Identifying Pleistocene *Ursus* fossils from dental morphology analyses of American black bear (*Ursus americanus*) and brown bear (*Ursus arctos*) specimens

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Introduction

The radiation and diversification of mammals has been facilitated by the evolution of heterodont dentition, the complex adaptations of which can strongly reflect ecological adaptations in addition to phylogenetic history (Jacobs et al. 1989; Luo 2007). Additionally, teeth are often better preserved than other types of bone due to their hard dentine layer. These traits mean that tooth morphology can be one of the most crucial tools researchers use when identifying mammalian skeletal material.

During the Pleistocene, Western North America possessed multiple taxa and species of bears, including the extant American black bear (*Ursus americanus*), and brown bear (*Ursus arctos*), and the extinct cave bear (*Ursus spelaeus*) and short-faced bear (*Arctodus*) (Heaton and Grady 2003; Pacher and Stuart 2009; Steffen and Fulton 2018). These taxa occupied multiple niches and several co-occurred at points in their ranges, which *U. americanus* and *U. arctos* still do to this day (Fedje et al. 2011; Kubiak et al. 2022). In fact, it is thought that during the Pleistocene black bears were more comparable in size to recent brown bears, making it useful to identify remains at locations where they overlap in the fossil record (Gordon 1986).

This project had two goals in mind: first, by quantifying dental proportions of known species of North American bears, this project aimed to test whether substantial molar morphological differences exist between black and brown bears to the extent that identifications can be made from current osteological material. Secondly, with the data gleaned from this project, we intended to build a discriminant function analysis tool that would help researchers identify fossil specimens to one of the two extant species.

We hypothesized that tooth proportions of *Ursus arctos* and *Ursus americanus* would significantly differ, such that one molar may be sufficient to make a confident species identification to either species from unknown and/or incomplete specimens possessing that molar.

Based on our hypothesis, we predicted that overall, brown bear molar ratios will be both wider and longer than American black bears due to their differences in body size. We believe that this tool can be applied to other incomplete fossil specimens, in order to be able to be identified as either *U. arctos* or *U. americanus*.

Materials & Methods

This study utilized upper and lower individual tooth measurements of previously identified *U. arctos* and *U. americanus* skulls collected from the wild, encompassing a North American geographic range. Measurements were standardized (when viewing from the transverse plane) to the specimen's right side, consisting of the tooth's maximum length (Fig. 1, posterior-anterior) and width (Fig. 2, buccal-lingual). The specific teeth included molars 1-2 (M1, M2) and fourth premolar (P4) on the maxilla, and on the dentary the fourth premolar (p4) and molars 1-3 (m1, m2, m3).

Specimens were sourced from UC Berkeley's Museum of Vertebrate Zoology, and Cal Poly Humboldt's Vertebrate Museum and Wildlife Museum collections. Unknown fossil specimens were sourced from UC Berkeley's Museum of Paleontology.

Collected data was assessed using an ANOVA test in order to test whether the sizes of individual teeth differ between species. Then, we used a stepwise discriminant function analysis to categorize our samples of teeth in each species and assigned a species identification to each unknown.

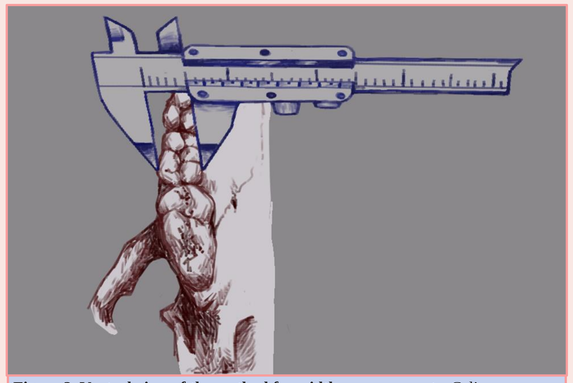

Figure 2. Ventral view of the method for width measurements. Calipers are placed buccal-lingually.

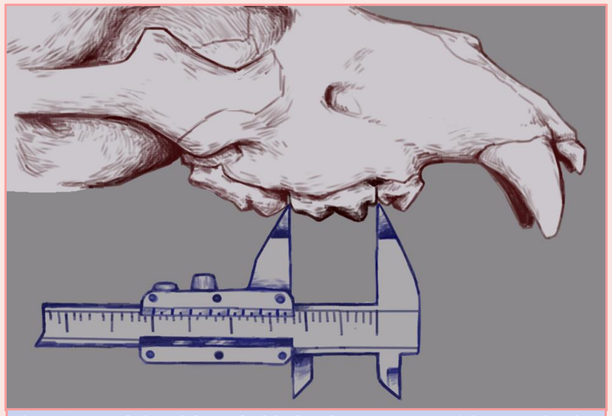

Figure 1. Lateral view of the method for length measurements. Calipers are placed posterior-anteriorly.

