# MAthesis

## Contents

## Time bins (stratigraphic stages)

Table 1: Smaller time bins with age range, epoch name, mean age and corresponding sample sizes (on individual, species and genus level)

| bin | EpochBins | Stages | MeanBins | nIndividuals | nSpecies | nGenera |
|---|---|---|---|---|---|---|
| (0,0.0117] | Modern | Modern | 0.00585 | 254 | 66 | 18 |
| (0.0117,0.126] | Upper Pleistocene | Upper Pleistocene | 0.06885 | 50 | 18 | 8 |
| (0.126,0.781] | Middle Pleistocene | Middle Pleistocene | 0.45350 | 53 | 13 | 7 |
| (0.781,1.81] | Lower Pleistocene | Lower Pleistocene | 1.29350 | 57 | 27 | 12 |
| (1.81,2.59] | Gelasian | Lower Pleistocene | 2.19700 | 33 | 15 | 9 |
| (2.59,3.6] | Piacencian | Upper Pliocene | 3.09400 | 24 | 15 | 10 |
| (3.6,5.33] | Zanclean | Lower Pliocene | 4.46600 | 31 | 17 | 8 |
| (5.33,7.25] | Messinian | Upper Miocene | 6.28900 | 12 | 9 | 6 |
| (7.25,11.6] | Tortonian | Upper Miocene | 9.42700 | 46 | 20 | 9 |
| (11.6,13.8] | Serravallian | Middle Miocene | 12.71400 | 27 | 8 | 6 |
| (13.8,16] | Langhian | Middle Miocene | 14.89500 | 18 | 14 | 9 |
| (16,23] | Burdigalian/Aquitanian | Lower Miocene | 19.50000 | 31 | 15 | 9 |

```
## [1] 0
```

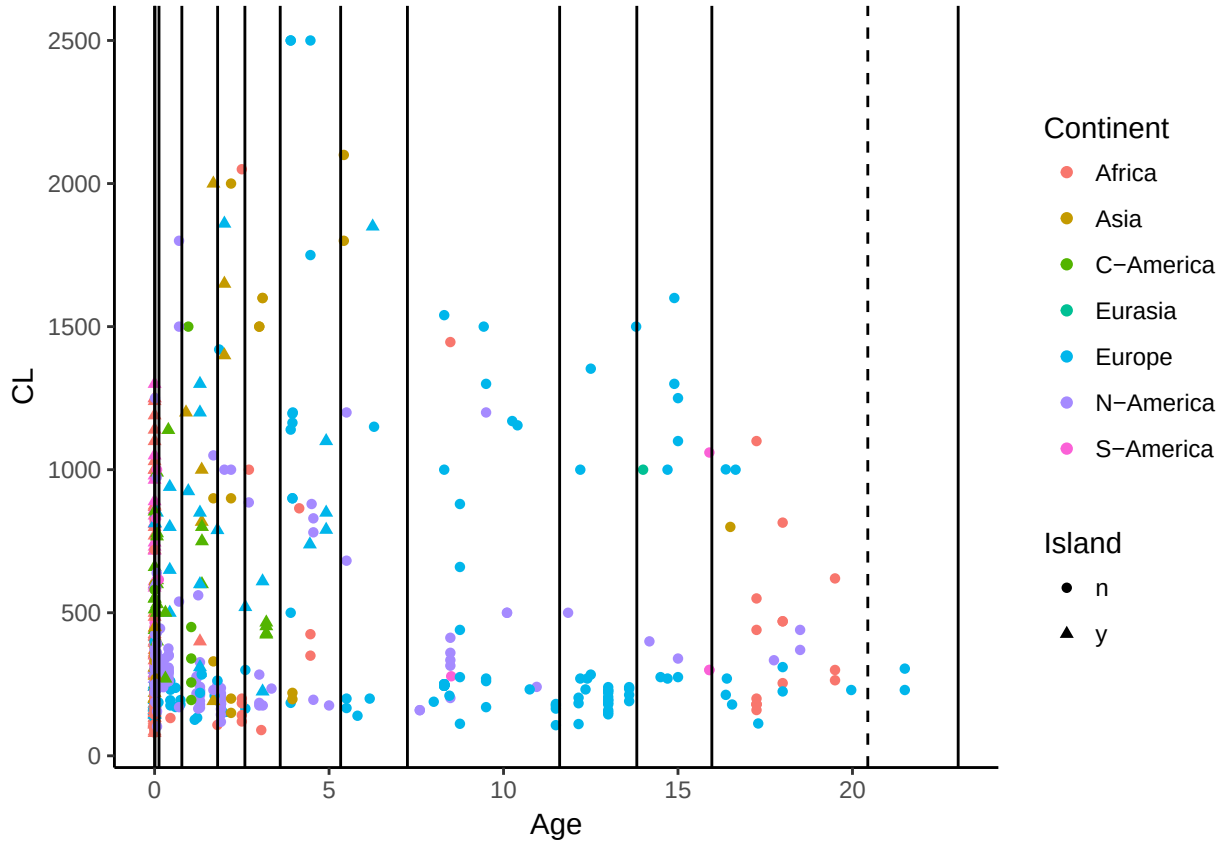



Figure 1: Scatterplot of CL over time, indicating insular (triangle) and continental (circles) and colour indicating continents. Lines indicte bins, dashed line = new bins.

# Maps

### fossil occurences of testudinidae

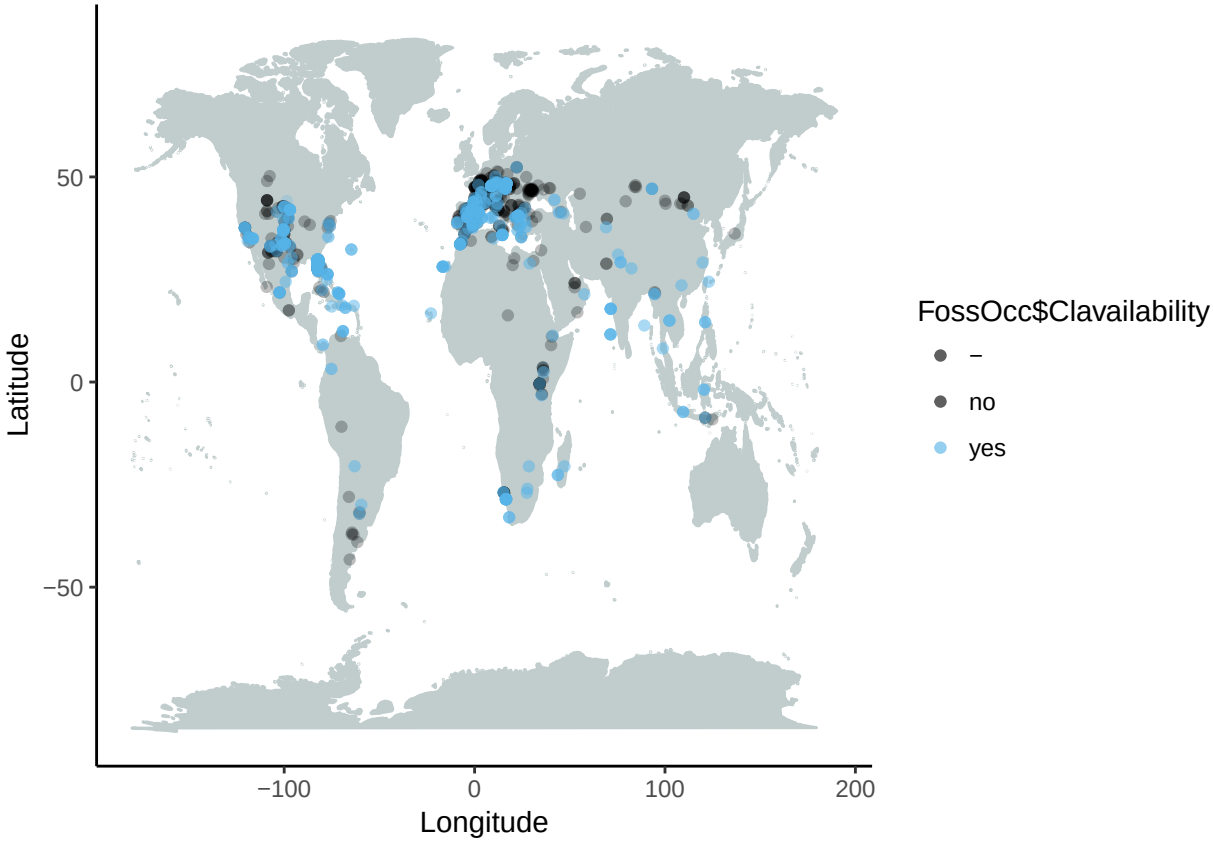



Figure 2: Map displaying all fossil occurrences of testudinids, with color indicating whether relevant literature was available (black if not) and if it was, whether body size data was available or not (yes and no, respectively).

**body size of testudinidae**

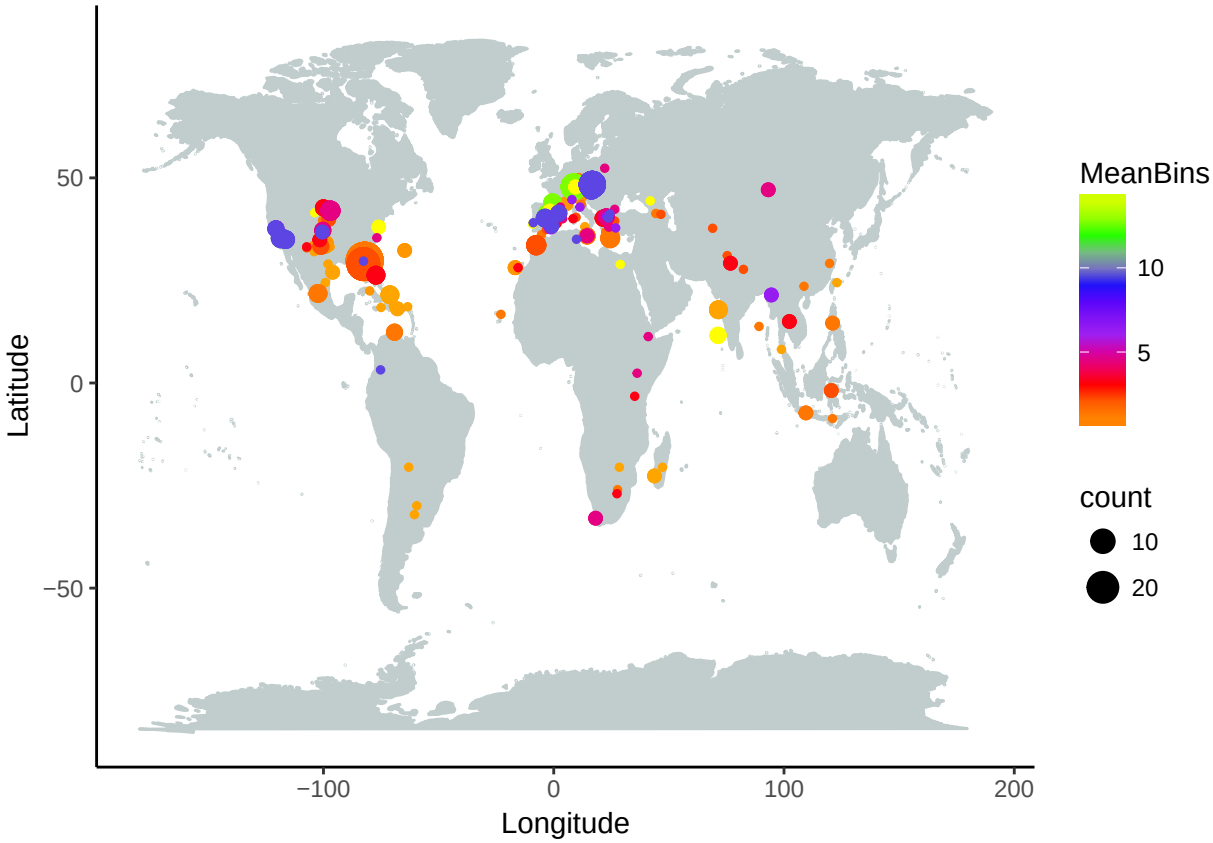
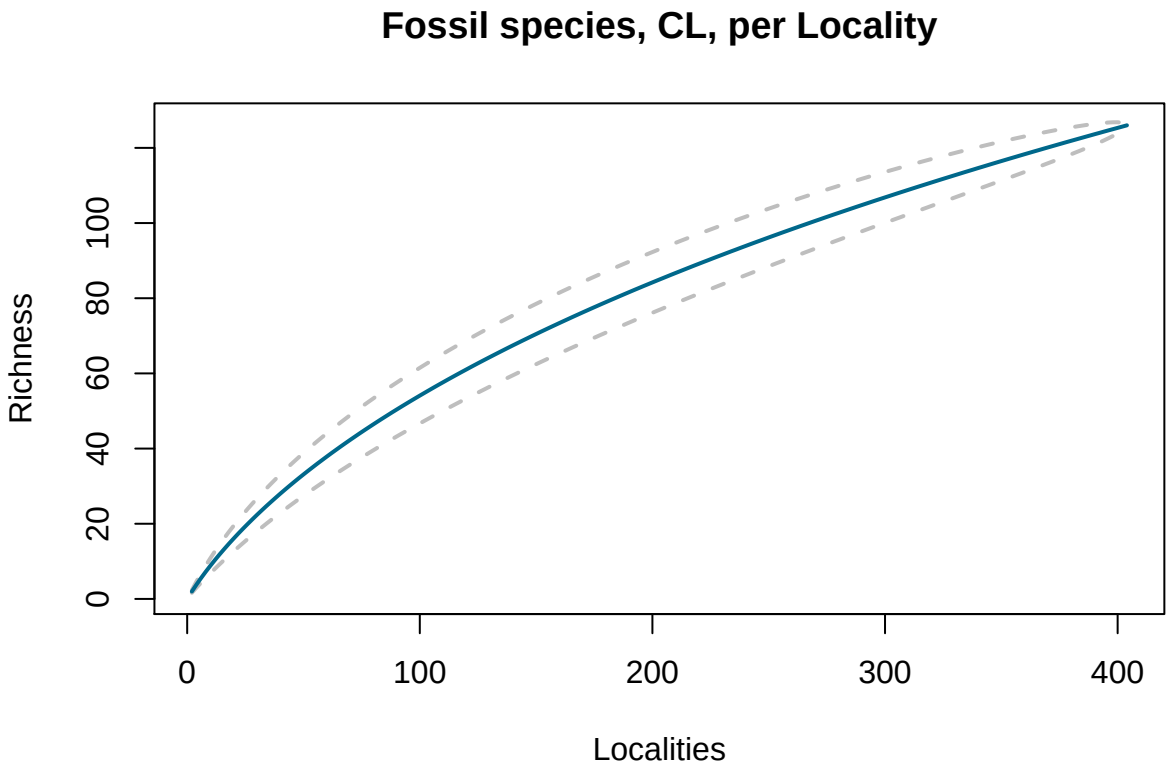
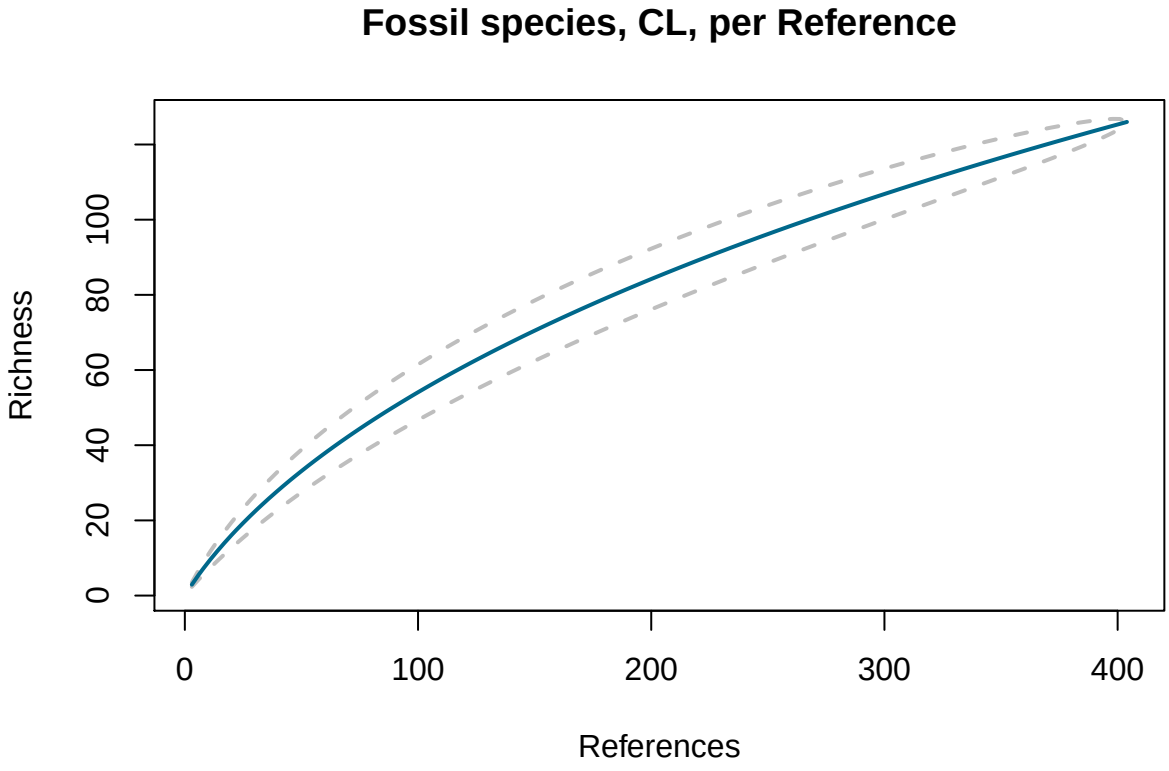



Figure 3: Map displaying all localities for which body size data for testudinids was available in the literature. Size of points denotes sample size, color denotes approximate age.

