A morphometric analysis of wing shape variation among Grouse (Aves: Tetraoninae).

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Introduction

The shape of the wing varies significantly among birds. These evolutionary changes in wing shape are directly related to aerodynamics such that wing shape and size varies with flight behaviour across species. For most birds, flight is of central importance to successful niche exploitation (e.g., locomotion, migration, foraging, territorial and courtship displays) and, as a result, a diverse array of wing shapes have evolved. Here, we use a combination of traditional and geometric morphometrics to examine interspecific variation in wing shape among grouse (Aves: Tetraoninae).

Hypotheses

We predicted that wing shape would reflect habitat preference. Additionally, we predicted that species which rely heavily upon the wings for courtship (i.e., Ruffed Grouse) will differ significantly in wing shape from closely related species.

Figure 1. Images representing species from each genus. From left: Spruce Grouse, Ruffed Grouse, Sharp-tailed Grouse, Sage Grouse, Willow Ptarmigan, Western Capercaillie. Scan QR code 1 (left) for supplementary YouTube videos.

Methods & Results

Traditional Morphometrics (TM)

Measurements were taken directly from spread wing specimens in the Burke Museum of Natural History (Seattle, WA) collection. Each spread wing was articulated with the leading edge fully extended, preserved in a natural flight position (Figure 2). Linear measurements (i.e., aspect ratio, primary feather length) were taken directly from spread wings using digital hand calipers. In addition to linear measurements, each spread wing was also photographed in the dorsal (e.g., surface area, porosity) and anterior (e.g., camber) position. Principal component analysis (PCA) was used to examine primary feather lengths and ANOVAs performed for each measurement with genus, species and sex as main effects.

