

Regionalisation of cervical vertebrae in plesiosaurs

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Introduction

- Vertebral regionalisation of the axial column into cervical, dorsal, sacral and caudal regions is constant in all vertebrates and fundamental to their biomechanics.
- These regions are governed by hox genes, and have been found to possess secondary regions [1;2].
- Extant archosaurs and Aves have additional cervical regions, facilitating neck elongation.
- Plesiosaurs are an extinct group of marine reptiles which possessed some of the longest necks seen in any animal.
- This work assesses the cervical regionalisation in the cryptoclidid plesiosaur *Muraenosaurus leedsii*.



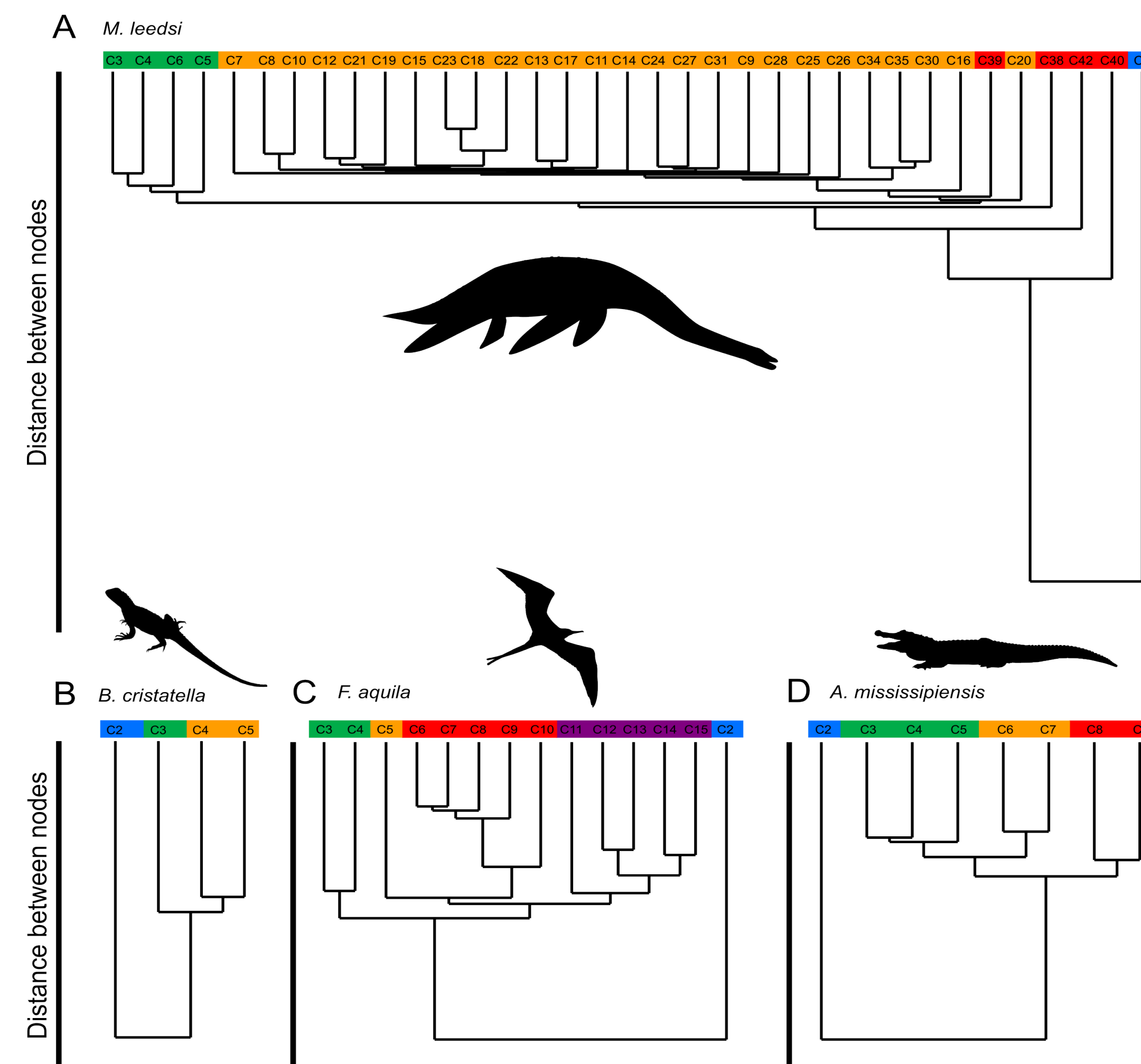
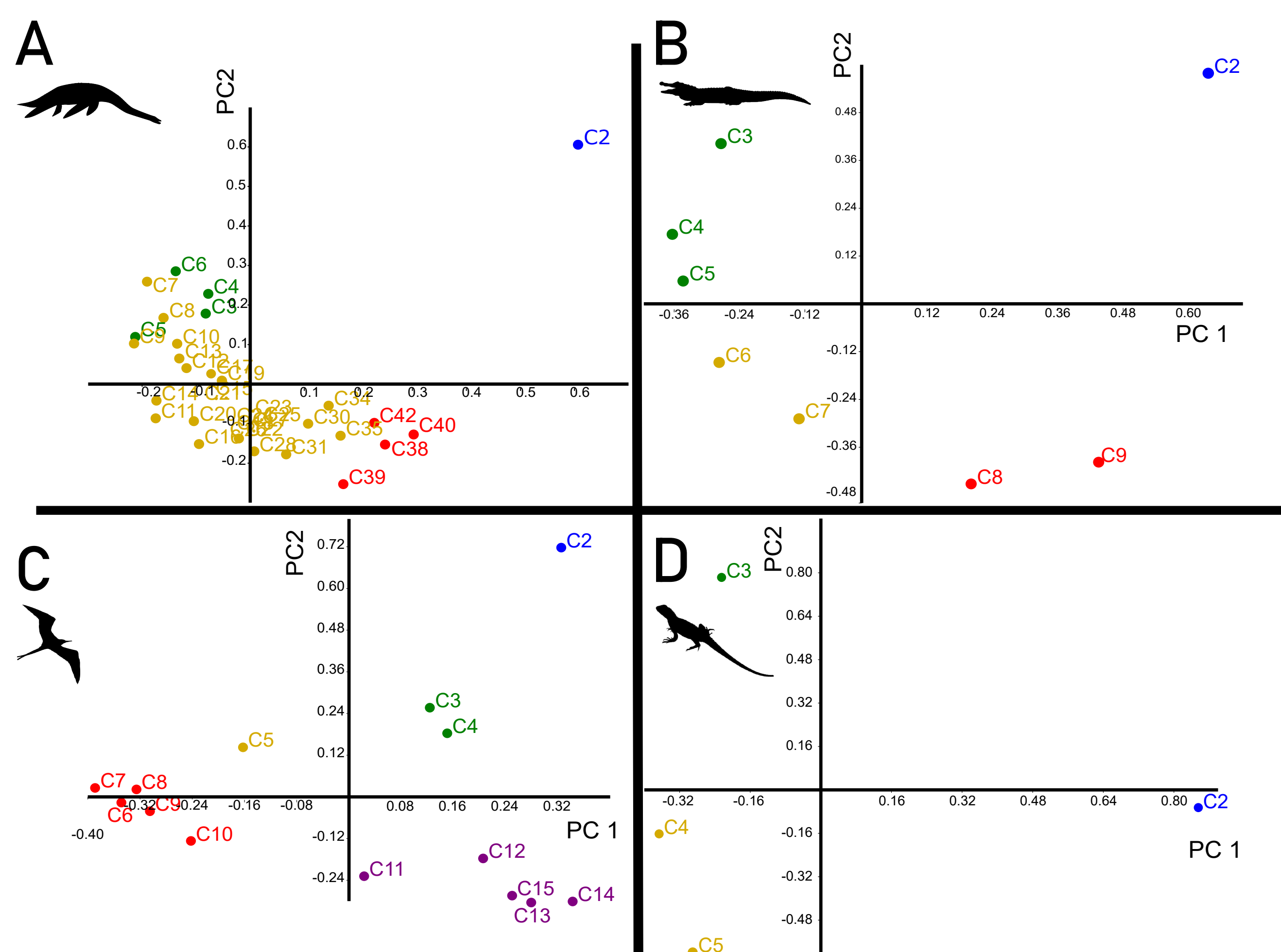
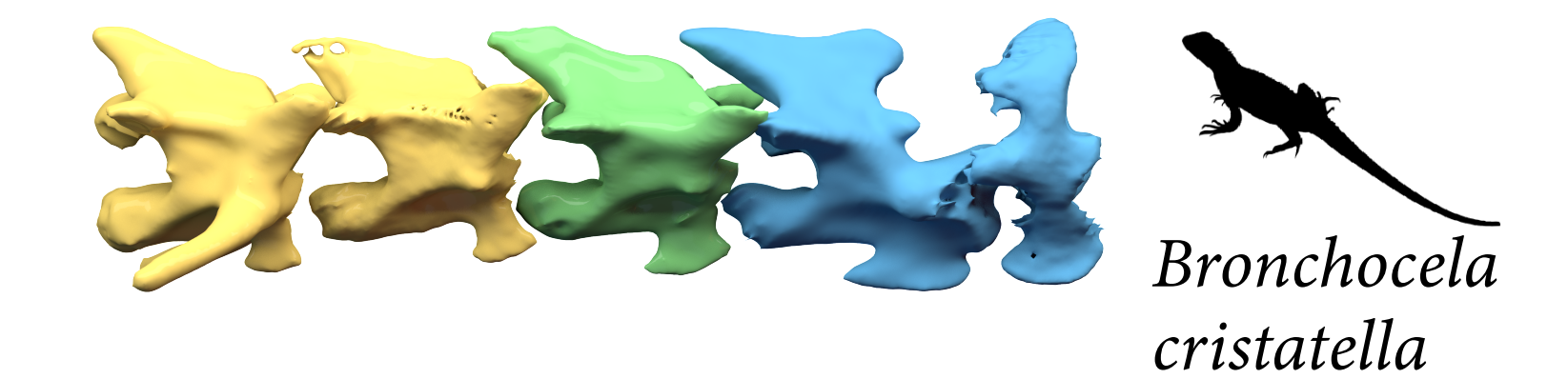
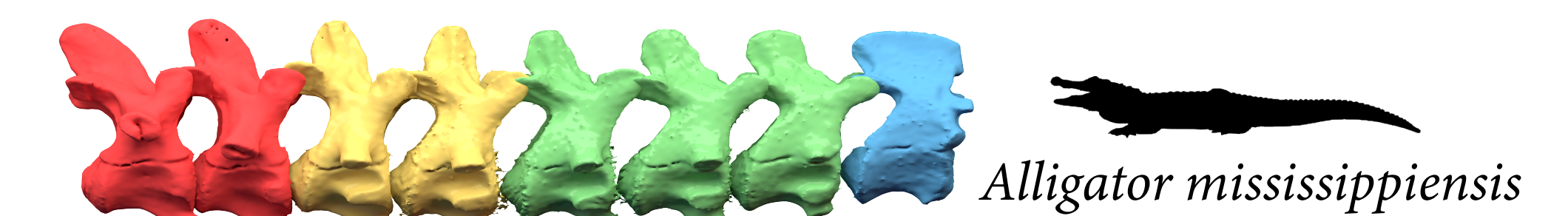
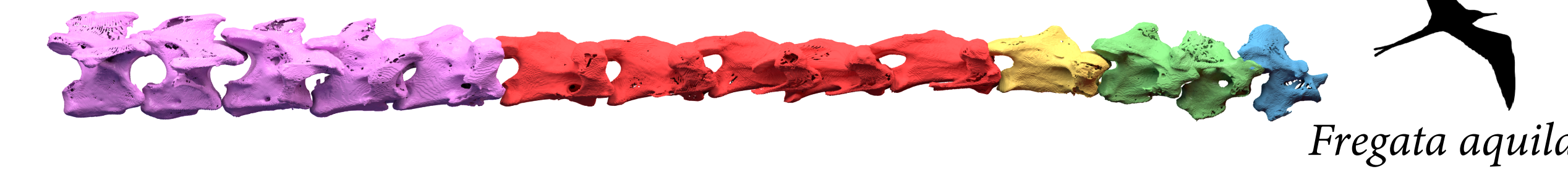
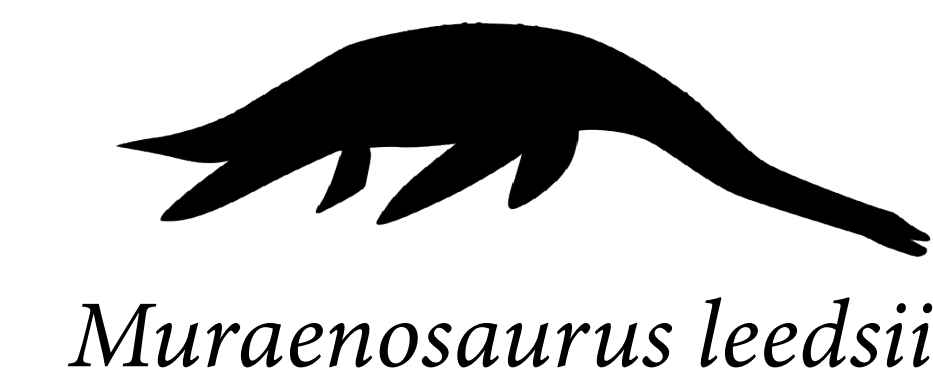
Methods