## Sampling Accumulation Curves



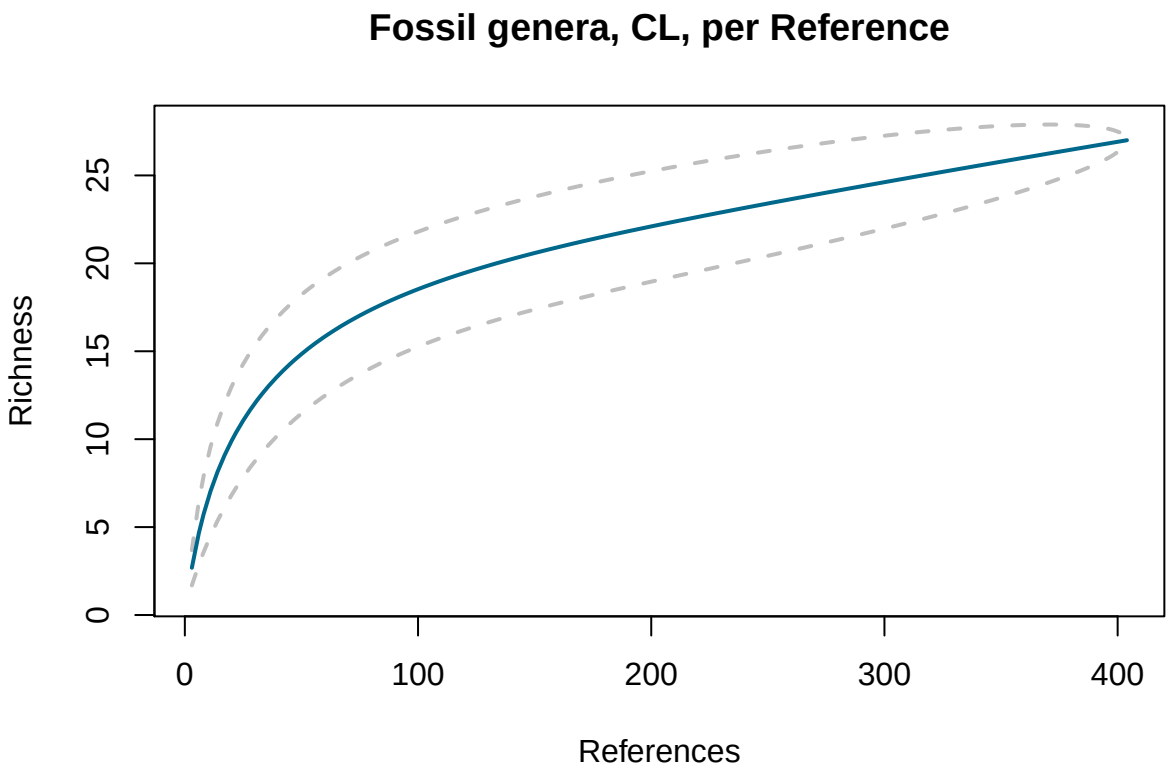



Figure 4: Sampling Accumulation Curve of fossil genera per reference

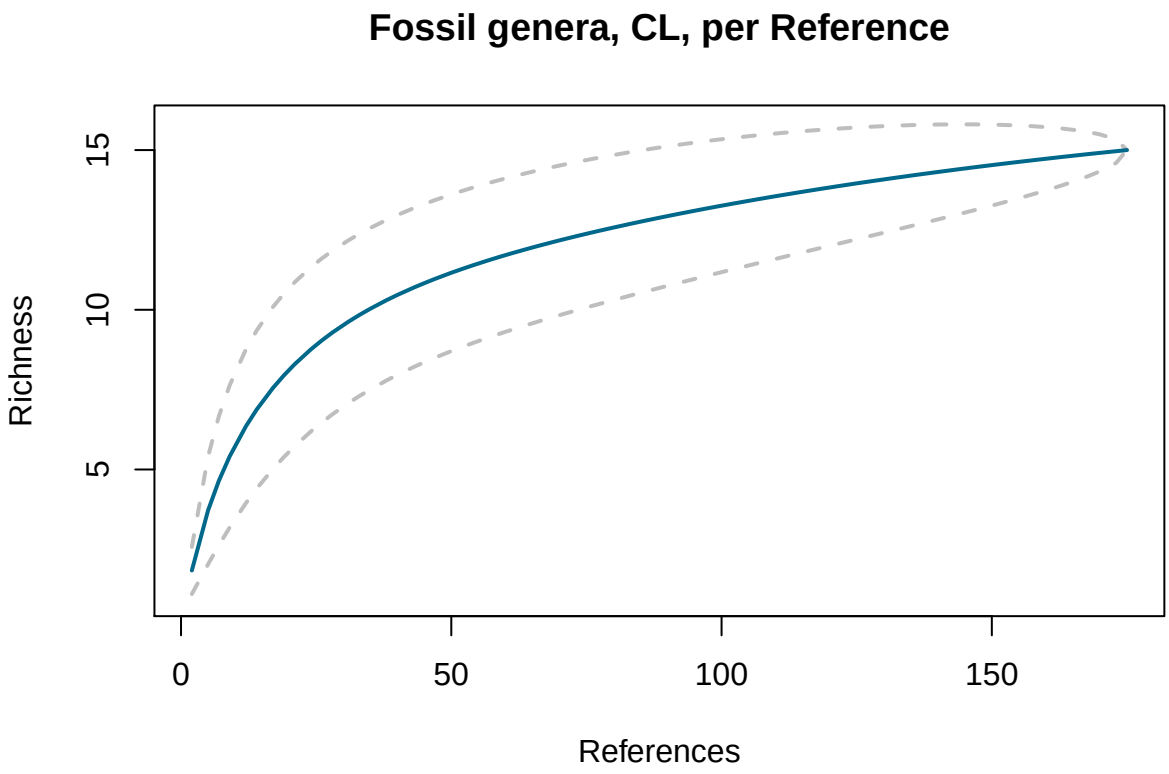



Figure 5: Sampling Accumulation Curve of fossil genera per reference, Eurasia

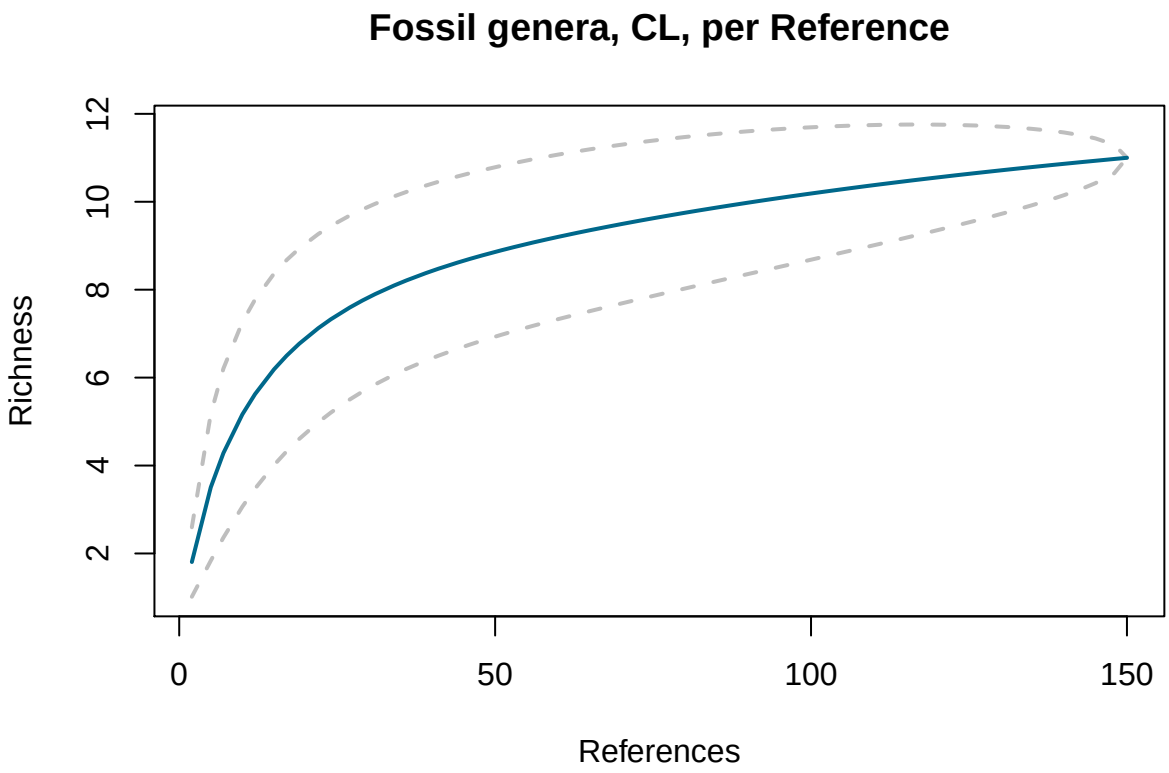



Figure 6: Sampling Accumulation Curve of fossil genera per reference, Europe

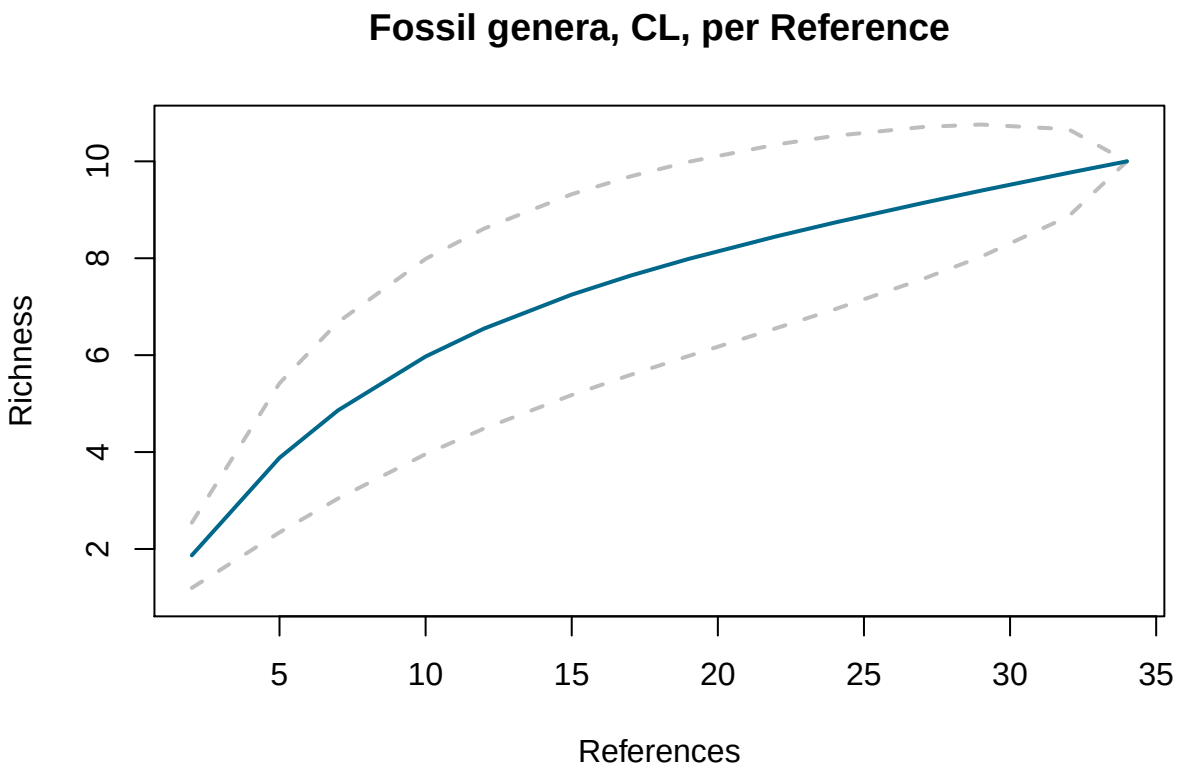



Figure 7: Sampling Accumulation Curve of fossil genera per reference, Africa

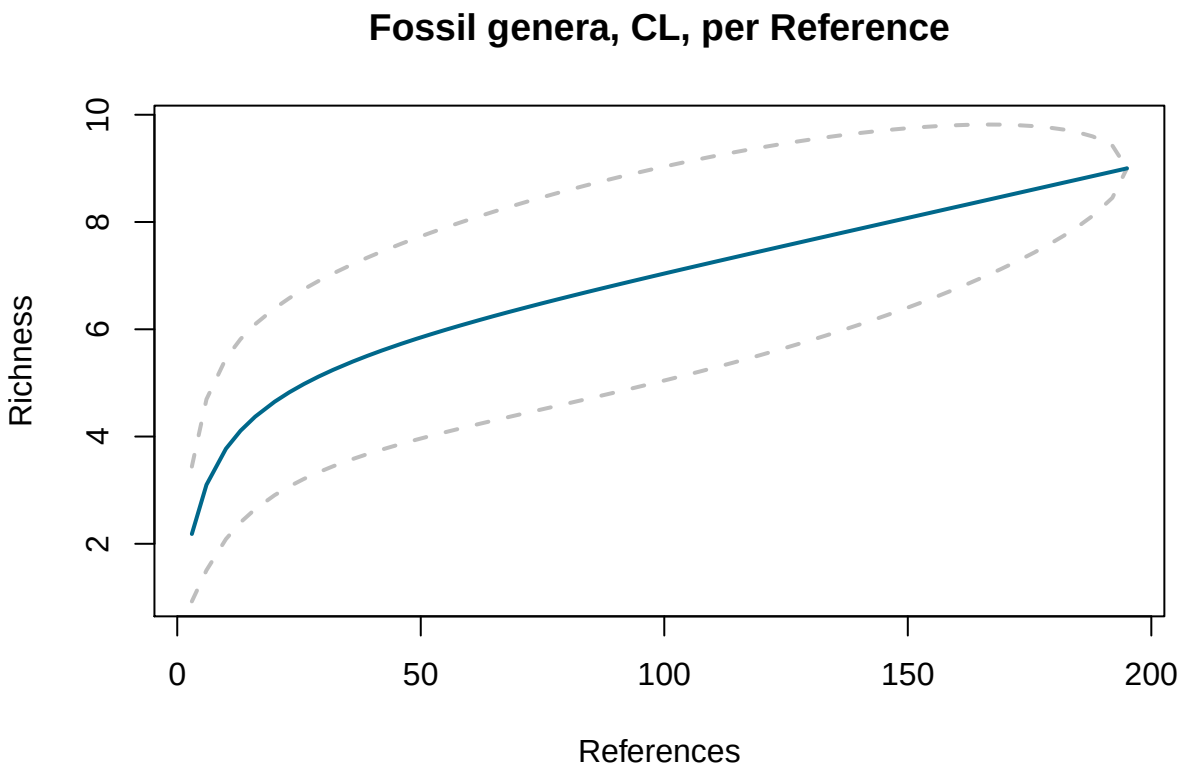



Figure 8: Sampling Accumulation Curve of fossil genera per reference, America

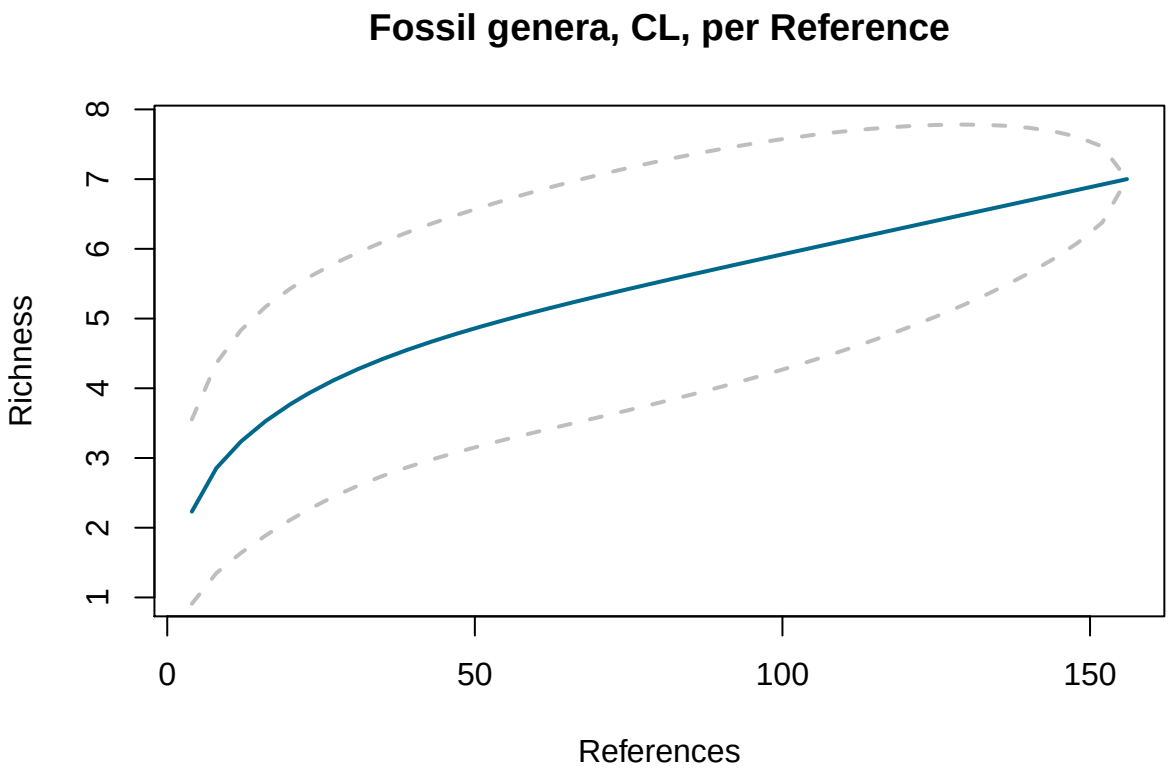



Figure 9: Sampling Accumulation Curve of fossil genera per reference, N-America

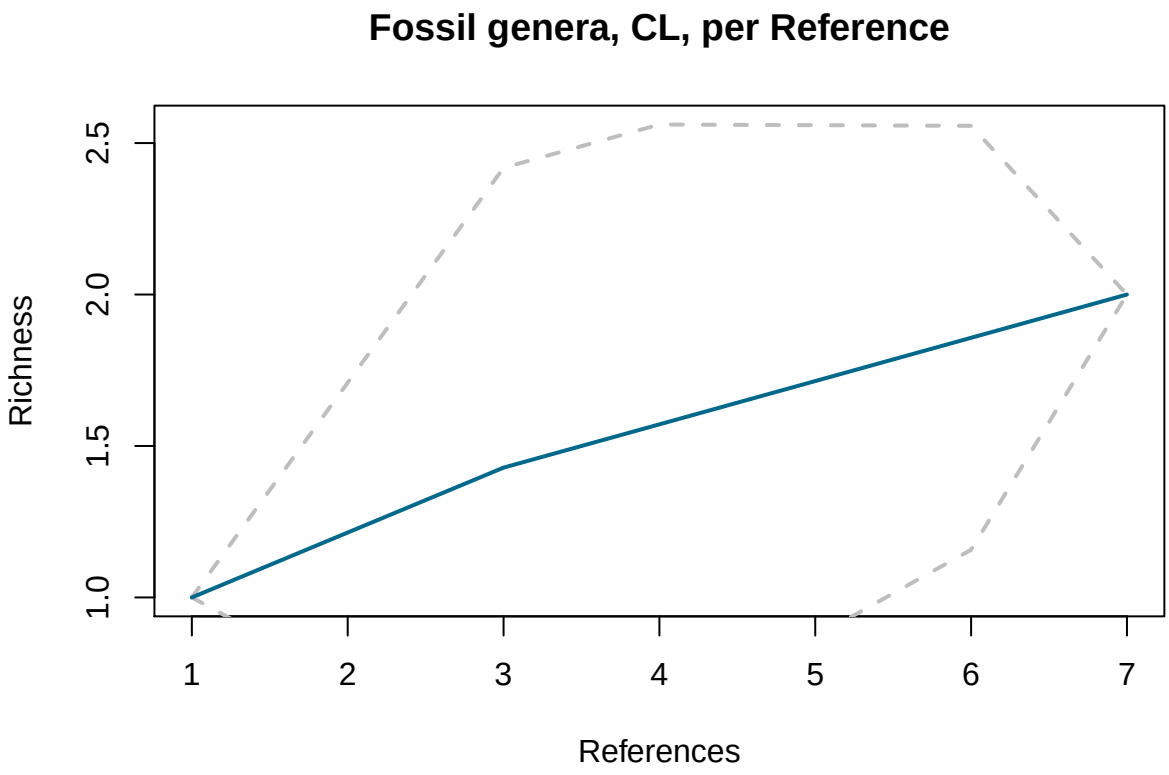



Figure 10: Sampling Accumulation Curve of fossil genera per reference, S-America

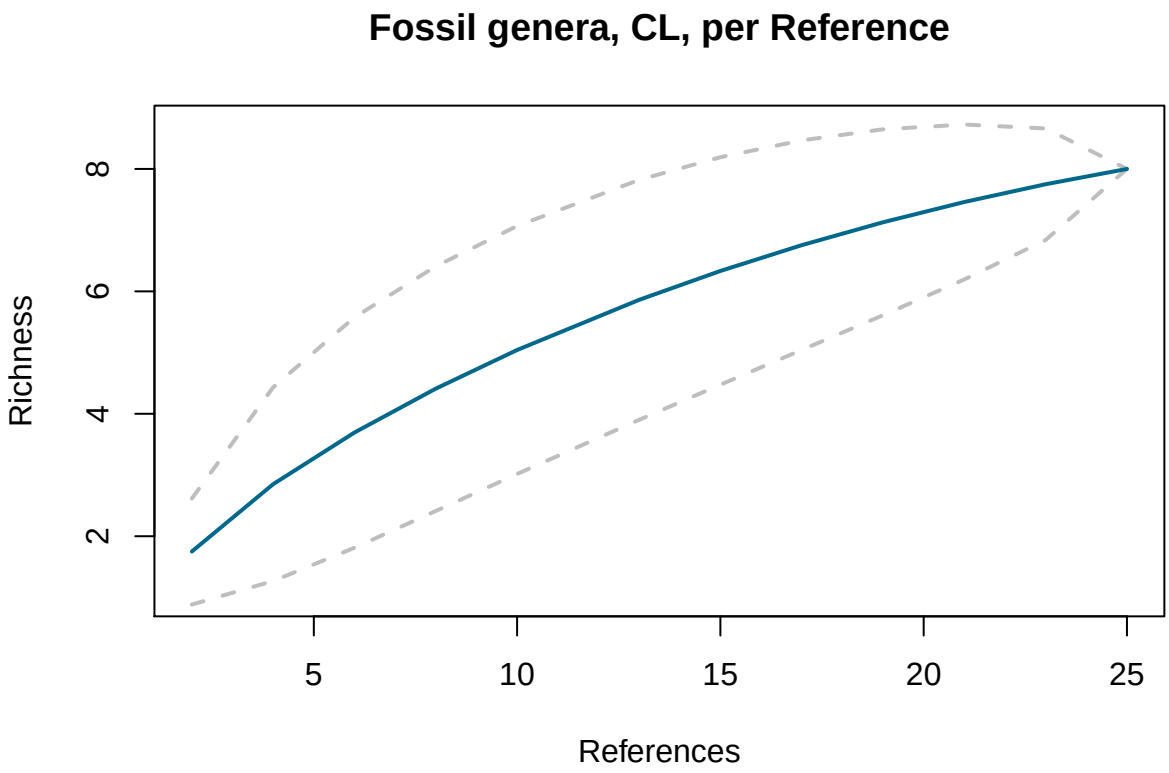



