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Old World *Canis* spp. with taxonomic ambiguity: Workshop conclusions and recommendations

Vairão, Portugal, 28th - 30th May 2019

Francisco Alvares^{1*}, Wieslaw Bogdanowicz², Liz A.D. Campbell³, Raquel Godinho¹, Jennifer Hatlauf⁴, Yadvendradev V. Jhala⁵, Andrew C. Kitchener⁶, Klaus-Peter Koepfli⁷, Miha Krofel⁸, Helen Senn⁹, Claudio Sillero-Zubiri^{3,10}, Suvi Viranta¹¹, and Geraldine Werhahn^{3,10}

¹ CIBIO-InBIO, Research Center in Biodiversity and Genetic Resources from Porto University, Vairão, Portugal. Email: falvares@cibio.up.pt

² Polish Academy of Sciences Poland.

³ Wildlife Conservation Research Unit (WildCRU), Department of Zoology, University of Oxford, UK

⁴ Institute of Wildlife Biology and Game Management, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria.

⁵ Wildlife Institute of India, India

⁶ National Museums Scotland, Department of Natural Sciences, Chambers Street, Edinburgh, EH1 1JF, UK

⁷ Smithsonian Conservation Biology Institute, Center for Species Survival, Washington, D.C. USA

⁸ Biotechnical Faculty, University of Ljubljana, Slovenia

⁹ Royal Zoological Society of Scotland, Edinburgh, UK

¹⁰ IUCN SSC Canid specialist Group, Oxford, UK

¹¹ University of Helsinki, Finland

* Convener

Introduction

In response to a need for answers to questions regarding the taxonomy of several Old World *Canis* taxa, a workshop of experts in taxonomy, evolution, biology and conservation of the Canidae took place in Vairão, Portugal, on 28th-30th May 2019, organised by CIBIO-InBIO and the IUCN SSC Canid Specialist Group. See appendix for a detailed agenda.

The meeting addressed the following goals:

1. Review available information on golden jackals and African wolves regarding: i) Systematics and nomenclature (range limits, taxonomy, suggested common and scientific names), ii) Ecology and behaviour (socio-biology, diet, breeding behaviour, habitat use, interspecific interactions, vocalizations), iii) Morphology (body mass and other morphological characteristics, morphometry); iv) Genetics and genomics (phylogeny, genetic diversity, population structure, hybridisation).
2. Provide a basis for reaching a consensus regarding the taxonomic status of African wolves.
3. Identify knowledge gaps and research priorities for African wolves and golden jackals.

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4. Discuss other similar taxonomic issues related to South Asian canids (i.e., *Canis (lupus) himalayensis*, *C. (l.) pallipes*, *C. (l.) chanco*, *C. (l.) laniger*), other African jackals (*Canis mesomelas*, *C. adustus*) and dingoes / New Guinea singing dogs (*Canis dingo* / *Canis hallstromi*), relevant for IUCN conservation planning and Red Listing purposes.
5. Discuss strategies and potential collaborations for future research, focusing on a wide geographical coverage of sampled individuals and populations.
6. Prepare a draft for a scientific paper based on the main conclusions and outcomes of the meeting and their implications.

Following presentations and fruitful deliberations, the participants of the workshop hereby summarise their conclusions and offer their recommendations, to be shared more widely within the canid research and conservation community.

Golden Jackals & African Wolves

1. Since 1939, the African wolf and the golden jackal were considered a single species (Allen 1939). The African wolf remained cryptic due to its morphological similarity with the golden jackal, until genetic sampling showed them to be different (Rueness *et al.* 2011; Gaubert *et al.* 2012; Koepfli *et al.* 2015; Viranta *et al.* 2017; Gopalakrishnan *et al.* 2018; Chavez *et al.* 2019).
2. Based on mitochondrial genome and nuclear genome sequence data, which show clear and deep monophyletic divisions between grey wolf, golden jackal and African wolf (Koepfli *et al.* 2015; Gopalakrishnan *et al.* 2018), there is genetic support for a species distinction for the African wolf.
3. Published papers on the morphology of golden jackal and African wolf are contradictory, with regard to distinguishing between the two taxa (Ferguson 1981; Spassov 1989; Krystufek and Tvrkovic 1990; Saleh and Basuony 2014; Koepfli *et al.* 2015; Viranta *et al.* 2017). Lack of robust statistical support based on morphology for species-level separation may be due to convergent adaptation/evolution but further research is needed to formally test and possibly confirm the findings from genetic studies.
4. The behavioural ecology and biogeography of the African wolf and the Eurasian golden jackal have not been reviewed independently of each other (see, e.g., Moehlman and Hofer 1997; Moehlman and Jhala 2013; Jhala and Moehlman 2013; Rutkowski *et al.* 2015; Yumnam *et al.* 2015, Moehlman and Hayssen 2018). Further research is needed on both of these topics.
5. The earliest valid name that may have been attributed to the African wolf is *Canis anthus* Cuvier, 1820 (see Koepfli *et al.* 2015). However, the location of the type specimen is currently unknown and the identification of the species described by Cuvier is considered by some as uncertain. Therefore, a re-evaluation of the basis for the name *Canis anthus* should be made to determine whether this is the earliest valid name for this taxon. Because of these doubts on specific identity of *Canis anthus*, this group recommends the use of *Canis lupaster* Hemprich and Ehrenberg, 1832 for now (Viranta *et al.* 2017).
6. More research is required to determine the causes of morphological variation amongst these taxa across their ranges (Demeter and Spassov 1993). Morphological variation may be caused by populations diverging due to drift or selection, population clines or due to vicariant events that may merit recognition of subspecies within both African wolves and Eurasian golden jackals.

