



Interspecific social interaction between golden jackal (*Canis aureus*) and red fox (*Vulpes vulpes*)

Felix Böcker¹ · Hannah Weber¹ · Janosch Arnold² · Sebastian Collet³ · Jennifer Hatlauf⁴

Received: 19 July 2023 / Accepted: 2 January 2024 / Published online: 16 January 2024
© The Author(s) 2024

Abstract

In south-western Germany, a territorial single male golden jackal (*Canis aureus*) was repeatedly photographed showing social interaction with a red fox (*Vulpes vulpes*) female and her cubs. This unusual behaviour was documented in two subsequent years (August–September 2020 and May–August 2021). The interspecific actions are not limited to encounters of the two species but include interactions such as feeding and related sociopositive behaviours. Thirty-two observations with both species appearing together were recorded within the study period. The observed behaviour raises questions about the coexistence of both species and on interspecific behaviour of wild canids in general. Social isolation of the observed male golden jackal could be one of the potential drivers for the interaction, as Germany is at the current edge of golden jackal distribution in central Europe.

Keywords Canids · Interaction · Social isolation · Sympatry · Mixed species group

Introduction

Despite the scientific interest in interspecific canid interactions, little is known about interspecific cooperative behaviour in canids. Reports on cooperation or other positive

social behaviour between canid species from different genera are mostly anecdotal. Mixed species groups, which are common in other mammals, are only rarely observed in carnivores (Dinets & Eligulashvili 2016; Stensland et al. 2003). Ghaskadbi et al. (2021) observed a single male wolf (*Canis lupus pallipes*) together with a pack of dholes (*Cuon alpinus*). Advantages in foraging and anti-predator behaviour are considered possible explanations for such mixed species groups (Ghaskadbi et al. 2021; Stensland et al. 2003).

Canids are known to form various systems of social organisation (Bekoff et al. 1981; Macdonald et al. 2019). Golden jackal (*Canis aureus*) and red fox (*Vulpes vulpes*) can be grouped in different types of social organization and can have a flexible social system (Cavallini 1996; Dorning & Harris 2019). Red foxes can live in single pair formations with offspring dispersing in the year of birth or form larger philopatric family groups. The latter is only observed occasionally and seems to be linked to different factors such as resource availability (Baker et al. 1998). Depending on density effects, group composition can also consist of non-related individuals due to, e.g., extraterritorial mating events or polygynous group reproduction (Iossa et al. 2008). Golden jackals in Europe usually live in family groups comparable to packs of related species, such as wolves (Pecorella et al. 2023). A pair of adult golden jackals marks its territory and raises its cubs together, which commonly stay in the

Communicated by: Rafał Kowalczyk

✉ Felix Böcker
Felix.Boecker@Forst.bwl.de
Hannah Weber
Hannah.Weber@Forst.bwl.de
Janosch Arnold
Janosch.Arnold@lazbw.bwl.de
Jennifer Hatlauf
Jennifer.hatlauf@boku.ac.at

- ¹ Forest Research Institute Baden-Württemberg, Wildlife Institute, Freiburg I. Br., Germany
- ² Wildlife Research Unit, LAZBW, 88326 Aulendorf, Germany
- ³ Center for Wildlife Genetics, Senckenberg Research Institute and Natural History Museum Frankfurt, Gelnhausen, Germany
- ⁴ Department of Integrative Biology and Biodiversity Research, Institute of Wildlife Biology and Game Management, University of Natural Resources and Life Sciences, Vienna (BOKU), Austria

parental territory until sexual maturity (Macdonald 1979; Demeter & Spassov 1993). Dispersing golden jackals can cover great distances to find a partner or a territory (Rutkowski et al. 2015; Lanszki et al. 2018).