Figure 11: Sampling Accumulation Curve of fossil genera per reference, Asia

# Histograms

## all

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

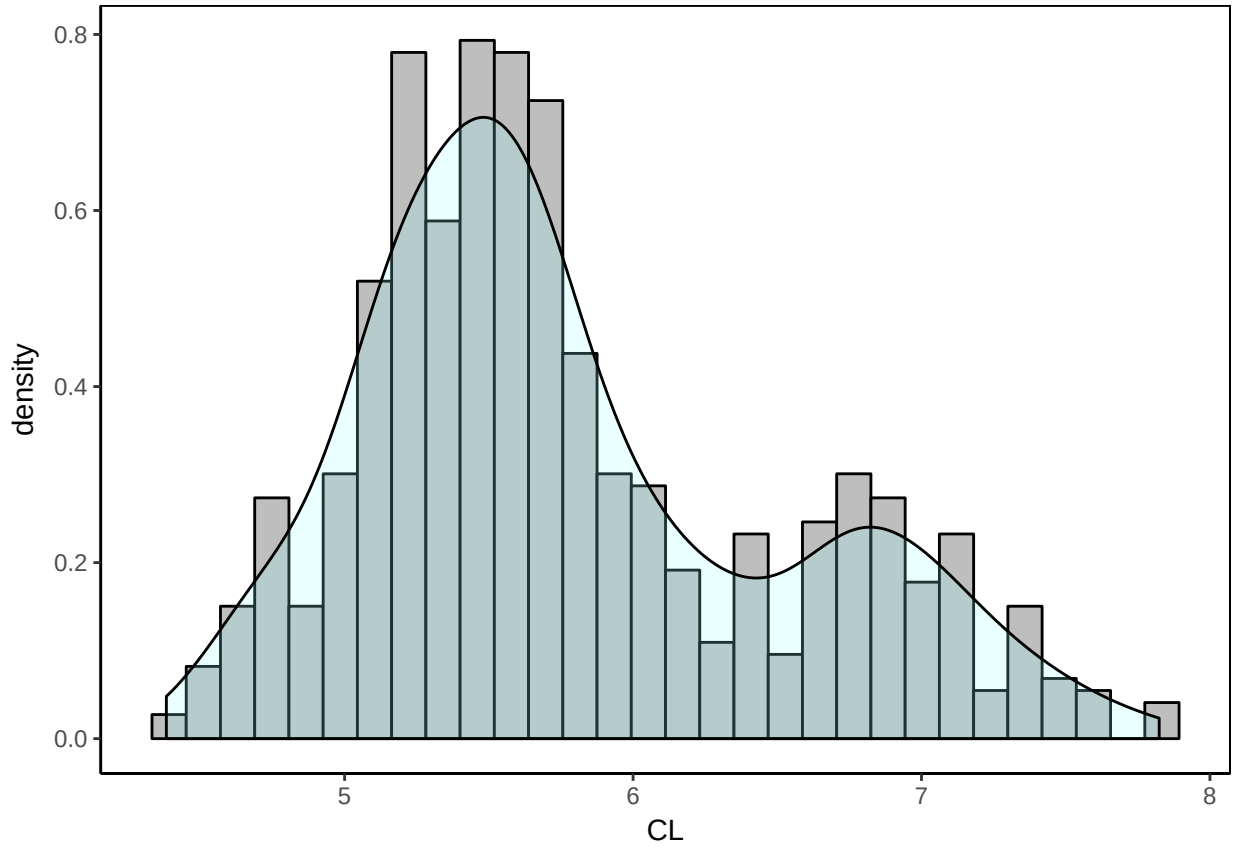
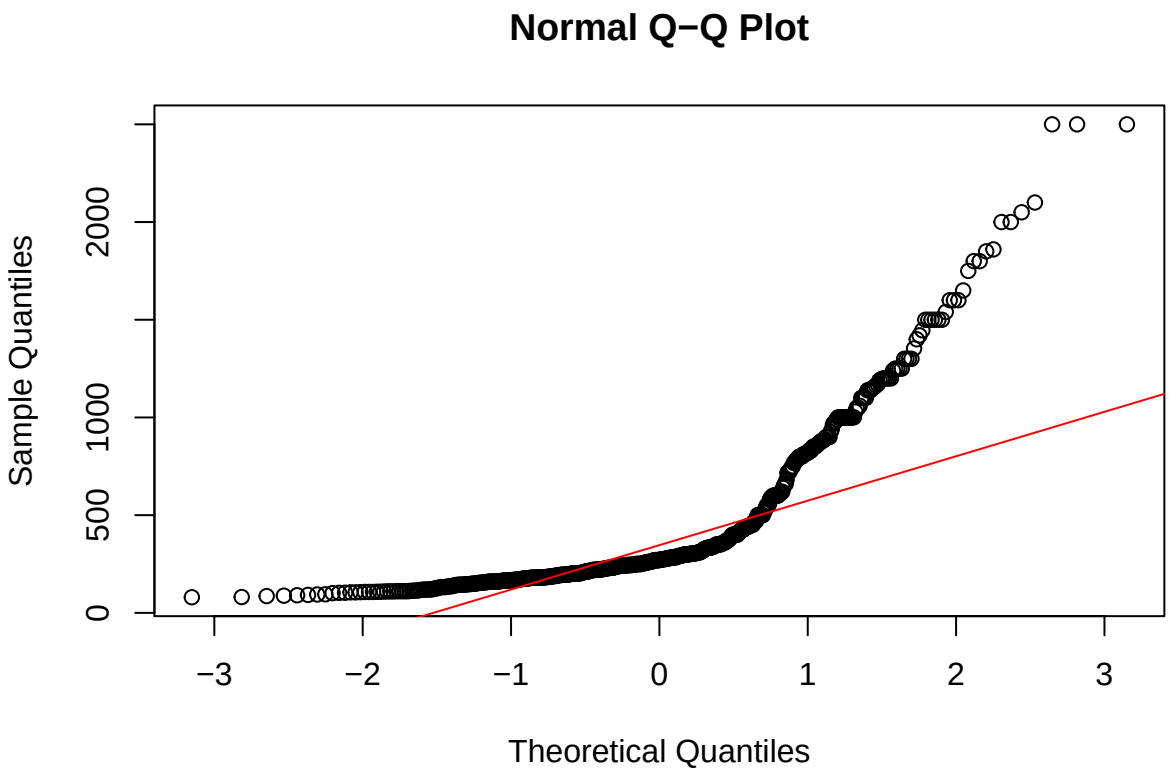
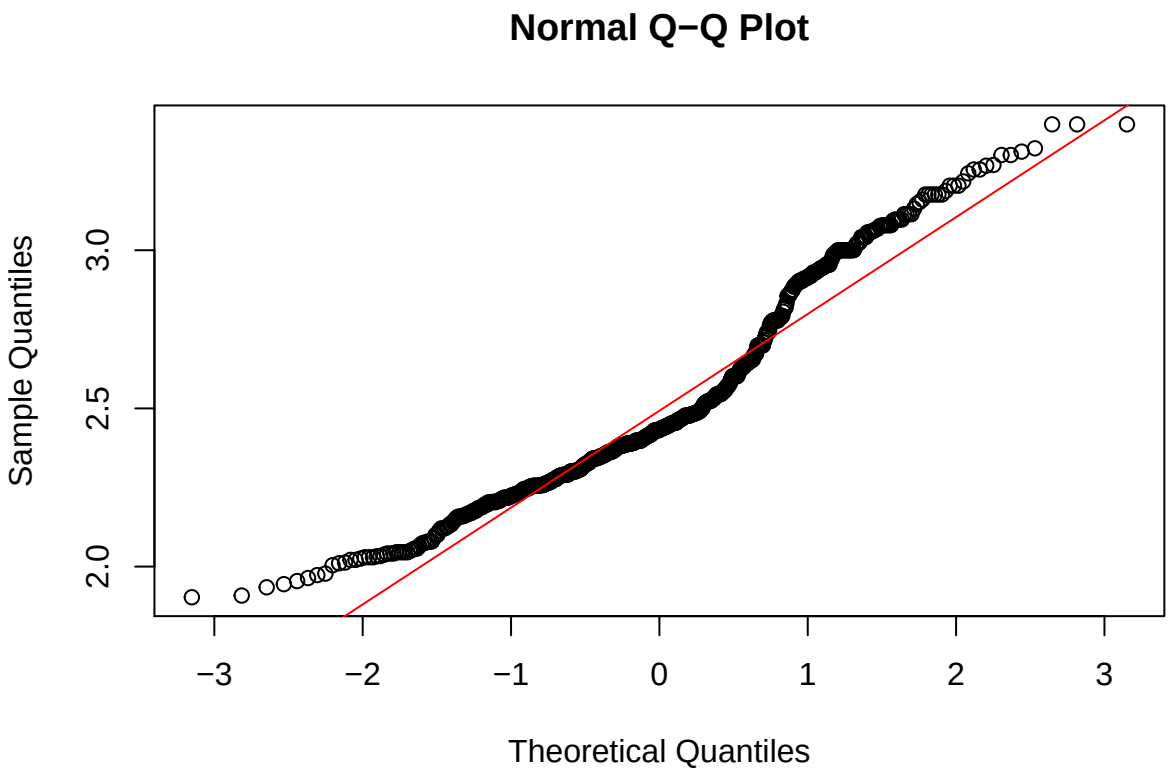



Figure 12: Distribution of body size data, logtransformed, all data.

```
qqnorm(PleiPlioCL$CL); qqline(PleiPlioCL$CL, col=2)
```




```
qqnorm(log10(PleiPlioCL$CL)); qqline(log10(PleiPlioCL$CL), col=2)
```


Normal Q−Q Plot
Sample Quantiles
2.0
2.5
3.0
−3
−2
−1
0
1
2
3
Theoretical Quantiles

**per time bin**

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

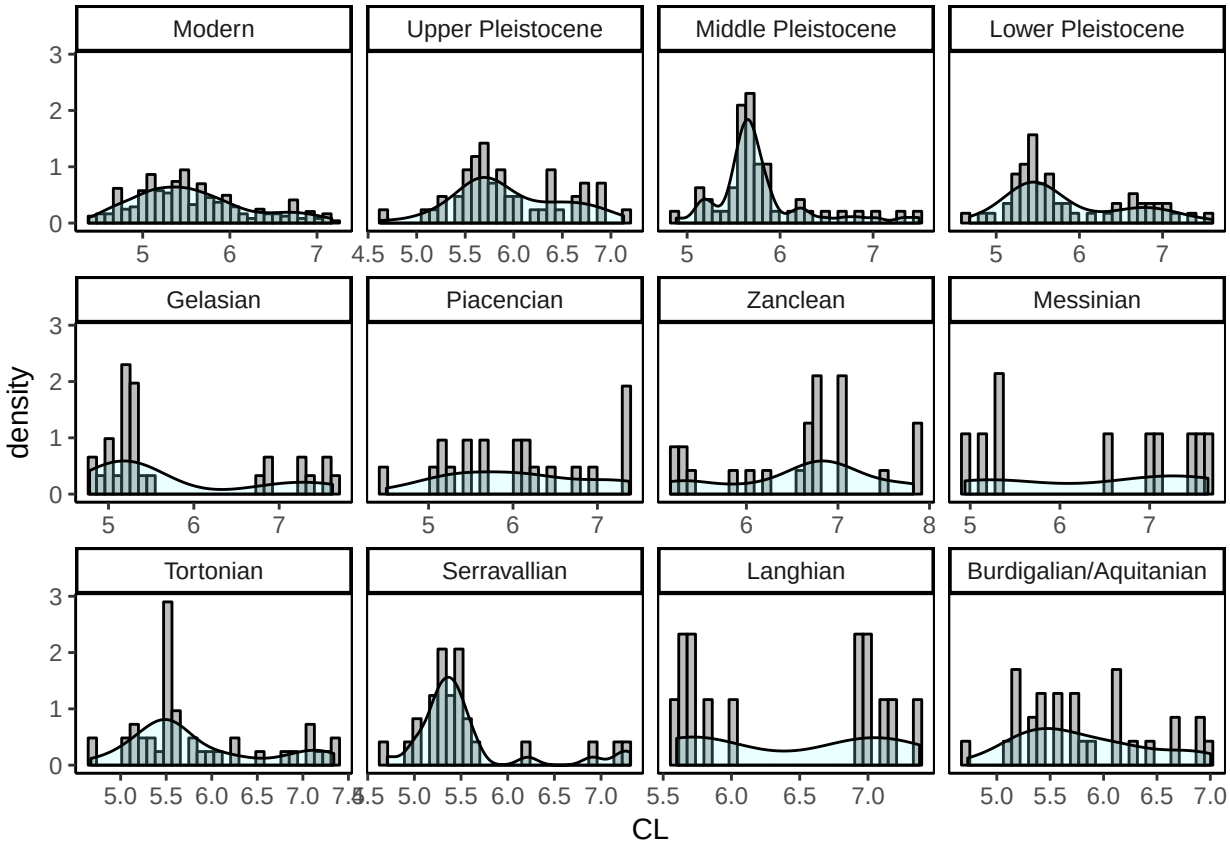



Figure 13: Distribution of body size data per time bin, logtransformed.

### modern vs. fossil

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

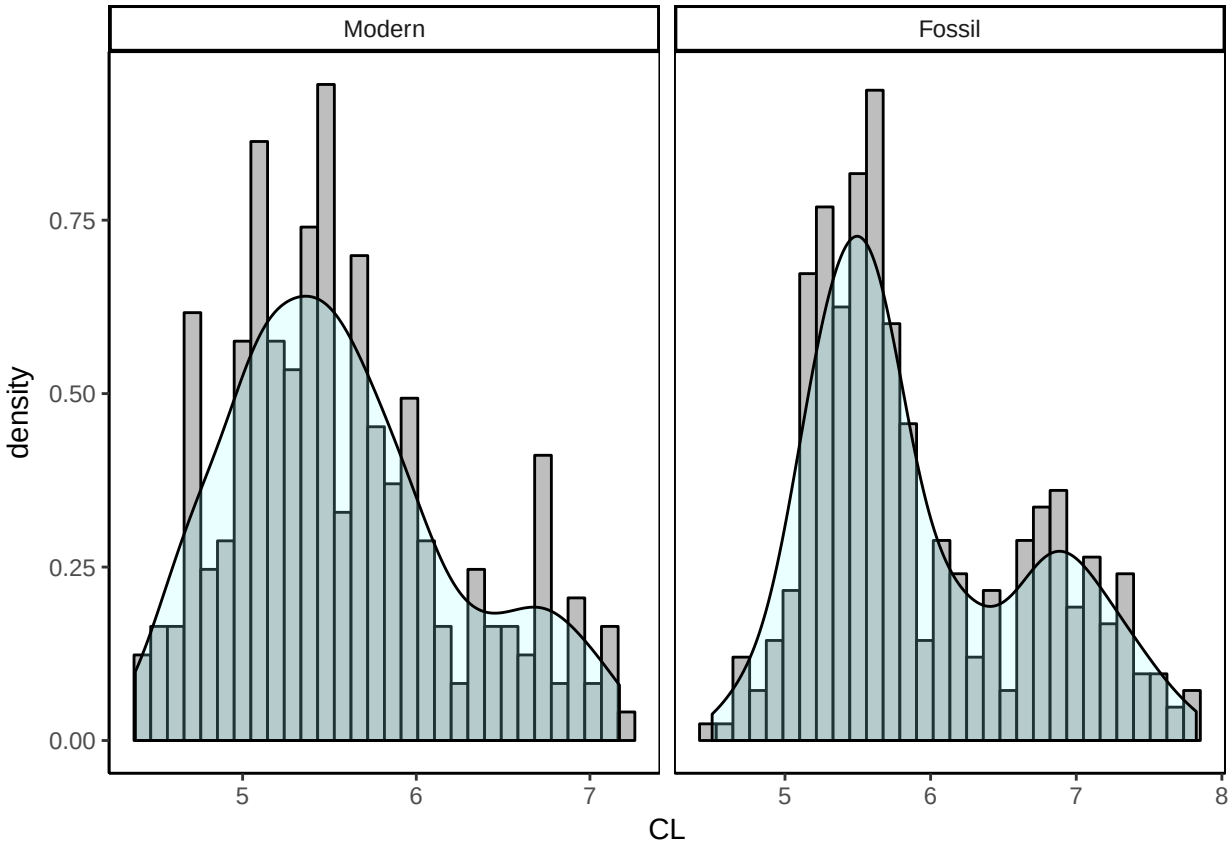



Figure 14: Distribution of body size data modern vs. fossil, logtransformed.

