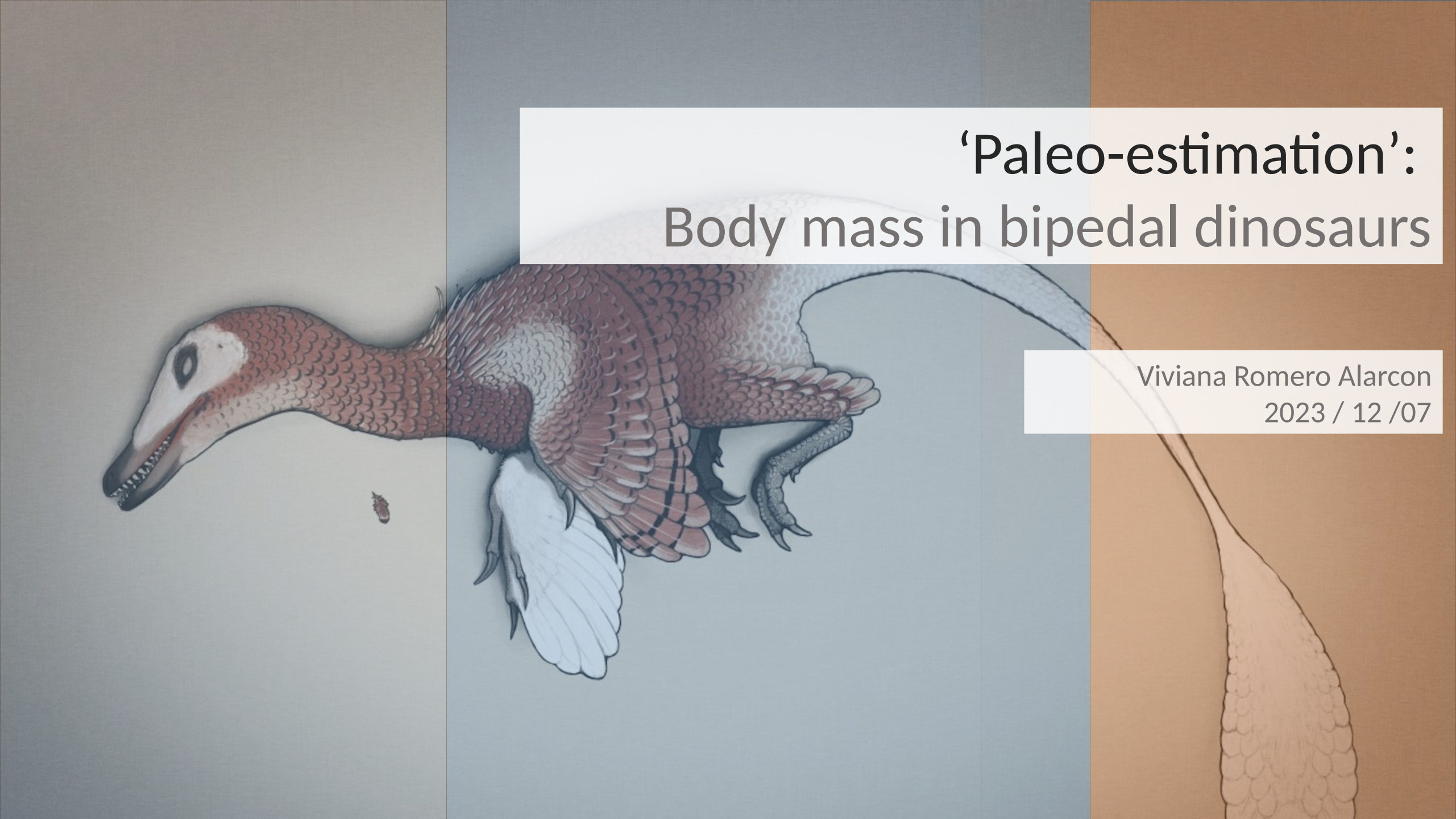


‘Paleo-estimation’:
Body mass in bipedal dinosaurs

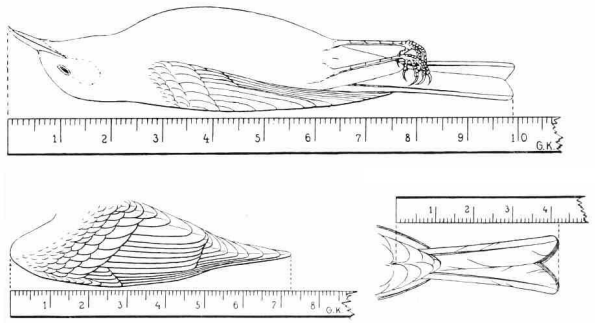
Viviana Romero Alarcon
2023 / 12 /07

Body mass

physiology

Ecology

phylogeny



Get body mass extant species => weigh

Get body mass extinct species => Prediction

Body mass - paleoEstimation

Volumetric-density (VD)

- Physical scale models
- Two-dimentional mathematical model
- Three-dimentional virtual model

Extant-scaling (ES)

$BM \sim 0.16\ C_{femur}^{2.73}$
(Anderson et al 1985)

$BM \sim 2.411 \log_{10} C_{femur} - 0.065$
(Cambell Jr & Marcus 1992)

$BM \sim 2.4 \log C_{femur} - 0.11$
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$BM \sim 2.754 \log C_{femur} - 0.683$
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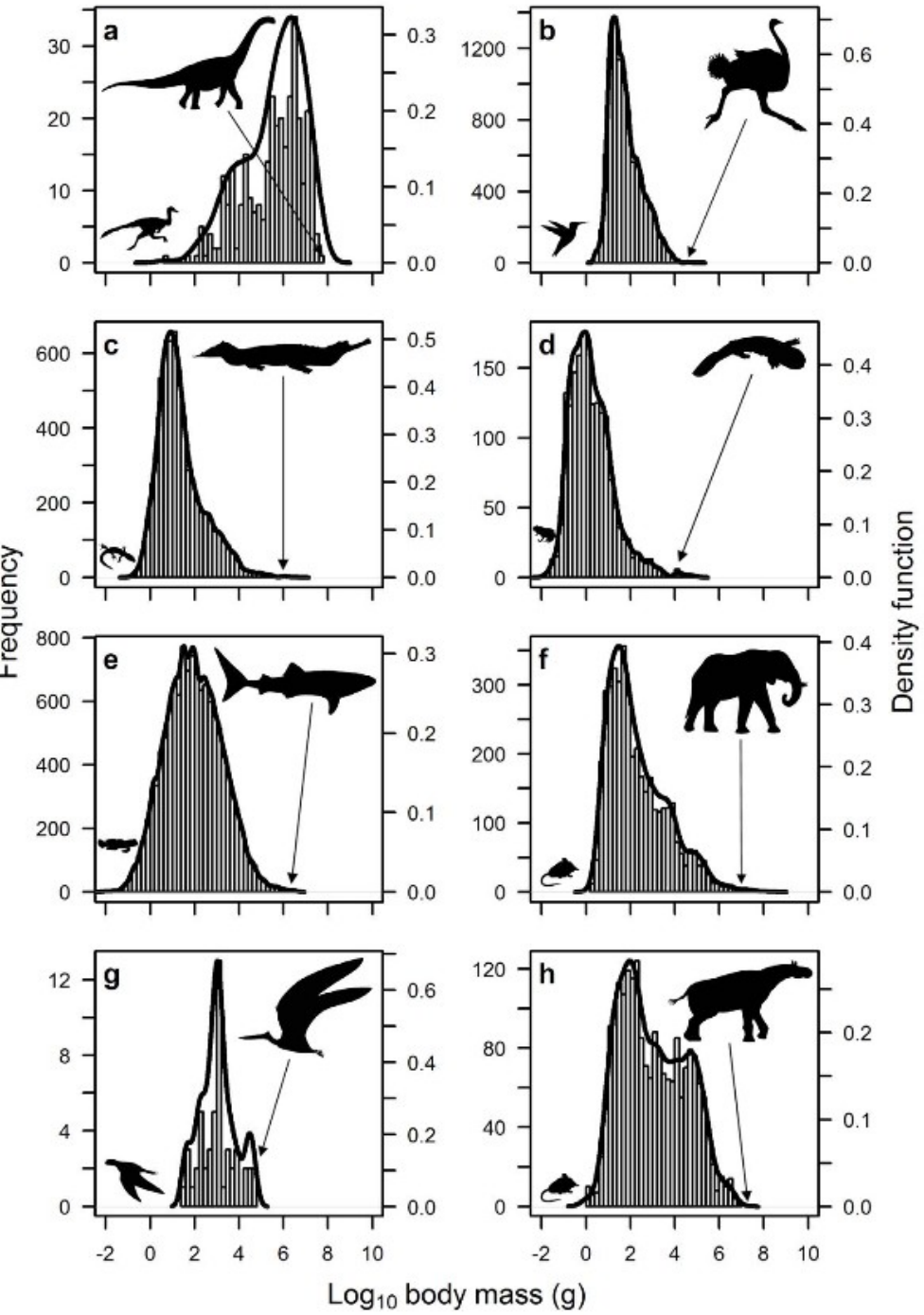

(O`Gornan & Hone 2012)

Body mass - paleoEstimation

Extant-scaling (ES)

Pros:

- Generate large data sets to reconstruct large-scale patterns of evolution
- Allow to study physiological and ecological on a macroevolutionary scale
- Cheap and easy to use

Cons:

Overestimation in theropods

No way to measure the actual weight

$BM \sim 0.16\ C_{femur}^{2.73}$ (Anderson et al 1985)

$BM \sim 2.411 \log_{10} C_{femur} - 0.065$ (Cambell Jr & Marcus 1992)

$BM \sim 2.4 \log C_{femur} - 0.11$ (Field et al 2013)

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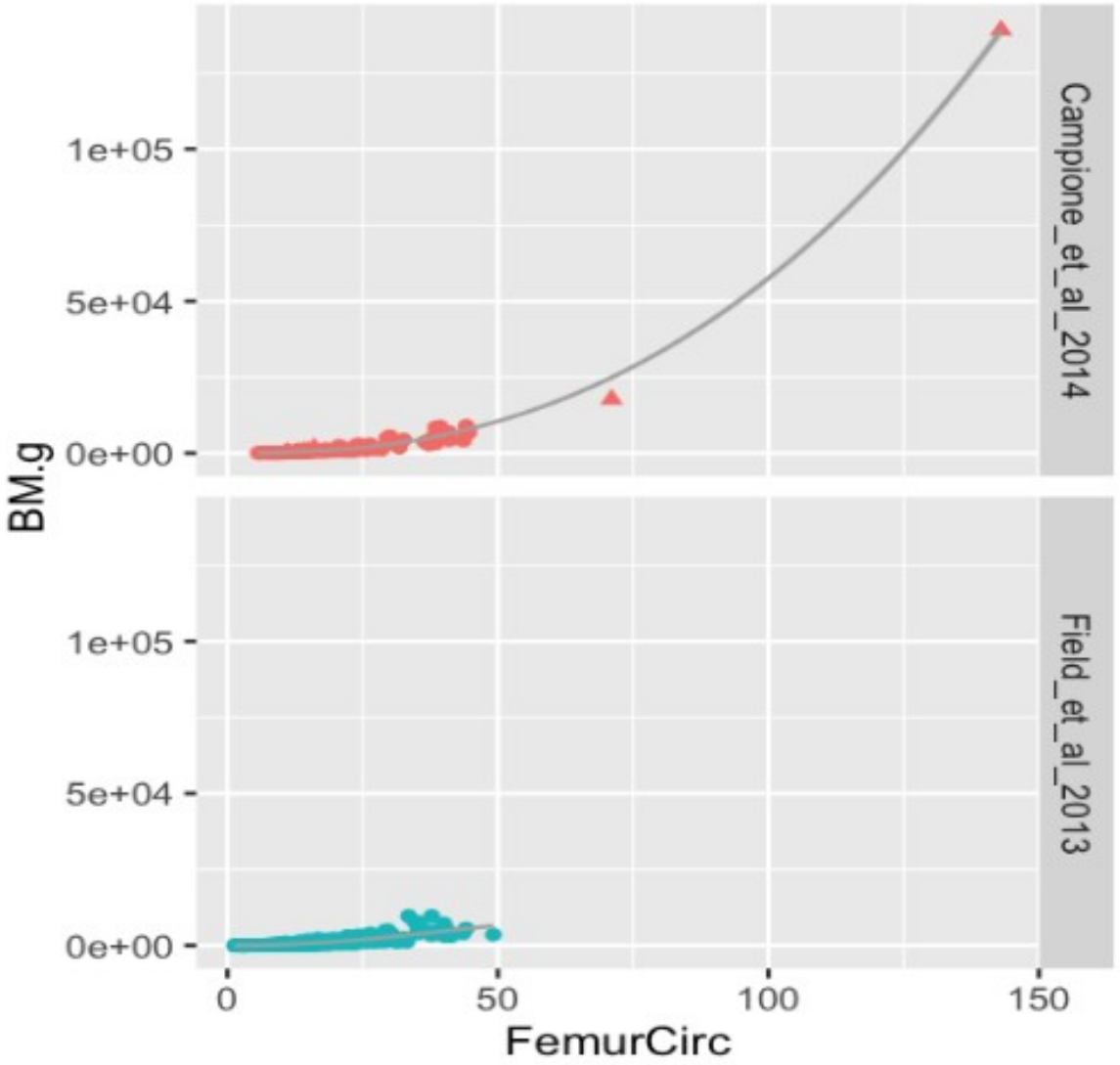

Ref

- Campione_et_al_2014
- Field_et_al_2013

Clade.1

- Neognathae
- Palaeognathae

Body mass - paleoEstimation

Extant-scaling (ES)