- Geometric morphometric analysis was used to assess the rationalization of *M. leedsii* along with seven extant taxa (including Crocodiles, Alligators, Birds and a lizard).
- Homologous landmark coordinates were placed on cervical vertebrae using Landmark 3.0.
- Previously established landmark coordinates and qualitative characteristics [1] were used.
- Coordinates were subject to principal component analysis in Morpho J, and qualitative characteristics were analysed in PAST 3.
- Partial preservation of *M. leedsii* vertebrae forced a reduced number of landmarks and prevented use of qualitative characteristics.

Results



Principal coordinates and cluster analyses of *M. leedsii* suggest 4 cervical regions are present, C2, C3-C6, C7-C37, C38-C42 (Fig. 2a; Fig 3a). PC1 represents changes in centrum length while PC2 represents changes in centrum height. Comparative taxa show similar trends in region defining anatomy (Fig 3+4). Region 1: blue, region 2: green, region 3: yellow, region 4: red and region 5: purple. Regions colours do not suggest homology between species.



Discussion and Conclusions

This study suggests that:

- The plesiosaur *M. leedsii* possessed four cervical regions, one more region than the basal cervical format (3 regions).
- Much of the neck elongation occurs in region 3, although without additional analyses it cannot be confirmed which region is novel to plesiosaurs.

Plesiosauria is a large clade exhibiting a disparate cervical vertebral count between species (16 to 76), therefore, we might expect to see different region numbers and sizes in other plesiosaur species, though the consistency among extant birds (5 regions) and crocodilians (4 regions) suggests 4 regions may be common to all plesiosaurs. It is currently unclear if the vertebrae comprising the expanded region 3 increased flexibility, or if the increase in this region's size was purely to extend the neck.

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References:
[1] Böhmer, C., Rauhut, O. and Worheide, G. (2015). Correlation between hox code and vertebral morphology in archosaurs. *Proc. R. Soc. B.* [2] Buchholtz, E. and Stepien, C. (2009). Anatomical transformation in mammals: developmental origin of aberrant cervical anatomy in tree sloths. *Evolution & Development*, 11(1), pp.69-79.