### modern vs. fossil, continental vs. insular

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

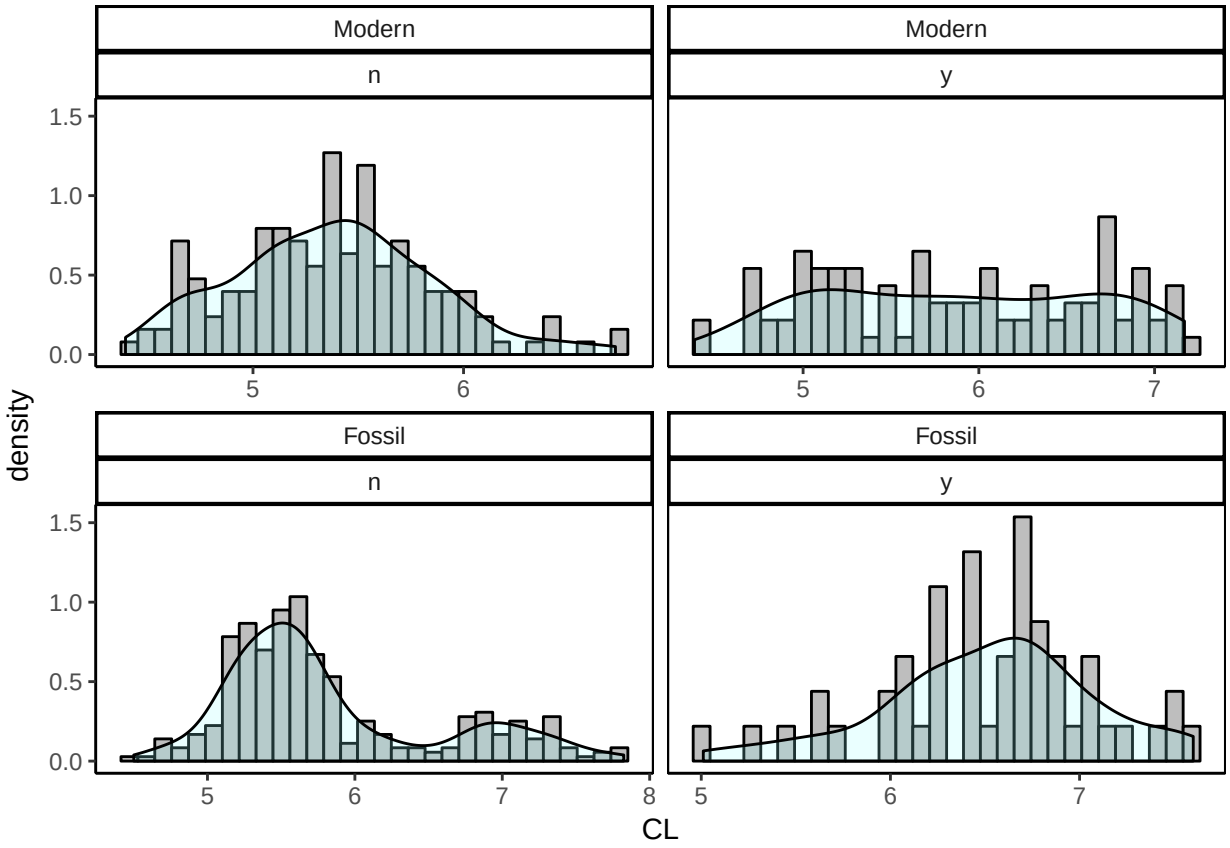



Figure 15: Distribution of body size data modern vs. fossil, continental vs. insular logtransformed.

### continental vs. insular

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

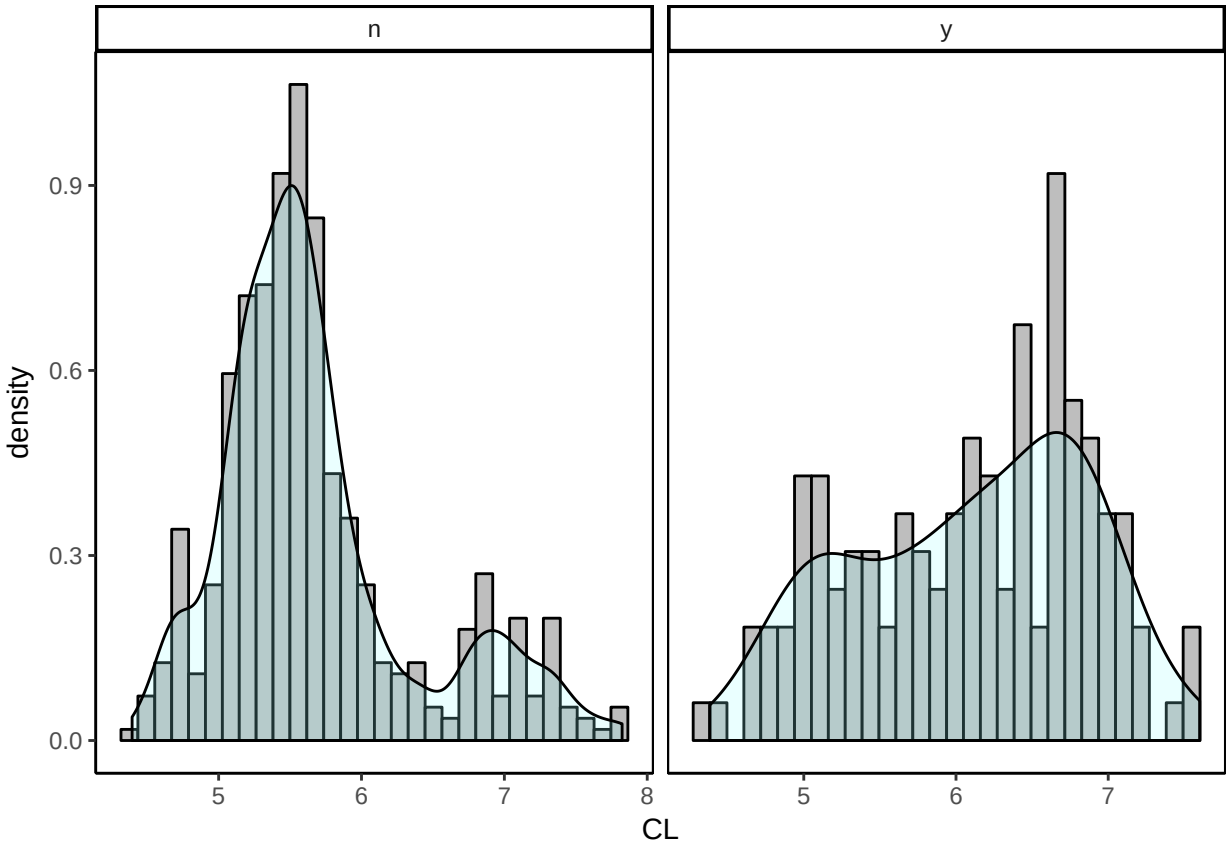



Figure 16: Distribution of body site data of continental (n) and insular(y) species, logtransformed.

**continents**

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

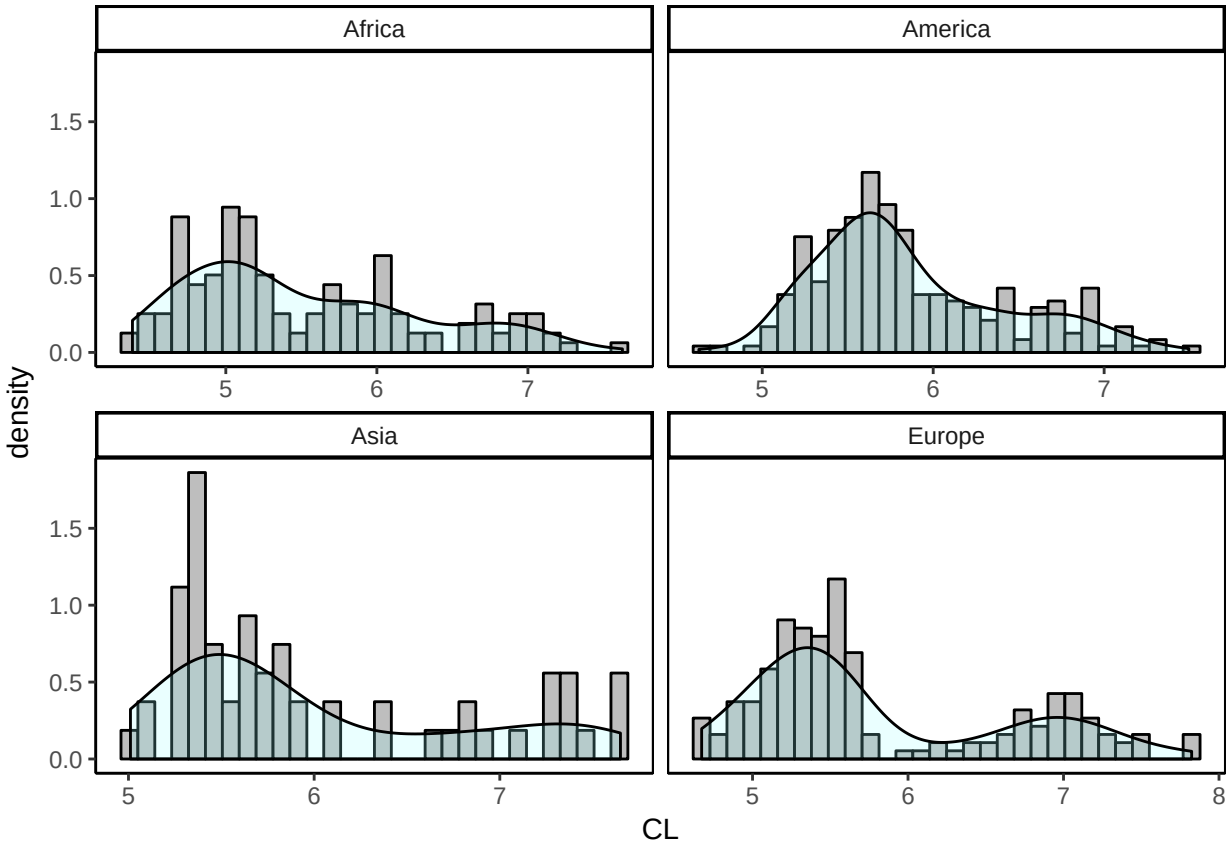



Figure 17: Distribution of body site data per continent, logtransformed.

## General statistics

Table 2: General statistics of body size data: all, per time bin, insular and continental, per continent (all referring to CL: min, max, variance, mean, logmean, median, logmedian, skewness, logskewness, kurosis, logkurtosis

| nCL | min | max | var | mean | logm | med | logmed | skew | logsk | kurt | logku | Variable |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 616 | 80.00 | 2500 | 164537.80 | 437.2 | 2.5 | 270.5 | 2.4 | 2.14 | 0.69 | 8.00 | 2.73 | all |
| 253 | 80.00 | 1300 | 67485.50 | 330.3 | 2.4 | 242.0 | 2.4 | 1.83 | 0.58 | 5.87 | 2.69 | Modern |
| 49 | 102.44 | 1250 | 69690.66 | 445.9 | 2.6 | 334.7 | 2.5 | 1.20 | 0.24 | 3.61 | 2.56 | Upper Pleistocene |
| 53 | 132.00 | 1800 | 97910.83 | 387.1 | 2.5 | 292.9 | 2.5 | 3.03 | 1.52 | 12.24 | 5.55 | Middle Pleistocene |
| 57 | 107.80 | 2000 | 161948.82 | 463.5 | 2.5 | 263.0 | 2.4 | 1.74 | 0.73 | 5.76 | 2.40 | Lower Pleistocene |
| 31 | 118.90 | 2050 | 411224.51 | 555.2 | 2.5 | 194.9 | 2.3 | 1.31 | 0.93 | 3.12 | 2.11 | Gelasian |
| 21 | 90.00 | 1600 | 270535.82 | 610.6 | 2.6 | 428.0 | 2.6 | 1.00 | 0.14 | 2.50 | 1.99 | Piacencian |
| 26 | 176.00 | 2500 | 476162.71 | 955.2 | 2.9 | 857.5 | 2.9 | 1.11 | -0.40 | 3.56 | 2.30 | Zanclean |
| 10 | 140.00 | 2100 | 602611.21 | 948.9 | 2.8 | 916.0 | 2.9 | 0.26 | -0.22 | 1.49 | 1.29 | Messinian |
| 45 | 107.00 | 1540 | 175470.12 | 462.7 | 2.5 | 250.0 | 2.4 | 1.49 | 0.81 | 3.74 | 2.54 | Tortonian |
| 27 | 111.00 | 1500 | 126060.40 | 337.7 | 2.4 | 220.0 | 2.3 | 2.49 | 1.77 | 7.77 | 5.30 | Serravallian |
| 14 | 270.00 | 1600 | 230451.33 | 747.9 | 2.8 | 700.0 | 2.8 | 0.30 | 0.03 | 1.55 | 1.18 | Langhian |
| 30 | 113.00 | 1100 | 76288.76 | 406.8 | 2.5 | 302.4 | 2.5 | 1.27 | 0.45 | 3.45 | 2.26 | Burdigalian/Aquitanian |
| 253 | 80.00 | 1300 | 67485.50 | 330.3 | 2.4 | 242.0 | 2.4 | 1.83 | 0.58 | 5.87 | 2.69 | Modern |
| 363 | 90.00 | 2500 | 219004.66 | 511.7 | 2.6 | 285.6 | 2.5 | 1.83 | 0.68 | 6.11 | 2.42 | Fossil |
| 469 | 81.00 | 2500 | 157808.79 | 392.9 | 2.5 | 250.0 | 2.4 | 2.65 | 1.07 | 10.57 | 3.74 | continental |
| 147 | 80.00 | 2000 | 160834.35 | 578.5 | 2.6 | 500.0 | 2.7 | 1.02 | -0.27 | 3.95 | 2.05 | insular |
| 157 | 81.00 | 830 | 17009.02 | 244.0 | 2.3 | 221.0 | 2.3 | 1.92 | 0.29 | 8.09 | 2.98 | modern-con |
| 96 | 80.00 | 1300 | 118641.09 | 471.5 | 2.6 | 353.0 | 2.5 | 0.82 | 0.01 | 2.47 | 1.77 | modern-ins |
| 312 | 90.00 | 2500 | 212116.79 | 467.9 | 2.5 | 270.0 | 2.4 | 2.11 | 0.96 | 7.25 | 2.96 | fossil-con |
| 51 | 150.00 | 2000 | 180825.40 | 780.0 | 2.8 | 750.0 | 2.9 | 1.11 | -0.40 | 4.02 | 3.18 | fossil-ins |
| 142 | 80.00 | 2050 | 112417.26 | 347.7 | 2.4 | 193.5 | 2.3 | 2.10 | 0.68 | 7.97 | 2.48 | Africa |
| 242 | 102.44 | 1800 | 82209.71 | 415.0 | 2.5 | 302.2 | 2.5 | 1.92 | 0.75 | 6.79 | 2.91 | America |
| 59 | 150.00 | 2100 | 323123.20 | 585.5 | 2.6 | 280.0 | 2.4 | 1.43 | 0.85 | 3.61 | 2.24 | Asia |
| 173 | 107.00 | 2500 | 254222.84 | 491.2 | 2.5 | 245.0 | 2.4 | 1.86 | 0.81 | 6.30 | 2.34 | Europe |

| nCL | min | max | var | mean | logm | med | logmed | skew | logsk | kurt | logku | Variable |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

# Boxplots

### genera per time bins

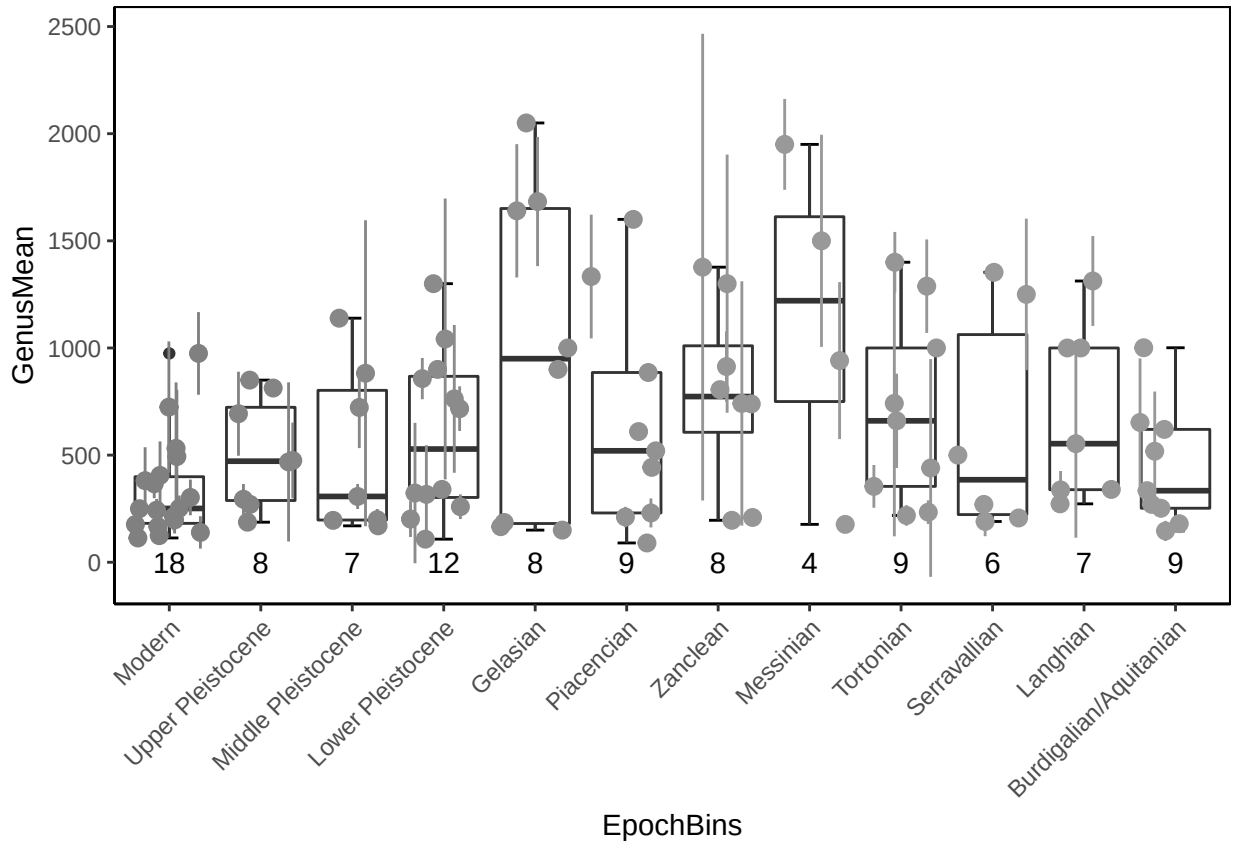



Figure 18: Boxplots of mean CL per time bin, including mean and sd CL for each genus (as pointrange).

