PRELIMINARY ANALYSIS OF BAT WING MORPHOLOGY USING CT DATA

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Introduction

Aspect ratio (AR) is a measure of the length and width of a wing (see Fig. 1), and is used to describe aerodynamic efficiency for flight. In animals with powered flight, aspect ratio is often used to describe wing morphology, and is correlated with species ecology (Aldridge and Rautenbach 1987). Previous studies in bats have manually measured or used radiography to collect data from wings (Swartz and Middleton 2007). However, this study leverages three-dimensional (3D) digital data to assess bat wing morphology and will be the first study to collect aspect ratio in this manner.

Questions:
- **Do phylogenetic relationships predict bat wing morphology and aerodynamic efficiency?**
- **Does bat wing morphology (specifically AR) affect species ecology?**

Project Goals:
- **Select specimens for representative taxa of the bat phylogenetic tree.**
- **Obtain 3D osteological data of each specimen using micro-computed tomography (µCT) scanning.**
- **Segment individual bat wing bones and collect measurement data using VGSTUDIO MAX 3D-visualization software.**
- **Calculate AR and map data onto existing bat phylogenies to determine if there are family level differences.**
- **Assess if any differences correspond to ecological behaviors such as feeding, diet, migratory patterns, etc.**

$$AR = \frac{b^2}{S} = \frac{b}{SMC}$$

Figure 1.—The equation used to calculate AR where *b* is span, *S* is wing area, and *SMC* is standard mean chord.

Materials & Methods

- **Whole-body, fluid-preserved specimens were selected from the mammal collection of the University of Michigan Museum of Zoology (UMMZ). Specimens from 16 of 19 extant bat families were examined in this study.**
- **To increase sampling and account for within family variation, two species (if available) from each family were scanned.**
- **All specimens were scanned on a Nikon XT H 225 ST µCT scanner.**
- **Scanning parameters: 85 kilovolts, 200µ-amperes, 250 millisecond exposure time, and 1601 radiograph images at 2x frame averaging.**
- **Raw datasets were reconstructed in CT 3D Pro (Nikon, USA).**
- **All scans were rendered into 3D models using VGSTUDIO MAX.**
- **To calculate AR, length measurements were taken from the humerus, ulna, radius, and digits 2-5 on both the left and right wing (See Fig. 2). Wing measurements were also taken in VGSTUDIO MAX. AR will be calculated for each specimen using these measurements.**

