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Introduction

Across various fields including biology, medicine, anthropology, and conservation biology, methods of quantification are used to compare and study anatomical shape both within and between species. Geometric morphometrics (GM) is a commonly used method to statistically characterize shape in both 2D and 3D. The primary difference between 2DGM and 3DGM is that 2DGM is based on images rather than surfaces, eliminating shape information from the z-axis. The methodology of 2DGM and 3DGM reflects this difference, as 2DGM is performed on a single plane of a structure, while 3DGM is done using photogrammetry, computed tomography, or with laser surface scanning allowing generation of a 3D object and retention of all three directional axes.

We assess the following questions using a large sample of skulls of the Virginia opossum (*Didelphis virginiana*). To assess the impact of the Z-dimension on shape analyses, we performed 2DGM and 3DGM on the same set of Virginia opossum crania.

QUESTION 1:

How does the z-dimension impact **shape** information derived from GM?

QUESTION 2:

How does the z-dimension impact **size** information derived from GM?

Methods

2D Landmark Configuration Taken in a Single Plane from Photographs

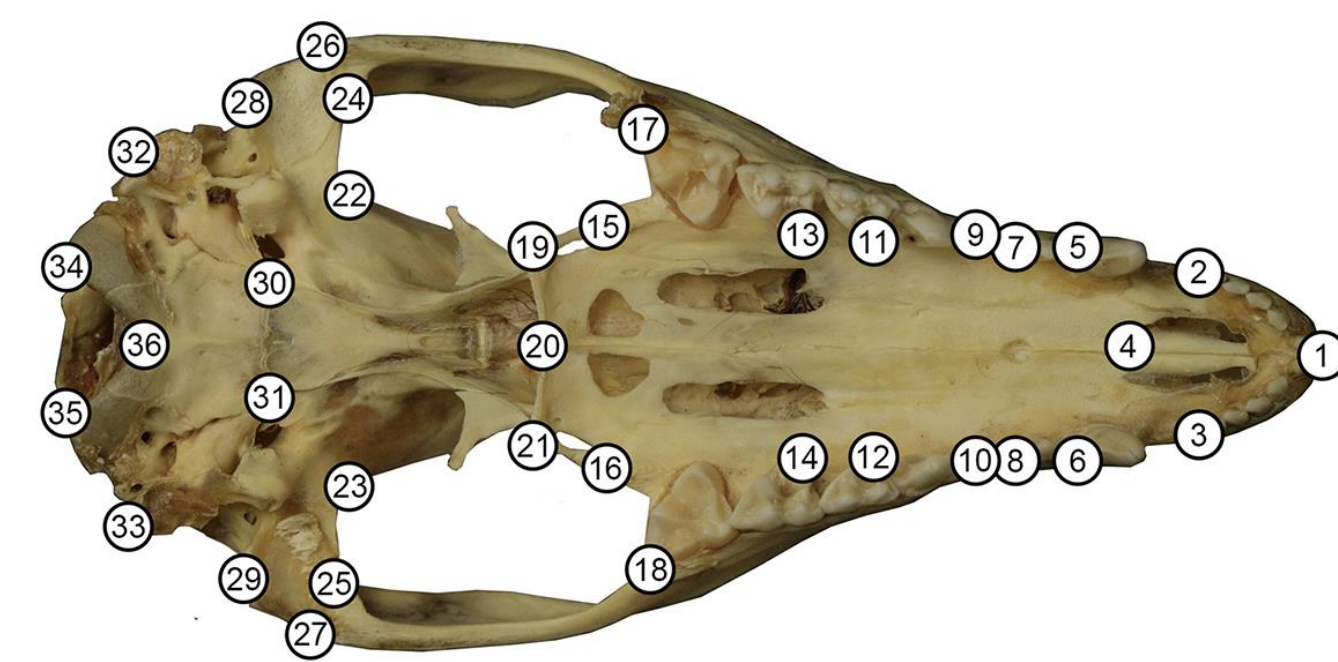


Figure 1A: Landmarks on ventral view of crania of *Didelphis virginiana*

3D Landmark Configuration Taken in 3D from Surface Scans

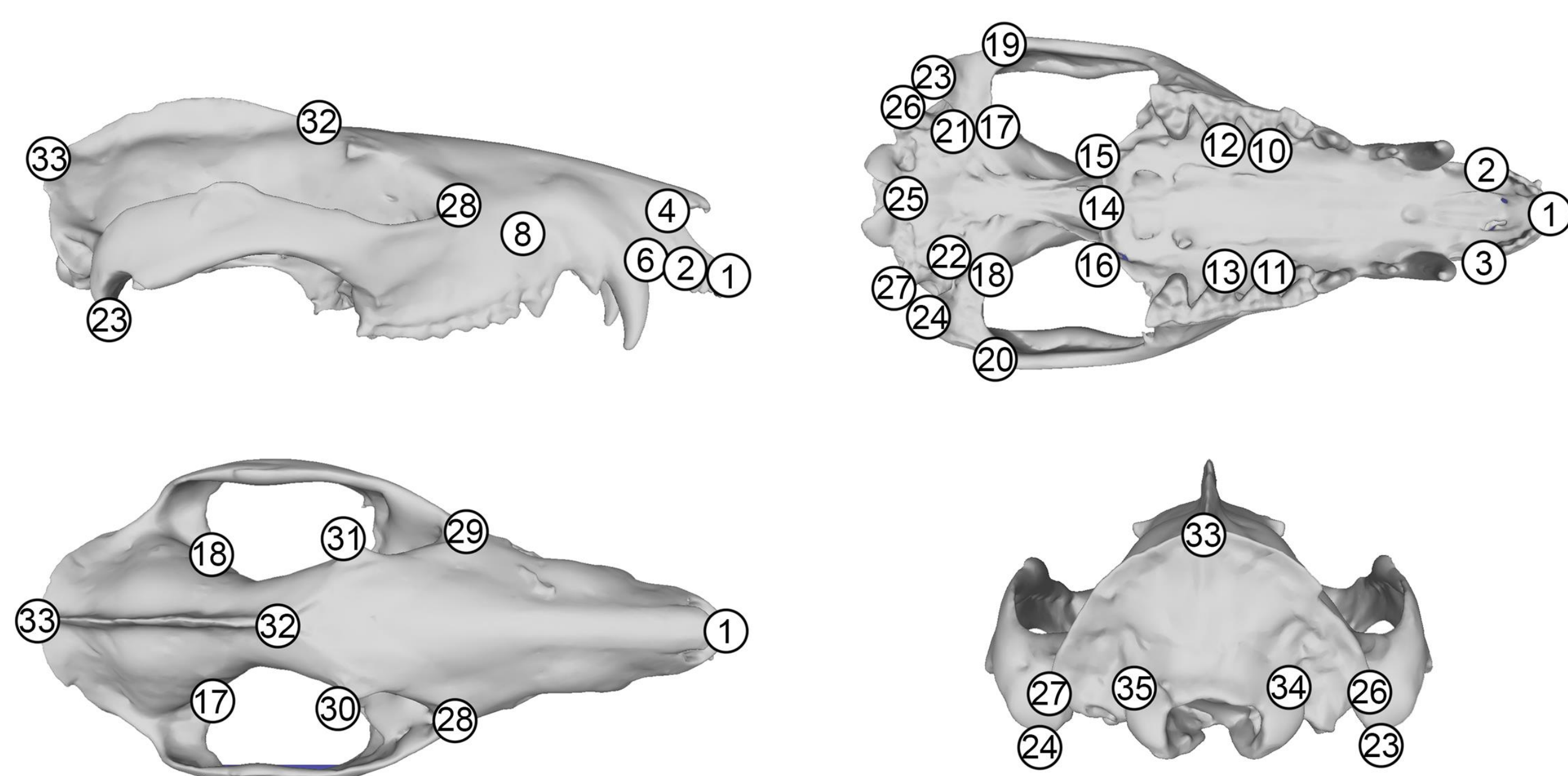


Figure 1B: Landmarks on lateral (upper left), ventral (upper right), dorsal (lower left), and caudal (lower right) view of crania of *Didelphis virginiana*

Geometric Morphometrics

Step 1: Landmarking

1. Select appropriate landmarks (lm) for GM analysis (35 were selected for study seen in Figure 1)
2. Load surface scans of specimens for lm analysis onto PC
3. Open Stratovan Checkpoint software and select landmark tab
4. Open landmark tab and place landmarks (1-35) in the same order for every specimen
5. Save lm information and put into a file format that can be read by the R programming language software