$BM \sim 0.16\ C_{femur}^{2.73}$
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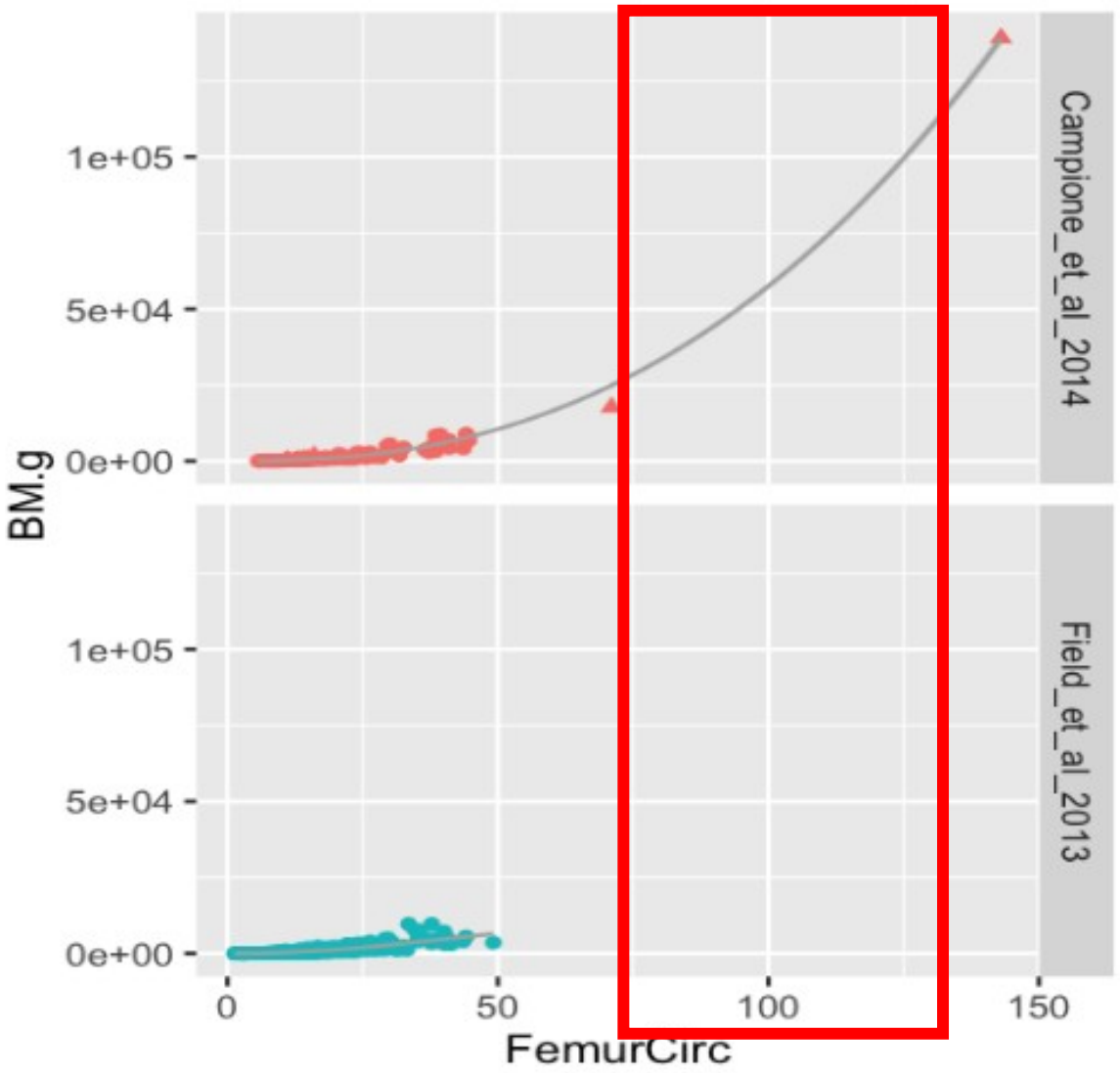

Ref
- Campione_et_al_2014
- Field_et_al_2013

Clade.1
- Neognathae
- Palaeognathae

No samples from the biggest modern birds

Body mass - paleoEstimation

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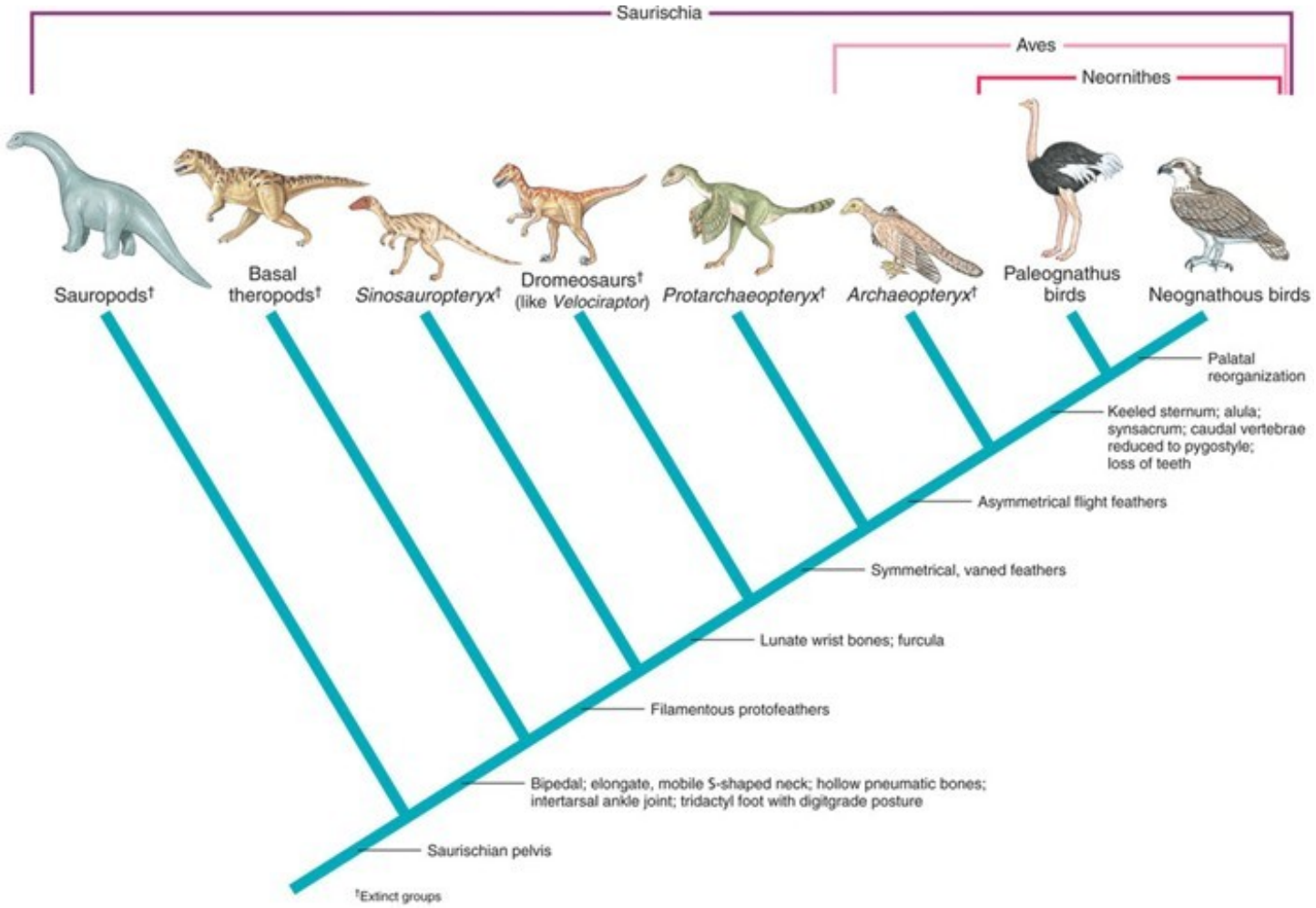
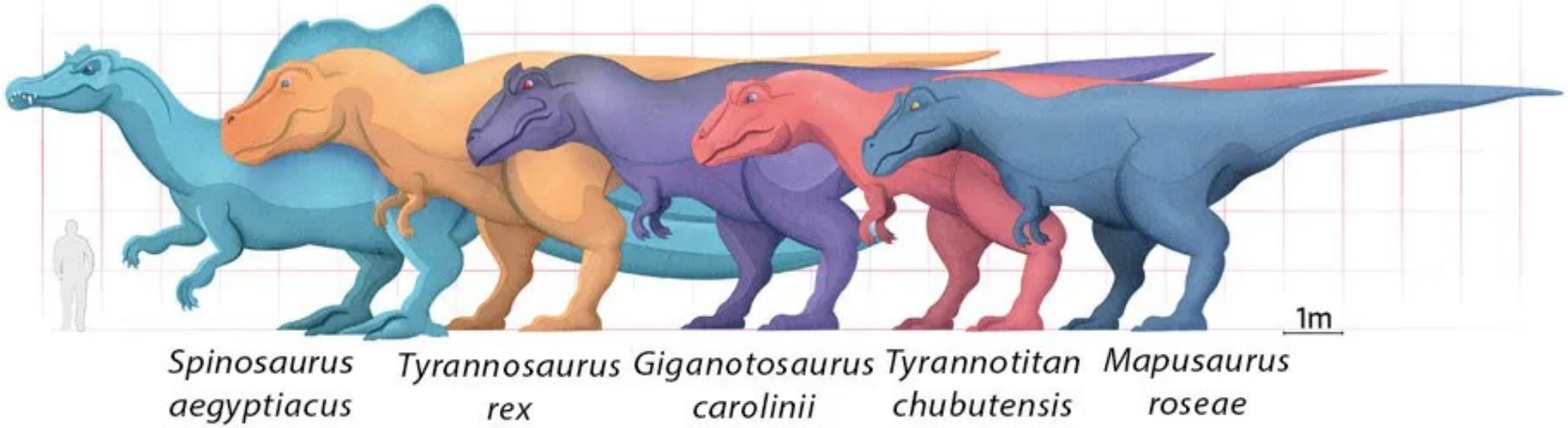


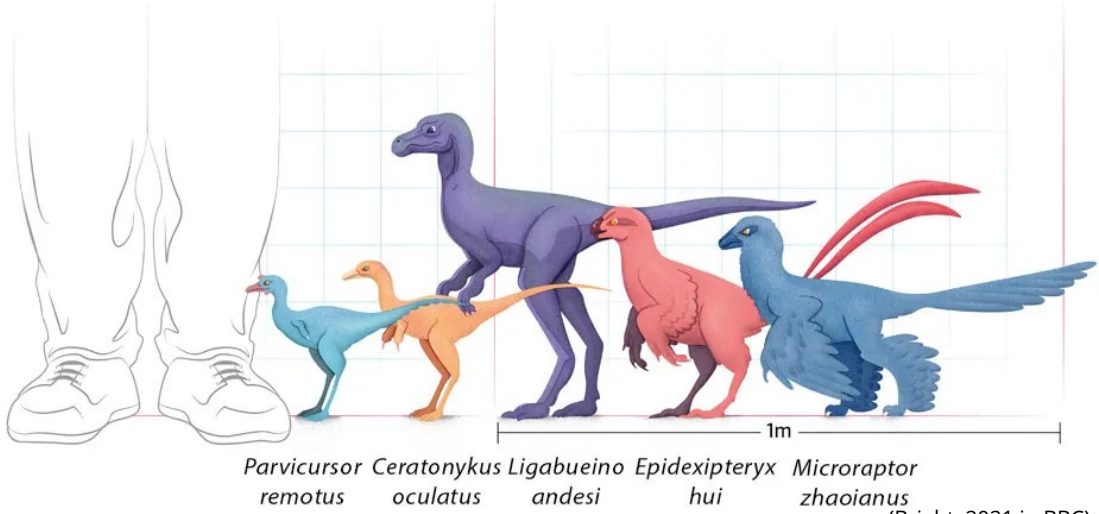
Palaeognathae group:

Heaviest modern birds (extant species)

Flightless birds ~ Theropods



Could I improve the model, if I included samples from the Palaeognathae group?



(Bright, 2021 in BBC)

Body mass - paleoEstimation

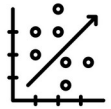
Seed:999

Campione&Benson 2020
Chan 2017
Field et al 2013
Campione et al 2014

Femur Circumference ~ Femur Length

Distributions

Relationship



Dataset

sp: 552
Orders: 32
Obs: 1172

- FC ~ FL
- FC ~ FL + Clade.1
- FC ~ FL + Clade.2
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- log(FC) ~ log(FL) + Clade.1
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- FC ~ poly(FL,2)
- FC ~ poly(FL,2) +Clade.1
- FC ~ poly(FL,2) + Clade.2

Train: 80%
Test: 20%

MSE

Whole dataset

AIC

Prediction

71 Observations

Canoville et al 2022
Chadwick et al 2014
Crouch&Clarke 2019
Elzanowski&Louchart 2022
Gatesy&Middleton 1997

Palaeognathae

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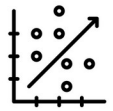

Dataset

sp: 446
Orders: 27
Obs: 1036

- BM.g ~ FC
- log(BM.g) ~ log(FC)
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- BM.g ~ poly(FC, 3)
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Train: 80%
Test: 20%

MSE

Kfold (10) -
Cross Valid.

MAE

Best Model

Prediction

Theropods

Dataset

sp: 35
Orders: 9
Obs: 111

Distributions

Relationship

Palaeognathae

Dataset

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Back transform

Log

$$\sum PPE = \frac{\sum Obs - pred}{pred} * 100 \over n$$

Body mass - paleoEstimation

Seed:999

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Chan 2017
Field et al 2013
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Femur Circumference ~ Femur Length

Distributions

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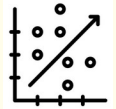

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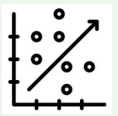

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MSE

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Cross Valid.

MAE

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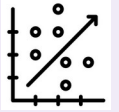

Palaeognathae

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Body mass - paleoEstimation

Seed:999

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Femur Circumference ~ Femur Length

Distributions

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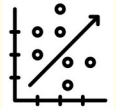

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MSE

Whole dataset

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MSE

Kfold (10) -
Cross Valid.