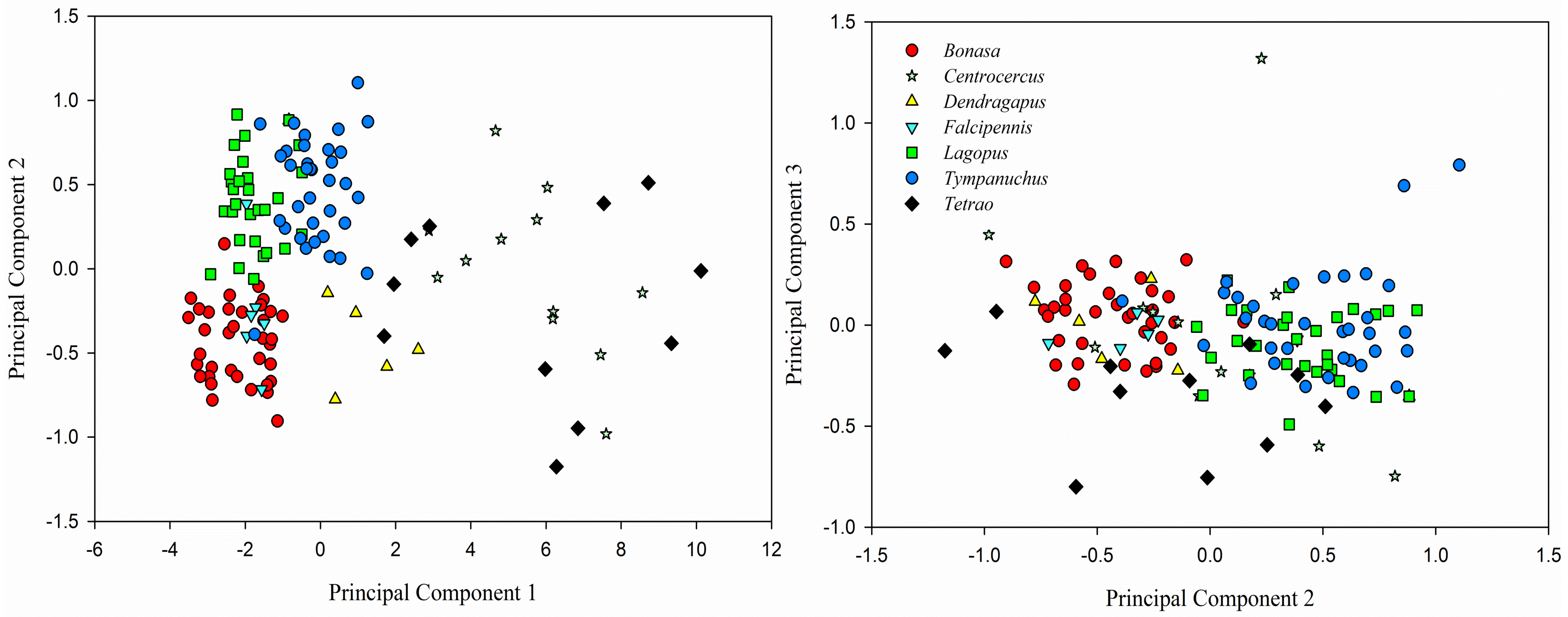


Figure 2. Scatterplots of principal components derived from a principal component analysis of primary feather lengths.

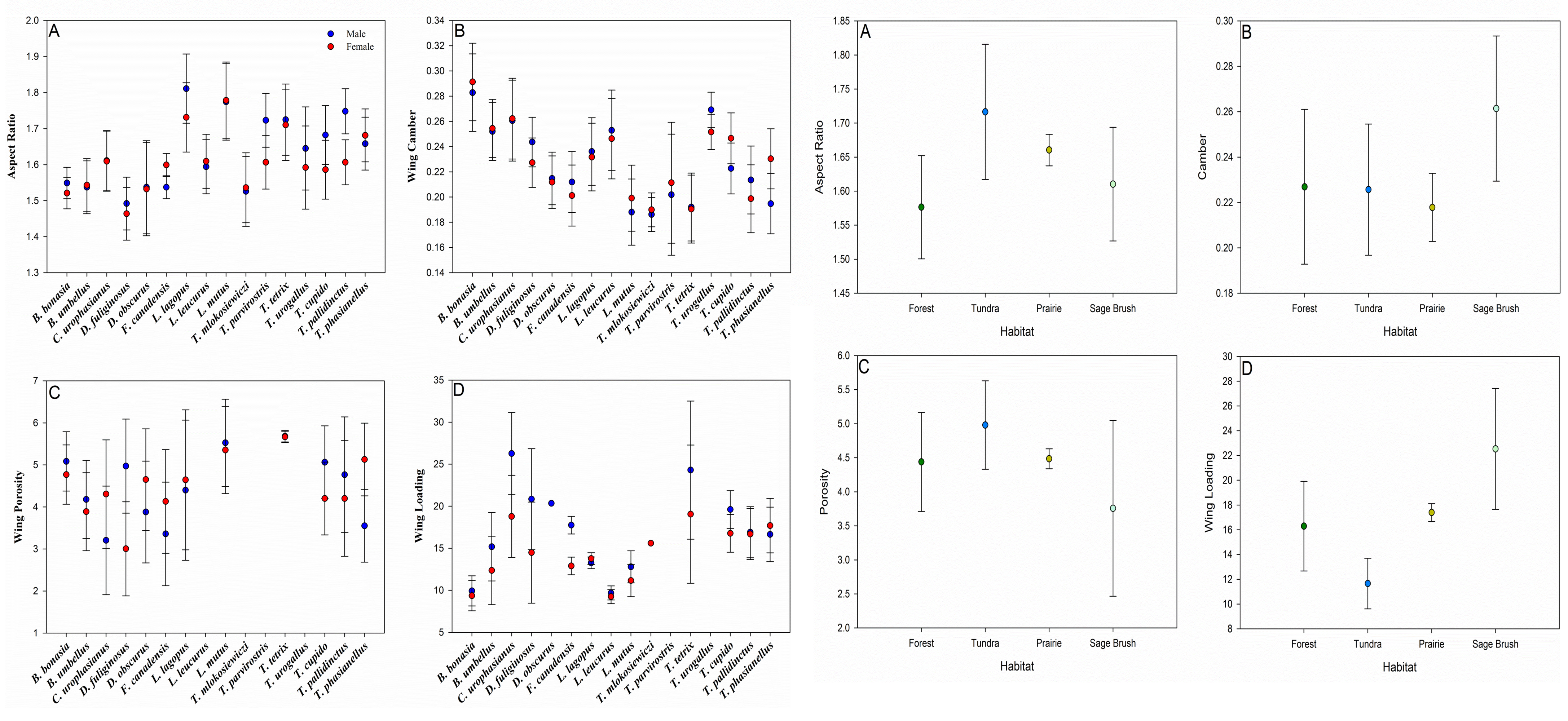


Figure 3. Box plots showing averages of morphometric measurements grouped by species (left) and habitat type (right): A) average aspect ratio, B) average wing camber, C) average wing porosity, D) average wing loading; error bars indicate +/-standard deviations.

