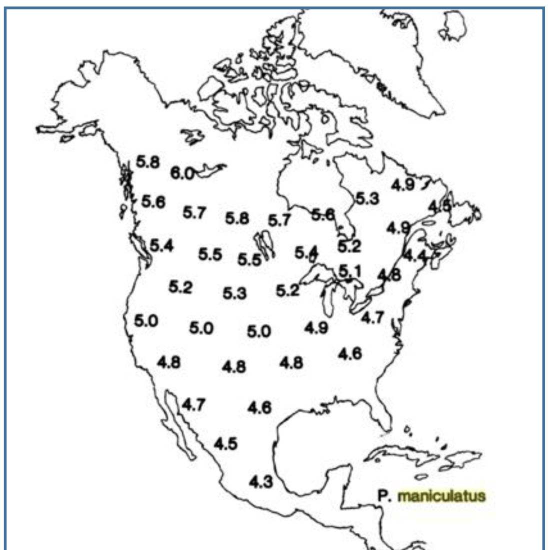


Its not just body measurements… but life history data

Bryan McLean

What controls rangewide litter size variation in *P. maniculatus* (PEMA)

- *P. maniculatus* has multiple litters per year.
- Shorter breeding season may lead to investment in more offspring since there are fewer opportunities to breed.



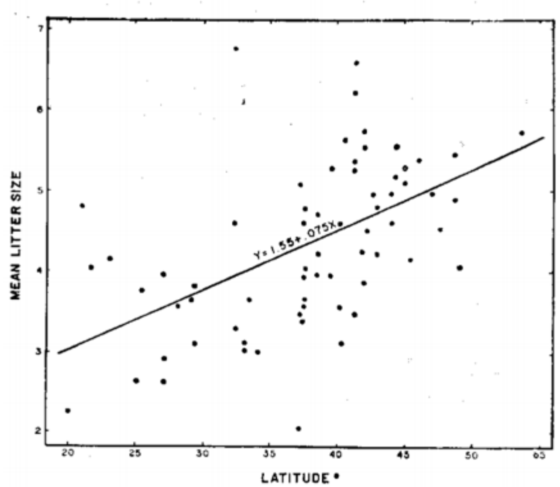


Fig. 1. Linear regression of mean litter size and latitude.

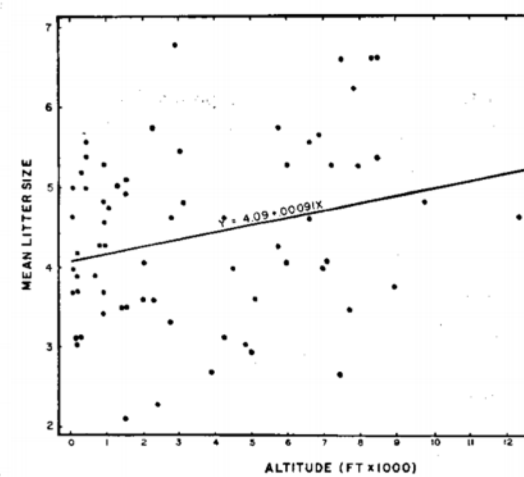


Fig. 2. Linear regression of mean litter size and altitude.

Advances in the Study of Peromyscus (Rodentia)
edited by Gordon L. Kirkland, James Nathaniel Layne

But, to quote one of the key researchers to look at broad litter size patterns (Millar, 1989): "It should be remembered that organisms do not respond to latitude, longitude, or elevation per se. Comparisons should involve meaningful measures of the environment.”