7. The region of Egypt, the Levant and Arabian Peninsula needs more research and sampling for genetics and morphology since this area may represent a parapatric zone between the two taxa (Saleh and Basuony 2014), showing maximum variability in terms of morphology and some evidence of past genetic introgression (Koepfli *et al.* 2015).
8. This group recommends further research on the morphology, genetics, distribution range, population status, ecology, behaviour, disease, conflicts with humans and conflict-mitigation measures required to better inform conservation actions for these species. Continuing research will improve our understanding of the evolutionary dynamics at the range boundary of these species and this should be considered a priority.

Black-backed & Side-striped Jackals

1. Phylogenetic analysis of two largely non-overlapping nuclear DNA datasets consistently support the placement of side-striped jackal (*Canis adustus*) and black-backed jackal (*C. mesomelas*) as a monophyletic lineage outside the clade that includes *Lycaon*, *Cuon*, and all other *Canis* species (Lindblad-Toh *et al.* 2005; Perini *et al.* 2010; Koepfli *et al.* 2015; Atickem *et al.* 2017; Viranta *et al.* 2017). Studies based on palaeontological data as well as a dataset of morphological characters and genetics support this placement (Geraads 2011; Zrzavý *et al.* 2018). However, some published papers indicate morphometric overlap between all jackal-like species, namely golden jackal, African wolf, black-backed jackal and side-striped jackal (van Valkenburgh and Wayne 1994; Moehlman and Hayssen 2018). Further research on the morphology, genetics, distribution range, population status, ecology, behaviour, and disease is needed for these species.
2. The group recommends that the side-striped jackal and the black-backed jackal should be placed in a distinct genus, *Lupulella* Hilzheimer, 1906 (the earliest valid name, re-established by Viranta *et al.* 2017) with specific names *Lupulella adusta* and *Lupulella mesomelas*, respectively.

Himalayan Wolves

1. Based on current evidence of mitochondrial DNA (D-loop and cytochrome *b*), nuclear microsatellites, sex-linked markers and SNPs within regions of the genome responsible for hypoxia adaptation, the Himalayan wolf lineage is distinct from other wolf lineages (Aggarwal *et al.* 2007; Sharma *et al.* 2003; Shrotryia *et al.* 2012; Werhahn *et al.* 2017, 2018, 2019; also see phylogenies in Koepfli *et al.* 2015 and Rueness *et al.* 2011). However, the only published whole nuclear genomes to date (Zhang *et al.* 2014; Fan *et al.* 2016) appear to place Himalayan wolves within the Old World wolf-domestic dog clade and therefore contradict other available DNA evidence. Owing to this contradiction, this group refrained from supporting a separate species status for this lineage until the cause of this discrepancy is better understood through more extensive analyses of samples of confirmed origin. There are two points to bear in mind in interpretation of this evidence:

i) there is uncertainty about the specific geographical origin and lineage of the four 'Highland wolves' sampled for the analysis of Fan *et al.* (2016), since they were derived from zoo animals;

ii) extensive sampling conducted across the Himalayan range and Tibetan plateau by Werhahn *et al.* (2017, 2018, 2019) revealed that there are a number of geographical regions where admixture is occurring between Himalayan and grey wolves and this must also be examined carefully in any interpretation of data.

Thus, satisfactory analysis would need to rely on genomic evidence from multiple individuals chosen from across the range, which also addresses the possibility of grey wolf/domestic dog/Himalayan wolf introgression.

- Continuing research will improve our understanding of the evolutionary dynamics at the range boundary of the Himalayan wolf (Werhahn *et al.* 2019). The individuals in these boundary regions should be considered in taxonomic and conservation decisions so as to conserve dynamic evolutionary processes.
- There is a need for a proper understanding of the population size and distribution of this unique lineage as well as ecological and behavioural studies. Additionally, the Himalayan wolf lacks a proper morphological analysis and this will be useful to inform future discussions about this taxon.
- The nomenclature for the Himalayan wolf has not been fully resolved to date due to the following uncertainty: The earliest valid name is *Canis chanco* Gray, 1863, which has some uncertainty related to the geographical origin and genetic lineage of the holotype; the next available name is *Canis filchneri* (Matschie, 1908). The earliest name *Canis laniger* (Hodgson, 1847) is unavailable, owing to the earlier use of this name by Hamilton Smith (1840) for a domestic dog. The group suggests that, until further information becomes available, the Himalayan wolf be named as *Canis lupus chanco*. The preferred vernacular name should be “Himalayan wolf” in recognition of its geographical locality and to give it a unique identity. The group recommends verifying the genetic lineage of the respective holotypes to resolve these uncertainties.

