



## Consequences of the misidentification of museum specimens: the taxonomic status of *Canis lupaster soudanicus*

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Researchers are increasingly using museum collections for taxonomy, systematics, phylogenetics, and faunal analyses, and they assume that taxonomic identifications on museum labels are correct. However, identifications may be incorrect or out of date, which could result in false conclusions from subsequent research. A recent geometric morphometrics analysis of skulls of African canids by Machado and Teta (2020) suggested that *Canis lupaster soudanicus* is a junior synonym of *Lupulella adusta*. However, the holotype of *soudanicus* was not measured and further investigation of the putative *soudanicus* specimens used in this study showed that these originally were identified as *L. adusta*. This original identification was confirmed by dental measurements, which also confirm that the holotype of *soudanicus* is *Canis lupaster*. Hence, *soudanicus* should not be synonymized with *L. adusta*. This example highlights the importance of careful checking of species identifications of museum specimens prior to research and, where possible, including (holo)types of taxa, before making taxonomic changes that could have important consequences for species conservation and management.

Key words: *Canis lupaster*, *Lupulella adusta*, misidentification, museum, taxonomy

Machado and Teta (2020) used a geometric morphometric analysis to compare skulls of African canids with those from Eurasia and North America. The results were broadly in accordance with recent genetic studies that showed that the African wolf, *Canis lupaster*, and the Eurasian golden jackal, *Canis aureus*, are separate species and that African jackals (*adustus* and *mesomelas*) are morphologically distinct from *Canis*, supporting their placement in the genus *Lupulella* (Rueness et al. 2011; Koepfli et al. 2015; Atickem et al. 2017; Viranta et al. 2017). Machado and Teta’s analysis showed that variation within the supposed taxon *C. lupaster* is much greater than in wide-ranging grey wolves, *Canis lupus*, from North America. The observed variation was discrete and unrelated to sexual dimorphism, forming three groups. Several authors observed previously the possible presence of at least two different, apparently sympatric, morphs of *C. lupaster* in northern Africa

(Gaubert et al. 2012; Saleh and Basuony 2014; Berté 2017; Stoyanov 2020).

Of the three discrete groups identified by Machado and Teta (2020) as *C. lupaster*, the group of smallest specimens was of the subspecies *Canis lupaster soudanicus*. Because these specimens mostly overlapped morphologically with *Lupulella adusta*, the authors suggested that *C. l. soudanicus* likely was a junior synonym of *L. adusta*. However, the holotype of *soudanicus*, which is in the Natural History Museum, London, was not included in the analysis. The seven specimens used in the analysis are in the National Museum of Natural History, Smithsonian Institution (USNM), but six of these originally were deposited in the Field Museum of Natural History, Chicago (FMNH). They were identified correctly when they entered the FMNH collection, but their identification was changed when they were transferred to NMNH.

