American deer: Morphometrics and taxonomy of the Mazama americana species complex (Mammalia: Cervidae)

Amy R. Rutter1,2, Eliécer E. Gutiérrez2, and Kristofer M. Helgen2
1Pennsylvania State University, University Park, PA; 2National Museum of Natural History, Smithsonian Institution, Washington, DC

Introduction
Neotropical deer (Cervidae: Capreolinae) are among the least-studied large mammals in the world despite being heavily hunted in many countries that lack proper management plans. Together with the genus Odocoileus, Mazama, which is widely distributed from Mexico to Brazil, is one of the most taxonomically complex genera of the tribe Rangiferini. Molecular studies have shown that the genus Mazama is not monophyletic and has extreme molecular and chromosomal variability1–2, indicating the need for taxonomic work at both the genus and species levels. In this study we investigated the morphological variability of species in the Mazama americana complex and discuss its taxonomic implications.

Methods
We assessed the morphological variability of the genus Mazama using linear morphometrics. We took sixteen cranial measurements from 185 specimens (Fig. 1). Measurements followed or were adapted from previous studies3–5. The analyses (see below) were based on data from adult specimens (i.e. those having complete dentition). Missing data (e.g. resulting from partially broken bones) were estimated using the average for the corresponding measurement of specimens of the same sex, taxon, and locality. The raw data was transformed utilizing the natural logarithm before analyses.

Based on the resulting dataset, we conducted a cluster analysis (CA) and a principal component analysis (PCA). Because previous studies did not find significant differences between males and females5, we combined data from both sexes for these analyses. The CA was conducted based on Euclidian distances; the PCA was conducted based on the correlation matrix to avoid artificial inflation of the variance in any particular variable.

Results
For the Mazama americana species complex, our analyses identified two large groups of specimens that differed mainly in size. Examination of the loadings derived from the PCA showed that the first component (PC 1) largely captured differences in size and explained 84.22% of the variation among analyzed specimens (Table 1). A bivariate plot of specimens’ scores for PC 1 and PC 2 showed separation of taxa (Fig. 2). Mazama americana specimens were the largest in our dataset, and M. temama and M. pandora the smallest.

The CA produced similar separation, identifying two major clusters. The first includes Mazama: cf. zetta and M. americana, and the second includes M. zamara and M. pandora (Fig. 3).

In both analyses we found a few specimens provisionally assigned to Mazama americana that were atypically small for that species. Mazama zetta, M. whiteleyi, and M. americana canidens were found embedded in clusters with M. a. sheila, M. a. americana, and M. temama, respectively.

Discussion
The results of our morphometric analyses have taxonomic implications. The specimens provisionally assigned to Mazama americana embedded in several clusters across the phenogram demonstrates the urgent need for a comprehensive taxonomic revision in this group. Despite this, our results yielded some broad patterns of variability relevant to taxonomic issues. Mazama zetta—a taxon traditionally treated as a synonym of M. americana—was found to be morphometrically distinctive. Similarly, our results support the recognition of Mazama temama at the species level. This species was previously considered a synonym of Mazama americana and raised to the species level based mainly on morphological data. In contrast, our results provide modest evidence against the recognition of Mazama whiteleyi—recently elevated to the species level by Groves and Grubb (2011)—as the single specimen analyzed was embedded within a large cluster of M. americana.

Future Directions
Our results showed similar morphologies between Mazama temama and two forms traditionally assigned to M. americana (sheila and rufa). Future studies should reevaluate the taxonomic status of these taxa. Our results and additional side-by-side comparisons of qualitative cranial traits did not reveal differences between two specimens identified in the USNM collection as Mazama americana from Venezuela and three specimens of M. zetta from Colombia. Consequently, we consider that all of these specimens are conspecific and likely correspond to M. zetta, which occurs in the inter-Andean valleys of Colombia. This remains to be confirmed via comparisons with typical material of M. zetta, in which case those specimens would represent the first records of M. zetta for Venezuela.

We plan to further investigate the taxonomy of deer traditionally included in the genus Mazama by gathering additional morphological data (including comparisons with typical material) and obtaining genetic data.

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References

Table 1—Loadings derived from the PCA of the Mazama americana complex. PC 1 primarily accounts for variation in size, whereas PC 2 accounts for variation in proportion.

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<th>PC 1</th>
<th>PC 2</th>
<th>PC 3</th>
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Figure 1—Measurements used for the cluster analysis and PCA. (a) dorsal: frontal length (FL), interorbital breadth (IB), upper length (UL), condylobasal length (CBL), foramen magnum to premaxillary length (MPL), palatine to premaxillary length (PPL); (b) lateral: zygomatic breadth (ZB), intercondylar width (IW), condylobasal length (CBL), foramen magnum to premaxillary length (MPL), palatine to premaxillary length (PPL); (c) palatal: maxillary diastema length (DLM) maxillary diastema length (DLM).

Figure 2—Bivariate plot of specimens’ scores on PC 1 and PC 2 from the PCA of the Mazama americana complex.

Figure 3—Phenogram resulting from cluster analysis of logarithmically transformed cranial measurements of specimens of the Mazama americana complex. The taxa analyzed included Mazama americana, M. temama, M. pandora, M. whiteleyi, M. zetta and some of their currently recognized subspecies.