**continental vs. insular per time bin**

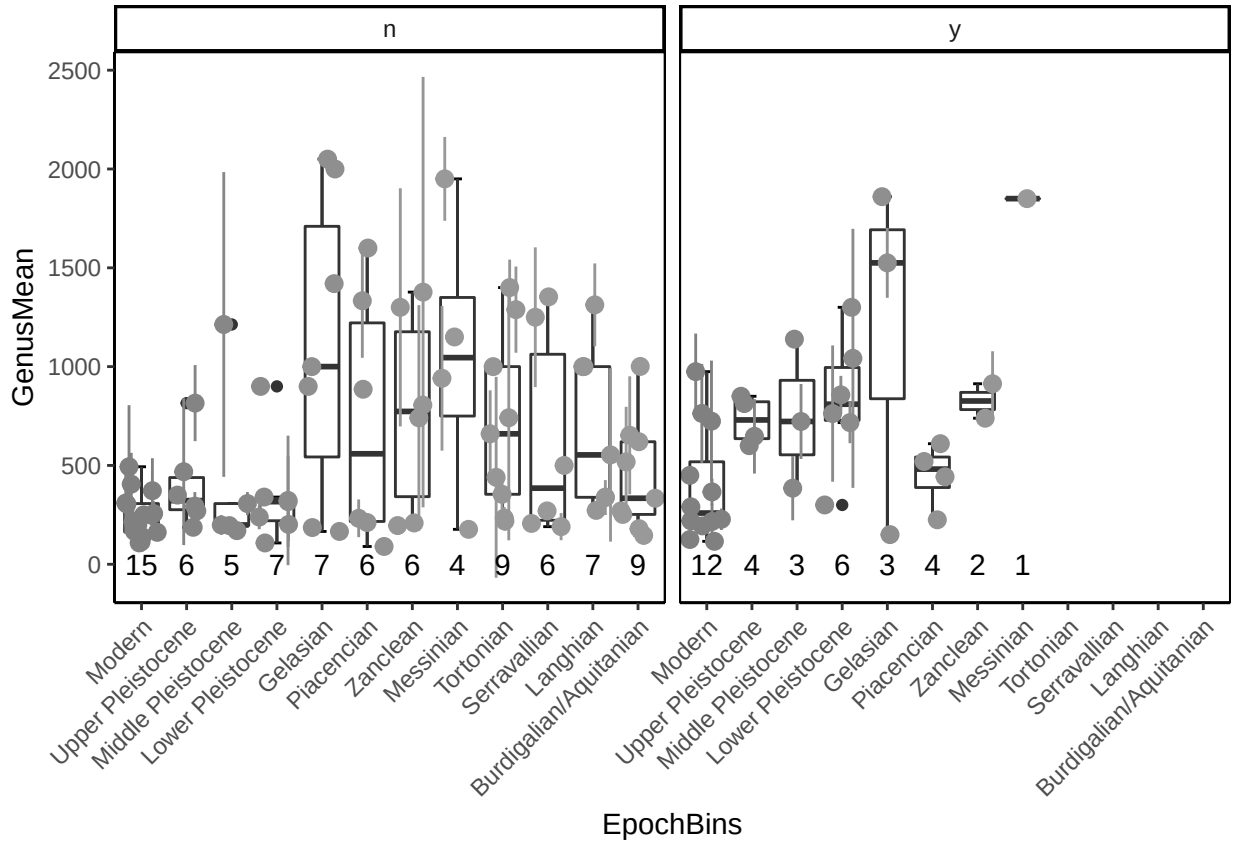



Figure 19: Boxplots of each genus per time bin, continental vs. insular species.

**fossil vs. modern**

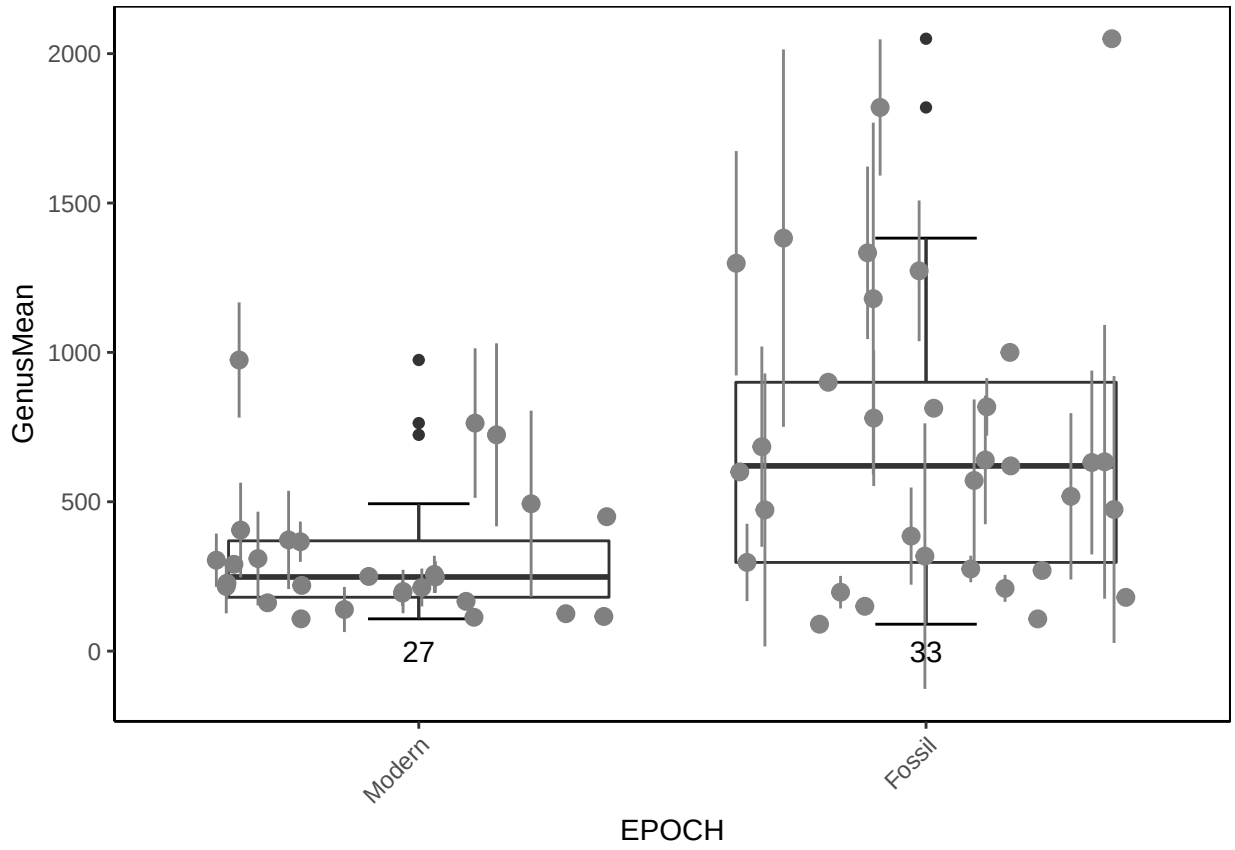
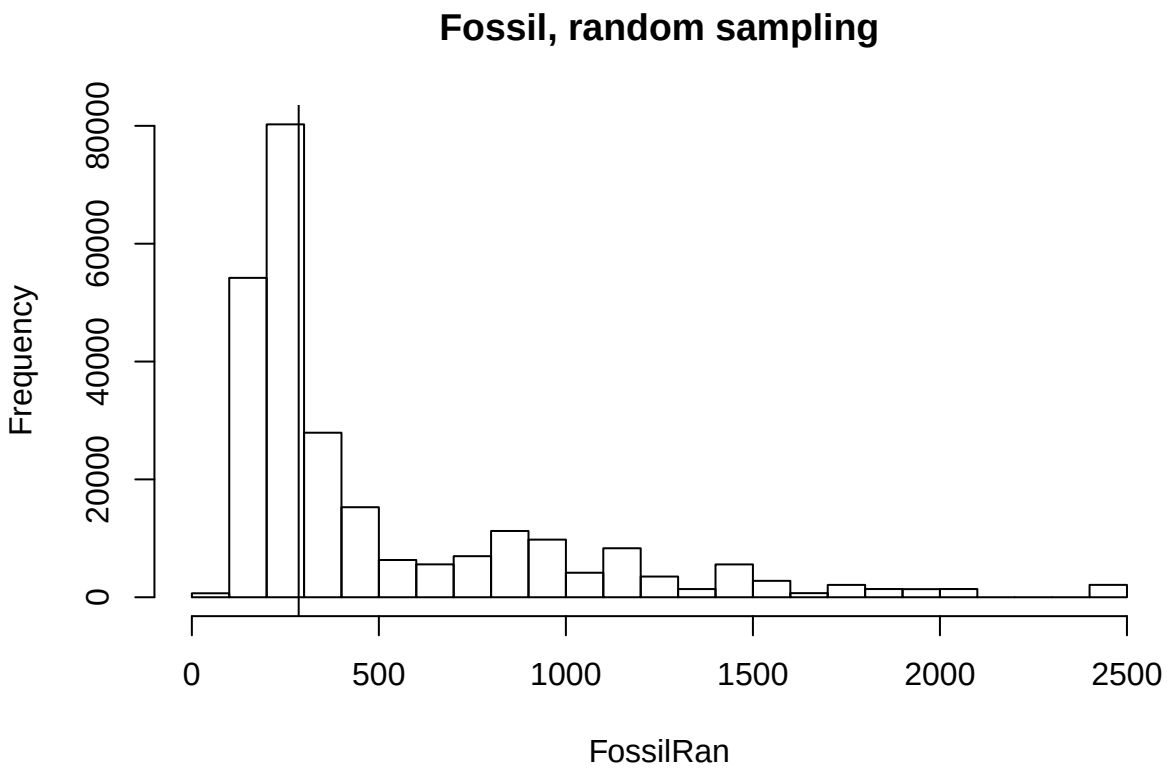



Figure 20: Boxplots fossil vs. modern.




```
## [1] 330.3495
```

```
## [1] 515.4103
```

```
##
```

```
##  Wilcoxon rank sum test with continuity correction
```

```
##
```

```
## data:  Modern and Fossil
```

```
## W = 23396, p-value = 1.603e-07
```

```
## alternative hypothesis: true location shift is less than 0
```

Wilcoxon Rank Sum Test (unpaired data):

modern $<$ fossil ($\mathrm{P} = 1.6026752 \times 10^{-7}$)

**fossil vs. modern, continental vs. insular**

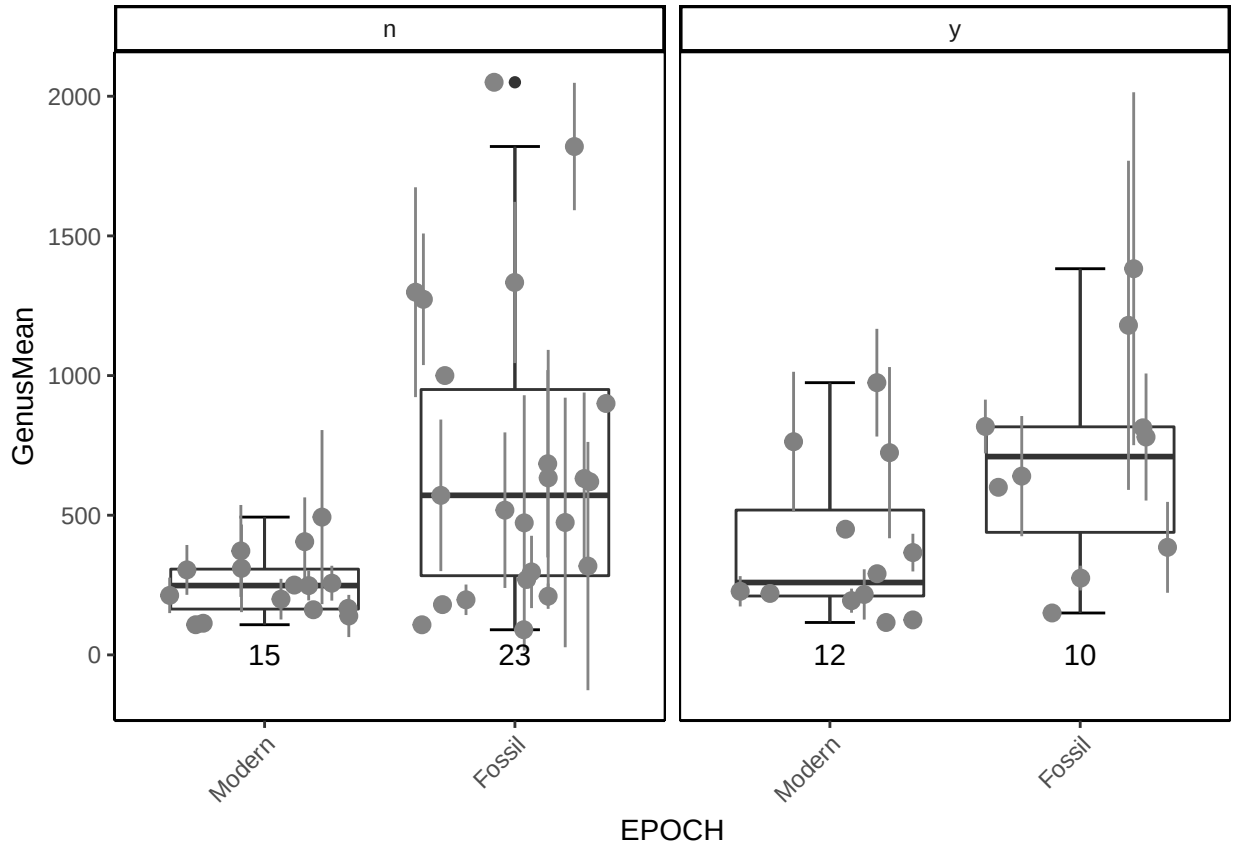
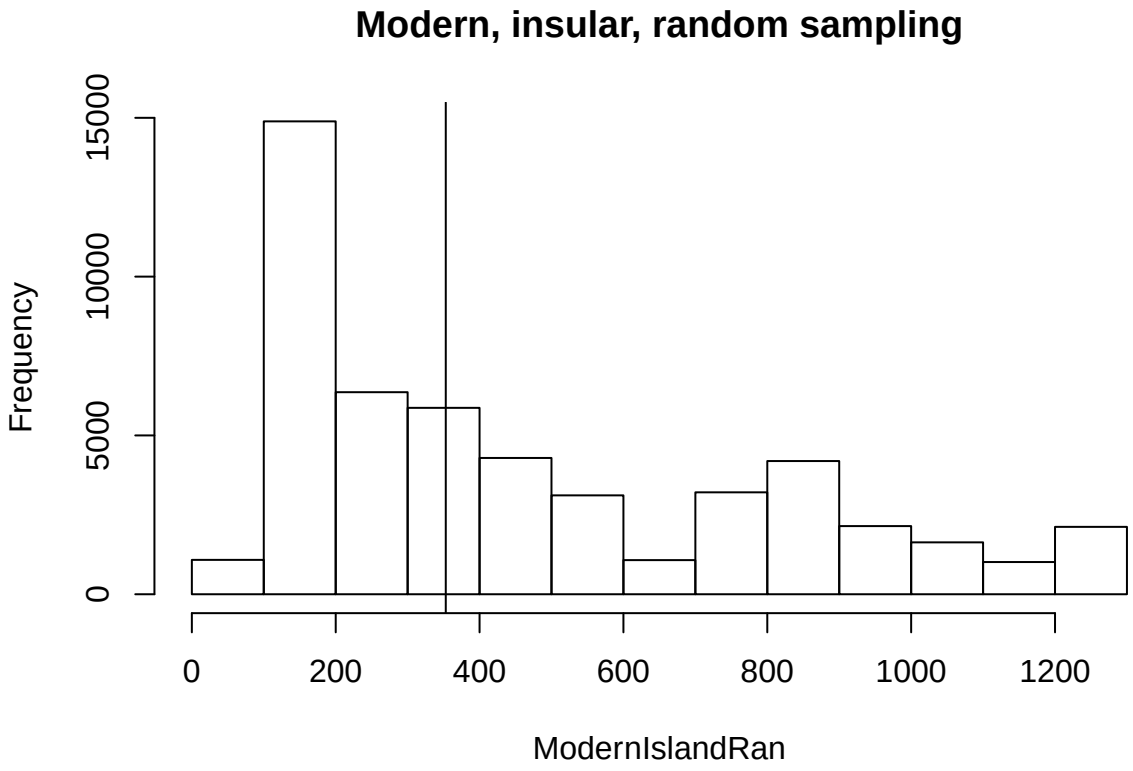