Step 2: Statistical Test

1. Load lm coordinates (1-35) into worksheet for 2D and 3D shape data
2. Open R programming language software
3. Using the lm data, run Principal Component Analysis (PCA) for 2D and 3D shape data (Q1)
4. Examine relationship between shape and size for both datasets (Q2)
5. Run Partial Least Squares (PLS) analysis of 2D and 3D shape data (Q1)
6. Run regression of 2D centroid size vs 3D centroid size (Q2)

Results

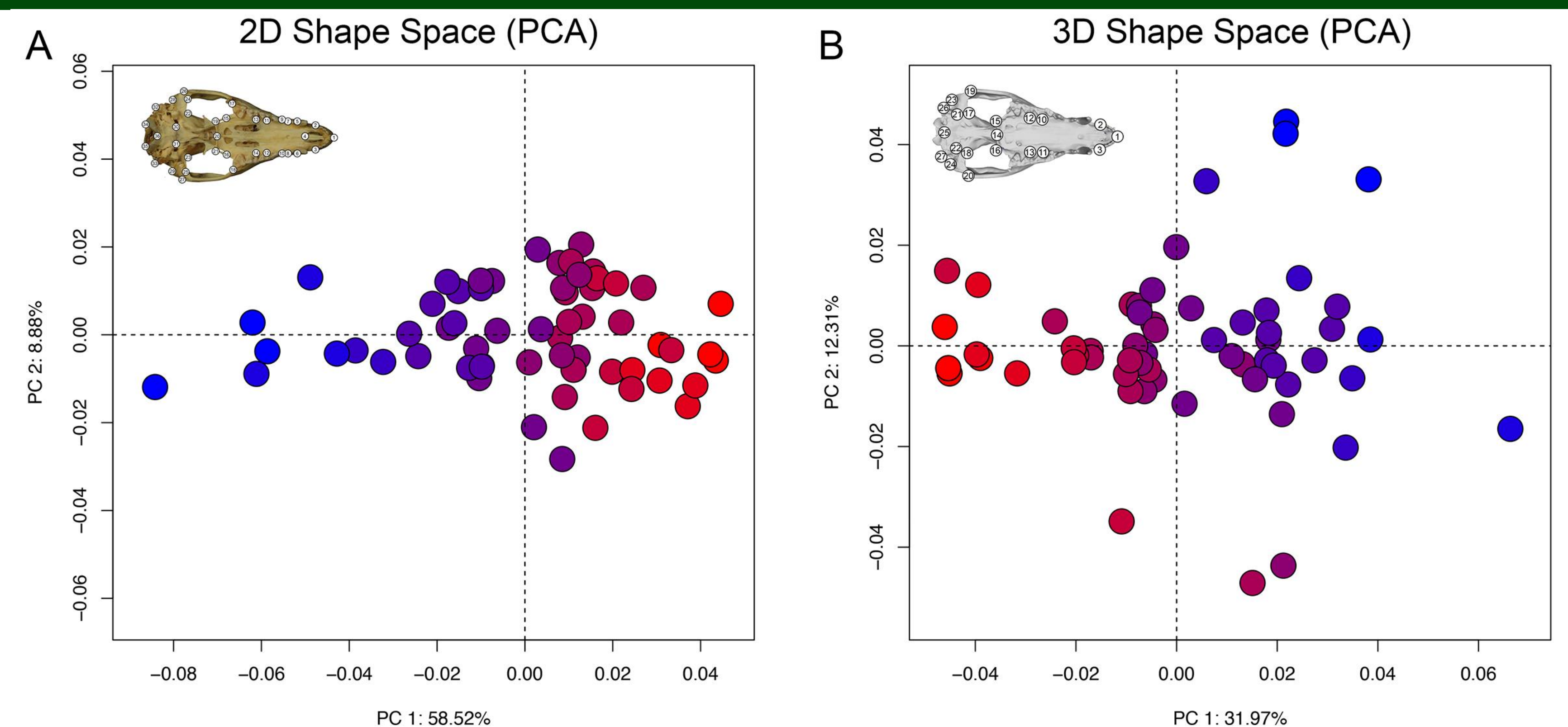


Figure 2: Principal Component Analysis (PCA) of possum crania in a (A) 2D shape space and (B) 3D shape space. Redder = larger individuals, Bluer = smaller individuals.