Thus, both species, the red fox and the golden jackal, are capable of forming various forms of intraspecific social bonds. However, neither species is currently known to establish social coalitions with interspecific partners. Current studies describe an antagonistic biology between red foxes and golden jackals (Scheinin et al. 2006; Lanszki et al. 2006; Torretta et al. 2021). Most research about interactions between red foxes and golden jackals prove or assume competition, a negative top-down effect, and show an increased vigilance in red foxes where golden jackals are present (Loveridge and Macdonald 2002; Scheinin et al. 2006, Torretta et al. 2021). No publications are known to the authors which described a sociopositive interaction between golden jackals and red foxes.

In Germany and all other neighbouring countries, golden jackal presence is increasingly registered after this species never existed in central European regions before (Arnold et al. 2012; Krofel et al. 2017; Hatlauf et al. 2021a, b). Since the first evidence of a golden jackal in Germany in 1997 (Möckel & Podany 2015), 360 confirmed signs and observations have been documented nationwide until March 1st, 2023 (author unpublished data) (Table 1, ESM). In two areas of southern Germany, Baden-Württemberg (rural districts Schwarzwald-Baar/Tuttlingen and Ravensburg), 258 out of all proofs were recorded and refer to a few territorial golden jackals (Böcker et al. 2020; Tillmann 2020; Hatlauf & Böcker 2022; author unpublished data).

The original aim of this study was to monitor a resident, single male golden jackal in Baden-Württemberg by camera traps and active searches for genetical samples using a trained scat detection dog (c.f. Hatlauf et al. 2020) to gain genetic information on the present individual. Based on our first observations, we aimed to explore the interspecific behaviour between this golden jackal and present red foxes.

Material and methods

Study area

The study area “Wurzacher Ried” is situated in the district of Ravensburg, an upland moor with a size of almost 700 ha, which is the heart of a protected area of the total size of 1.812 ha and part of the Natura 2000 network (ESM Fig. 1). Other present species are roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), brown hare (*Lepus europaeus*), badger (*Meles meles*), marten (*Martes* sp.), small mammals, birds, amphibians, and reptiles. In total, the area is

encompassing 1.700 animal and 800 plant species (Linderoth et al. 2020).

All registered evidence was assessed and categorised referring to “Recommendations for the documentation and assessment of golden jackal (*Canis aureus*) records in Europe” (Hatlauf & Böcker 2022). To describe the following observations, only evidence with C1-assessment was taken into account.

Camera traps and picture classification

A single golden jackal was spotted in the study area by an ornithologist in May 2020. Subsequently, eight infrared camera traps (Bushnell CoreCam and Cuddeback C-series) were set up in an area of approximately 0.35 km². Cameras were installed at trees located close to wildlife tracks. As there was only one location where interactions of golden jackal and red fox could be documented, additional camera traps were installed at this specific location. This area was located in a small forested area (< 1 ha) directly adjacent to the bog. A maximum of four camera traps with a maximum distance of 30 m were active at this location in summer 2021.

The cameras were set to take pictures without delay and a series of 3–5 pictures for every registered movement. During some periods, single cameras were set on video recording. Events were distinguished from each other if there was a time delay of > 60 s between pictures of one triggered series to the next. The cameras were checked regularly every 4 to 8 weeks. No bait was used at camera trap locations.

The observed behaviour was categorised (Table 3; (ESM Table 2)). The described behaviours always refer to the golden jackal and at least one red fox. In some cases, other red foxes can show different behaviours in the same event.

Scat detection and bioacoustic monitoring

To gain further individual information on the golden jackal, a trained scat detection dog (Hatlauf et al. 2020) was used to search for scat and receive the golden jackals’ genetic identification. Furthermore, bioacoustic monitoring (BAM; Giannatos et al. 2005; Hatlauf & Hackländer 2016) was used at two different spots a few hundred metres from the camera traps. BAM was used on 3 days in total (03/06/2020, 27/08/2020, 04/02/2021) with 3 to 4 repetitions per spot.

Genetic analysis

Following DNA extraction, an initial species determination was performed using the hypervariable domain of the mitochondrial control region (D-loop). In confirmed golden jackal samples, we amplified 13 unlinked autosomal microsatellite loci as well as two sex markers for individualization

and sex determination (see Hatlauf et al. 2021a, b for more details).