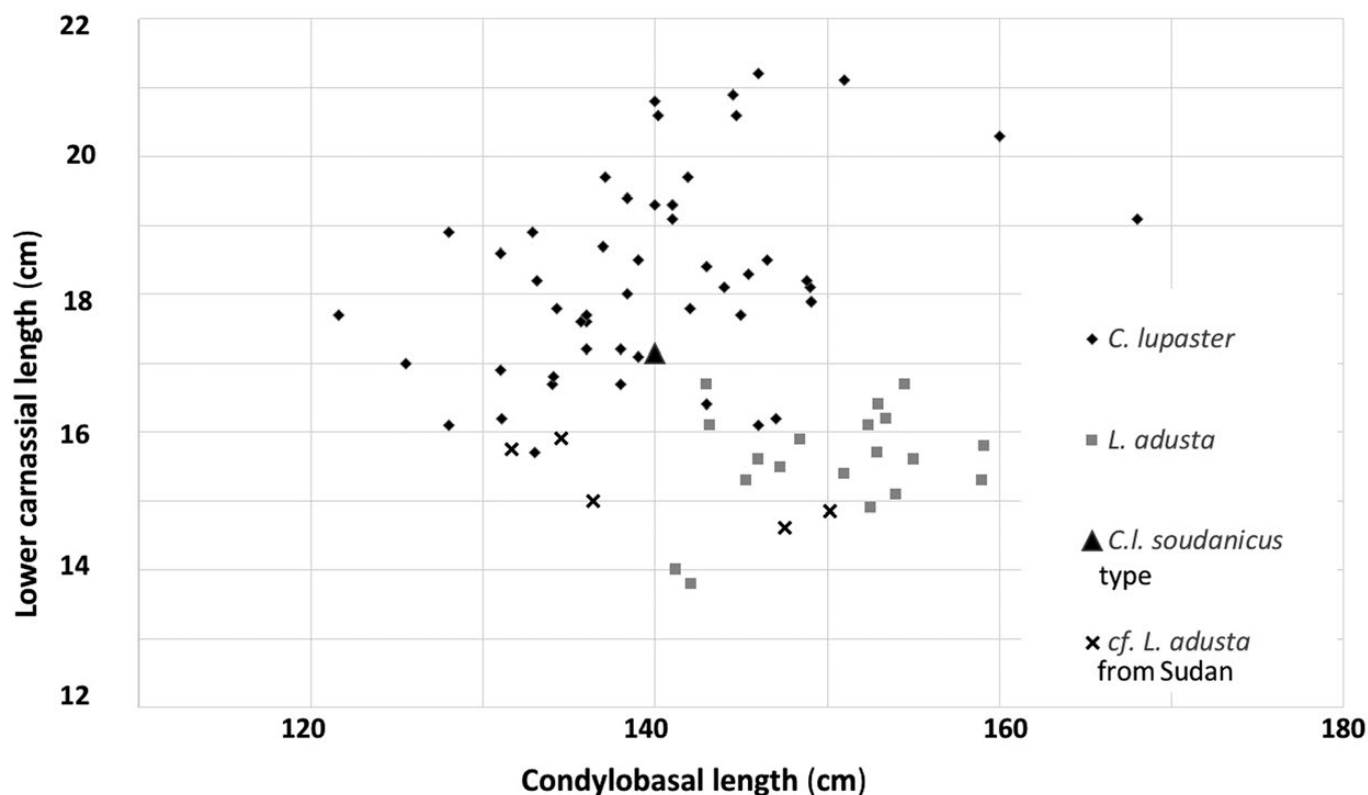
The principal components analysis of Machado and Teta (2020) showed that of these seven specimens, one was in a group with the small East African *lupaster* and the remaining six grouped with *adusta*, although all were close to *adusta* in the linear discriminant analysis in the same study. The USNM specimen tags show that all seven specimens were collected in the mid-20th century and that six of these were collected by H. Hoogstraal. All six Hoogstraal specimens had two museum tags (either on the skin or the skull), one from the FMNH and a newer USNM tag. Hoogstraal's five 1961 specimens were collected in South Sudan in the upper Nile delta region; the older FMNH tags identified them as *C. adustus* (USNM 342085 = FMNH 93852; USNM 350071 = FMNH 93854; USNM 342087 = FMNH 93858; USNM 342088 = FMNH 93860; USNM 350072 = FMNH 93882). The sixth Hoogstraal specimen (USNM 299841 = FMNH 67001) was collected in 1950 in a similar area in South Sudan and the older FMNH tag identified the specimen as *Canis aureus soudanicus*. The seventh specimen (USNM 318095) apparently was collected in 1948 by Alison and Evans in the far south of South Sudan and the original museum tag identification was "*adusta*." Taxonomic identification on the newer USNM tags for all seven specimens was *C. a. soudanicus*.

One of us (SV) has studied briefly the *soudanicus* holotype (NHMUK ZD 1903.2.8.8) collected from El Obeid, Sudan (ca. 13°11'N, 30°13'E [WGS84], 575 m). The holotype clearly