MAE

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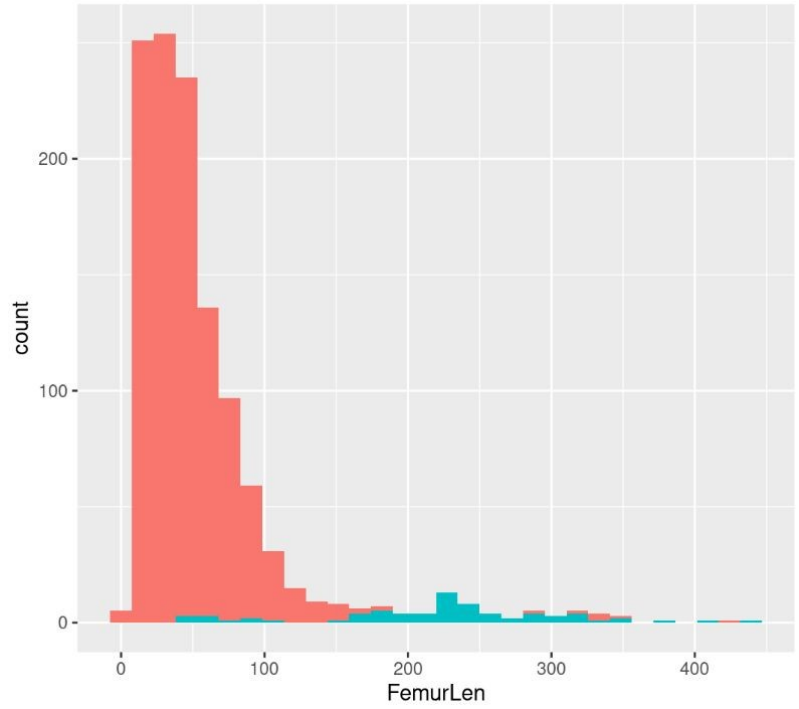
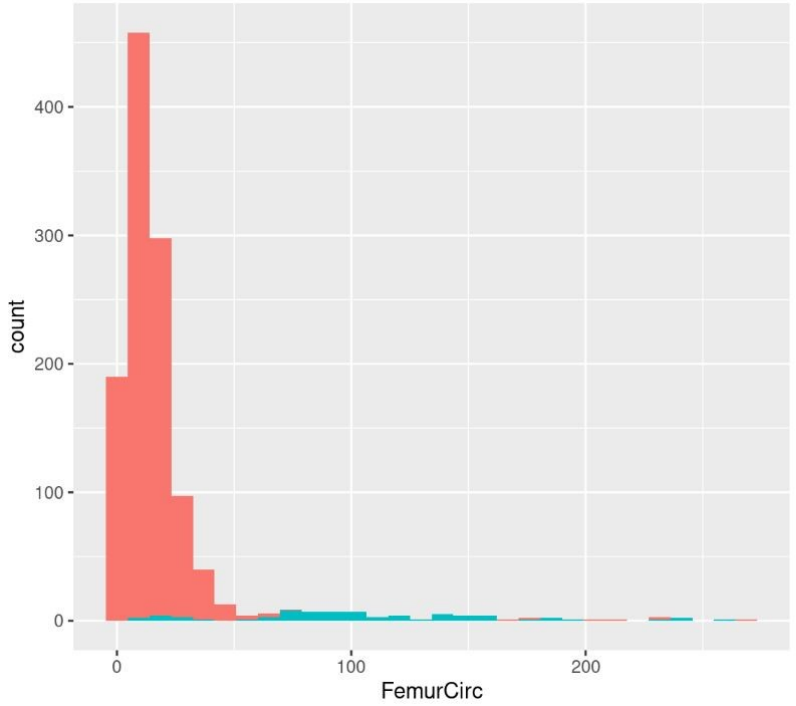
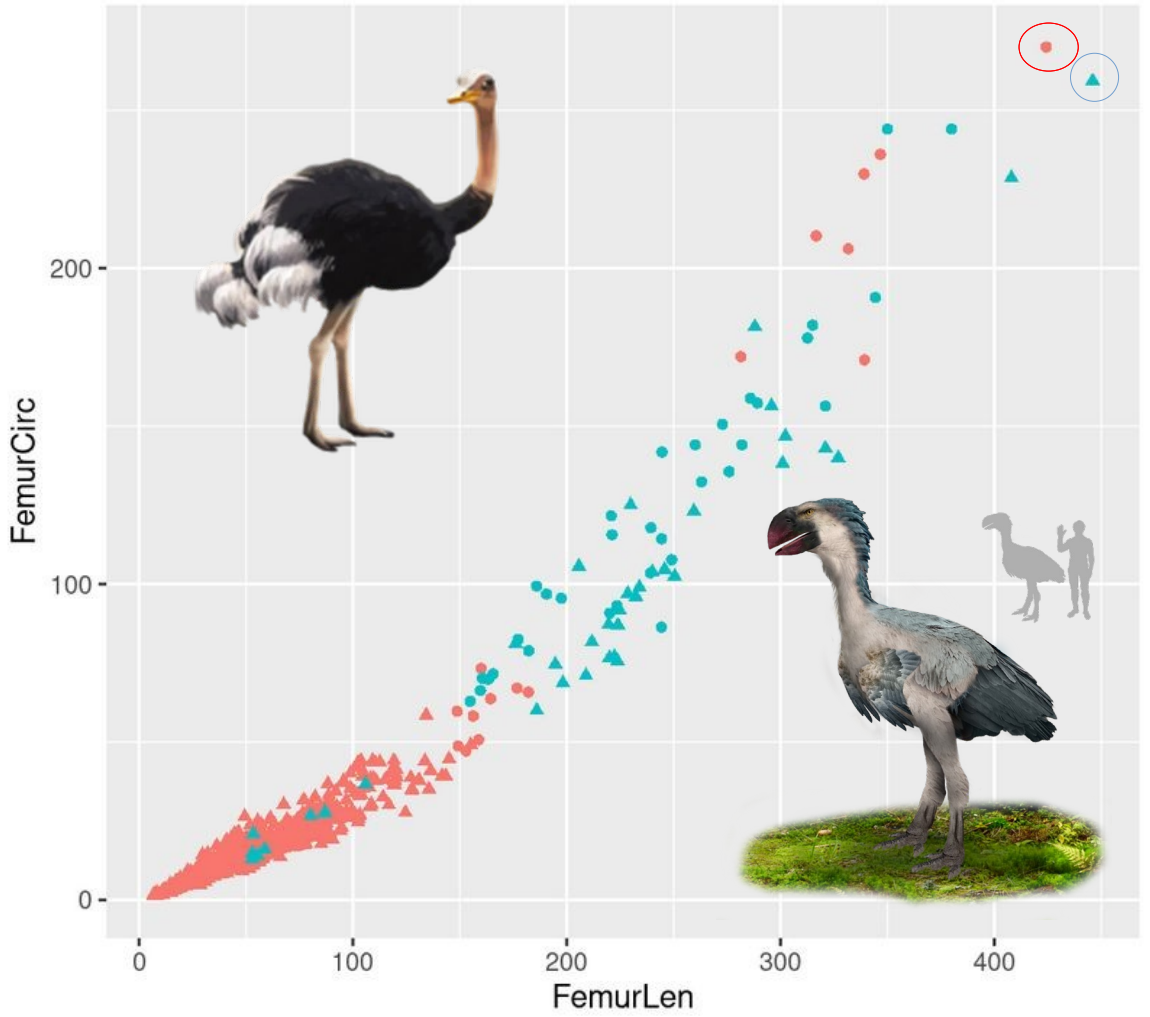