What controls rangewide litter size variation in *P. maniculatus*

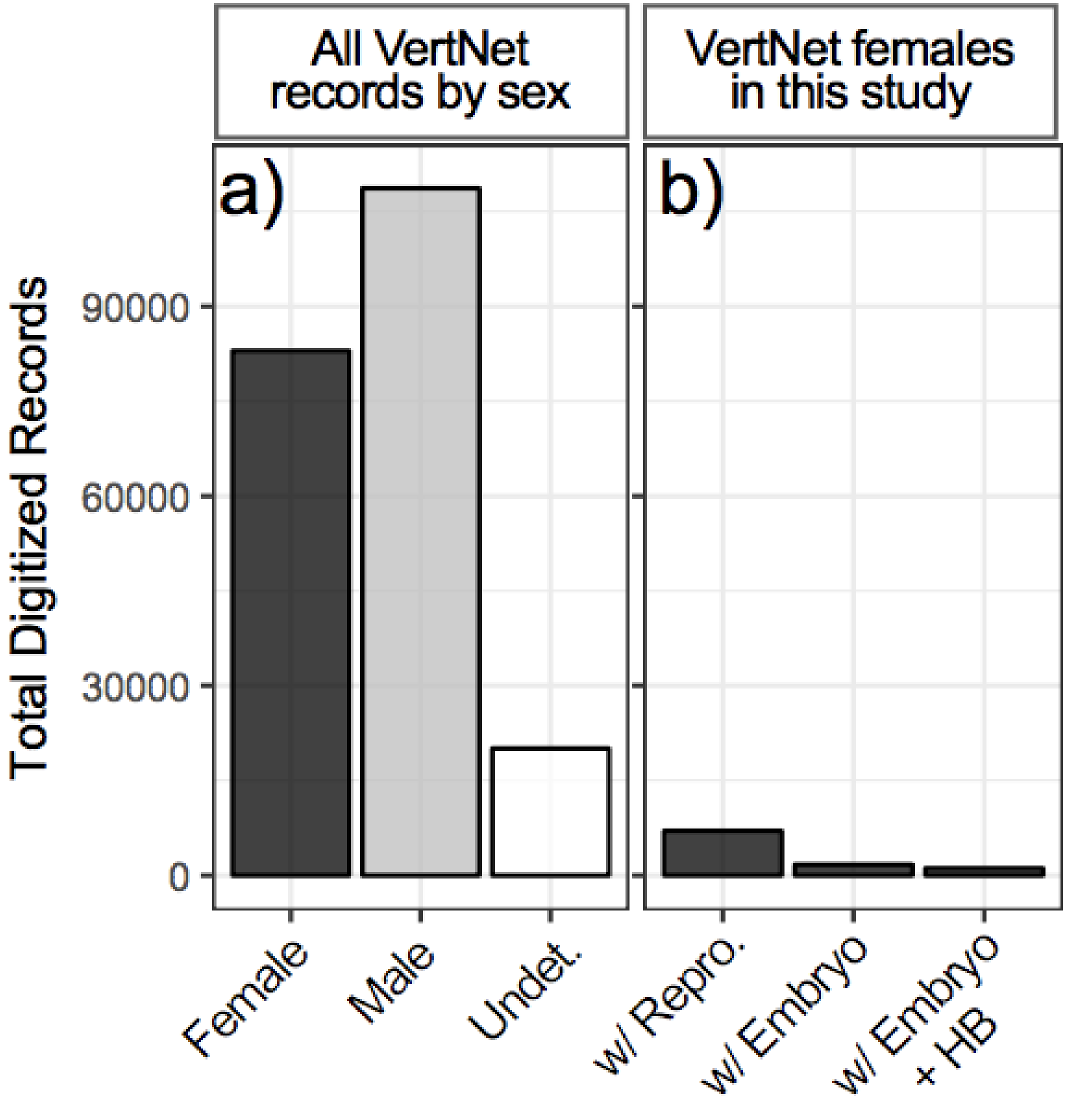
- How do instantaneous variables (temperature of the past few weeks) and more long-term (10 year average of season length) variables affect litter size/embryo count variation?

- Can we preliminarily pick up a signal of change over longer time-scales (decadal changes) with these data?