Results

From June 2020 on, a single golden jackal was documented regularly by different camera traps in the area. The greatest distance between two of those cameras was approx. 1 km. Due to the given circumstances, it is assumed that there was only one individual present in the study area in the years 2020–2022. In 2020, a total of 26 camera trap picture series of the single golden jackal were recorded of which four also show red foxes (one adult and cubs), displaying diverse behaviours with differing frequencies (Table 1). The first pictures and videos showing the golden jackal with red fox cubs were taken on 09/08/2020 (see ESM, picture 2). The individuals show relaxed behaviour which we assume is indicating familiarity. Similar behaviour could again be documented again 5 days later and subsequently in September 2020.

In 2021, 93 camera trap series were recorded showing the golden jackal, of which 28 also show red foxes. The first pictures showing red fox and golden jackal interaction in this year were taken on 28/05/2021. The pictures show an interaction between a red fox female, her cubs, and the golden jackal. Another picture series shows the golden jackal regurgitating food and providing it to one of the red fox cubs (see ESM, picture 3).

In total, the cameras recorded 32 C1 events (c.f. Hatlauf & Böcker 2022) containing 358 pictures showing the presence of up to four red foxes and the single golden jackal together. All events showing the golden jackal and red foxes originated from a single location that was covered by 1–4 camera traps (distance 2–30 m between cameras). The documented behaviour of the red foxes and the golden jackal was in both years social. Besides the C1-evidence described above, there have been additional C3 evidence that were not taken into account for this study due to insufficient quality (74 golden jackal C3 in 2021 of which 8 probably show also at least one red fox).

Five scat samples were found while searching with a trained scat detection dog on three occasions (03/06/2020, 27/08/2020, 06/09/2021). Genetic analysis revealed that four of these samples were golden jackal and one red fox. Two of the four samples could be linked to a male golden jackal which was given the genotype code GG008m (03/06/2020, 06/09/2021). This individual had not been recorded before, and its origin is unknown. The quality of the two remaining samples was not sufficient for individual identification (28/08/2020, 06/09/2021). Meanwhile, no other golden jackal could be recorded in the study area or close surroundings. The closest known territorial golden jackals in 2020 and 2021 were located in Austria and Italy (Hatlauf, personal communication; Lapini et al. 2022).

The bioacoustic monitoring at all calling stations was negative (no answer from a golden jackal to a playback of a golden jackal howling) (Figs. 1 and 2).

Table 1 Observed behaviour of red foxes and a golden jackal in 2020 and 2021 (only C1-camera events)

Category/behaviour	Count	Dates
Golden jackal regurgitating	1	19/06/21
Contact	10	10/06/21, 10/06/21, 11/06/21, 11/06/21, 15/06/21, 21/06/21, 25/06/21, 26/06/21, 29/06/21, 04/07/21
Red fox following golden jackal	8	14/08/20, 28/05/21, 13/06/21, 19/06/21, 25/06/21, 02/07/21, 04/07/21, 04/07/21
Golden jackal following red fox	9	09/08/20, 02/09/20, 14/09/20, 13/06/21, 13/06/21, 23/06/21, 02/07/21, 08/08/21, 30/08/21
Indefinite	4	06/06/21, 11/06/21, 19/06/21, 29/06/21

Fig. 1 A golden jackal interacting with a female red fox and two playing red fox cubs (from right to left) (11/06/2021)





Fig. 2 A golden jackal and red fox are socially interacting (21/06/2021)