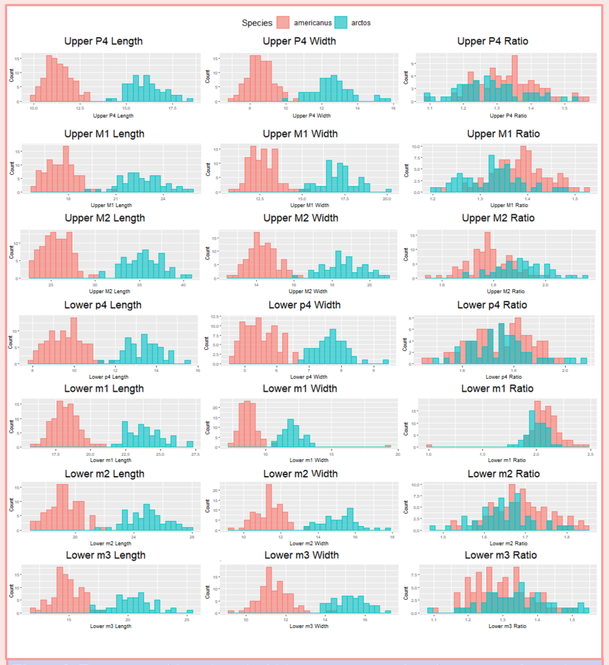

Figure 3. Frequency of length and width measurements in reference specimen data. Colors correspond to species, *U. arctos* in blue, and *U. americanus* in pink. Tooth ratio graphs plot length measurements divided by width measurements. Upper P4 is the only tooth where there is not a significant difference between species (P= >0.05).

Results

154 identified specimens were measured across 4 Californian natural history museums.

The T-test revealed that there was a significant difference in individual measurements of teeth between species for all measured teeth except for the upper fourth premolar (P = >0.05). The molar with the highest significance in determining species is the upper M2 (P= <0.05).

A stepwise discriminant function analysis was used to train the model on the identified specimens, and then tested against 17 unknown UCMP fossil specimens (Fig. 4). Only 3 were identified with a less than 95% confidence interval.

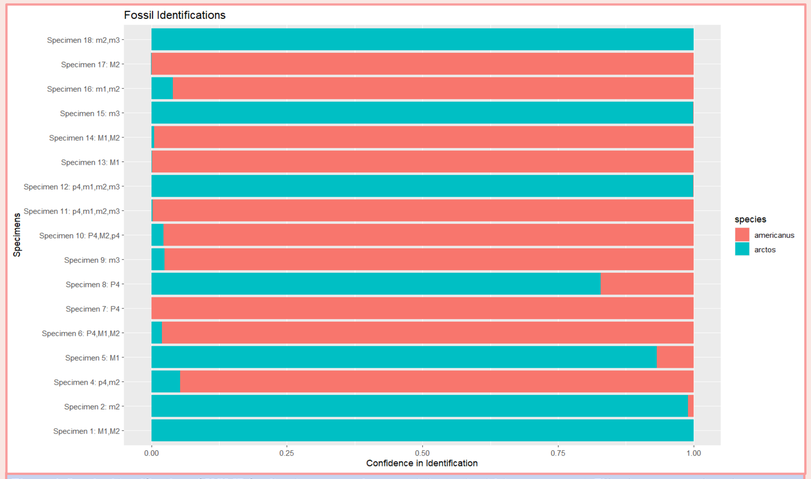

Figure 4. Species identification of UCMP fossil unknown specimens and the teeth which were present. Fill color corresponds to the percent confidence in identification between species. Teeth that were present are listed next to each specimen's number.

Conclusions

Individual measurements were shown to be more reliable at identifying differences between species than the tooth ratios of each tooth, likely due to similarities in allometry, genetics, and historical habitats.

This project found that the width of upper M2 is a significant, singular measurement that can identify between *U. arctos* and *U. americanus*. These observed results are consistent with current literature on diagnostic criteria, which state that *U. arctos* specimens can be identified by having an upper M2 that is more than half as long as its width (Kelt and Patton 2020).

Although all measured teeth except upper P4 were determined to have significant differences in size between species, we recommend that confident identifications should utilize only the upper M2 since it had the highest accuracy when blind testing against identified specimens.

To test the reliability of identification from upper M2 length and width measurements alone, 20 of the 154 reference specimens were selected at random, withheld from the data, and tested by the model. Accuracy of species identification from this one tooth ranged between 95% and 100%.

Figure 5. Front view of Cal Poly Humboldt Vertebrate Museum specimens. *U. americanus* (left) and *U. arctos* (right).

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