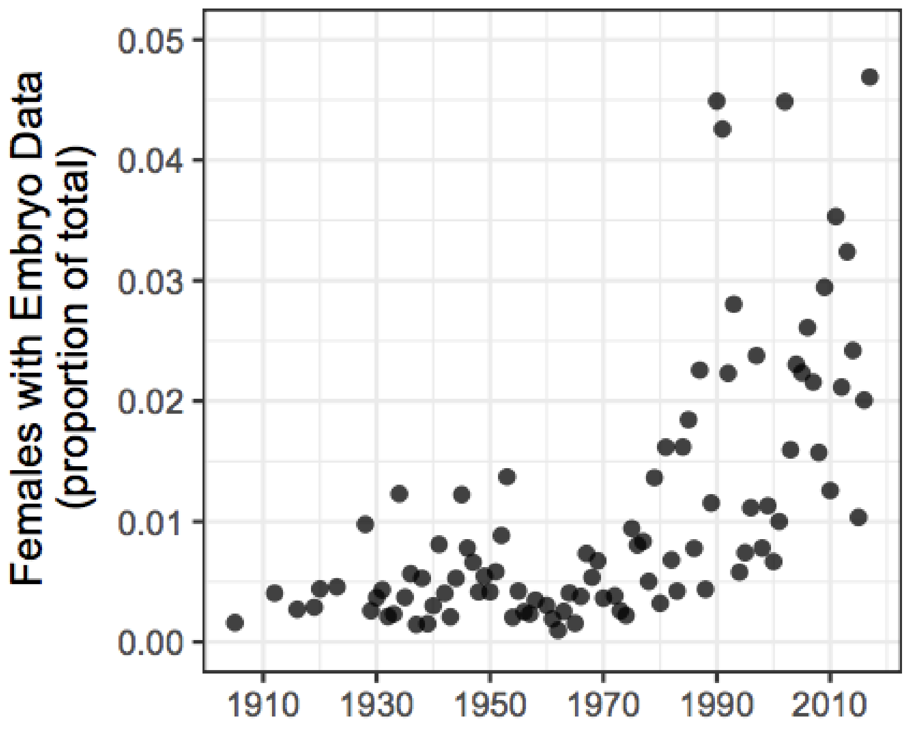
What data resources exist for examining litter size trends?

OccurrenceID	http://arctos.database.museum/guid/DMNS:Mamm:11198?seid=372073
CatalogNumber	11198
OtherCatalogNumbers	DZTM: Denver Zoology Tissue Mammal=173; collector number=JRD418
RecordNumber	JRD418
RecordedBy	Collector(s): John R. Demboski; Preparator(s): Kayce C. Bell
IndividualCount	1
Sex	female
Preparations	liver (frozen); heart, kidney (frozen); skin, study; skeleton; embryo (ethanol)
DynamicProperties	sex=female ; total length=153 mm; tail length=66 mm; hind foot with claw=20 mm; ear from notch=21 mm; weight=21.9 g; reproductive data=embryos: 3R, 2L ; crown-rump length=15 mm
OrganismID	http://arctos.database.museum/guid/DMNS:Mamm:11198
EventDate	2007-07-12
StartDayOfYear	193
EndDayOfYear	193
Year	2007
Month	07
Day	12
VerbatimEventDate	11 July 2007

How many litter size records are there for PEMA in VertNet?