Methods & Results

Geometric Morphometrics (GM):

Wing shape variation was also compared across species using 2D landmark based geometric morphometrics via generalized Procrustes analysis (hereafter GM). Landmarks (LM) and curves were placed onto digital photos of spread wings. A configuration of 26 LM (Fig. 4) was examined in MorphoJ (1.05a) via GM. Covariation matrices were generated from Procrustes coordinates and then used in principal component (PCA) and canonical variate analyses (CVA) of Procrustes distances in MorphoJ.

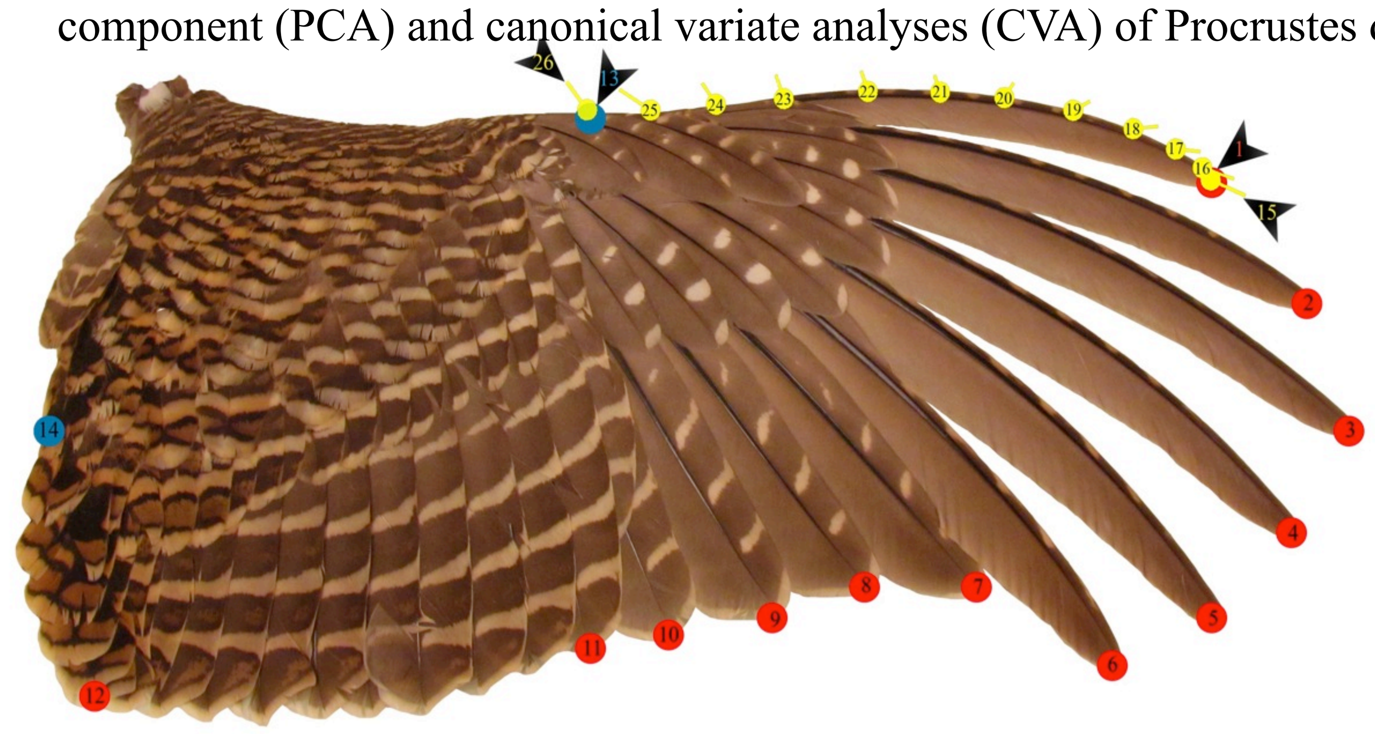


Table 2. P-values from permutation tests of Procrustes distances among genera.