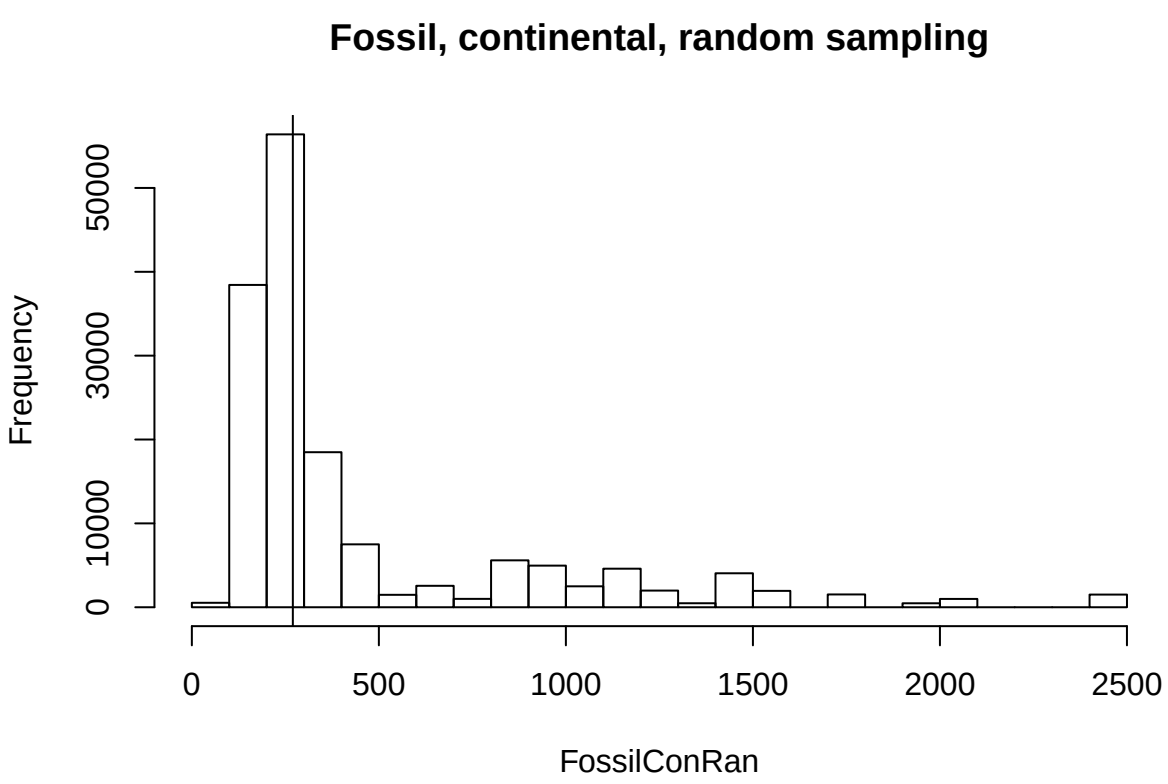

Figure 21: Boxplots fossil vs. modern, continental vs. insular species.

```
## [1] 51
```

```
## [1] 51
```




```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  ModernIsland and FossilIsland
## W = 758.5, p-value = 0.0001448
## alternative hypothesis: true location shift is less than 0
## [1] 157
## [1] 157
```




```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  ModernCon and FossilCon
## W = 7737.5, p-value = 5.92e-09
## alternative hypothesis: true location shift is less than 0
```

Wilcoxon Rank Sum Test (unpaired data):

modern continental < fossil continental ($P = 5.9202322 \times 10^{-9}$)

modern insular < fossil insular ($P = 1.4478883 \times 10^{-4}$)

**continental vs. insular**

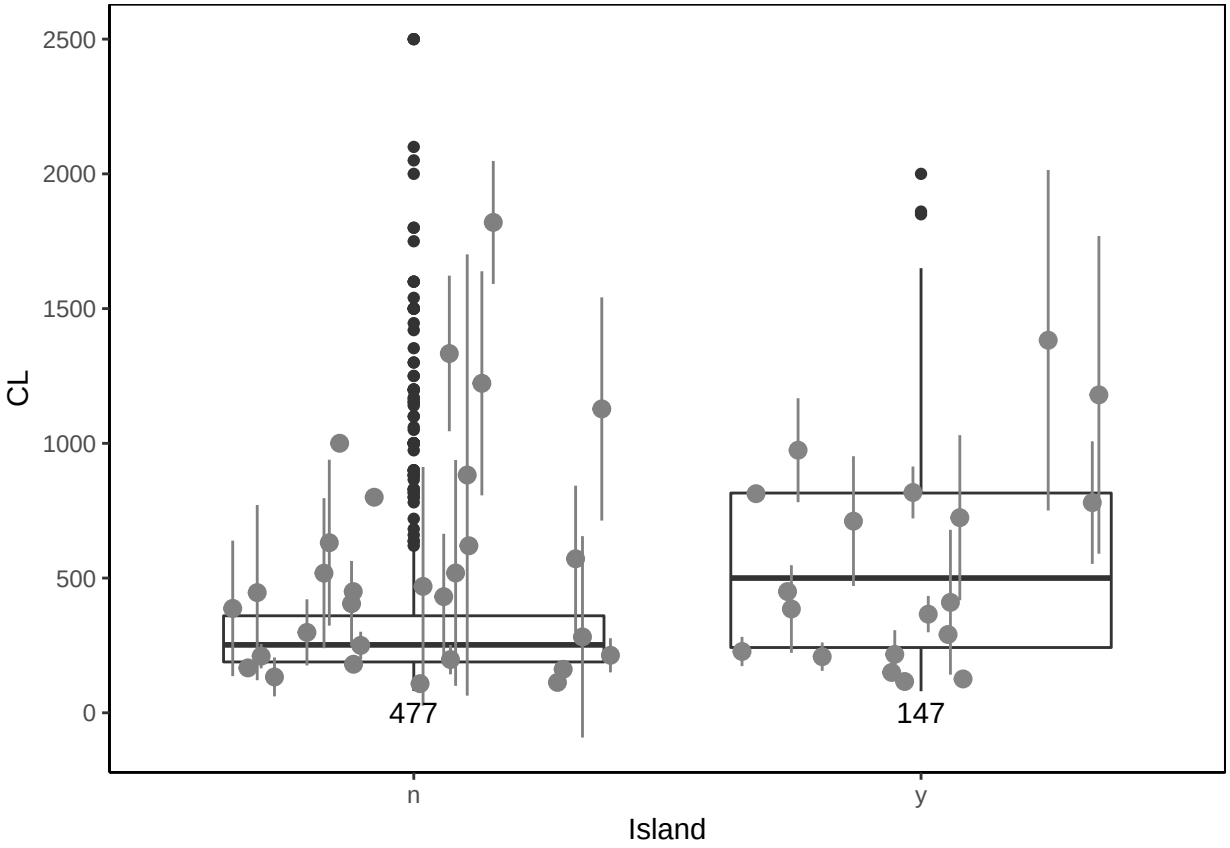
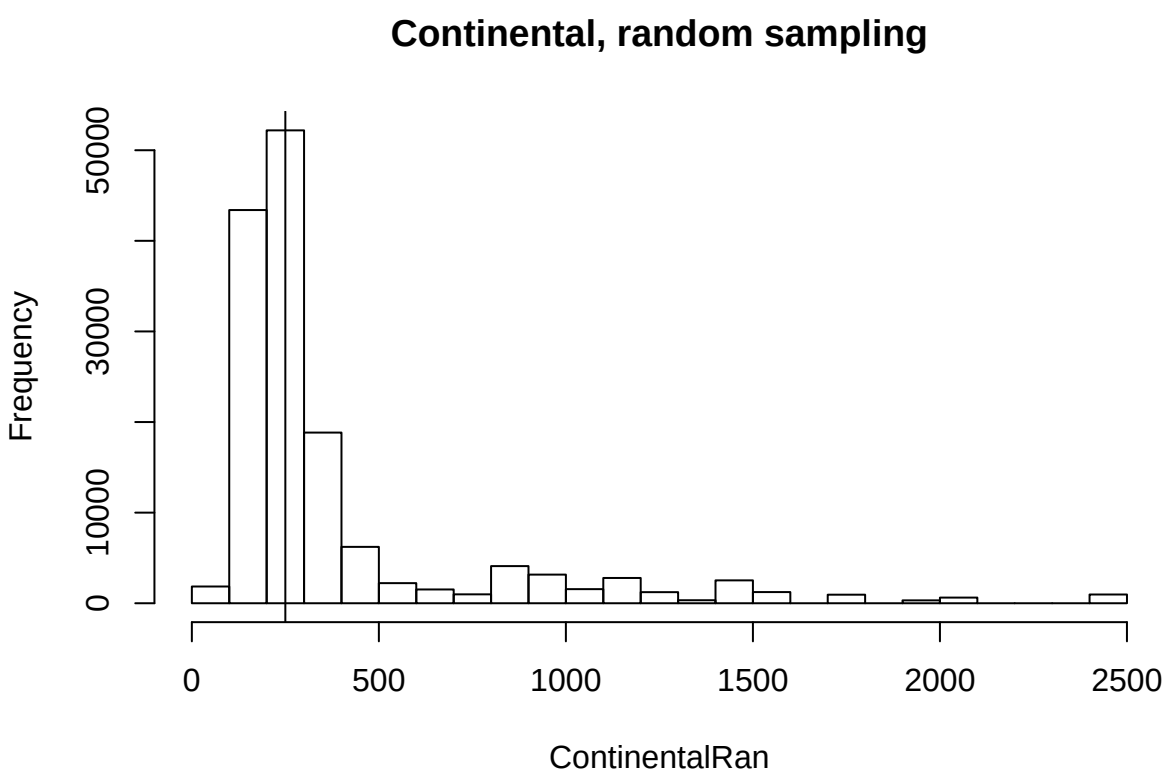



Figure 22: Boxplot continental vs. insular, genera summarised

```
## [1] 147
```

```
## [1] 147
```




```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  Insular and Continental
## W = 14353, p-value = 5.634e-07
## alternative hypothesis: true location shift is greater than 0
```

Wilcoxon Rank Sum Test (unpaired data):

continental $<$ insular ($\mathrm{P} = 5.6343766 \times 10^{-7}$)