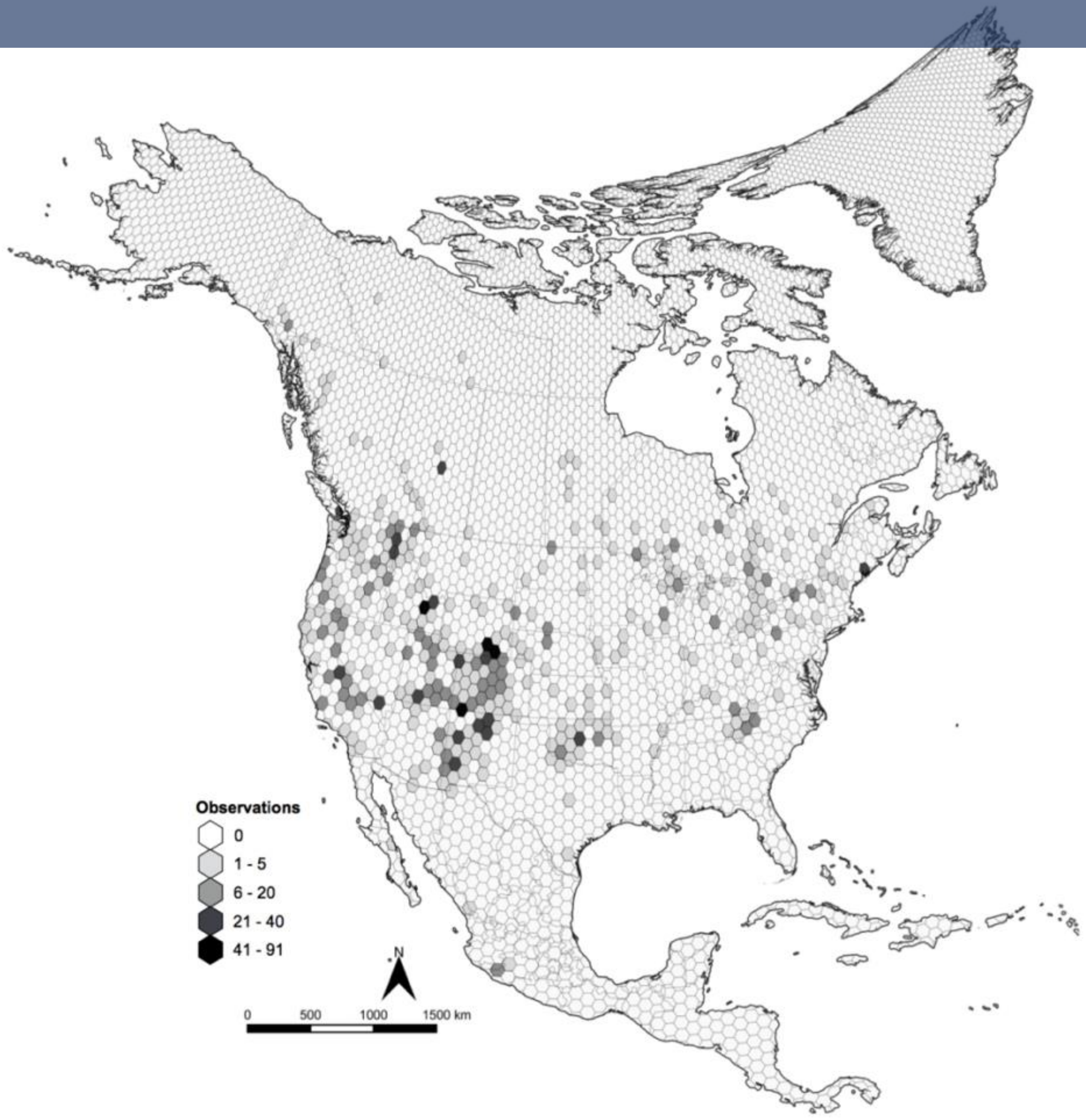


Is reporting of embryo counts changing over time?



Yes, improving….

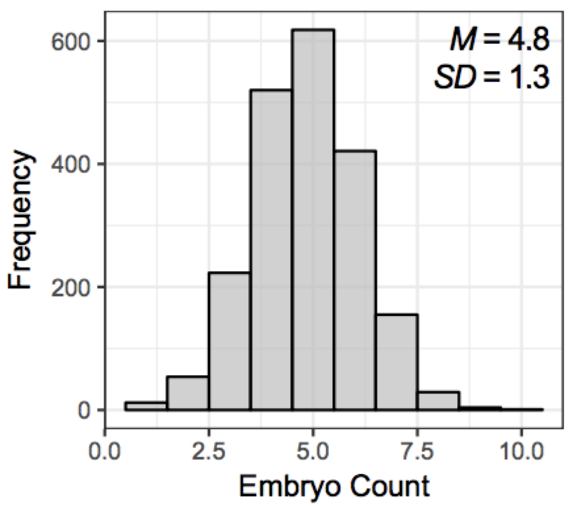
Where are these records?