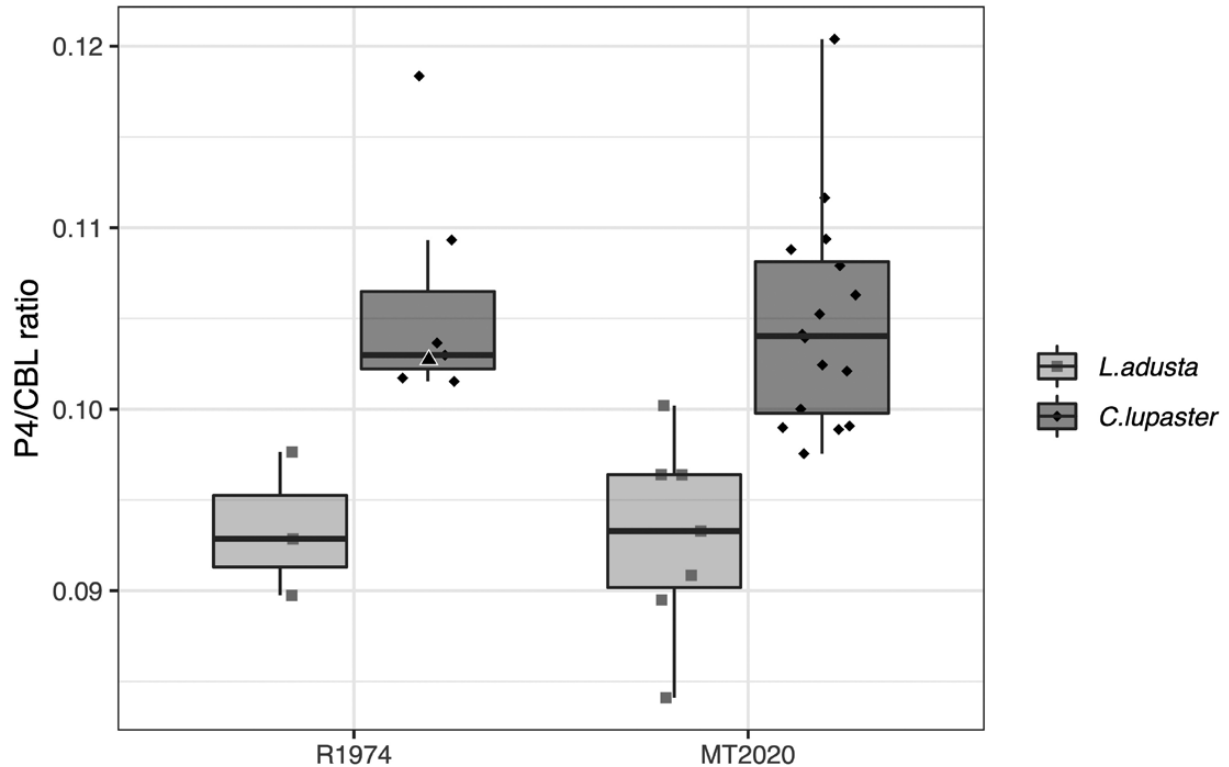
shows closer affinities to *C. lupaster* than to *L. adusta*, based on the following characters. The lower carnassial is larger in relation to skull length in *C. lupaster* than in *L. adusta* (Fig. 1). The holotype also is lacking the well-developed protocone and strong cingulum that make the lingual aspect of the *Lupulella* M1 wider than in *Canis* (Spassov 1989). The most obvious character of *L. adusta*, the heightened frontonasal area, results in the straight dorsal line of the skull (Geraads 2011) and is not present in the *soudanicus* holotype. Instead, the holotype has a slightly concave profile just anterior to the orbits that is present in *Canis*, e.g., in *lupaster*.

Rosevear (1974) also undertook comparisons of the skulls of West African *aureus* (= *lupaster*), including the holotype of *soudanicus*, with *adusta*, and found clear differences despite small sample sizes. For example, both m1 and P4 lengths are greater in *lupaster* (minimum 16.3 and 14.2 mm, respectively) than in *adusta* (maximum 15.5 and 13.7 mm, respectively). Regarding P4, we were able to compare its relative size from both Rosevear's (1974) and Machado and Teta's (2020) samples (Fig. 2). The results confirm that all Machado and Teta's (2020) *C. l. soudanicus* probably are *L. adusta* and that the *C. l. soudanicus* holotype matches the proportions of a *C. lupaster*. This suggests that it is incorrect to synonymize *soudanicus* with *adusta*.

Mislabeled museum specimens have important ramifications for taxonomy, systematics, phylogenetics, and faunal



**Fig. 1.**—The lower carnassial, m1, plotted against skull size (condylbasal length [CBL]), showing the relatively larger carnassial in *Canis lupaster* compared to *Lupulella adusta*. Data for *C. lupaster* and *L. adusta* from Viranta et al. (2017). *Canis l. soudanicus* measured by SV. USNM specimens labeled as *C. aureus soudanicus* are considered here as *cf. L. adusta* (USNM 342085, 342087, 342088, 318095, 299841) and were measured by VH and PDM.



**Fig. 2.**—Ratio between fourth upper premolar (P4) and condylobasal length (CBL), showing the difference between *Lupulella adusta* and *Canis lupaster* for data from Rosevear (1974) and Machado and Teta (2020) (R1974 and MT2020, respectively). For MT2020, *L. adusta* and *C. lupaster* refer to *C. lupaster soudanicus* and *C. lupaster bea* specimens from that publication. Holotype specimen measured by Rosevear is highlighted as in Fig. 1. Box plots show medians and interquartile ranges.

analyses, where researchers using these collections assume that identification labels are correct. A review of specimens in museum collections is recommended to ascertain and, if necessary, emend identifications, especially in groups such as canids where species discrimination may be difficult and confused by morphological convergence. We urge researchers to check species identifications of specimens routinely prior to commencing measurements and sampling. In addition, it would be useful to secure and analyze genetic samples from each specimen if possible. This would provide additional insight as to both the morphological and genetic composition of (in this case, canid) species as well as ensuring that subsequent wider research is on a more robust footing.

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