	Bonasa	*Centrocercus*	*Dendragapus*	*Falcipennis*	*Lagopus*	*Tympanuchus*
Centrocercus	0.0082					
Dendragapus	0.0340	0.1410				
Falcipennis	0.0059	0.1906	0.5649			
Lagopus	<0.0001	0.0118	0.0028	0.0565		
Tympanuchus	<0.0001	0.0010	0.0128	0.2404	<0.0001	
Tetrao	<0.0001	0.0144	0.3406	0.2262	<0.0001	0.0119

Figure 4. On the left, a spread wing of a lesser prairie chicken (*Tympanuchus cupido*) with the 26 landmarks used in the GM analysis shown in red (Type 1), yellow (Type 2) and blue dots (Type 3).

Figure 5. Below, a scatterplot of canonical variates 1 and 2 derived from a canonical variate analysis of Procrustes distances among the landmarks (Fig. 4). The transformation grid graphs derived from CV1 of Procrustes distances for each genus surround their species' respective quadrant.

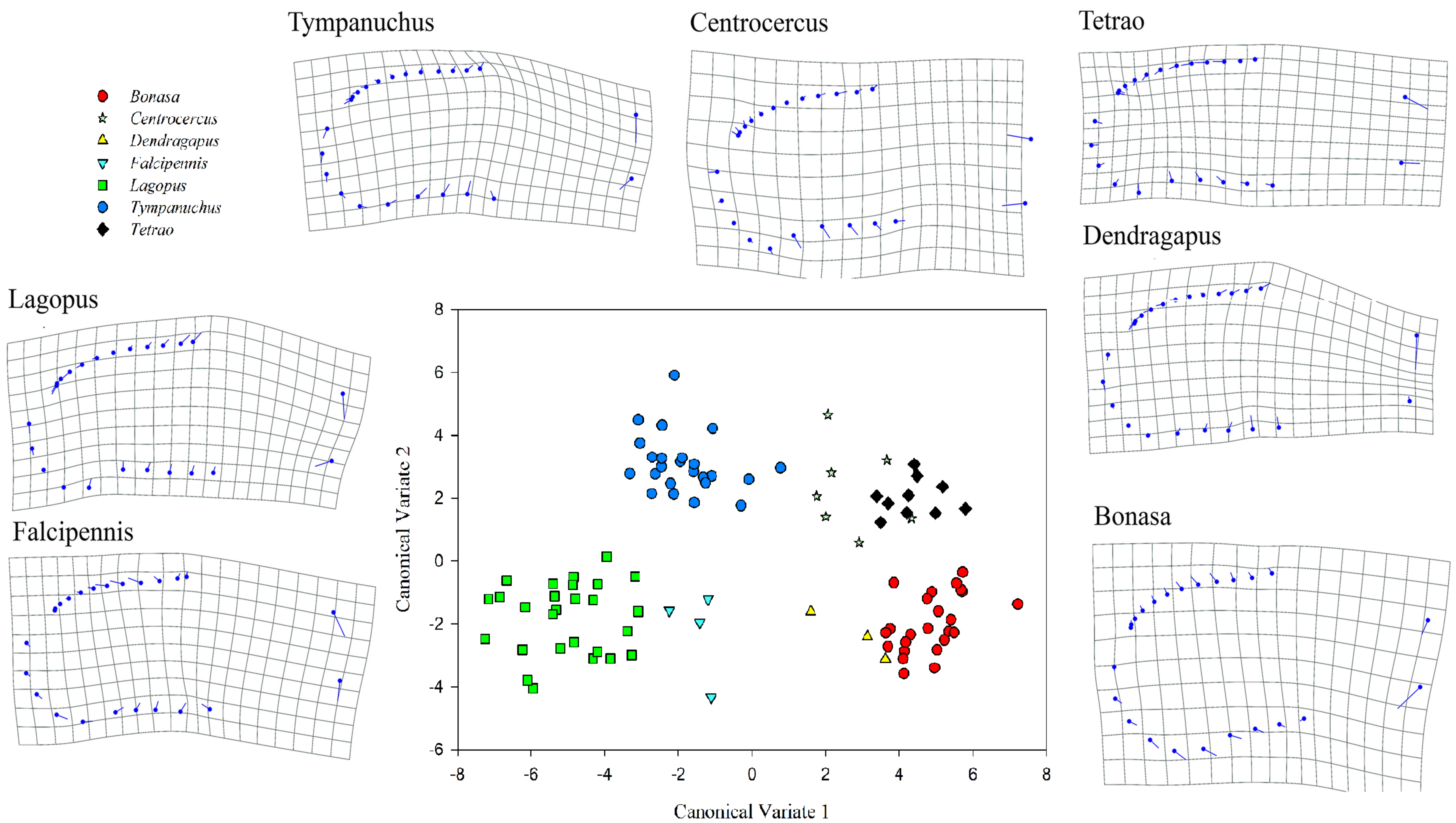
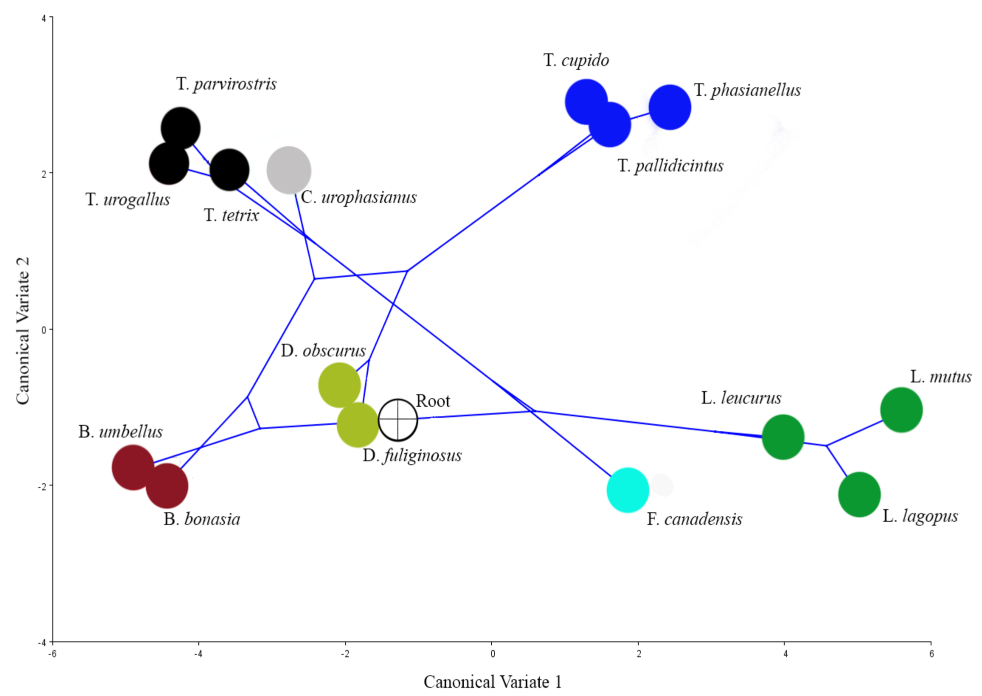


Figure 6. Grouse phenogram built using unweighted squared-change parsimony method, based on CV scores derived from Procrustes distances. The locations of species correspond to the first two CVs of shape variation among genus means. The open circle near coordinates (0, 0) indicates the root of the phenogram.



Conclusions

1) PCA of primary feather lengths differentiated genera
2) Aspect ratio, camber and porosity differed significantly among species and between sexes, but only aspect ratio was significantly different across habitats.
3) GM analyses yielded significant differences in wing shape among genera.
4) GM analyses also yielded significant differences among prairie, forest, sagebrush and tundra species.
5) Wing shape of Ruffed Grouse differs significantly from other grouse species (see QR1).

Acknowledgements

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