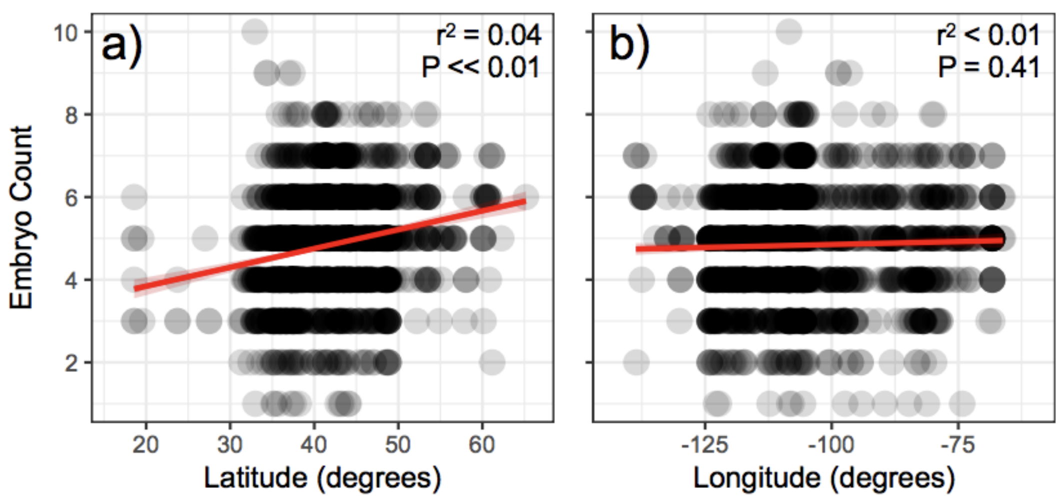
What key factors might influence PEMA embryo count?

Variable Acronym	Variable	Decription	Classification	Source
TS	Temperature Seasonality	10-year standard deviation of monthly temperature (degrees Celcius)	long-term	ClimateNA
PS	Precipitation Seasonality	10-year standard deviation of monthly precipitation (millimeters)	long-term	ClimateNA
NFFD	Number of Frost-Free Days	10-year average of annual number of frost free days	long-term	ClimateNA
TB	Mean Breeding Temperature	Average temperature during breeding month and previous month (degrees Celcius)	instantaneous	ClimateNA
PB	Total Breeding Precipitation	Total precipiation during breeding month and previous month (millimeters)	instantaneous	ClimateNA
NFFD_anomaly	Number of Frost-Free Days Anomaly	Annual deviation from decadal mean number of frost free days	instantaneous	Climate NA
FDD_anomaly	Freezing Degree Days Anomaly	Annual deviation from decadal mean number of freezing degree days	instantaneous	ClimateNA
DFFP	Day during Frost-Free Period	Days elapsed after beginning of frost-free period	instantaneous	ClimateNA
HB	Head-body Length	Total length - tail length (in millimeters)	individual-based	VertNet, NACSM