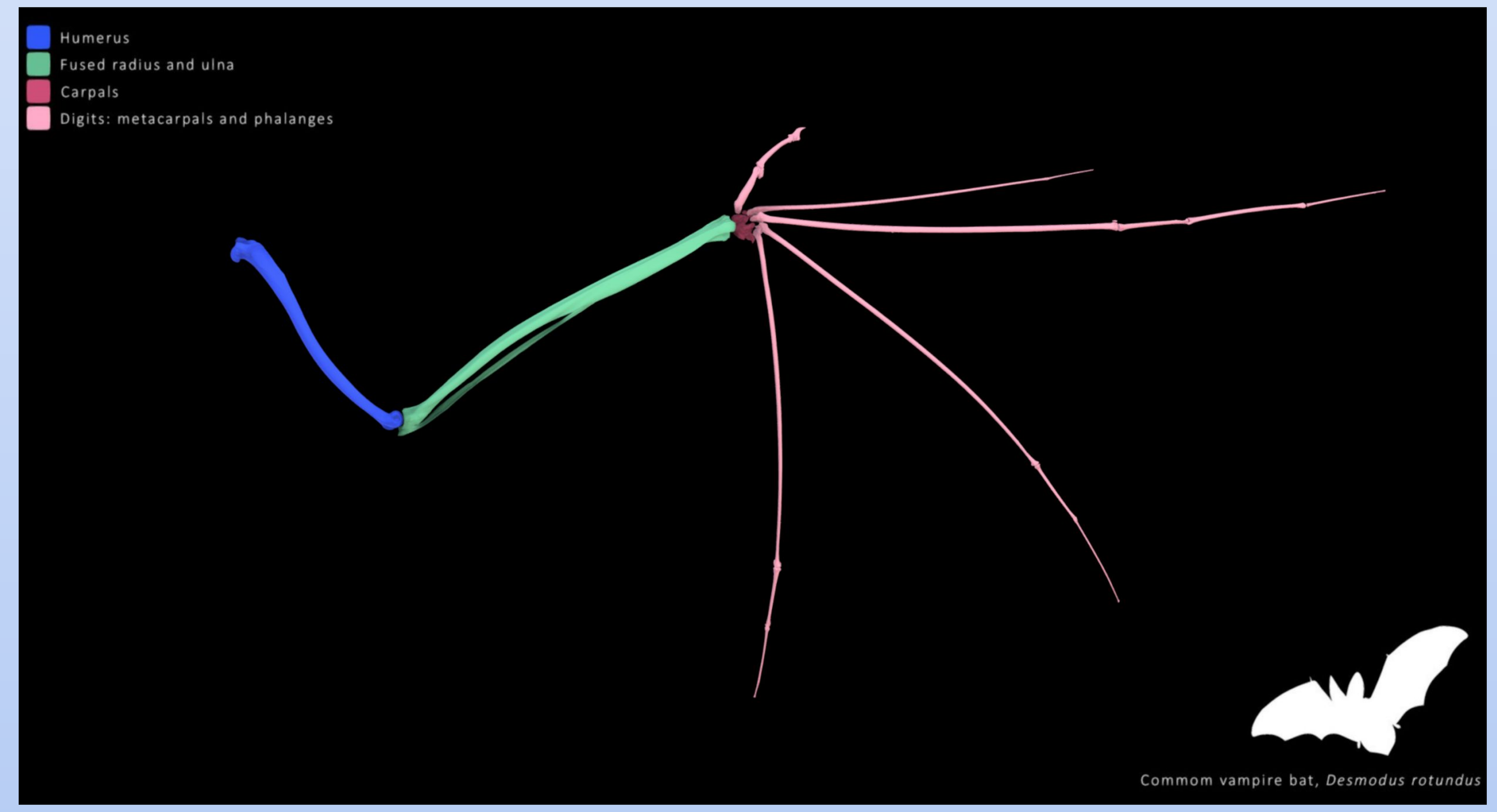

Figure 2.—Measurements were taken of the humerus (blue), radius and ulna (green), and digits (pink). See Table 1 for all specific measurements, including those belonging to individual phalanges.

Table 1.--Raw wing bone measurements of representative species selected from 16 bat families. Measurements in orange are the largest per element, and measurements in purple are the the smallest per element.

Family	Species	Humerus (mm)	Radius (mm)	Ulna (mm)	2nd Digit (mm)	3rd Digit (mm)	4th Digit (mm)	5th Digit (mm)
Emballonuridae	*Taphozous phillipinensis*	36.6	59.2	29.42	51.71	95.55	62.51	51.65
Furipteridae	*Furipterus horrens*	18.97	34.92	**9.77**	28.18	54.17	42.84	42.67
Hipposideridae	*Hipposderos diadema*	42.74	71.05	27.02	62.31	107.73	86.64	83.3
Megadermatidae	*Megaderma spasma*	27.39	50.04	20.65	44.05	86.16	66	67.71
Molossidae	*Cheiromeles torquatus*	51.28	71.61	50.64	**68.91**	**159.35**	**135.16**	76.62
Mormoopidae	*Mormoops megalophylla*	33.4	51.17	15.01	48.19	95.02	68.12	59.69
Mystacinidae	*Mystacnia tuberculata*	21.62	37.64	14.14	34.14	65.78	58.03	49.52
Natalidae	*Natalus stramineus*	21.27	35.32	14.42	36.37	71.42	52.95	49
Noctilionidae	*Noctilio albiventris*	30.29	56.75	22.22	52.3	102.31	83.23	62.33
Nycteridae	*Nycteris thebacia*	21.06	41.12	12.43	35.6	77.16	58.24	59.21
Phyllostomidae	*Phyllonycteris poeyi*	28.67	44.75	21.66	37.12	73.88	60.55	59.76
Pteropodidae	*Rousettus amplexicaudatus*	**45.84**	**74.55**	**52.79**	46.18	121.76	100.4	**93.25**
Rhinolophidae	*Rhinolophus cornutus*	22.97	37.34	10.88	30.62	53.08	46.7	47.08
Rhinopomatidae	*Rhinopoma hardwickii*	24.02	44.24	21.98	36.26	**49.27**	**42.65**	43.12
Thyropteridae	*Thyroptera tricolor*	17.66	33.98	11.25	**9.27**	57.05	45.91	42.47
Vespertilionidae	*Glischrops tylops*	**16.96**	**25.07**	12.07	24.66	51.07	43.47	**39.83**