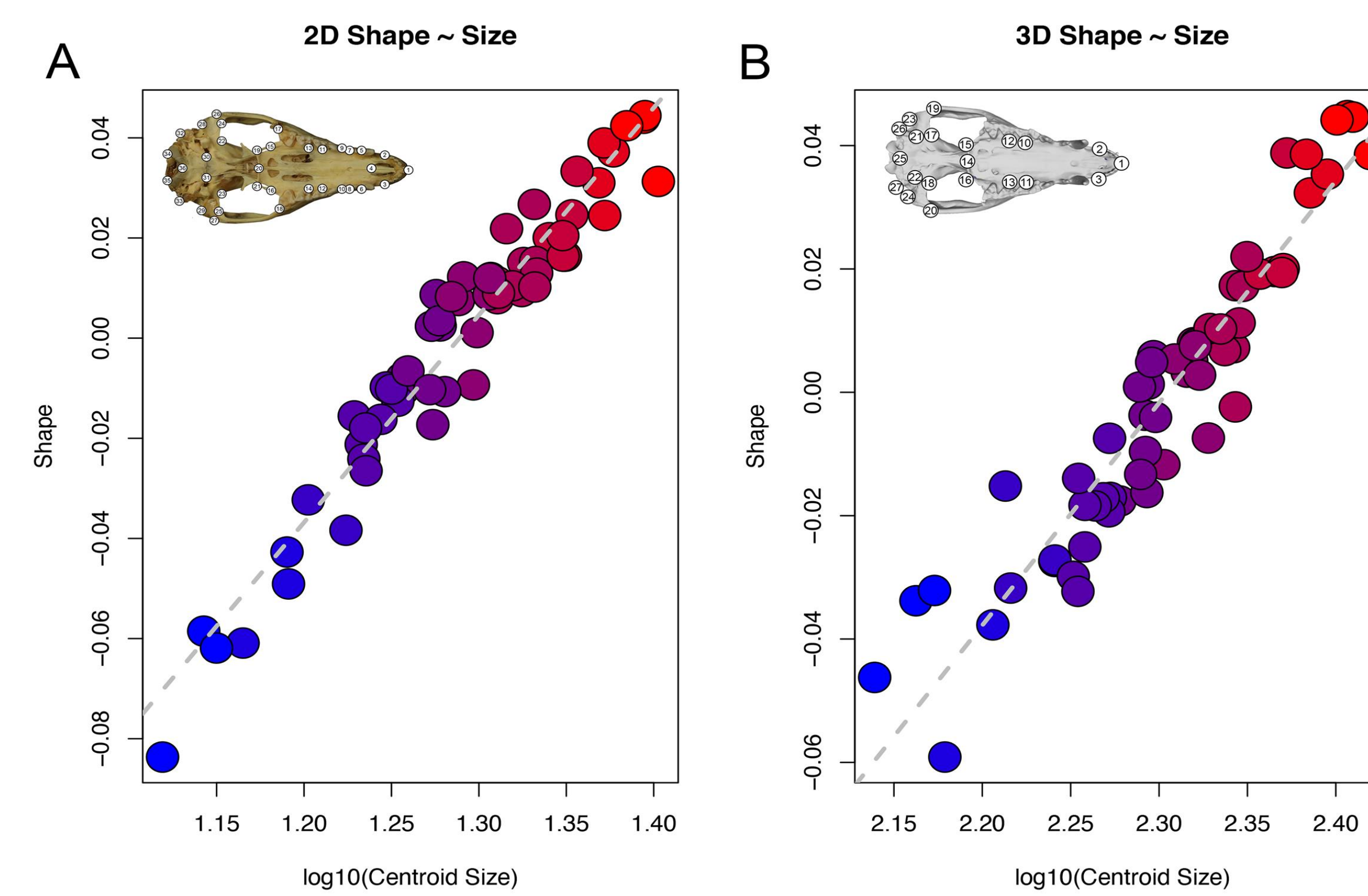


Figure 3: Shape vs size trends in (A) 2D crania in ventral view, and (B) 3D crania. Redder = larger, Bluer = smaller. Both 2D shape and 3D shape are strongly correlated with 2D size and 3D size respectively. However, the 2D data are more tightly clustered on the trend line than the 3D data, suggesting that shape is more correlated with size in 2D than 3D. This was also shown by the PCA data where PC1 is strongly associated with size in 2D and accounts for more than half of total shape variation. The variation is split between size and other shape factors in 3D.