First Look: Simple Summaries



Overall distribution of embryo counts

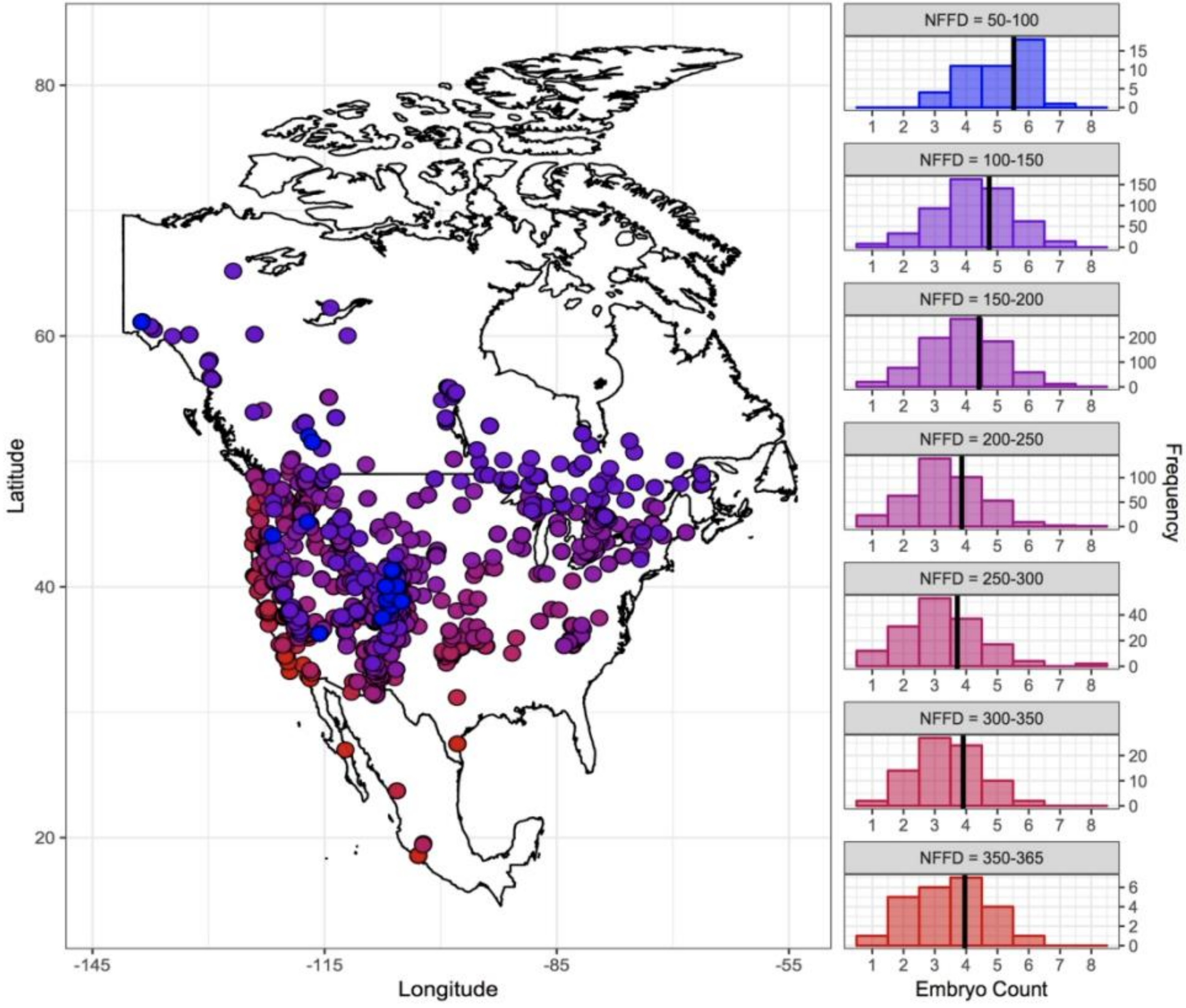


There is a signal of latitude just not very strong and latitude is not the predictor of interest

More in Depth: Multivariate Model Summary

- Models with just 10 year average number of frost free days (NFFD) are only marginally worse than models including all climate variables
- Embryo count strong negative relationship with NFFD
- NFFD as a sole predictor explains about 9% of the variance in embryo count
- Including head-body (HB) length marginally improves these models (HB + relationship)