Femur Circumference ~ Femur Length



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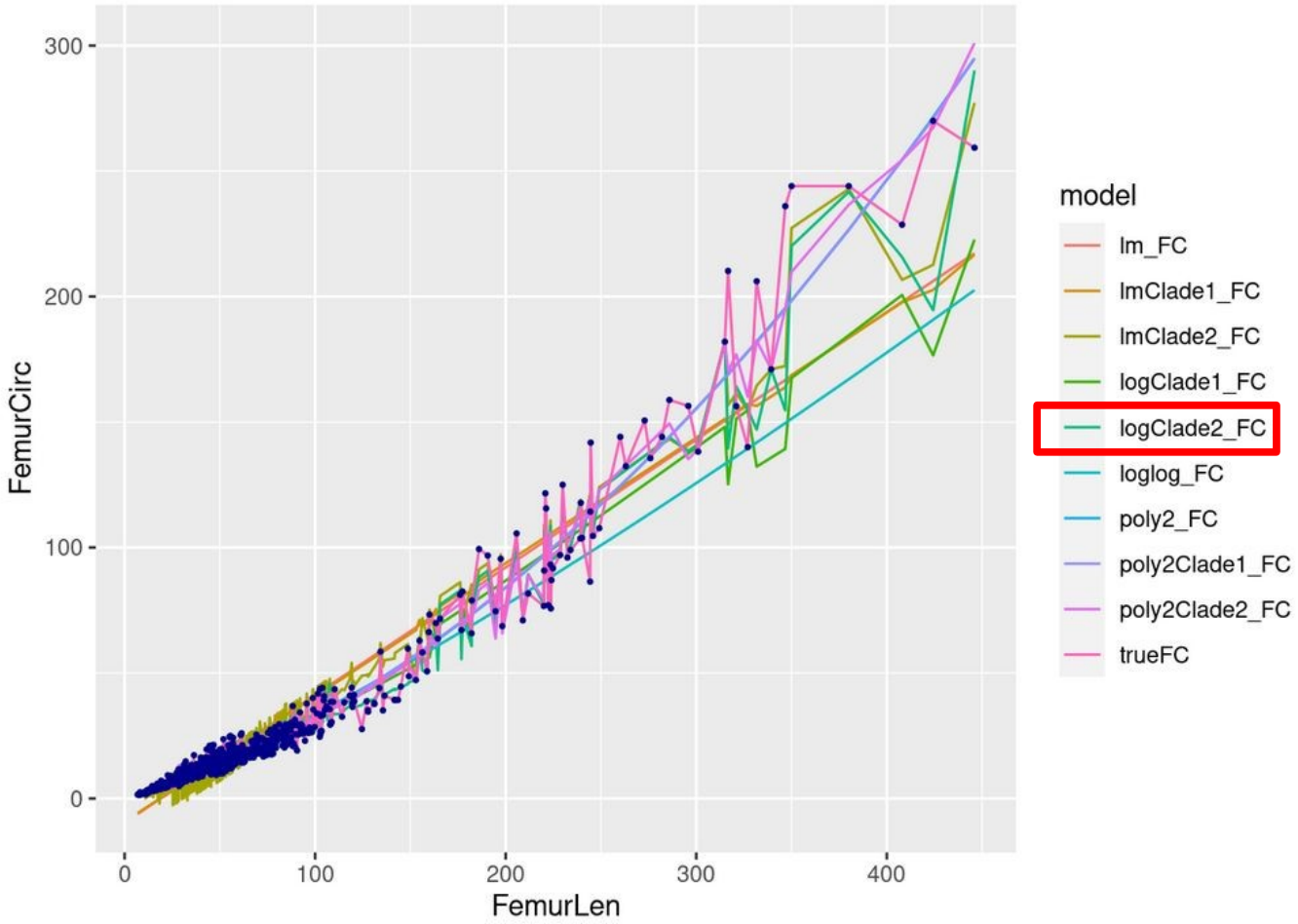
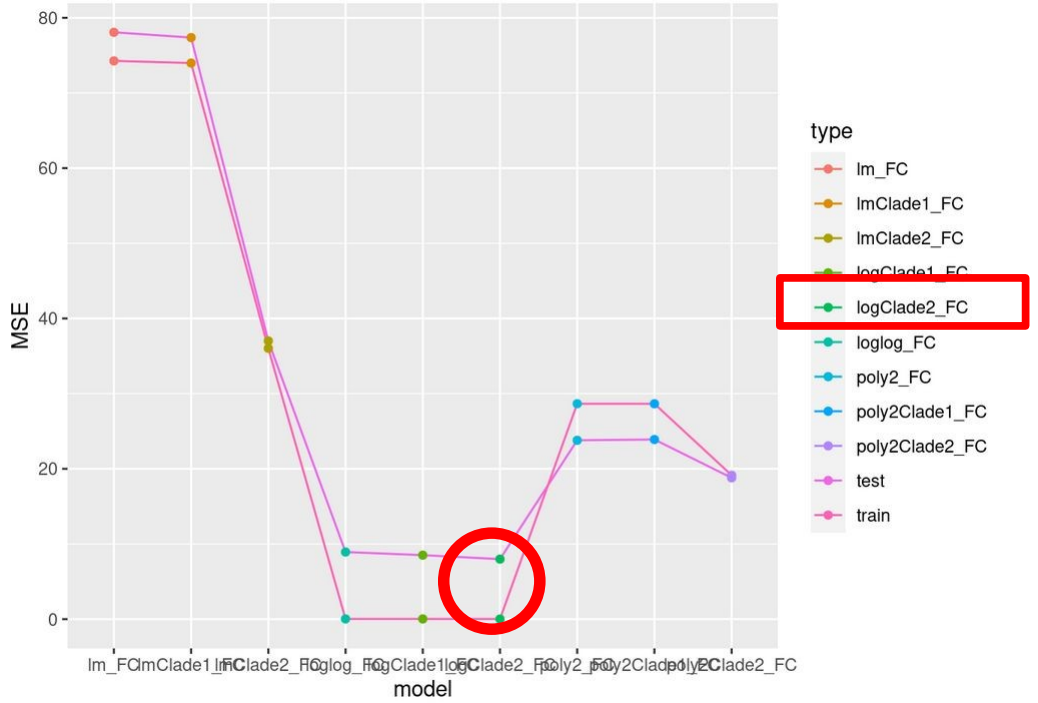
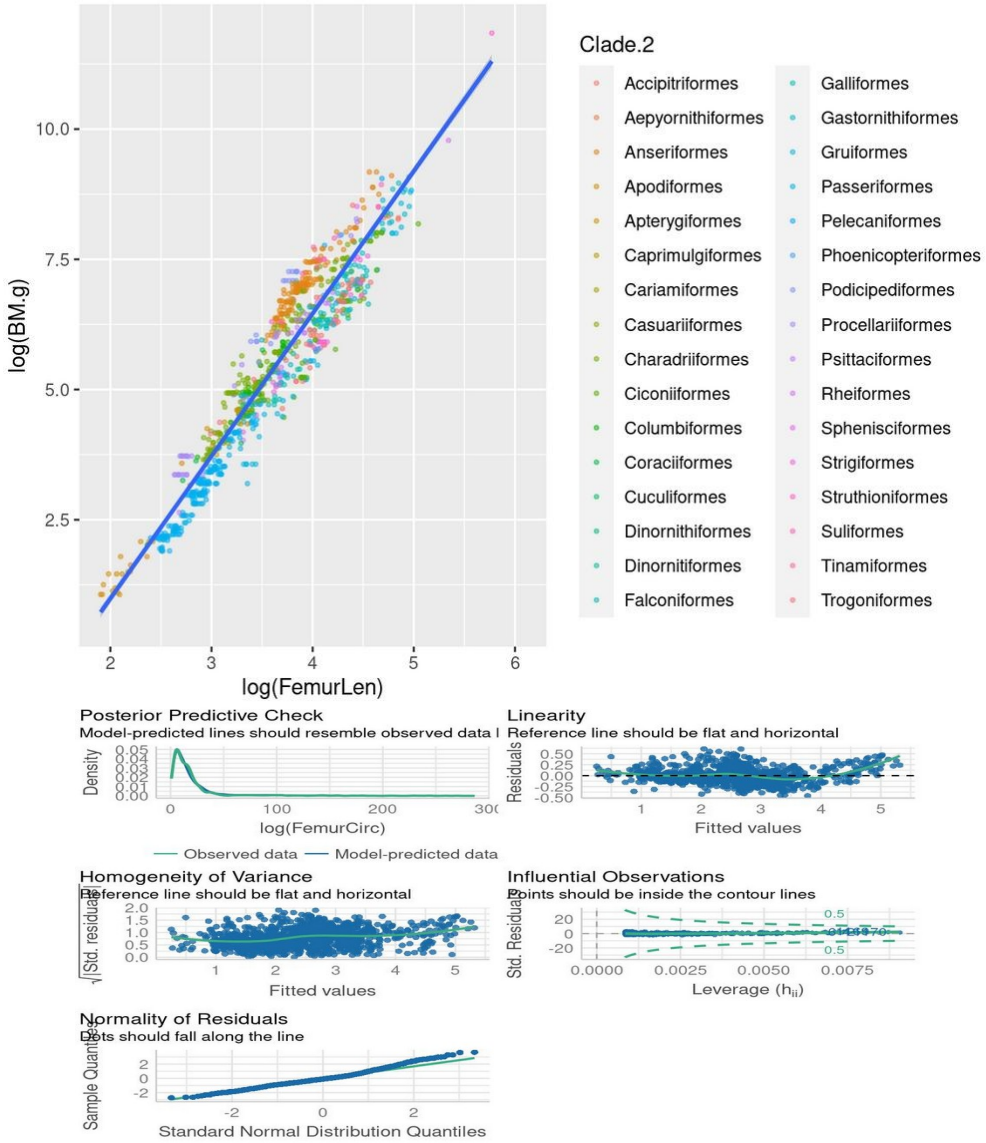
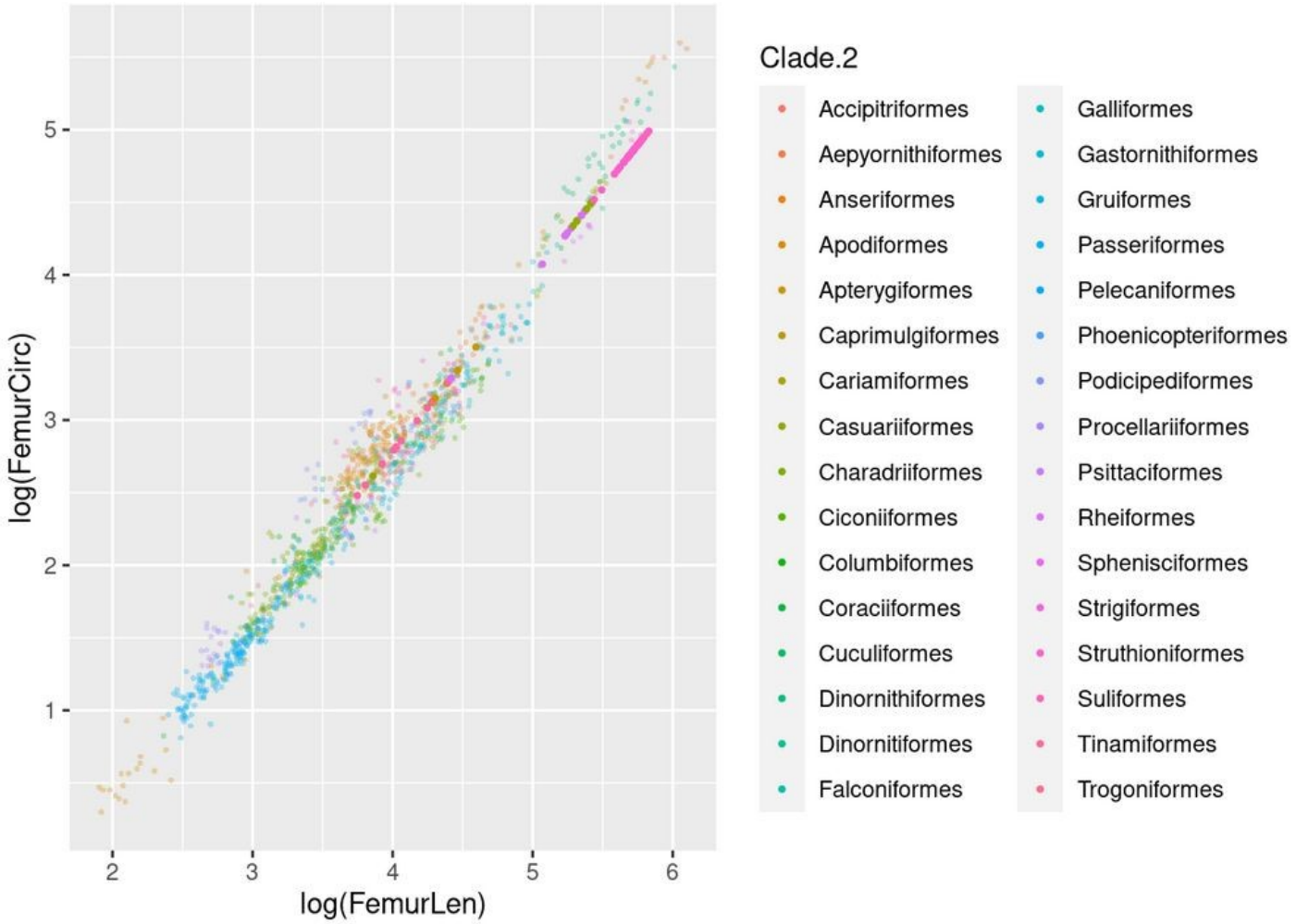




	df <dbl>	AIC <dbl>	adjR2 <dbl>
lm_FC	3	6780.0611	0.9243
lmClade1_FC	4	6781.6477	0.9243
lmClade2_FC	33	6212.0096	0.9600
loglog_FC	3	-701.6656	0.9685
logClade1_FC	4	-750.6794	0.9701
logClade2_FC	33	-1362.2089	0.9849
poly2_FC	4	5875.5790	0.9712
poly2Clade1_FC	5	5875.9012	0.9712
poly2Clade2_FC	34	5589.9289	0.9794

Log(Femur Circumference) ~ log(Femur Length) + Orders





Body mass - paleoEstimation

Seed:999

Campione&Benson 2020
Chan 2017
Field et al 2013
Campione et al 2014

Distributions

Relationship

Dataset

sp: 446
Orders: 27
Obs: 1036

- BM.g ~ FC
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- BM.g ~ spline(FC, 25, 50)

Train: 80%
Test: 20%

MSE

Kfold (10) -
Cross Valid.

MAE

Best Model

Femur Circumference ~ Femur Length

Distributions

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sp: 552
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Whole
dataset

MSE

AIC

Prediction

71 Observations

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Chadwick et al 2014
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Palaeognathae

Prediction

Theropods

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Distributions

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Palaeognathae

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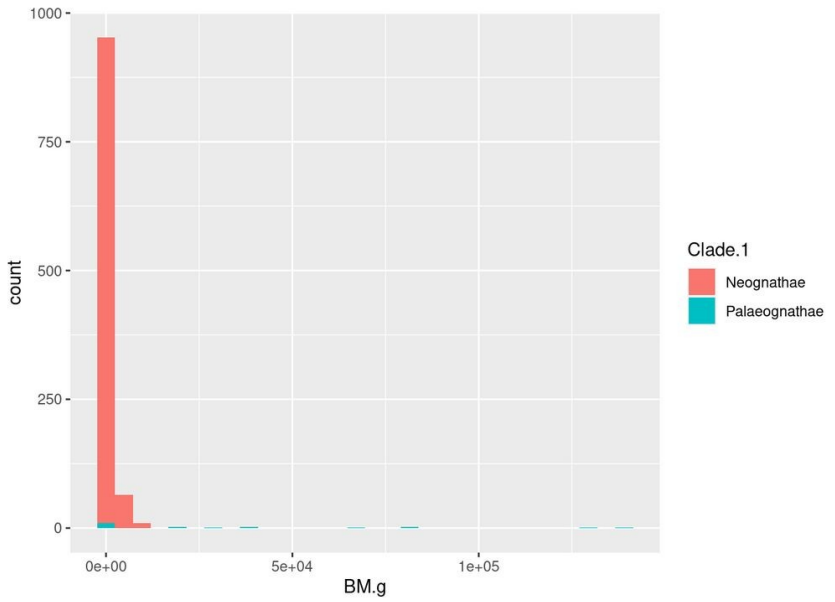
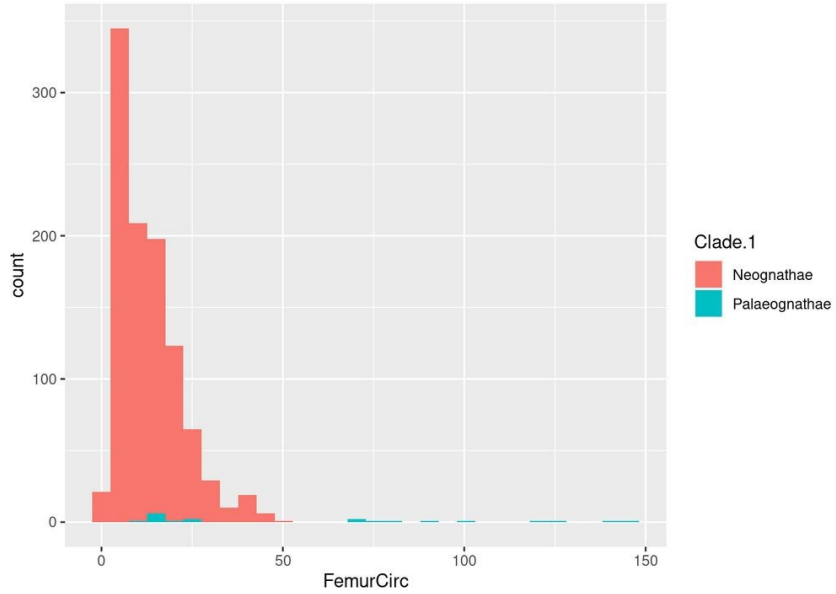
Back transform