**continental vs. insular per time bin**

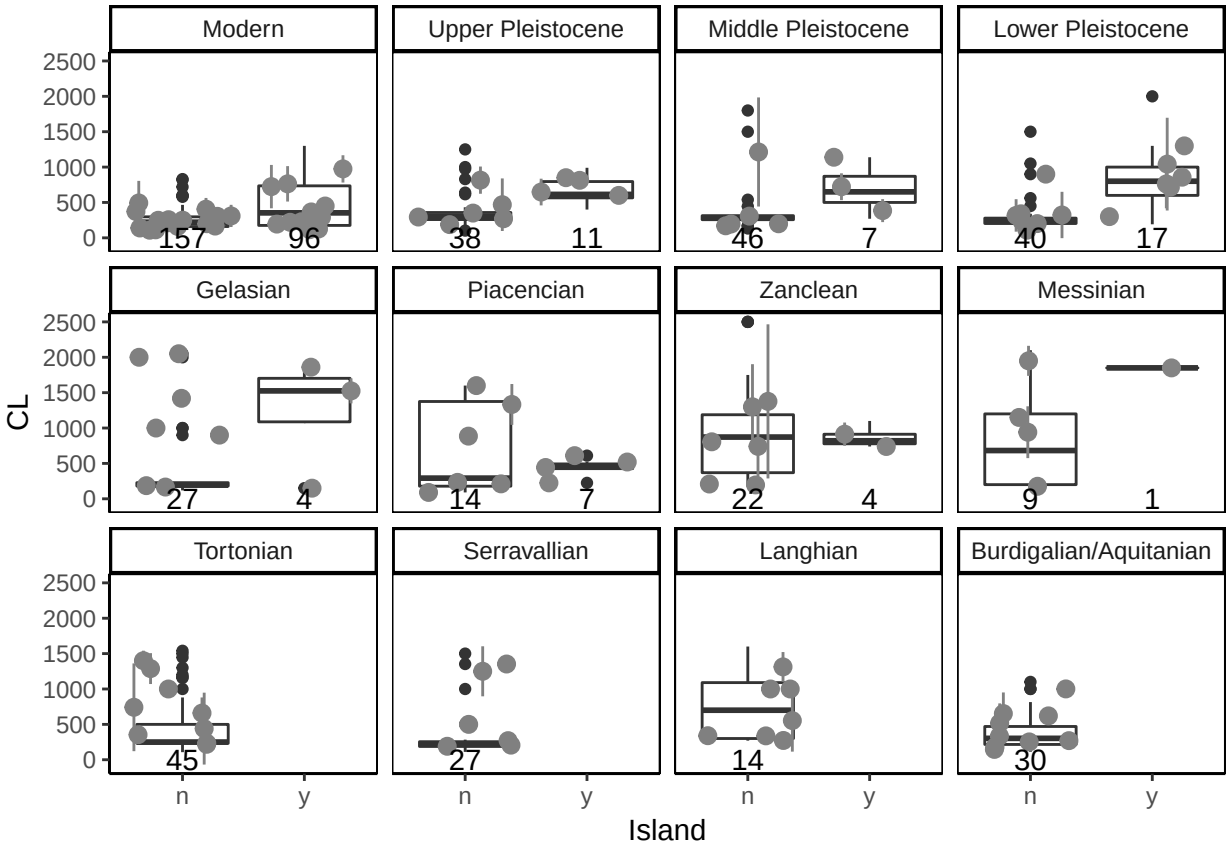



Figure 23: Boxplot continental vs. insular, genera summarised

**continents**

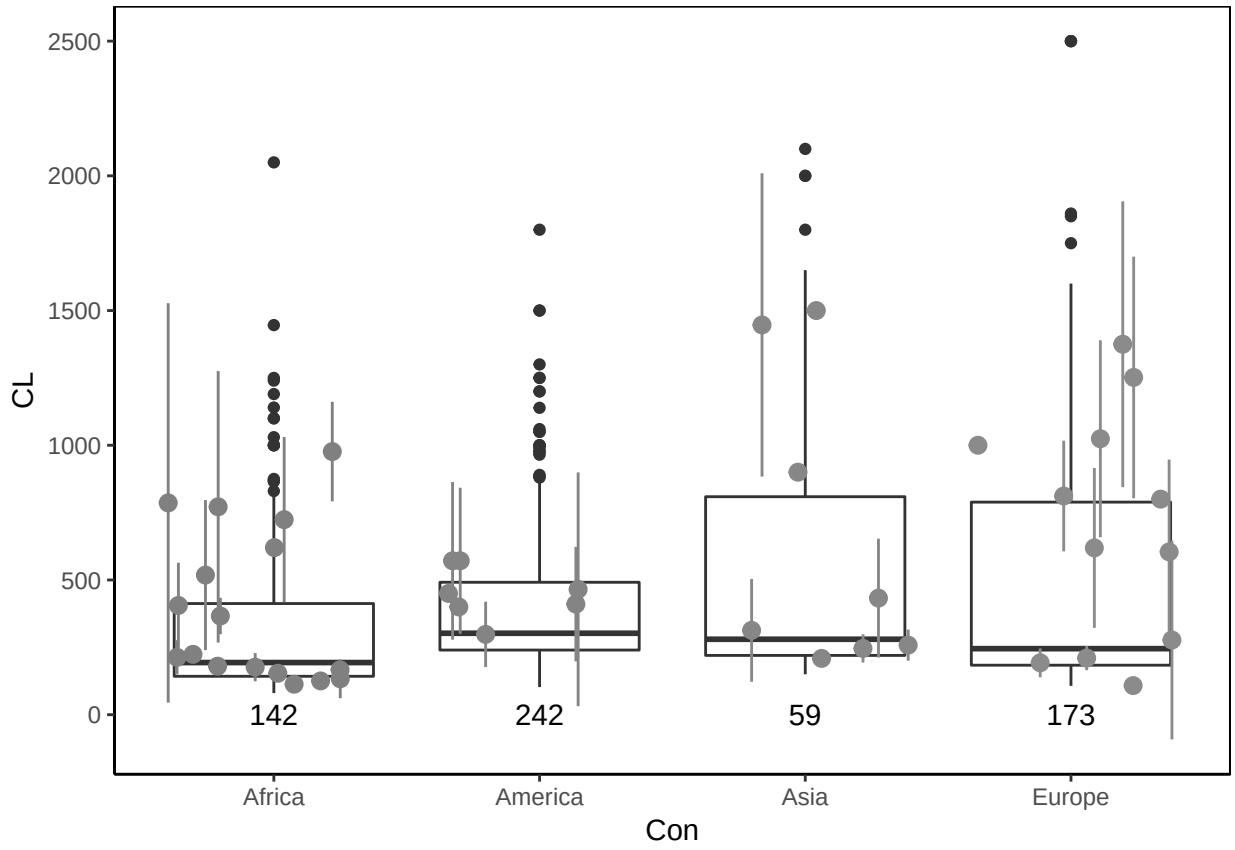
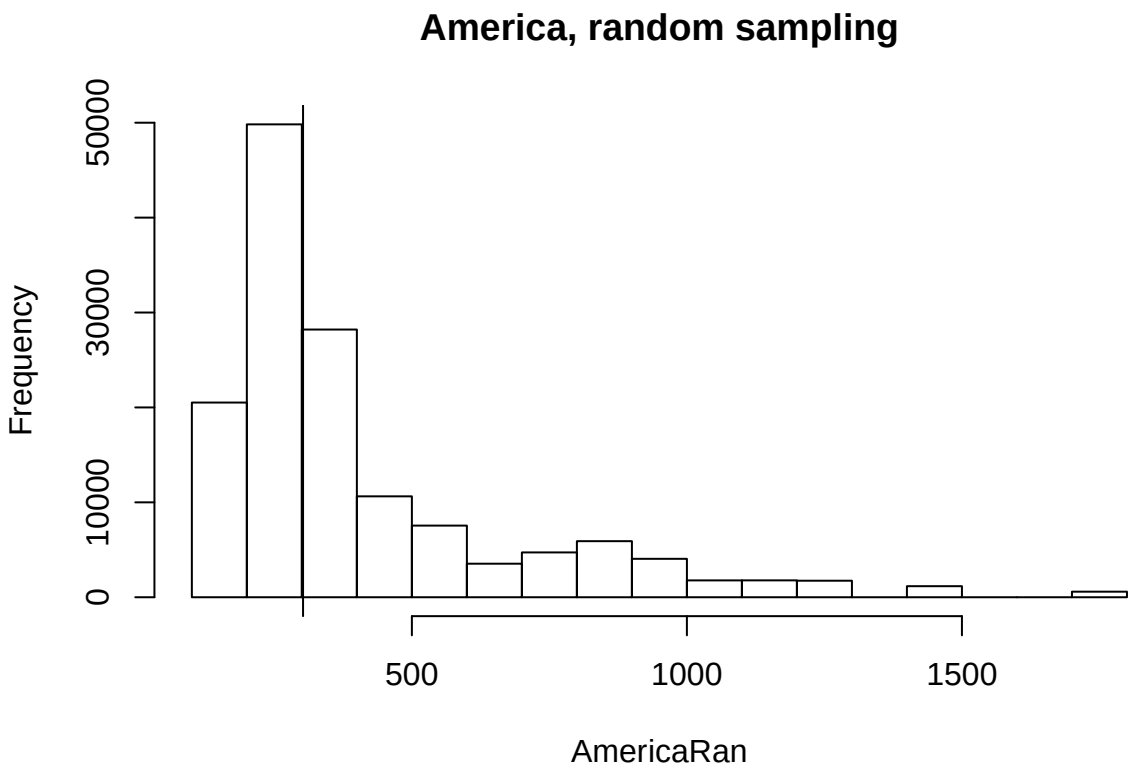
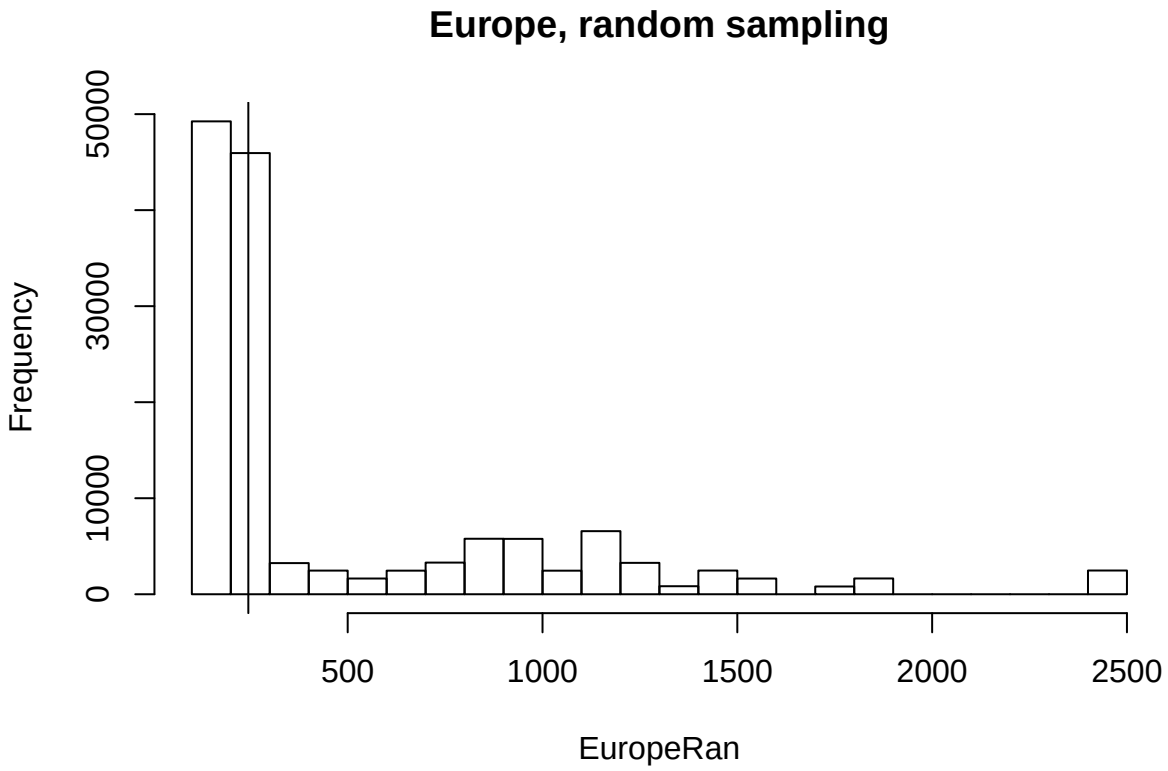
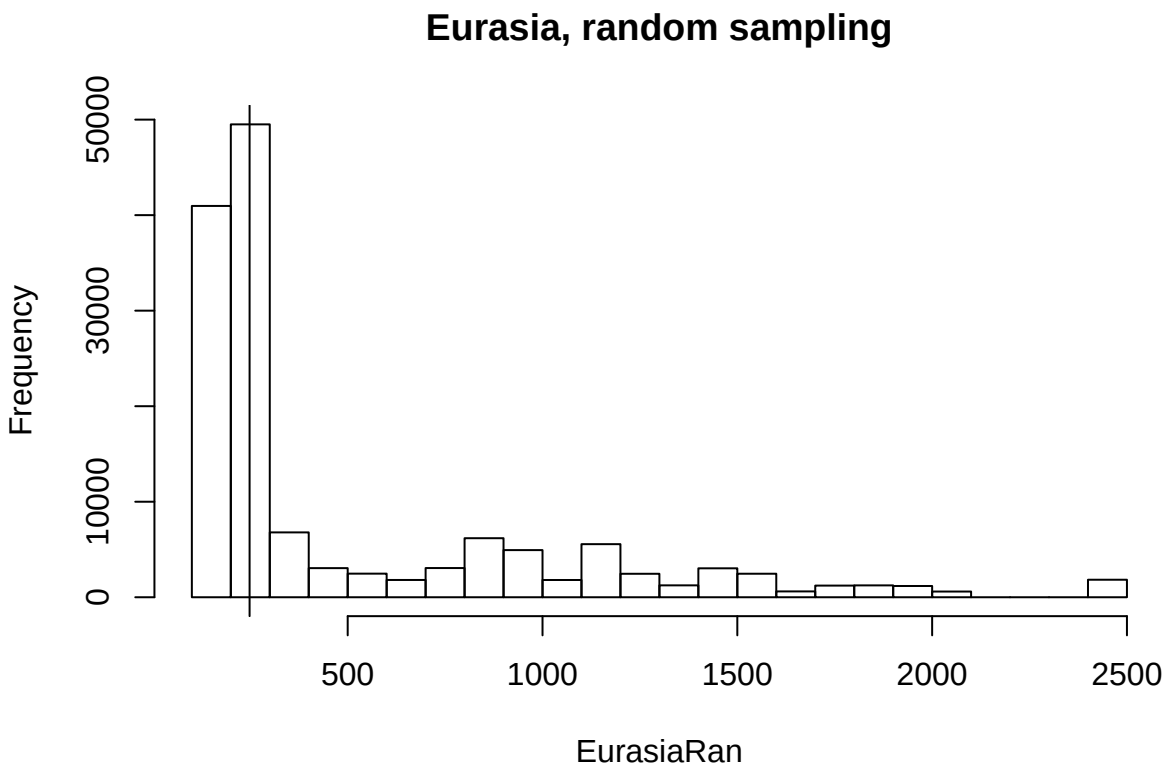



Figure 24: Boxplot: body size on different continents, genera summarised

```
## [1] 142

## [1] 347.6887

## [1] 142

## [1] 437.2697

## [1] 59

## [1] 173

## [1] 142

## [1] 515.7585
```


America, random sampling
Frequency
0
10000
30000
50000
500
1000
1500
AmericaRan


Europe, random sampling
Frequency
0
10000
30000
50000
500
1000
1500
2000
2500
EuropeRan




```
##
##  Kruskal-Wallis rank sum test
##
## data:  list(Africa, America, Eurasia, Europe)
## Kruskal-Wallis chi-squared = 31.847, df = 3, p-value = 5.636e-07
```

Kruskal-Wallis-Test:

Continent means differ ($P = 5.6359048 \times 10^{-7}$) (still have to look into the details...)

**continents, continental vs. insular**

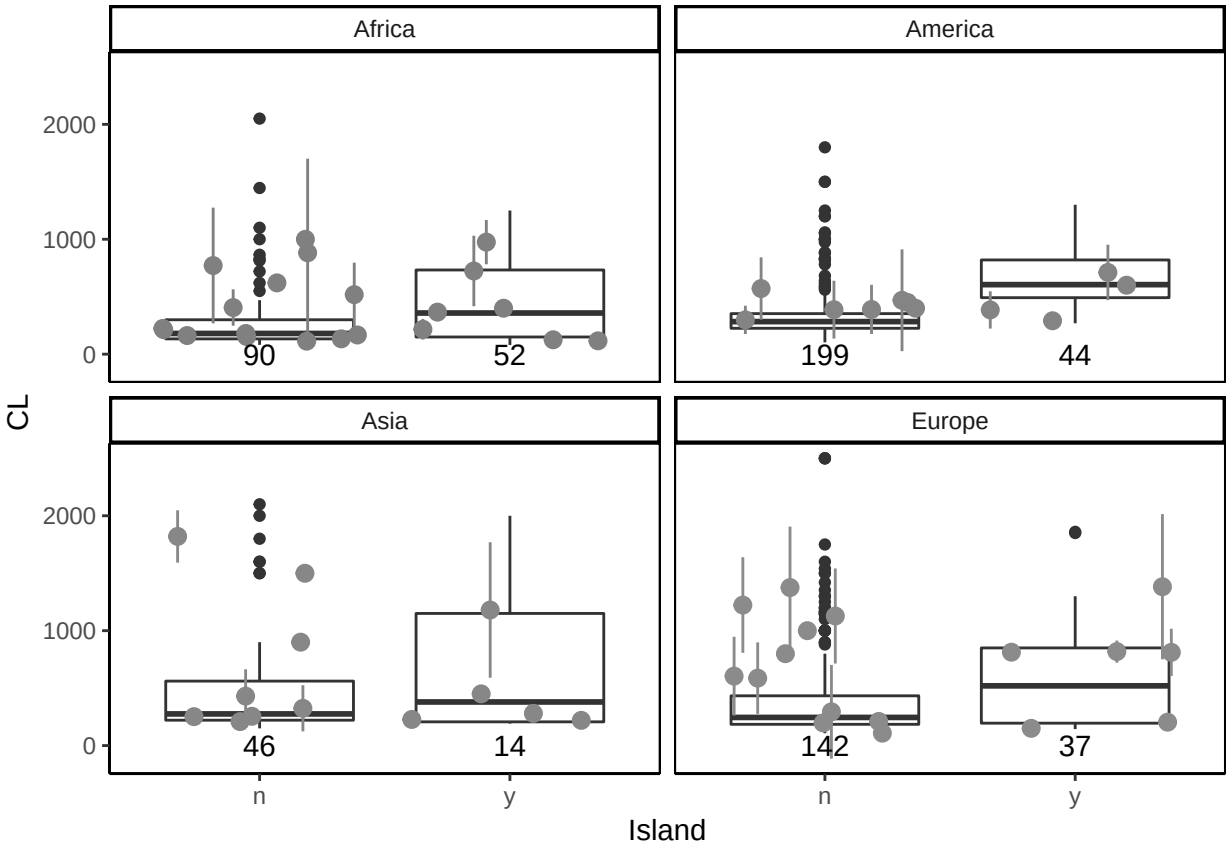



Figure 25: Boxplot: body size on different continents, genera summarised

# paleoTS analysis

## all (continental and insular)

### genera (all)

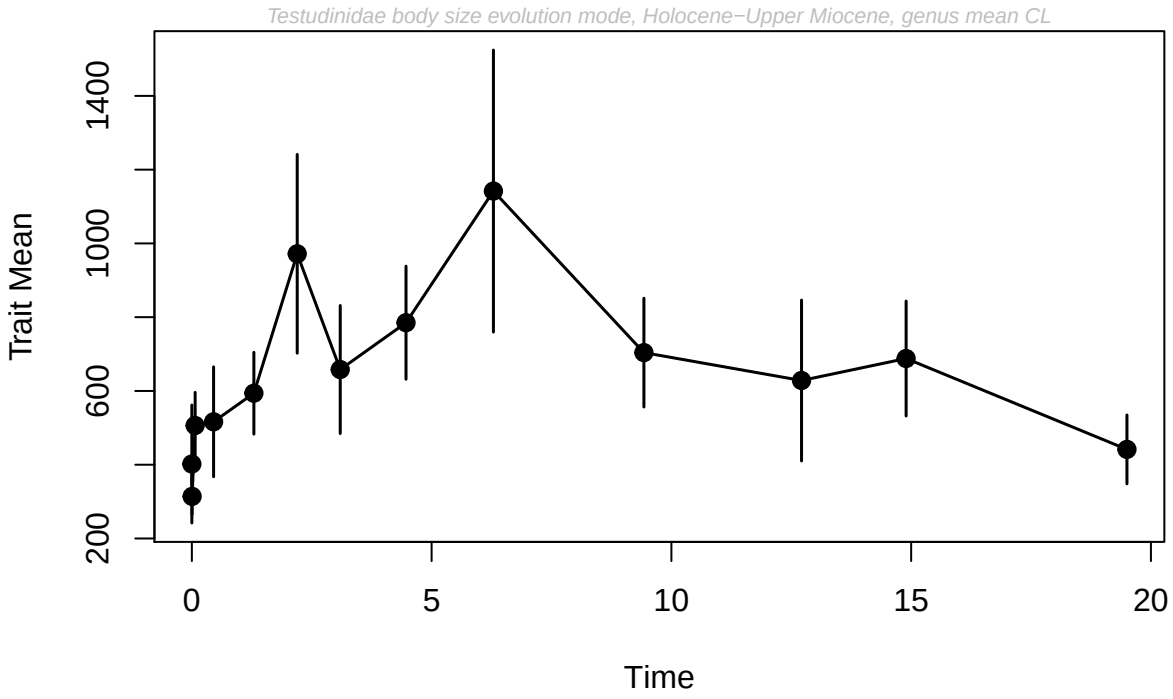



Figure 26: paleoTS plot with genus mean, including island species

Table 3: Model-fitting results for testudinidae, genera, including island species

| | logL | K | AICc | Akaike.wt |
|---|---|---|---|---|
| GRW | -81.31790 | 2 | 167.9691 | 0.161 |
| URW | -82.05721 | 1 | 166.5144 | 0.332 |
| Stasis | -80.16802 | 2 | 165.6694 | 0.507 |

## continental (excluding insular species)

### genera (continental)

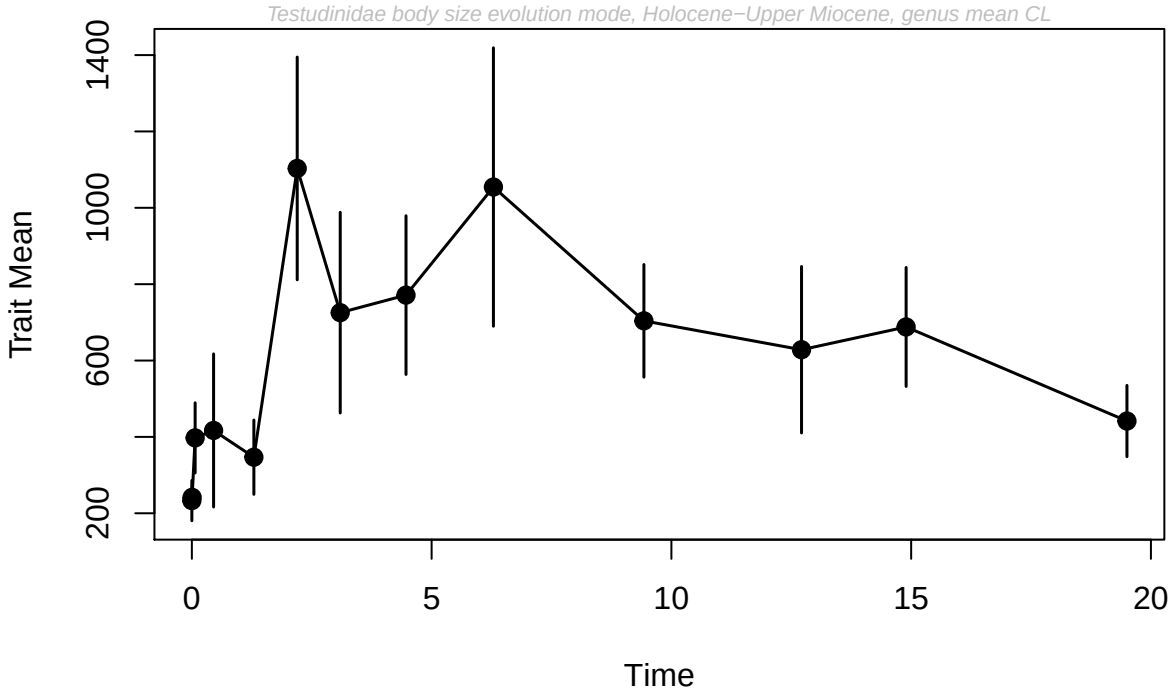



Figure 27: paleoTS plot with genus mean, excluding island species

Table 4: Model-fitting results for testudinidae, genera, excluding insular species

| | logL | K | AICc | Akaike.wt |
|---|---|---|---|---|
| GRW | -82.26287 | 2 | 169.8591 | 0.300 |
| URW | -83.12577 | 1 | 168.6515 | 0.548 |
| Stasis | -82.93984 | 2 | 171.2130 | 0.152 |

## insular (excluding continental)

### genera (insular)

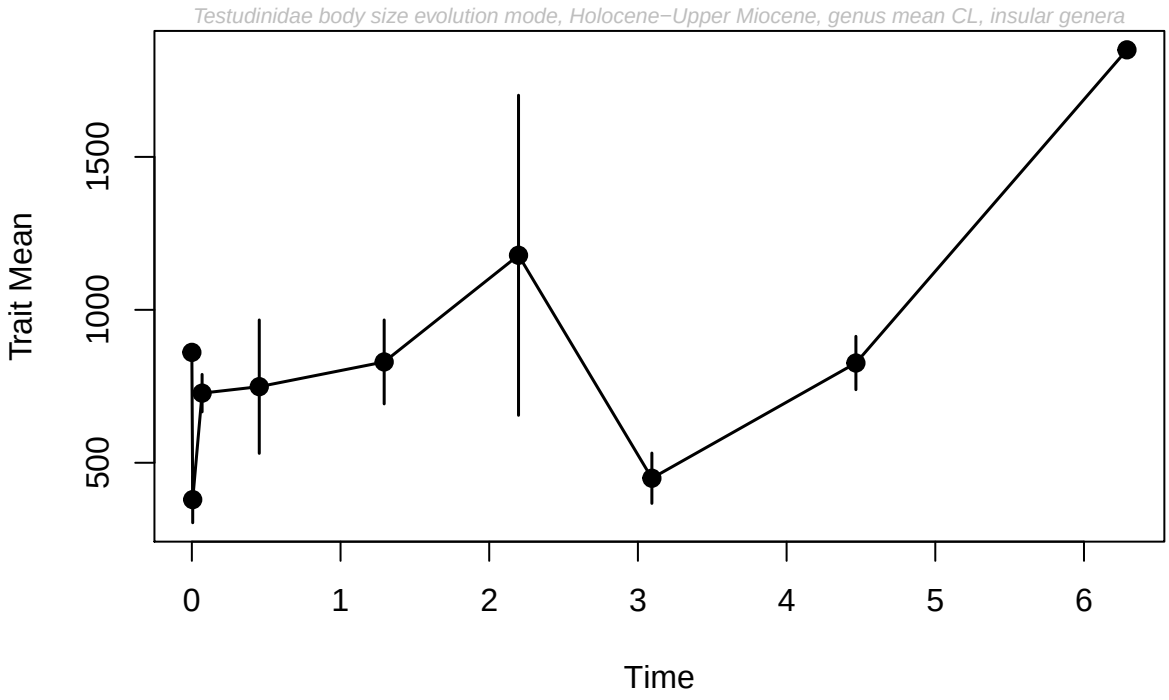



Figure 28: paleoTS plot with genus mean, only insular species

Table 5: Model-fitting results for testudinidae, genera, only insular species

| | logL | K | AICc | Akaike.wt |
|---|---|---|---|---|
| GRW | -68.57344 | 2 | 143.5469 | 0 |
| URW | -75.76576 | 1 | 154.1982 | 0 |
| Stasis | -60.41581 | 2 | 127.2316 | 1 |

