Introduction

Shrews (Mammalia: Soricidae) occupy a wide range of locomotory behaviors including climbing, swimming, and burrowing. Within the sister genera Blarina and Cryptotis, primary locomotory behaviors are ambulatory (running) and fossorial (burrowing). These two locomotory modes are facilitated by anatomical specializations, such as broad, robust bones, reoriented muscle attachment sites, and rotational moments (Woodman and Stabile, 2015). Banfield (1974) stated B. breviceuda is the most fossorial American shrew, but how does B. breviceuda and other Blarina species’ anatomical specializations compare to the skeletal modifications of other known burrowers like Cryptotis? To assess the degree of burrowing capability present in different shrew species we examined postcranial morphology with PCA and mean percentile ranking.

Materials and Methods

We measured 71 individuals representing 4 species of the genus Blarina. Due to their size (Fig. 1), individual bones are difficult to handle and precisely measure. We used photographs of postcrania (Fig. 2) and x-ray imaging (Fig. 3) to overcome this challenge. We used a Kevex X-Ray Source and Varian Image Viewing and Acquisition software (VIVA) in the Division of Fishes to obtain images of the fore and hind feet from skin specimens (Fig. 4). ImageJ scientific photo analysis software (Schneider et al., 2012) to measure the rays and postcraniaal bones (humerus, femur, tibiofibula, radius, ulna; Fig. 5). Measurements (mm) were recorded to the nearest 0.01 mm. These measurements were then used to create 33 indices that describe different aspects of functional anatomy related to locomotory behavior. These indices were compared to similar measures from 14 species of Cryptotis reported by Woodman and Gaffney (2014). We combined these indices to analyze morphological variation related to digging ability in two ways: (1) we carried out principle component analysis (PCA) of the 33 indices and interpreted the first factor axis as a relative scale of fossorial adaptation (Fig. 6); (2) we calculated mean percentile ranks for each species and used those ranks as a scale of digging ability (Fig. 7).

Results

Blarina and Cryptotis show varying degrees of morphological specialization and functional capacity. The mean percentile rank scale (Fig. 7) and the PCA Factor 1 scale (Fig. 6) show a gradient in burrowing modifications and provide superficially similar results. The 4 species of Blarina cluster tightly along both the percentile rank and PCA Factor 1 scales. In both graphs, Blarina is an intermediate between two functional groups of Cryptotis, a group that show considerable modifications for fossorial and ambulatory behaviors, respectively. Interestingly, the two spectra are not completely identical. While functional groups tend to stay in fixed places along the two graphs, the order of individual species within these groups is less static.

Discussion

Our anatomical investigation of Blarina and Cryptotis postcranial revealed three discrete groupings based on the functionality of the humerus, manus, and other postcranial elements that facilitate fossoriality of North American shrews. Adding taxa to the mean percentile rankings creates a continuous spectrum of fossoriality. Broader, more robust humeri and rays are better modified for the mechanics of fossoriality, which requires greater bending resistance and target muscle forces. Gross observations of Blarina humerus morphology and PCA of Blarina indicate its species are all very similar with no extreme modifications for either classical ambulatory behavior or fossorial bavior. This contrasts with the sample of Cryptotis (Fig. 3), some of which show broad, robust anatomical features that are hypothesized to aid in fossorial behavior, others of which align more closely with the functional modifications observed in Blarina, and others that appear to be more adapted for ambulatory behavior. We hypothesize the variation between the PCA Factor 1 graph and mean percentile rank graph suggests that species more modified for fossoriality are not obligated to perform this behavior and species less modified for fossoriality are still able to burrow, establishing gradients within the three different clusters and broader spectrum among all the sampled taxa.

Conclusions

- There is variation between features associated with fossoriality and mean percentile ranking of fossorial capacity. PCA illustrate isolated groupings of fossorial adaption, while mean percentile ranking demonstrates a spectrum of fossorial ability.
- More postcranial anatomical variation is present within Cryptotis than between Cryptotis and Blarina.
- Blarina exhibits little morphological variation, but does show a slight morphological and functional gradient.
- B. breviceuda is not the most fossorial North American shrew.

Acknowledgements

We would like to thank Elizabeth Cottrell, Gene Hunt, and Virginia Power for coordination and assistance of the NHRE program, Rilla McKeegan for aesthetic guidance and proofreading, and Ian Ocampo for moral support. Funding was provided by the National Science Foundation Grant 1560088.

References


Woodman, Alec T. Wilken, and Neal Woodman 2

1 University of Missouri-Columbia, Columbia, MO, 2 USGS Patuxent Wildlife Research Center, National Museum of Natural History, Smithsonian Institution, Washington, D.C.