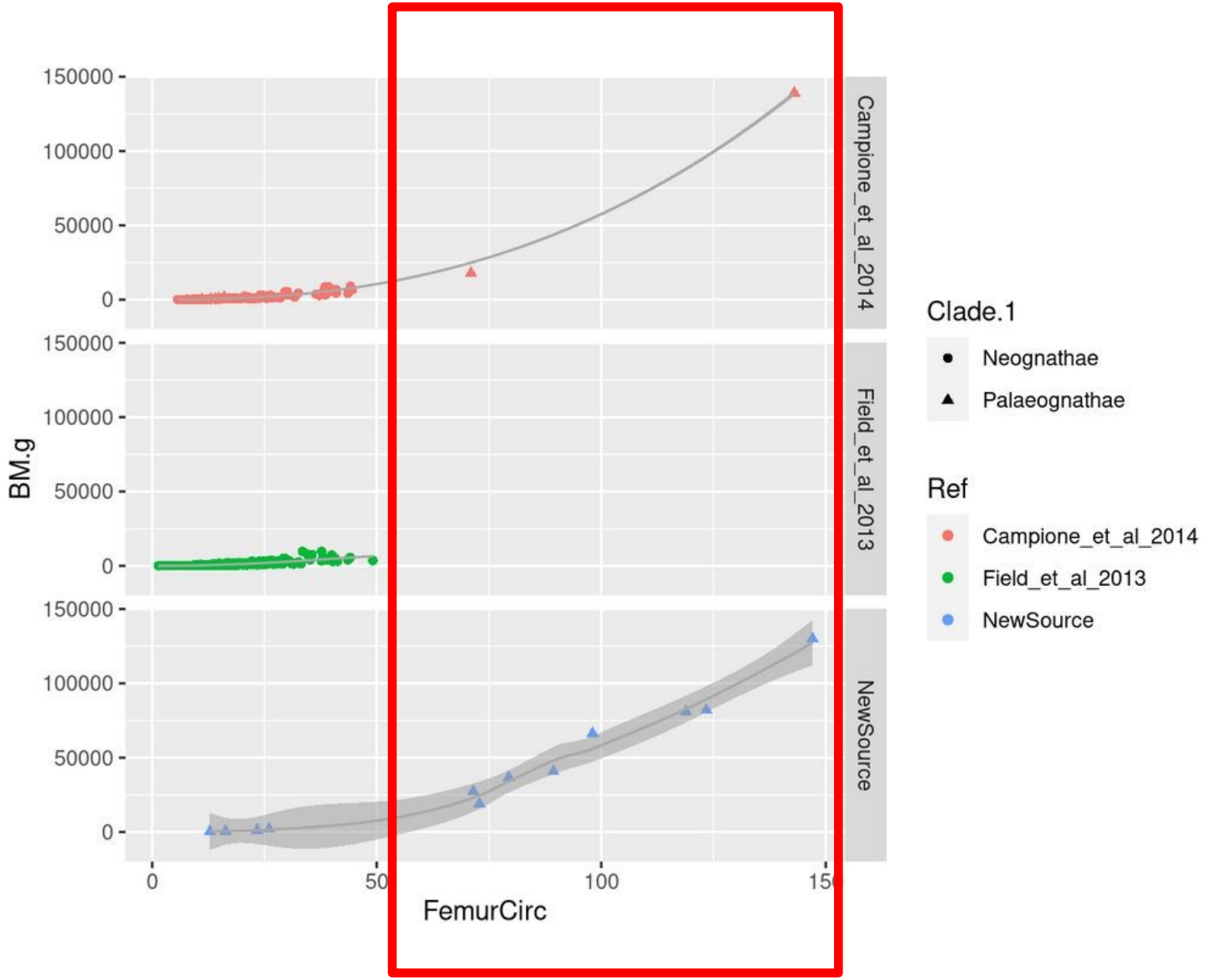
Log

$$\sum PPE = \frac{\sum \frac{Obs - pred}{pred} * 100}{n}$$

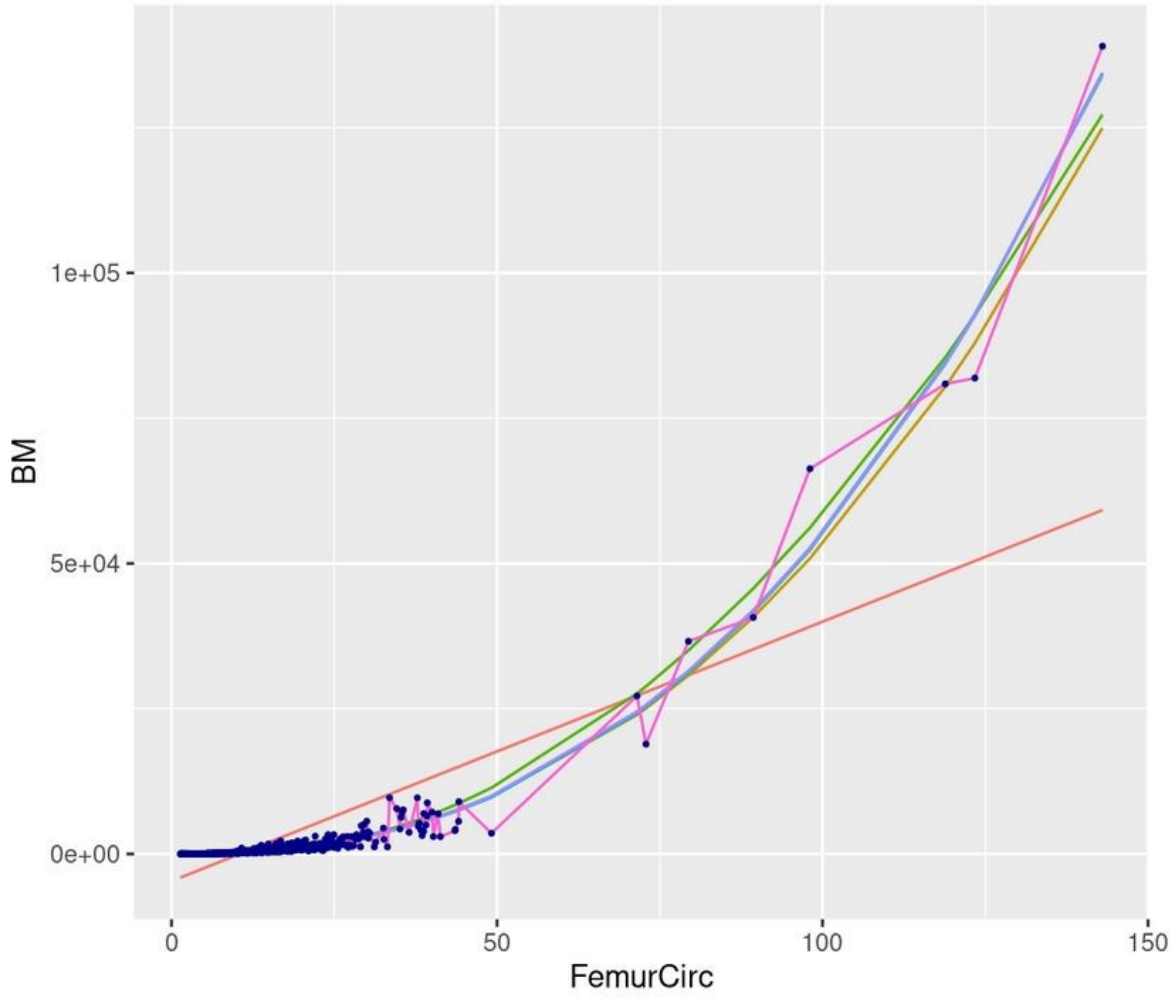
Body mass ~ Femur Circ



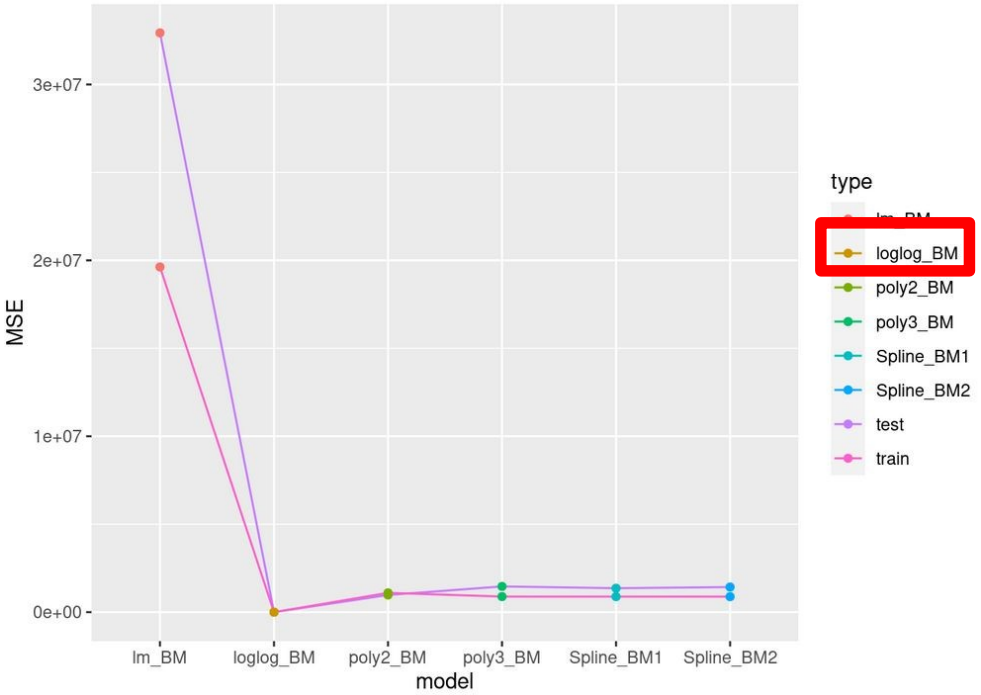


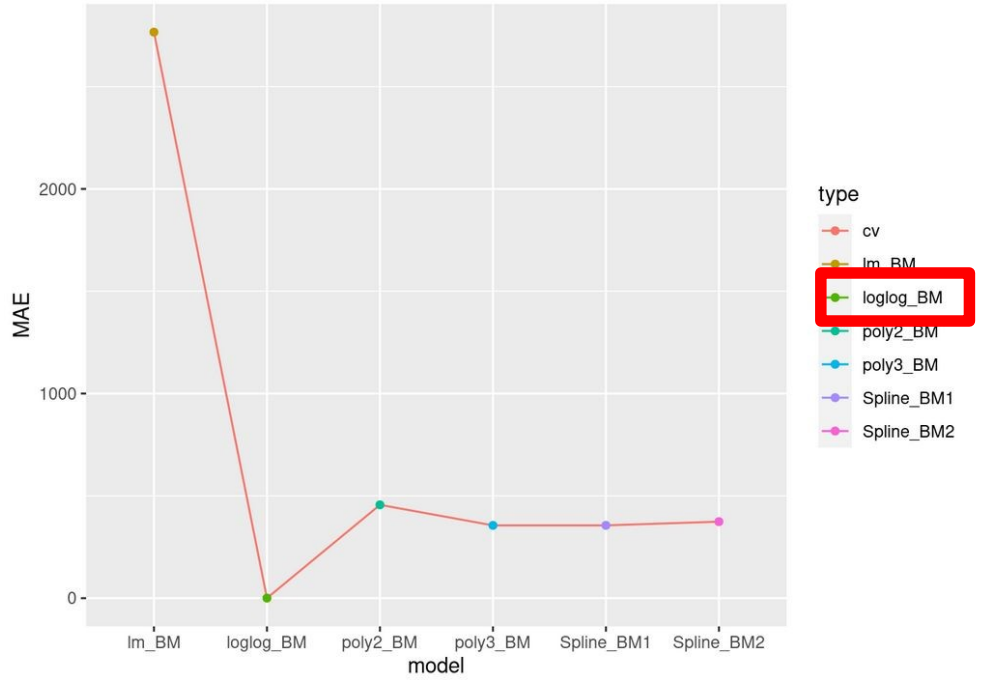


log(Body mass) ~ log(Femur Circ)



model	Adj R2
lm_BM	0.6062
loglog_BM	0.9547
poly2_BM	0.9813
poly3_BM	0.9839
Spline_BM1	0.9845
Spline_BM2	0.9846
trueBM	





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Seed:999

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Femur Circumference ~ Femur Length

Distributions

Relationship

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Train: 80%
Test: 20%

Whole dataset

MSE

AIC

Palaeognathae

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Cross Valid.

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Best Model

Prediction

Theropods

Palaeognathae

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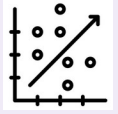
Distributions

Relationship



Dataset

sp: 15
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Obs: 20

$BM \sim 0.16\ C_{femur}^{2.73}$ (Anderson et al 1985)

$\log_{10}(BM) \sim 2.411 \log_{10} C_{femur} - 0.065$ (Cambell Jr & Marcus 1992)

$\log(BM) \sim 2.4 \log C_{femur} - 0.11$ (Field et al 2013)

$\log(BM) \sim 2.754 \log 10\ C_{femur} - 0.683$ (Campione et al 2014)

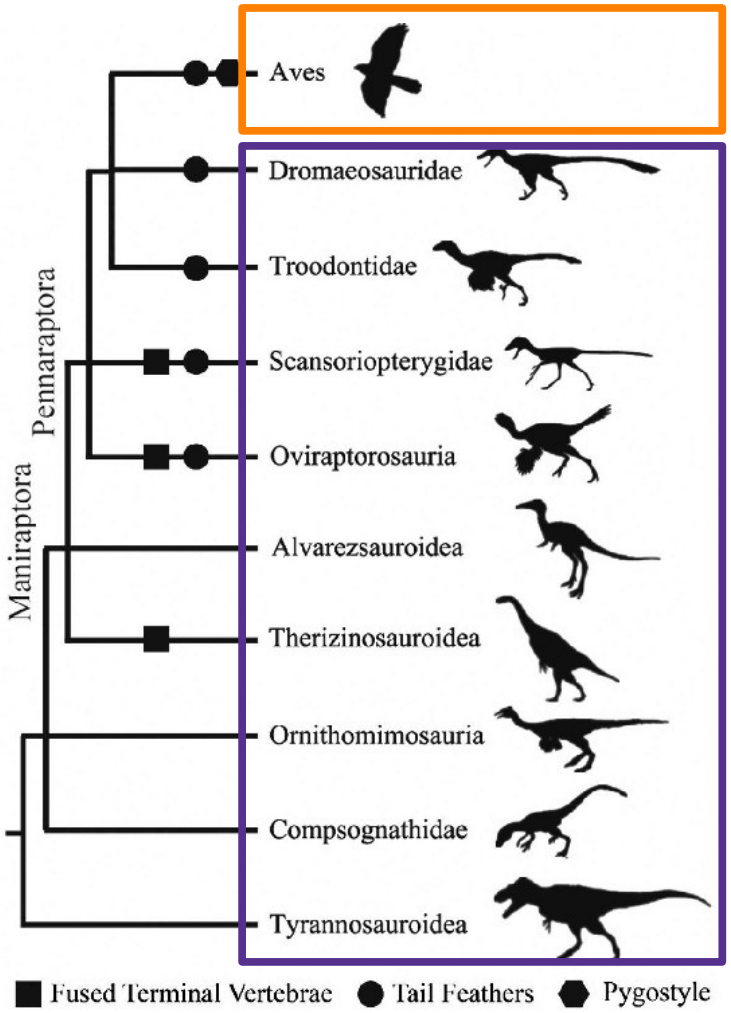
$\log(BM) \sim 2.37699 \log C_{femur} - 0.09121$ (This analysis)