A visual view: Embryo Count Histograms Over NFFD Bins

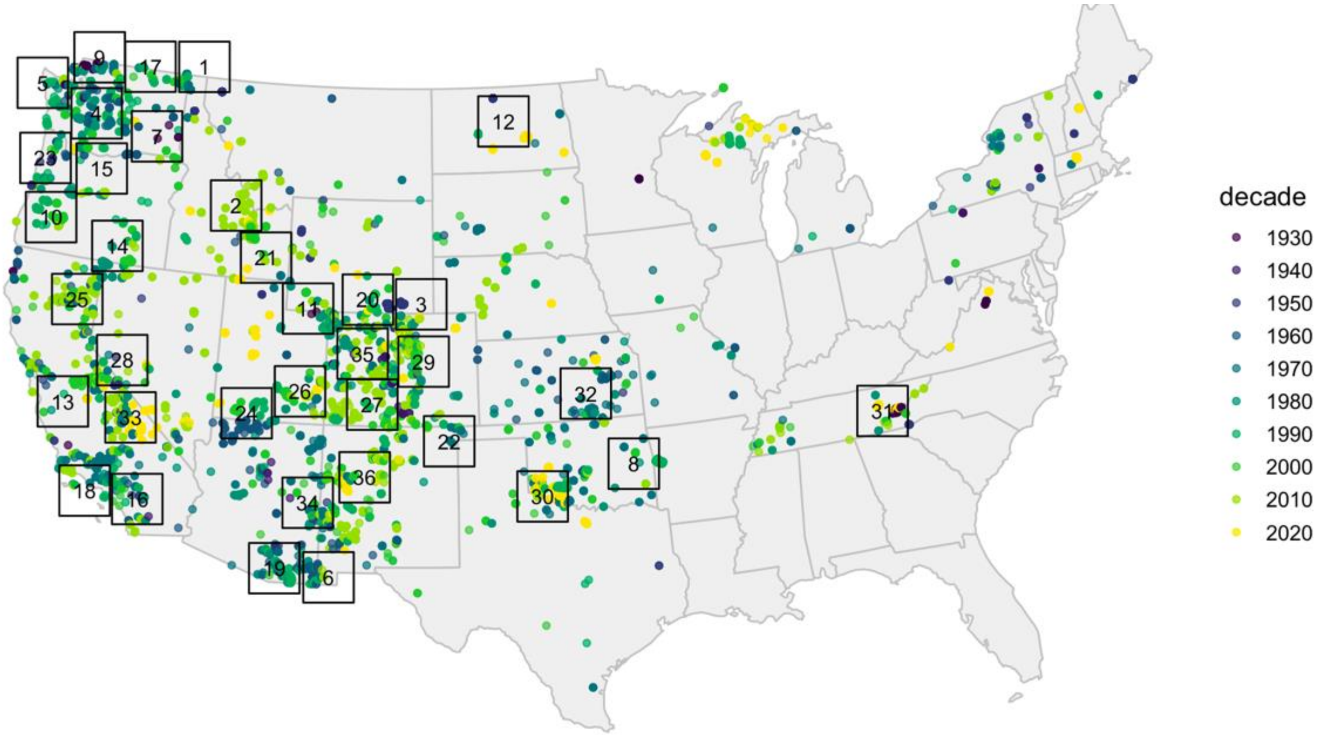


What about temporal trends?

- Examining temporal trends with incidental data is **fraught with bias issues**
- However, very preliminary analysis using temporal bins of 20 years, and fitting a model with litter size as a response and NFFD, 20 year decadal bins and their interaction as predictors
- Results: We find a significant, negative trend over 20 year bins – which would be expected direction of change
- But…. Hard to believe these results quite yet

Digging into temporal trends?

- The place to start to examine temporal trends is with body mass and length given significant availability of data
- Assembled a large, multisource (>25,000) record adult dataset
- Spatially constrained analysis to 200km grid cells with >100 record and at least 4 decades with >10 records.
- Tested hypotheses of reduced body size due to climate or human pressure



Preliminary Results Using Body Mass

- We assembled MAT (Bergmann's), MAP, human population density, sex and season collected as predictors of body mass and…

- Treating each cell independently, if we fit this model per cell: `lm(mass_g ~ year + sex + season + MAT + MAP + pop_10km2_log10)` **30 of 35** cells have negative year trends , 12 significant negative, and 1 significant positive.

- A linear mixed model with cell as random effect also shows a strong overall size decrease over year or decade BUT there is no relationship with population density or MAT. There is a negative, significant relationship with MAP.

- We still don't know why we see body size declines. Much more to do…

About Team Workshop Use Cases Data

The Functional Trait Resource for Environmental Studies (FuTRES) project is a collaborative project among four universities (University of Oregon, University of Arizona, University of Florida, and Howard University). The key deliverables of FuTRES are a workflow for assembling functional trait data measured at the specimen level, a database to serve that data, and scientific publications demonstrating the utility of the assembled data.

THE FuTRES OF TRAIT ASSEMBLY ENDEAVORS