Dingoes and New Guinea Singing Dogs

- This group considered that these canids are feral domestic dogs, *Canis familiaris* (Jackson *et al.* 2017), and that therefore they should not be assessed for the IUCN Red List. However, the group recognised the potential ecological role of these dogs as top predators in their fragile insular environments and their socio-cultural value. The group therefore recommended that the CSG considers offering, if requested, advice on research, management, and potential sources of funding to those actively involved in the study and conservation of these animals.

General Recommendations

- This group recommends establishing a common minimal panel of microsatellites and/or SNPs useful for genotyping of non-invasive samples for studies on genus *Canis*, so that various genetic studies on multiple species become comparable across researchers, laboratories and countries.
- In case good quality tissue samples (other than non-invasive) are available, then low-coverage whole-genome sequencing would offer a better approach for generating genetic data across the genus for population and phylogenetic inference.
- A comprehensive review of genetic, morphological and biogeographical data is needed to determine if there should be a revised classification of *Canis* and *Lupulella* species and of the Canidae in general, similar to the recently revised classification of the Felidae (Kitchener *et al.* 2017).



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Participants biographical sketches

Francisco Alvares is a wildlife biologist working on ecology, conservation and management of grey wolves and other canids, particularly in Europe and North Africa.

Wiesław Bogdanowicz is the head of the Laboratory of Molecular and Biometric Techniques at the Museum and Institute of Zoology in Warsaw. He works on population genetics, phylogeographic and admixture patterns, evolutionary history, and taxonomy of canids.

Liz Campbell is a wildlife biologist and conservation practitioner focused on African wolves and other species in the Atlas Mountains of North Africa.

Raquel Godinho is a population geneticist working on carnivores and antelopes in Africa, Europe and South America.

Jennifer Hatlauf is a wildlife ecologist, studying carnivores, specifically observing golden jackals in central Europe.

Yadvendradev Jhala is a scientist at the Wildlife Institute of India where he leads the Conservation Genetics Laboratory, and teaches biometry and population ecology.

Andrew Kitchener is the Principal Curator of Vertebrates at National Museums Scotland. He led the Cat Classification Task Force of the IUCN SSC Cat Specialist Group.

Klaus-Peter Koepfli is a conservation biologist in the Center for Species Survival at the Smithsonian's National Zoological Park-Conservation Biology Institute. His research focuses on the application of genomic data to captive and wild populations of endangered species,

Miha Krofel is a wildlife biologist working on carnivore conservation and research in Eurasia, Africa, and North America.

Helen Senn specialises in the application of genetic data to conservation management decision making.

Claudio Sillero-Zubiri is a conservation biologist working on carnivore conservation and human-wildlife coexistence in Africa, Asia and South America and is the Chair of the Canid Specialist Group.

Suvi Viranta is a paleobiologist and anatomist working on the Pleistocene and modern carnivores.

Geraldine Werhahn is a carnivore conservation biologist and has extensively worked on the phylogeny, ecology and conservation of wolves in the Asian high altitudes of the Himalayas and the Tibetan Plateau.

Appendix - Workshop Agenda

Day 1:

Short introduction (5 min) by each of the participants presenting current work on canids.

Presentations by each participant (15-20 min) on current state-of-art related to systematics, morphology, genetics and behavioural/ecological traits on African wolves (covering North vs East African range), golden jackals (covering European vs Asian range) and South Asian canids (Himalayan wolves and Indian wolves).

- Morphology and Systematics of African wolves and golden jackals – **Suvi Viranta**
- Phylogeny of Old World jackals and wolves – **Klaus-Peter Koepfli**

Day 2:

- Population genetics of African wolves and golden jackals – **Raquel Godinho**
- Complex genetic structure of the expanding golden jackal populations in Europe - **Wieslaw Bogdanowicz**
- Status and ecology of the golden jackals and wolves in India - **Y. Jhala**
- Golden Jackal: global range and ecological insights from Iran - **Francisco Álvares**
- Golden jackal ecology in Europe: what do we know and what we don't - **Miha Krofel & Jennifer Hatlauf**
- Behavioural Ecology of African wolves in Serengeti (East Africa) – **Patricia Moehlman**
- Ecology of African wolves in North Africa - **Liz Campbell**
- African wolf ecology in Ethiopia - **Claudio Sillero-Zubiri**
- African wolf: potential range and ecological insights from Senegal - **Francisco Álvares**

Day 3:

- Insights on golden jackals from Sri Lanka - **Jennifer Hatlauf**
- Genetics and ecology of Himalayan wolves - **Geraldine Werhahn & Helen Senn (by skype)**
- Taxonomic status of African wolves, golden jackals, Himalayan wolves, and African jackals - **All**
- Dingoes and New Guinea singing dogs - **Claudio Sillero-Zubiri**
- Final discussion, conclusions and outcomes of the meeting, future tasks - **All**