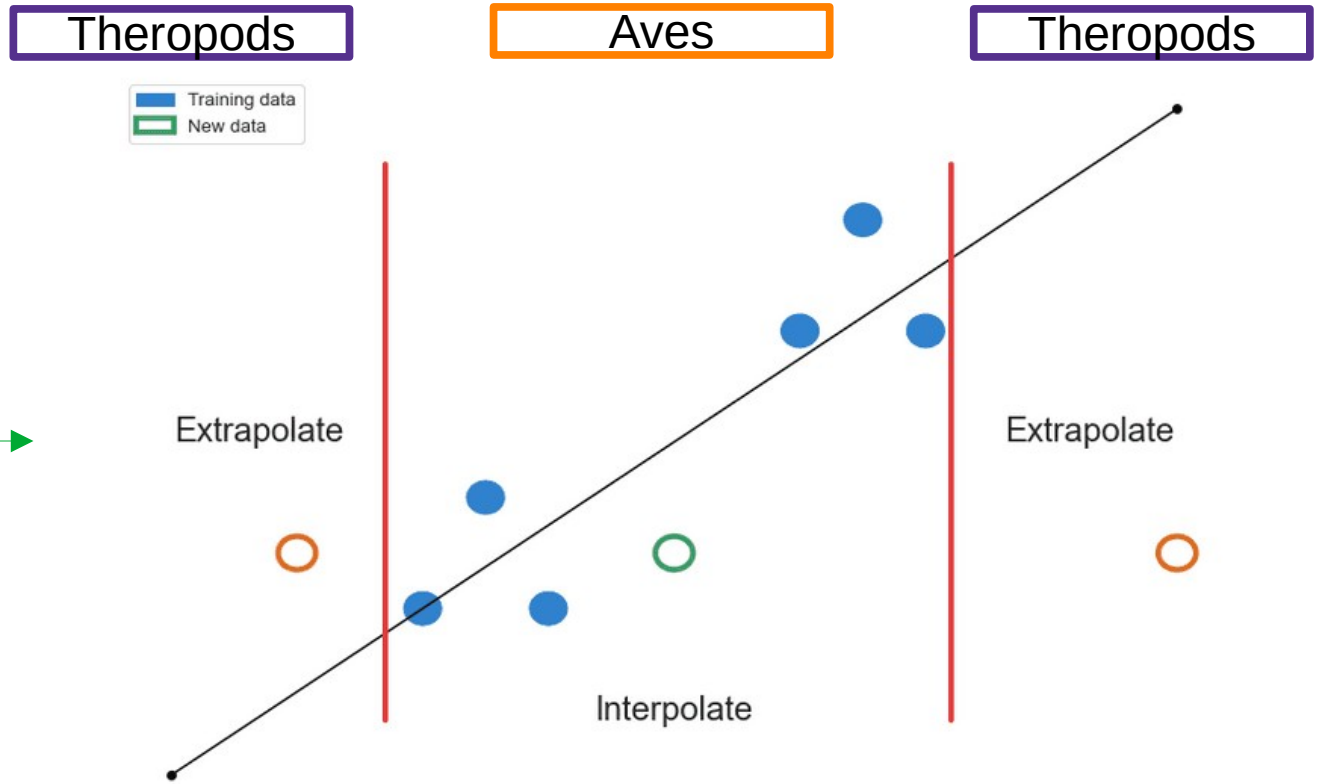
Back transform

Log

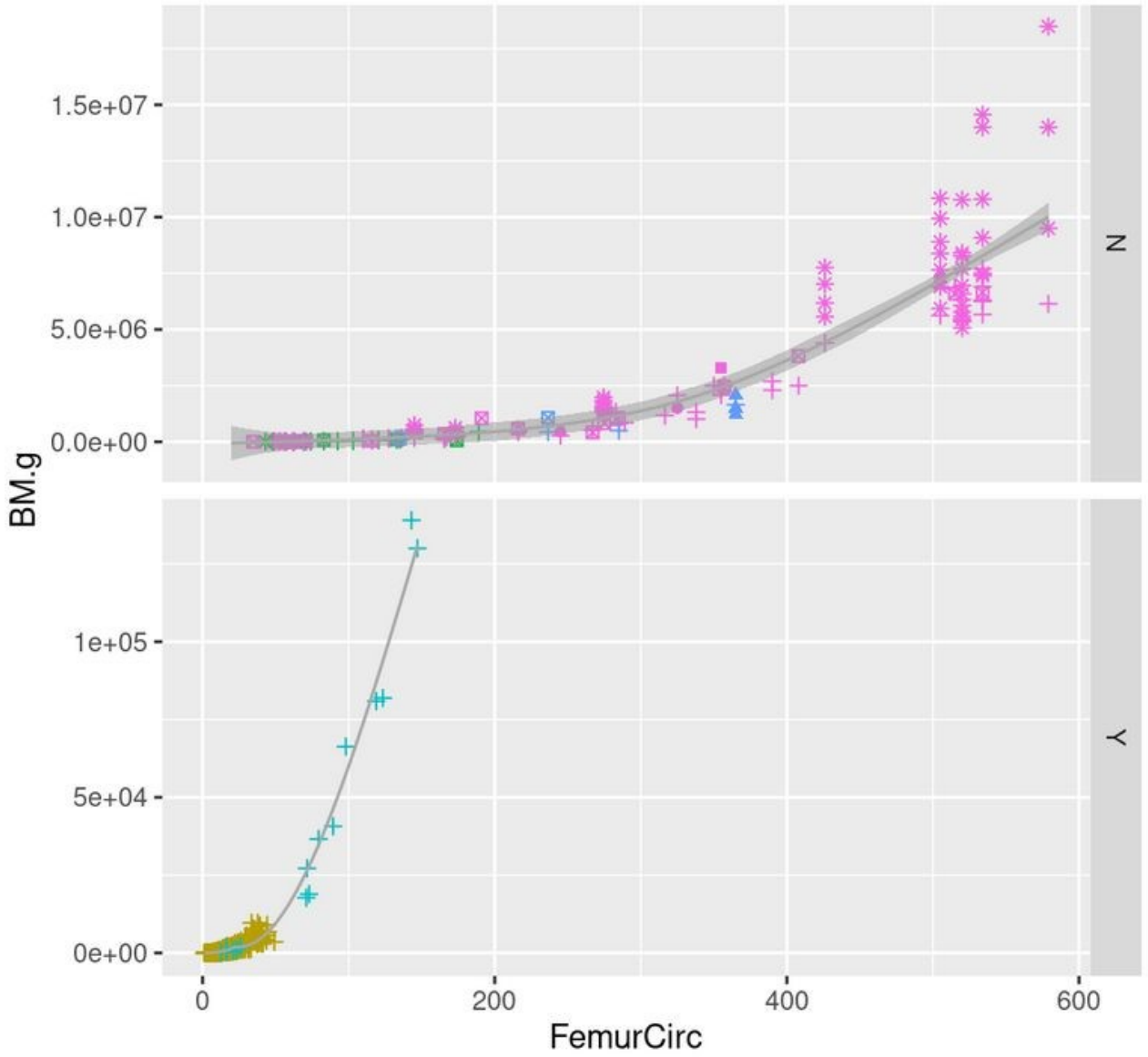
$$\sum PPE = \frac{\sum \frac{Obs - pred}{pred} * 100}{n}$$

Aside Note


Aves
Dromaeosauridae
Troodontidae
Scansoriopterygidae
Oviraptorosauria
Alvarezsauroidea
Therizinosauroidea
Ornithomimosauria
Compsognathidae
Tyrannosauroidea
Pennaraptora
Maniraptora
Fused Terminal Vertebrae
Tail Feathers
Pygostyle


Theropods
Aves
Theropods
Training data
New data
Extrapolate
Extrapolate
Interpolate

Predicting and comparing models



Method
- GDI
- MCH
- Photogrammetry
- Physical
- Polynomial
- Scan
- Slicing

Clade.1
- Dinosauromorpha
- Neognathae
- Ornithischia
- Palaeognathae
- Sauropodomorpha
- Theropoda

$BM \sim 0.16\ C_{femur}^{2.73}$
(Anderson et al 1985)

$\log_{10}(BM) \sim 2.411 \log_{10} C_{femur} - 0.065$
(Cambell Jr & Marcus 1992)

$\log(BM) \sim 2.4 \log C_{femur} - 0.11$
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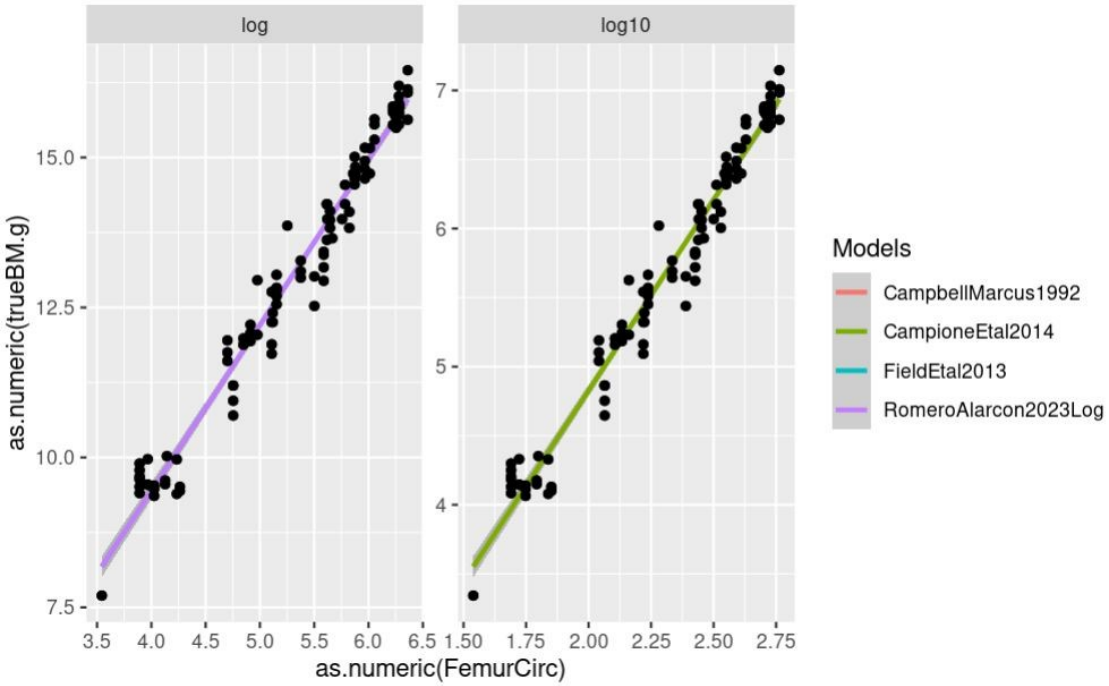
(Campione et al 2014)

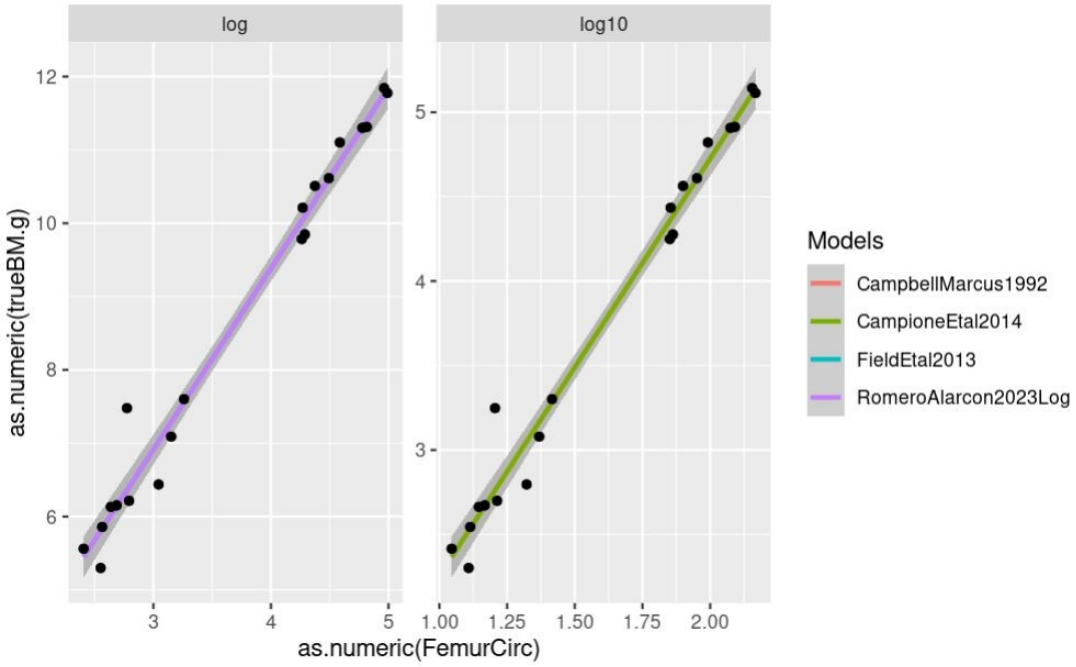
$\log(BM) \sim 2.37699 \log C_{femur} - 0.09121$
(This analysis)