**per continent**

**Europe, smaller original bins (see Table 2), genera**

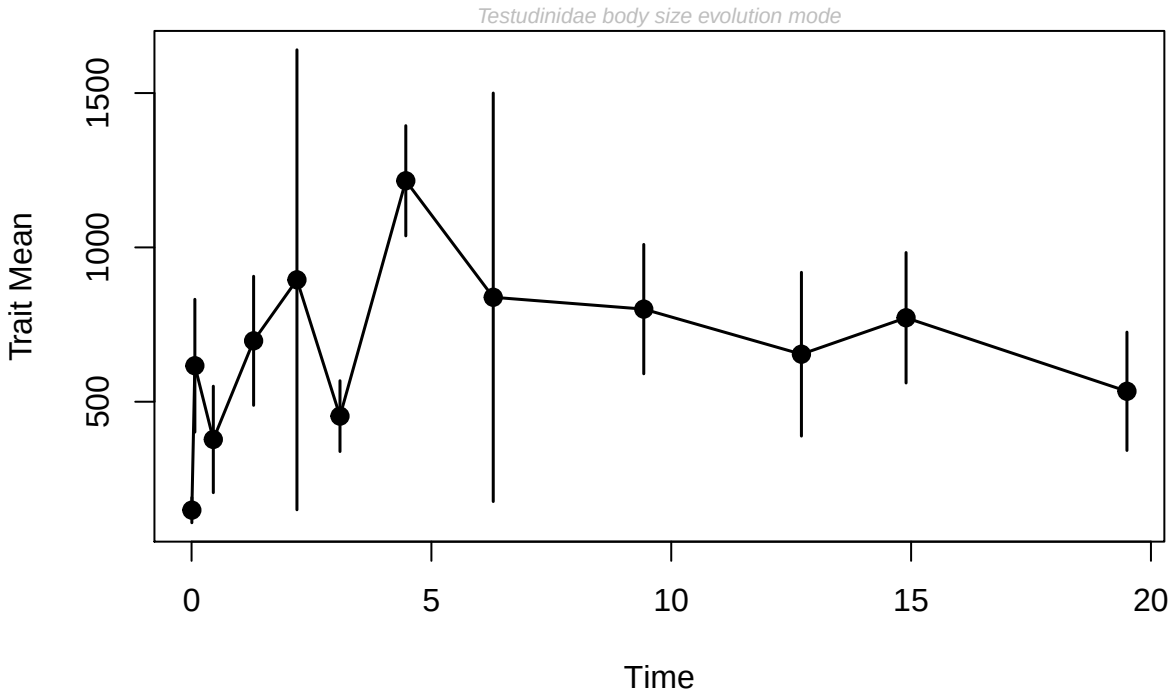



Figure 29: Smaller original bins, genera, Europe

Table 6: Model-fitting results for testudinidae, no bins, genera

| | logL | K | AICc | Akaike.wt |
|---|---|---|---|---|
| GRW | -84.14010 | 2 | 173.7802 | 0.006 |
| URW | -85.90727 | 1 | 174.2590 | 0.005 |
| Stasis | -79.01365 | 2 | 163.5273 | 0.990 |

**Europe, smaller original bins (see Table 2), genera, continental**

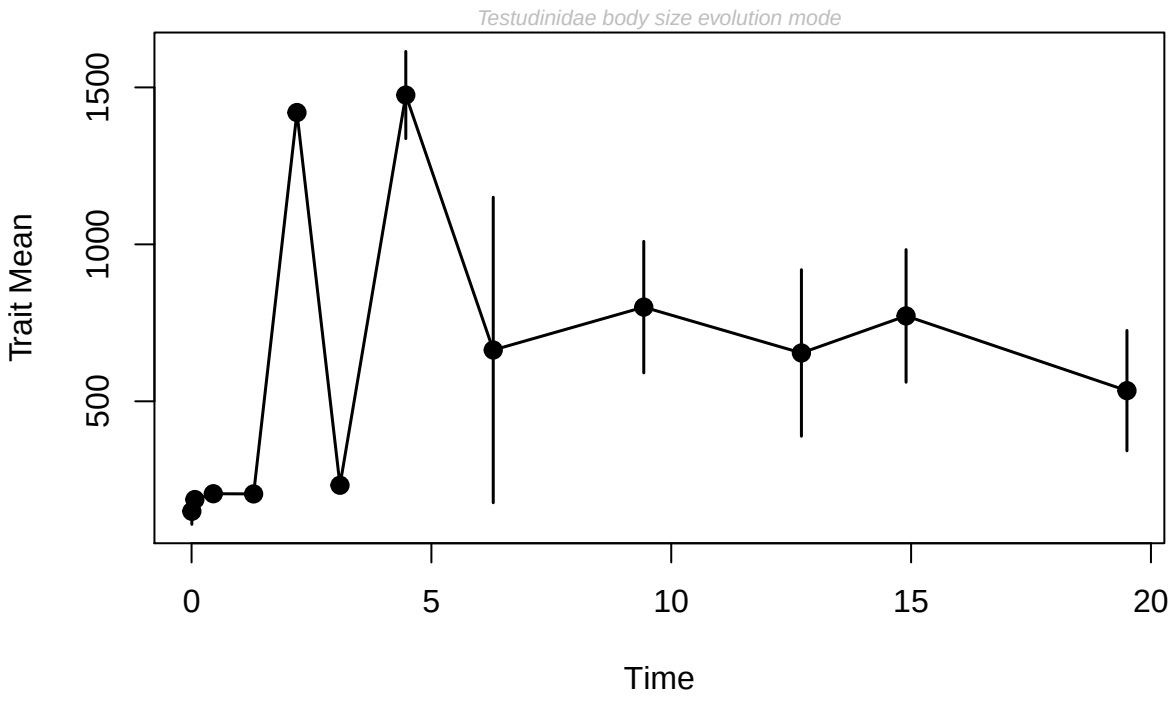



Figure 30: Smaller original bins, genera, Europe, continental

Table 7: Model-fitting results for testudinidae, no bins, genera

| | logL | K | AICc | Akaike.wt |
|---|---|---|---|---|
| GRW | -87.93137 | 2 | 181.3627 | 0.009 |
| URW | -92.56882 | 1 | 187.5821 | 0.000 |
| Stasis | -83.21073 | 2 | 171.9215 | 0.991 |

**Europe, smaller original bins (see Table 2), genera, insular**

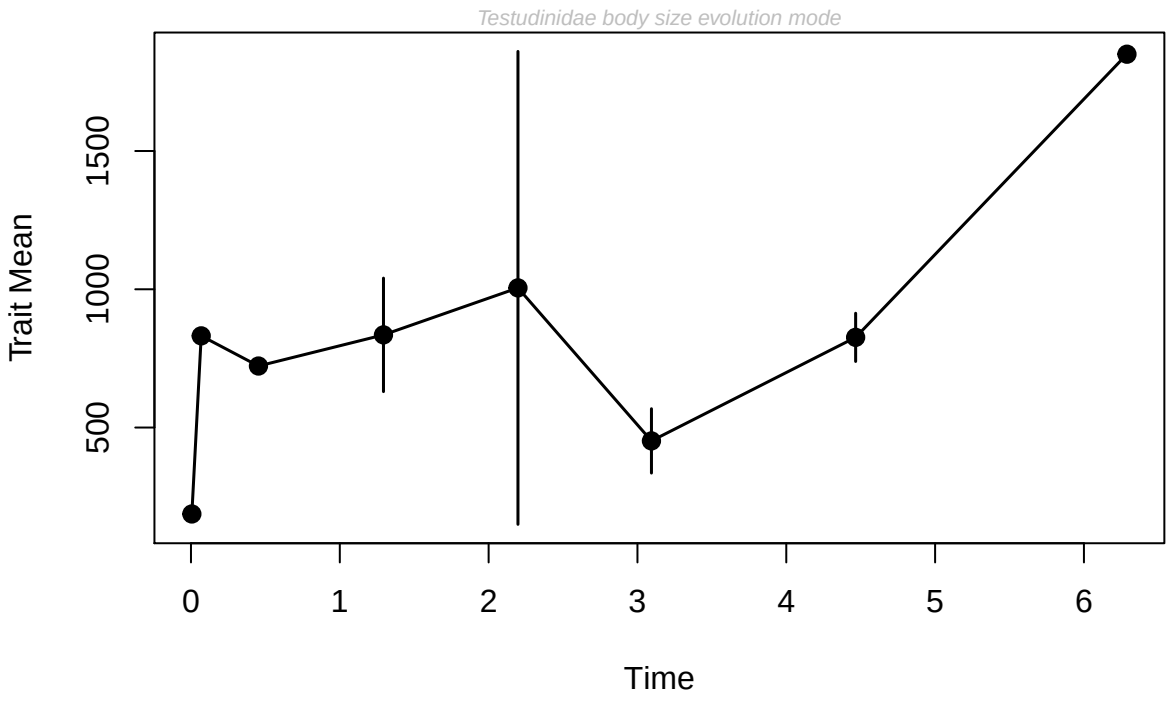



Figure 31: Smaller original bins, genera, Europe, insular

Table 8: Model-fitting results for testudinidae, no bins, genera

| | logL | K | AICc | Akaike.wt |
|---|---|---|---|---|
| GRW | -67.12192 | 2 | 141.2438 | 0.000 |
| URW | -57.51634 | 1 | 117.8327 | 0.074 |
| Stasis | -52.89638 | 2 | 112.7928 | 0.926 |

**Eurasia, smaller original bins (See Table 2), genera**

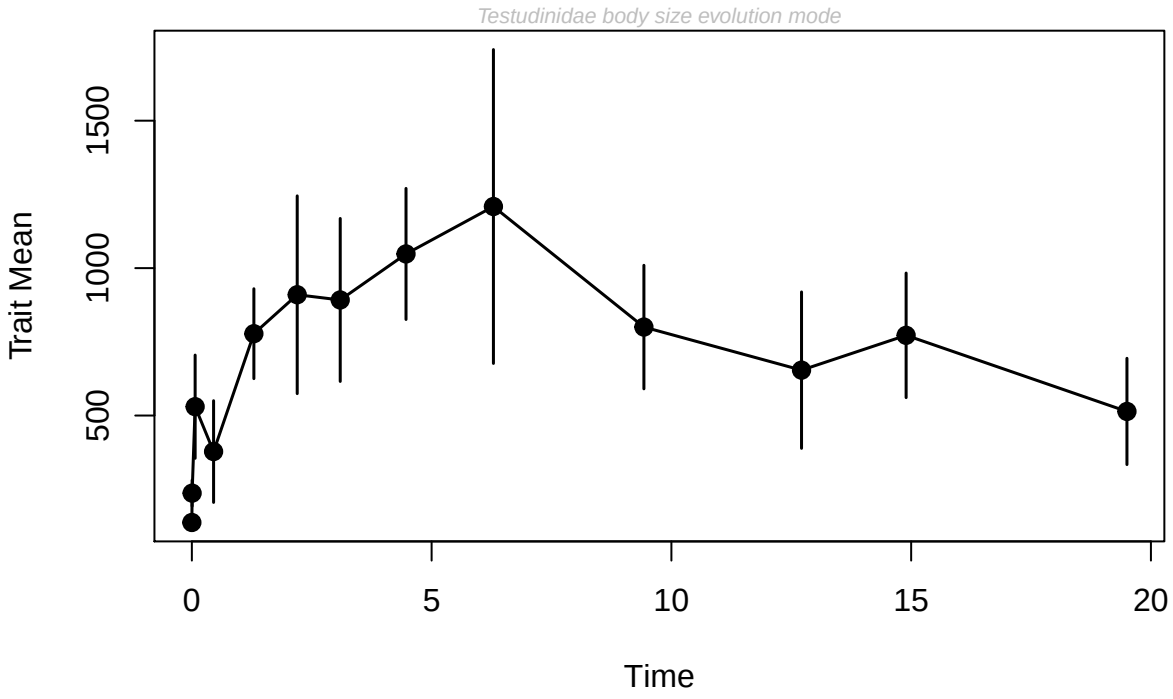



Figure 32: Smaller original bins, genera, Eurasia

Table 9: Model-fitting results for testudinidae, no bins, genera

| | logL | K | AICc | Akaike.wt |
|---|---|---|---|---|
| GRW | -85.25195 | 2 | 175.8372 | 0.149 |
| URW | -85.39072 | 1 | 173.1814 | 0.562 |
| Stasis | -84.58890 | 2 | 174.5111 | 0.289 |

**Eurasia, smaller original bins (See Table 2), genera, continental**

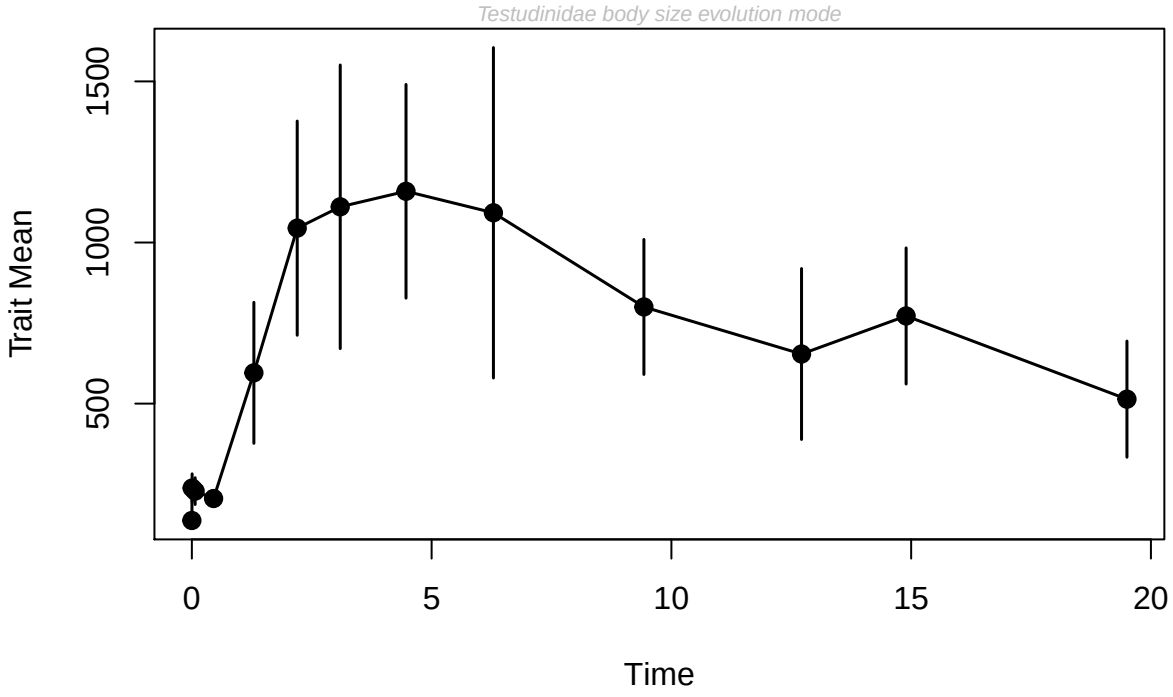



Figure 33: Smaller original bins, genera, Eurasia, continental

Table 10: Model-fitting results for testudinidae, no bins, genera

| | logL | K | AICc | Akaike.wt |
|---|---|---|---|---|
| GRW | -82.20698 | 2 | 169.7473 | 0.222 |
| URW | -82.42344 | 1 | 167.2469 | 0.776 |
| Stasis | -87.19538 | 2 | 179.7241 | 0.002 |

**Eurasia, smaller original bins (See Table 2), genera, insular**

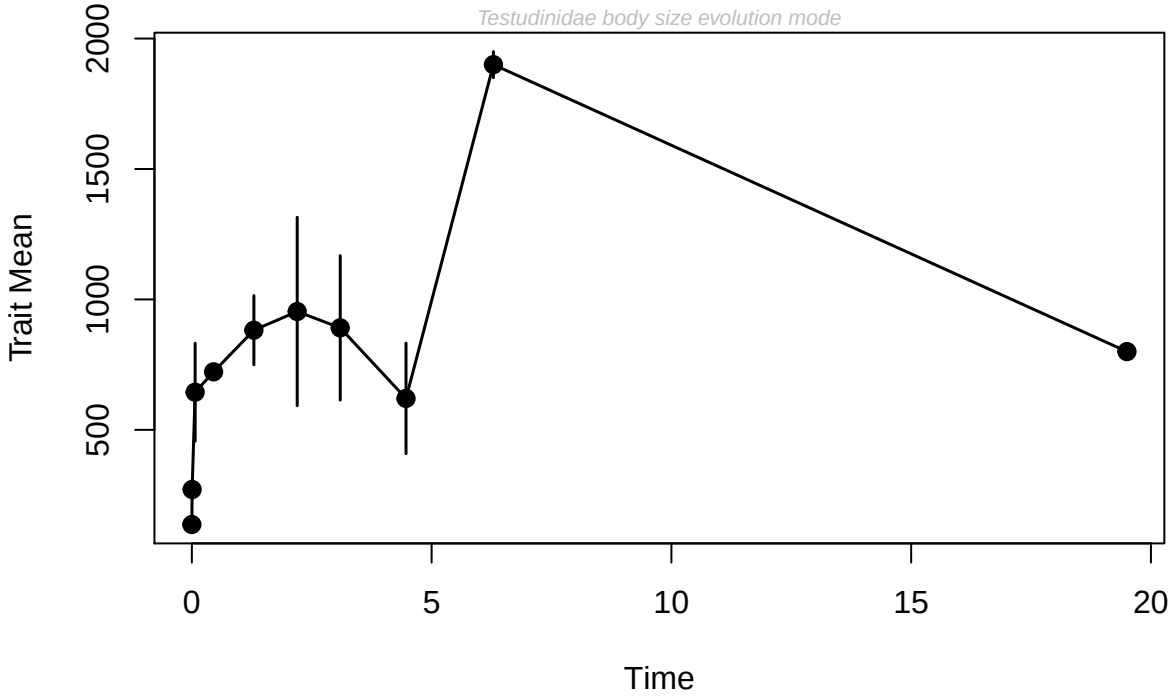



Figure 34: Smaller original bins, genera, Eurasia, insular

Table 11: Model-fitting results for testudinidae, no bins, genera

| | logL | K | AICc | Akaike.wt |
|---|---|---|---|---|
| GRW | -69.56419 | 2 | 145.1284 | 0.193 |
| URW | -71.67437 | 1 | 145.9202 | 0.130 |
| Stasis | -68.31026 | 2 | 142.6205 | 0.677 |