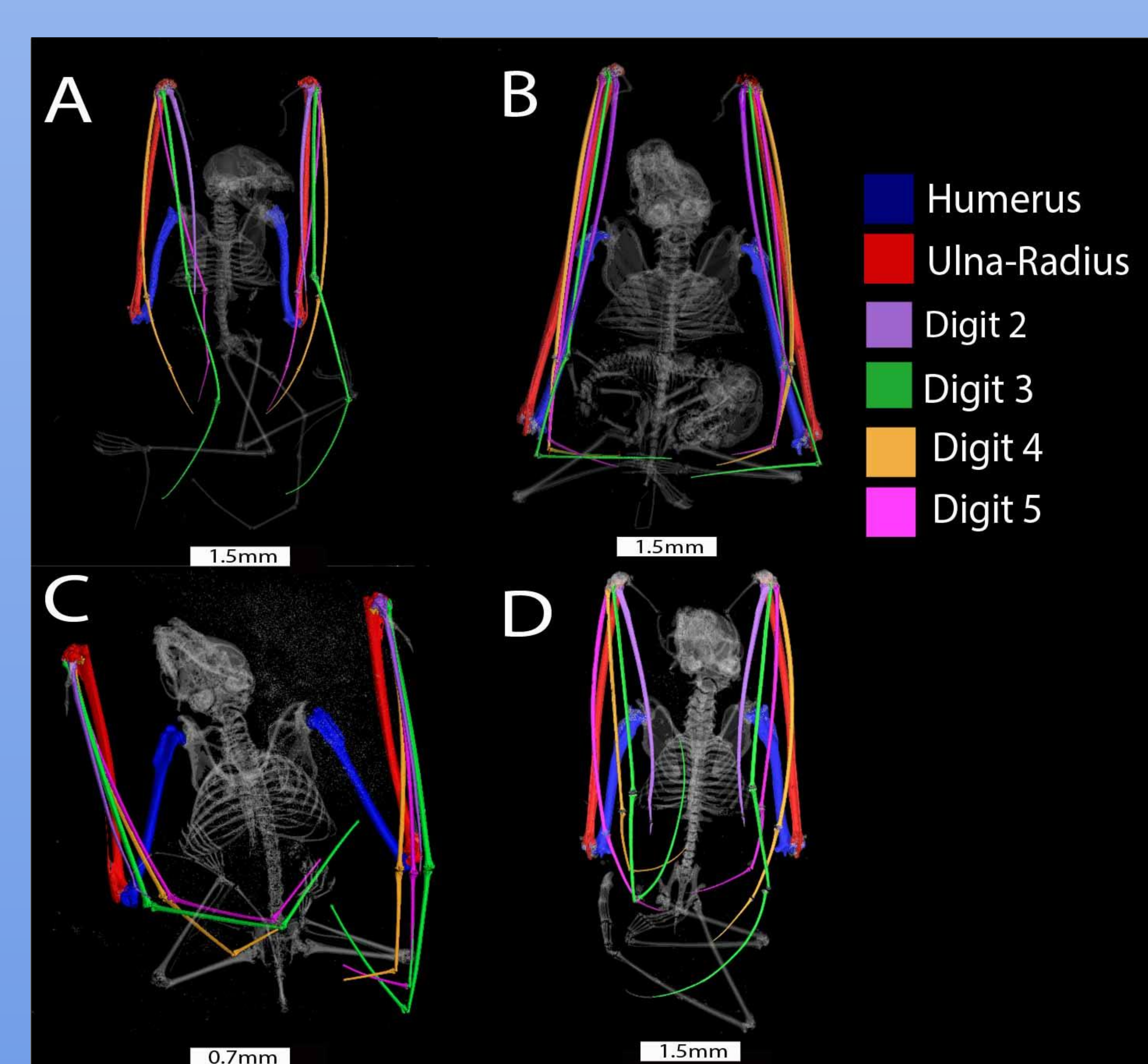

Figure 3.—Three-dimensional renderings of A) *Nycteris thebaica*, B) *Rhinolophus cornutus*, C) *Glischrops tylopus*, and D) *Megaderma spasma*. Highlighting indicates wing bone elements measured for this study.

Preliminary Results

- **24 specimens representing 24 species and 16 bat families have been scanned using µCT.**
- **21 of 24 specimens have been segmented with VGSTUDIO MAX.**
- **Complete wing bone measurements have been obtained from 16 species.**
- **Raw data for 16 species are presented in Table 1.**

Discussion

Although AR has not been measured for each specimen that has been scanned, our available measurement data suggests family-level variation in bat wing morphology. Additional data from the other species measured will provide more insight, as well as account for size variation of individual species. This additional information also will aid in determining any phylogenetic signal in bat wing morphology.

Future Directions

To complete the study, segmenations will be completed for the three remaining specimens, and measurement data will be obtained from the remaining eight specimens. AR will be calculated for all species examined, and will be used to assess taxonomic differences. If possible, additional specimens will be selected to complete taxonomic sampling for all 16 bat families.

Literature Cited

1. Aldridge, H.D.J.N., and I.L. Rautenbach. 1987. Morphology, echolocation and resource partitioning in insectivorous bats. Journal of Animal Ecology 56:763–778.
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Acknowledgments

Thank you to the University of Michigan Undergraduate Research Opportunity Program and the National Science Foundation for funding. Thanks also to Katy Frank, Lexi Frank, Michael Lyons, Shion Otsuka, and Rumaan Malhotra for helpful comments on this presentation. Finally, thanks to Alison Davis Rabosky for access to VGSTUDIO MAX workstations.