Log-Log Models

Theropods

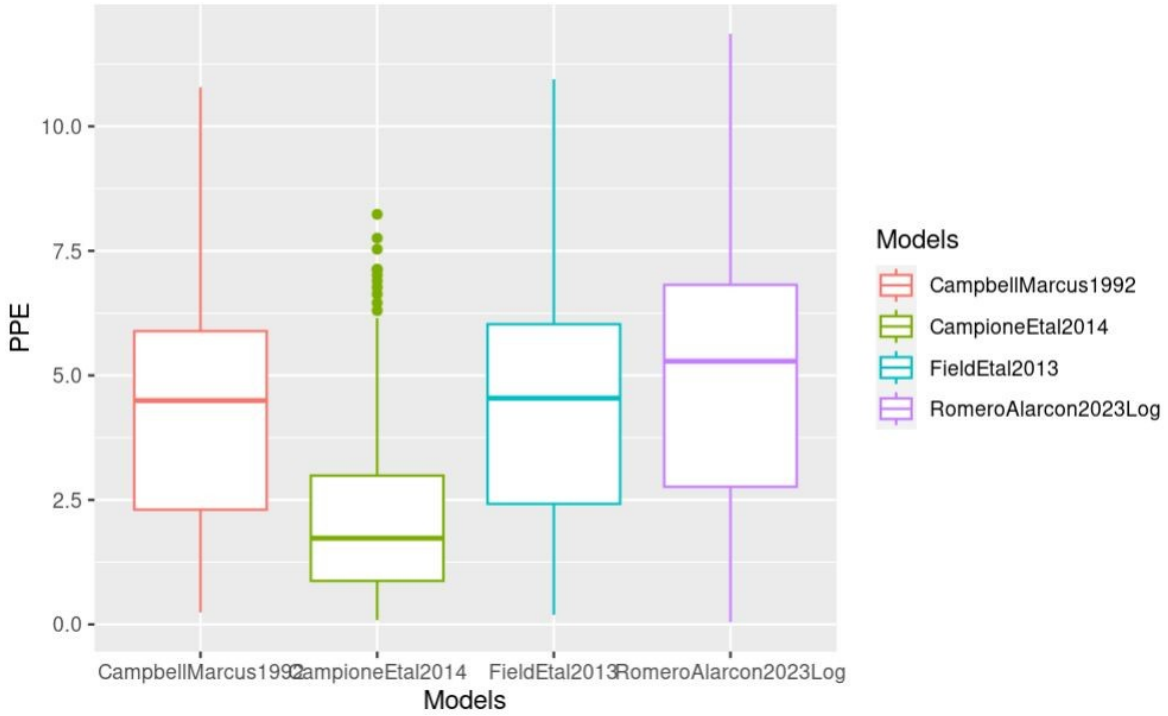


Palaeognathae



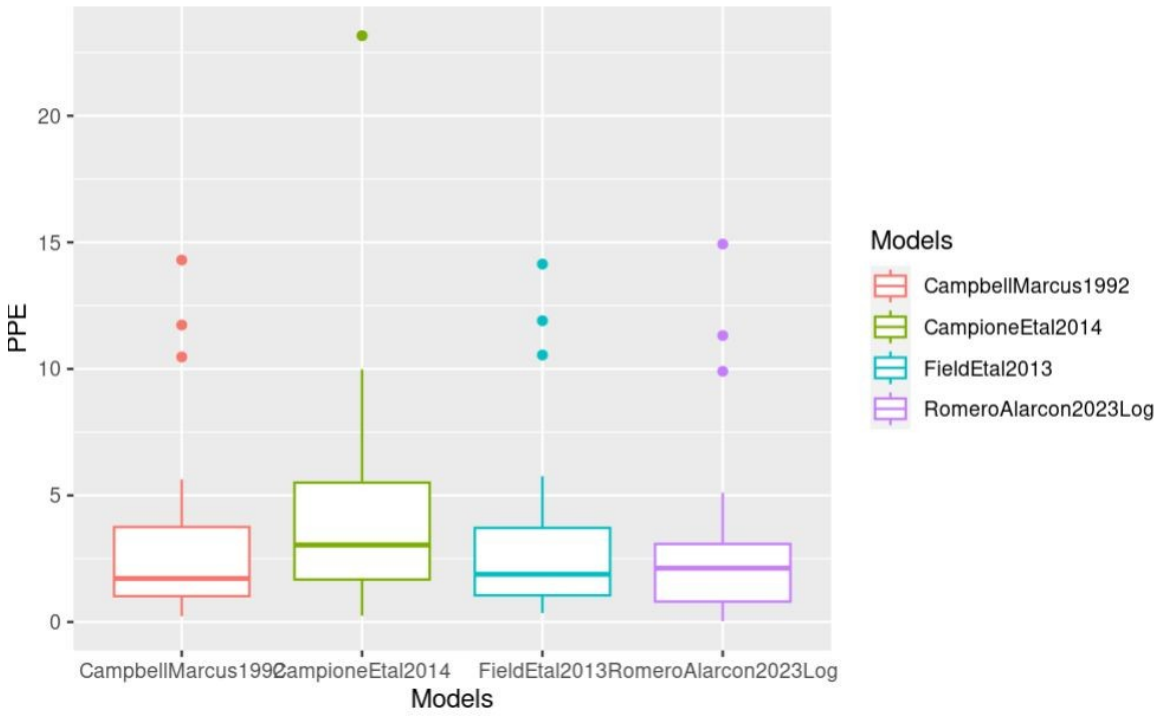
Log-Log Models

Theropods



Models <chr>	MPPE <dbl>	sdPPE <dbl>
CampbellMarcu...	4.235394	2.237335
CampioneEtal2...	2.363300	2.086955
FieldEtal2013	4.348867	2.283260
RomeroAlarcon...	4.929396	2.532902

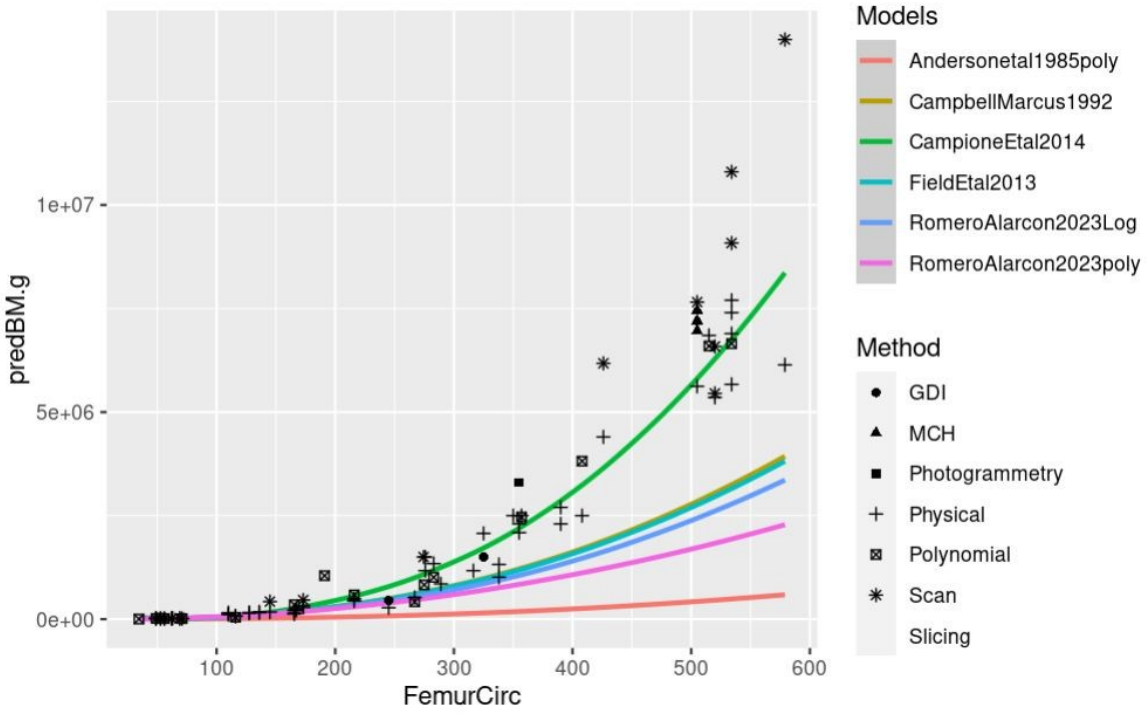
Palaeognathae



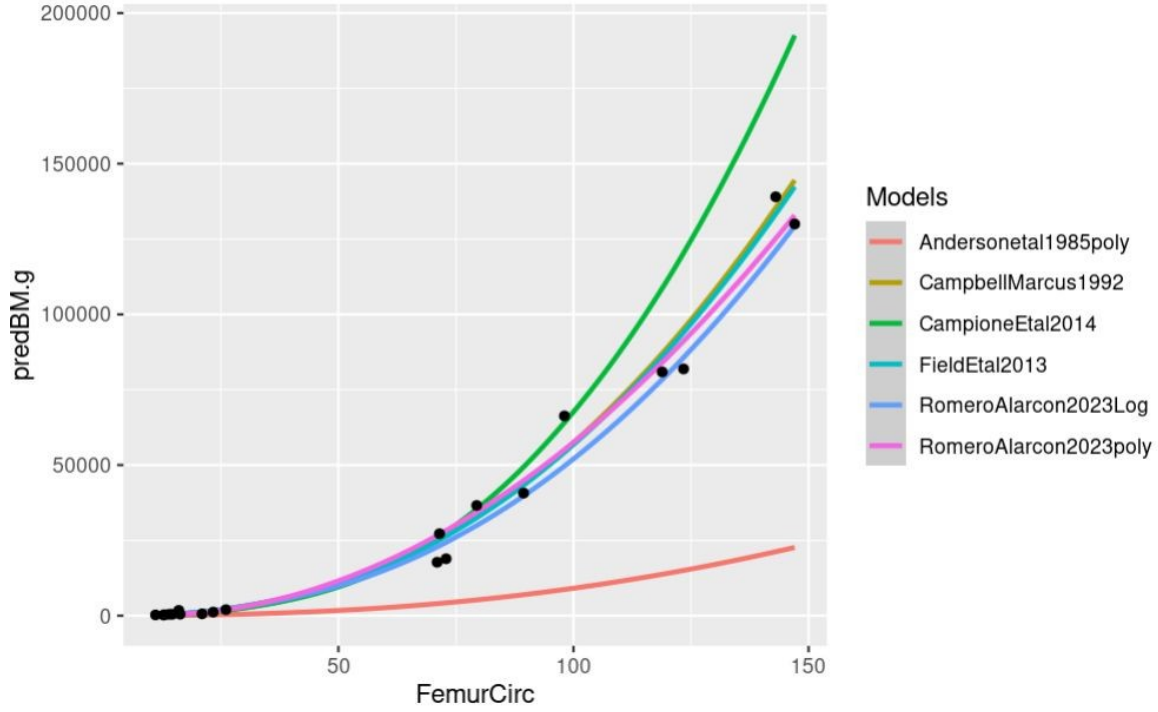
Models <chr>	MPPE <dbl>	sdPPE <dbl>
CampbellMarcu...	3.552147	4.029236
CampioneEtal2...	4.354151	5.140786
FieldEtal2013	3.595184	4.026062
RomeroAlarcon...	3.322330	4.067564