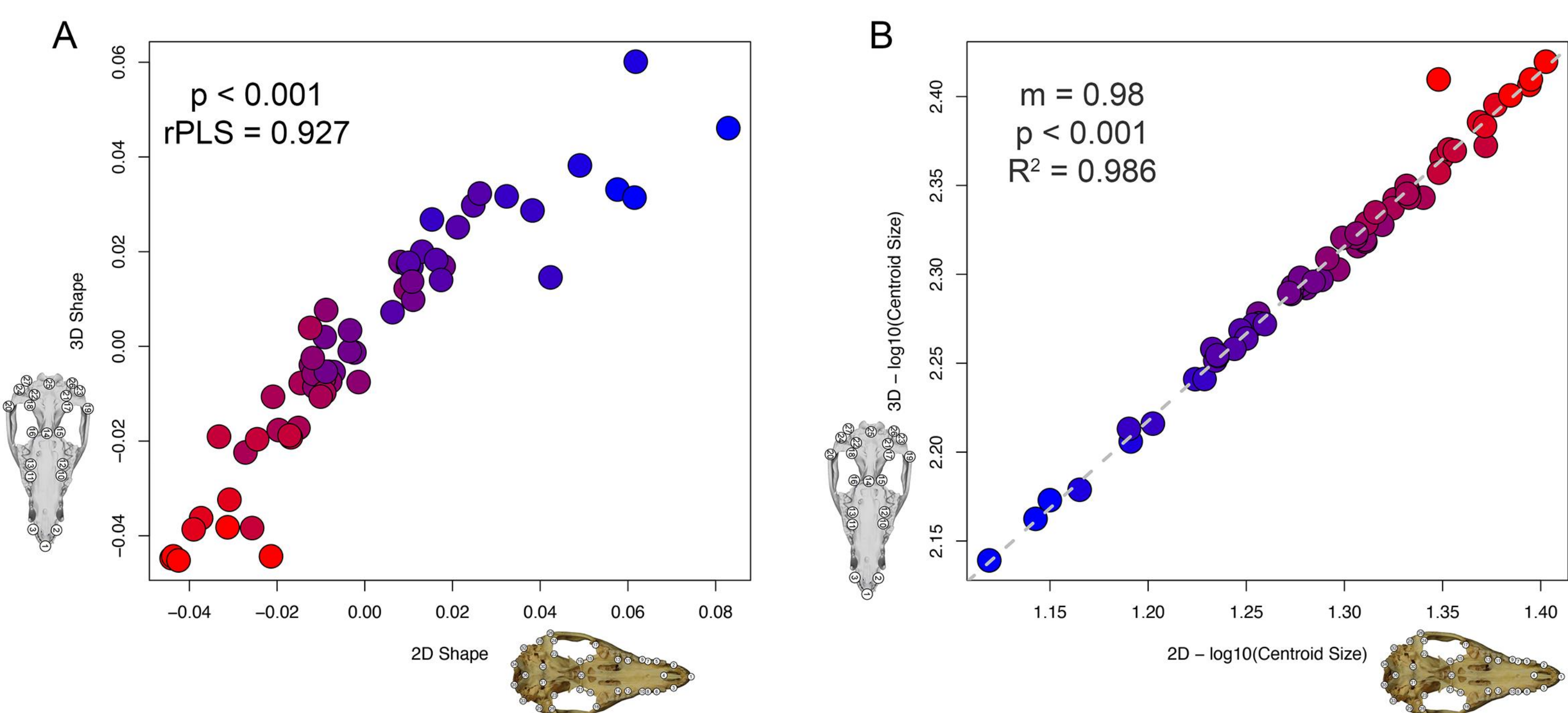


Figure 4: (A) PLS analysis of shape where 2D shape is on x-axis and 3D shape is on y-axis. These are strongly correlated. (B) Regression analysis of size where 2D size is on x-axis and 3D size is on y-axis. There is a very strong relationship.

Conclusions

The results from the PCA in Figure 2 indicate that the Z-dimension in 3DGM provides additional shape information that is not related to size. When comparing trends in shape vs size data in 2D and 3DGM respectively, the 2D trend is more linear compared to 3D suggesting that shape and size are more strongly correlated in 2D than in 3D. The PLS analysis (Figure 4a) shows that the 2D and 3D data are strongly correlated, suggesting that 2D may adequately capture 3D shape in Virginia opossums. Further, size in 2D and size in 3D are nearly perfectly correlated (Figure 4B).

FUTURE DIRECTIONS: In the future, we will collect additional 3D data using a different photogrammetric technique on the same sample and compare cranial shape captured using that technique to the 3D data we have collected here using laser scans, as well as to our 2D data.