Back transform Models

Theropods

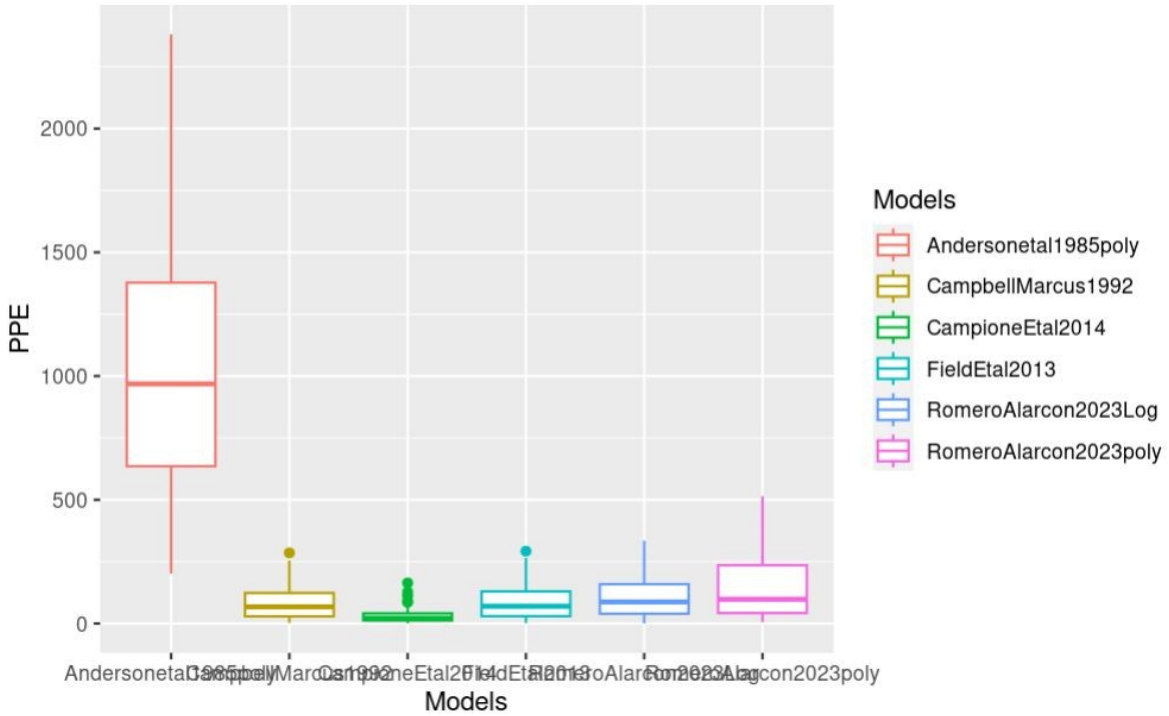


Palaeognathae



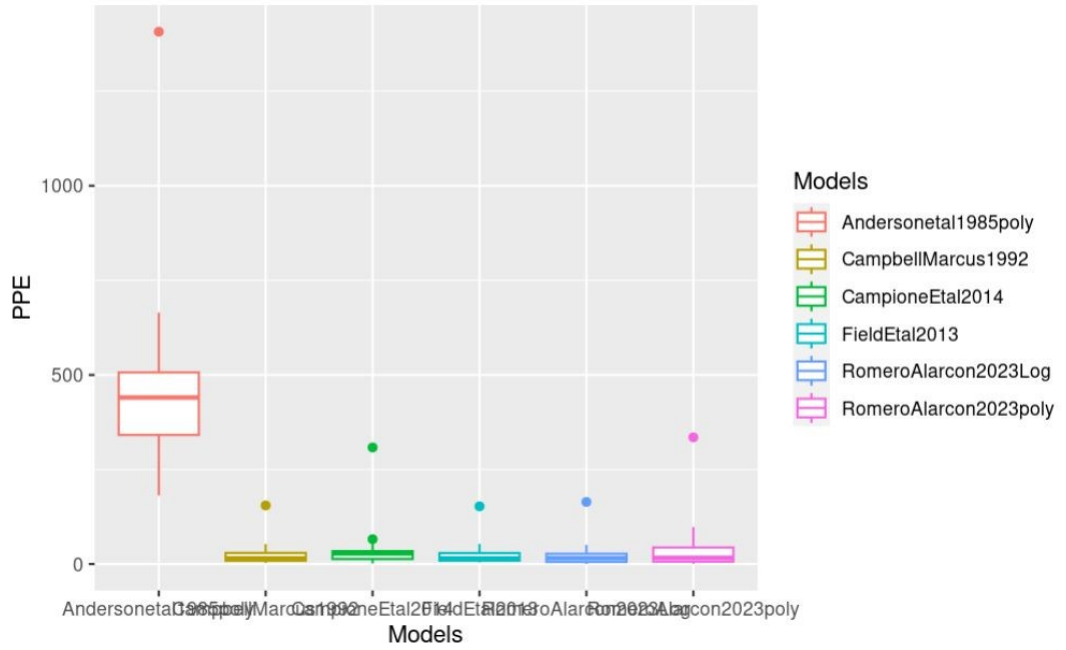
Back transform Models

Theropods



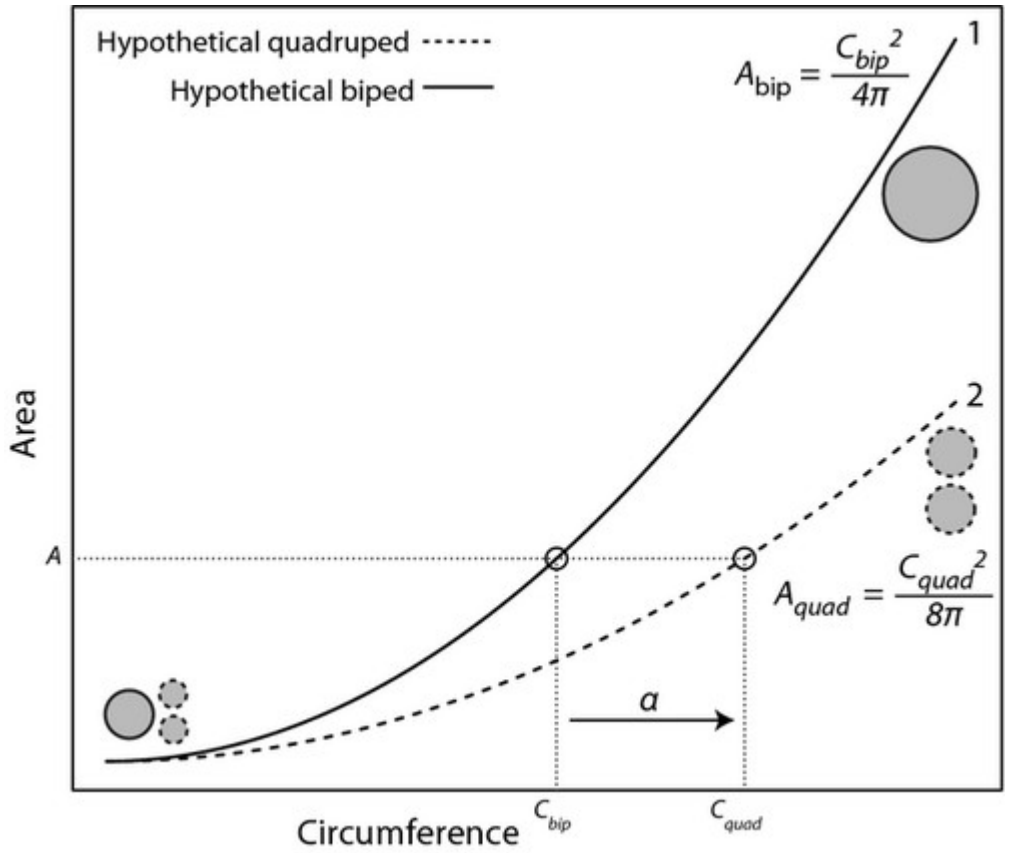
Models <chr>	MPPE <dbl>	sdPPE <dbl>
Andersonetal1...	1008.83347	482.56612
CampbellMarcu...	80.00550	60.71872
CampioneEtal2...	29.88848	26.69551
FieldEtal2013	83.41068	63.36741
RomeroAlarcon...	101.26724	76.09345
RomeroAlarcon...	143.48717	121.31531

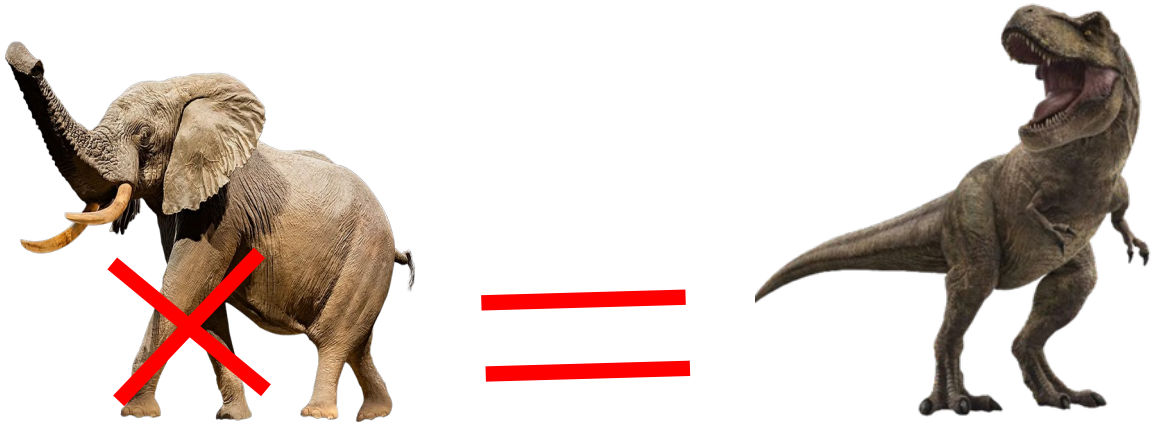
Palaeognathae

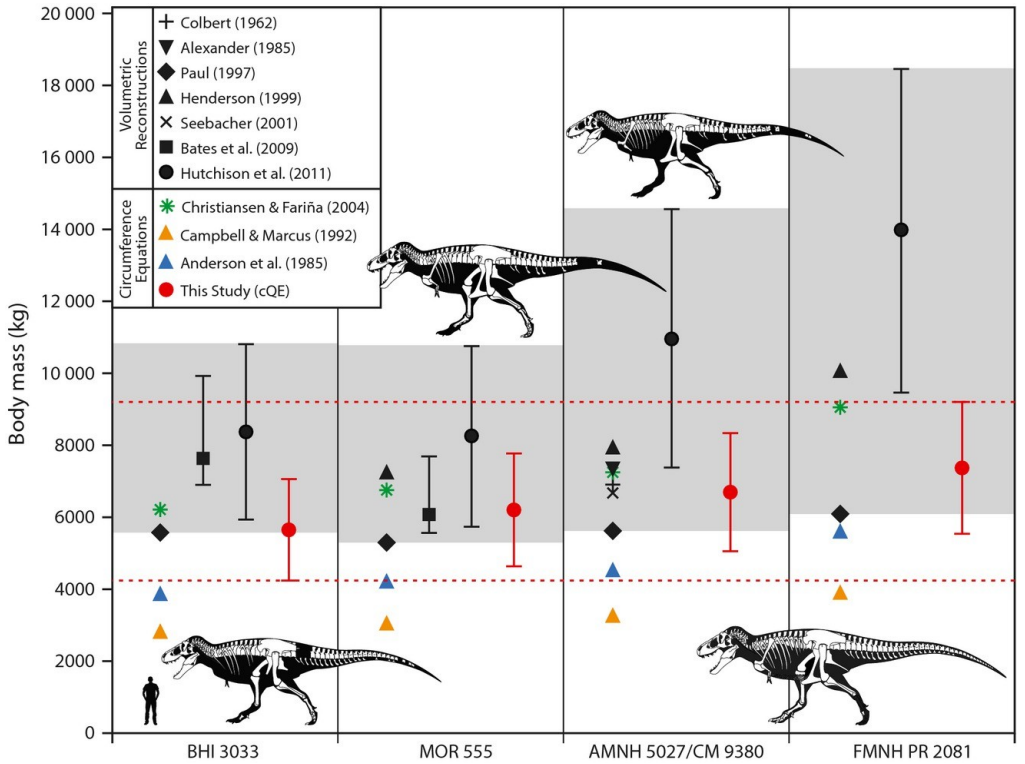


Models <chr>	MPPE <dbl>	sdPPE <dbl>
Andersonetal1...	473.15819	252.25959
CampbellMarcu...	25.87224	33.50940
CampioneEtal2...	39.62167	65.52757
FieldEtal2013	26.00687	33.00532
RomeroAlarcon...	25.36192	35.75194
RomeroAlarcon...	43.04509	74.76129

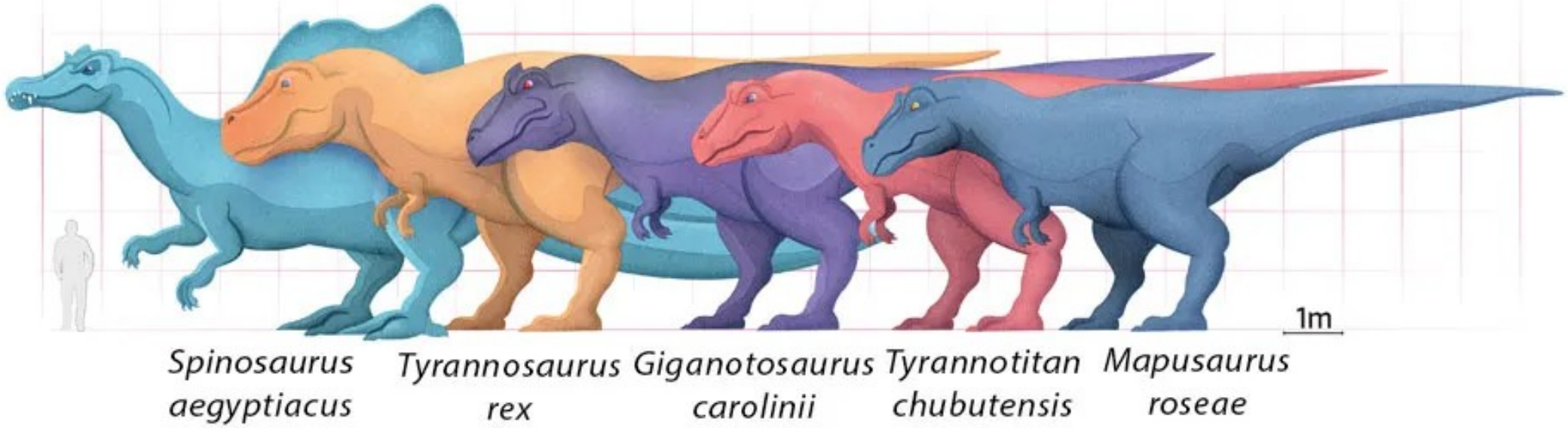
Why is Campione et al 2014 especial?





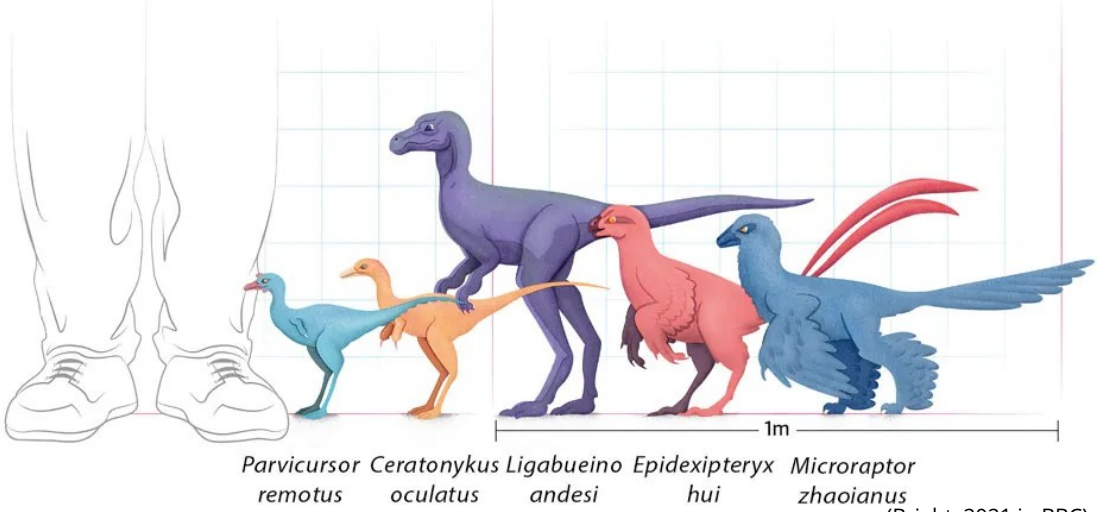


Campione et al 2014



Could I improve the model, if I included samples from the Palaeognathae group?

No, it is not possible



(Bright, 2021 in BBC)

What did we learn?

1) Campione et al 2014 model are better for extrapolating/predicting Body Mass in bipedal dinosaurs.
Or at least, it is the model that better predicts VD estimation.

2) The model fitted in this study is the best one for interpolating. It is relevant because most of BM estimations in Terror birds has been estimated using Campione's et al 2014 model..

3) Even though some authors support the idea that Femur Circumference is not affected/influenced by ancestry, my analysis confirm that there is a effect at order level.