Discussion

In the study area, social interactions of red foxes and a single golden jackal were observed repeatedly in two following years. Documented observations of mixed canid species groups are rare and often anecdotal. These records provide new questions regarding interspecific behaviour of wild canids and the effects of ongoing golden jackal distribution in Central Europe. To address these questions, the current state of research concerning interspecific behaviour as well as the general biological and behavioural background of both species should be considered. To the authors' knowledge, this is the first record of a socio-positive behaviour between golden jackals and red foxes, which are commonly regarded as competitive species (Lanszki et al. 2006; Torretta et al. 2021). Coincidence is considered to be unlikely, due to the repeated occurrence of similar behaviour. The observation raises several questions concerning interspecific behaviour on multiple scales. It is important to consider the fact that the golden jackal observed here is a single male individual isolated from other golden jackals. Thus, isolation from other territorial golden jackals could be a driver for interaction and social bonding with another species. Red foxes generally show a similar social behaviour and might therefore be an attractive alternative for golden jackals in situations where there is a lack of conspecifics. We assume that the golden jackal in this case benefits from the red foxes' company in a psychological way, fulfilling the basic social needs of the individual (comparing to wolf and dholes, Ghaskadbi et al. 2021). On the other hand, the benefits for the red fox female and her cubs seem easier to comprehend. The golden jackal as being the larger species is probably having an indirect effect, shown as a deterring or maybe even defensive effect on possible competitors for food and for securing protected space for rearing the cubs. Similarly, foraging advantages and predator avoidance are also

considered to explain mixed species groups in other mammals (Stensland et al. 2003). Moreover, observations also indicate that the golden jackal might play an active role in raising the cubs which can be interpreted as a direct positive effect for the survival of the red fox cubs. The situation observed brings up the question of interspecific reproduction. According to the state of knowledge, reproduction of golden jackals and red foxes is not naturally possible due to their different amount of chromosomes (Wurster & Benirschke 1968). Even though hybrids of mammal species with different amounts of chromosomes are known in some cases (e.g., mules as offspring of donkey and horse, Gabryś et al. 2021), the morphology of the fox cubs in this study clearly indicates that they are no hybrids.

Interspecific relationships between the two species should be considered a possible scenario at the edge of the golden jackal's distribution range. The fact that golden jackal and red fox coexistence is well possible on an individual scale should also be kept in mind when planning further research about interspecific behaviour of these two interguild species. More research is necessary to understand potential underlying general mechanisms beyond individuality. In a comparable situation, where single golden jackals meet other relatives of the genus *Canis*, hybridization should also be taken into account as a possible scenario (Moura et al. 2014; Galov et al. 2015). Further research on such interspecific relationships at the edge of one species' distribution range is necessary in order to figure out whether the observed situation is an individual or a common occurrence. Telemetry studies and long-term monitoring could be implemented to help answering these questions.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s13364-024-00737-2>.

Acknowledgements We thank the staff members from the Nature Conservation Center Wurzachener Ried as well as the local hunters not only for the good contact but for the constant support and implementation of the field work.

Author contribution FB and HW: conceptualization, methodology, data collection, data analysis, and writing: first draft, review, and editing. JH and JA: data analysis and writing: review and editing. Sebastian Collet: genetic analysis and interpretation and writing: review and editing.

Funding Open Access funding enabled and organized by Projekt DEAL. No funding was received for conducting this study.

Data availability Raw data were generated at Forest Research Institute Baden-Württemberg, Wildlife Institute. Derived data supporting the findings of this study are available from the corresponding author, FB, on request.

Declarations

Competing interests The authors declare no competing interests.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Arnold J, Humer A, Heltai M, Murariu D, Spassov N, Hackländer K (2012) Current status and distribution of golden jackals *Canis aureus* in Europe. *Mammal Rev* 42:1–11
- Baker PJ, Robertson CPJ, Funk SM, Harris S (1998) Potential fitness benefits of group living in the red fox, *Vulpes vulpes*. *Animal Behaviour* 56(6):1411–1424
- Bekoff M, Diamond J, Mitton JB (1981) Life-history patterns and sociality in canids: body size, reproduction, and behavior. *Oecologia* 50:386–390
- Böcker F, Jokisch S, Klamm A (2020) Erste Hinweise auf residente Goldschakale (*Canis aureus*) in Deutschland. *Säugetierkundliche Inf* 11(57):281–290
- Cavallini P (1996) Variation in the social system of the red fox. *Ethol Ecol Evol* 8(4):323–342
- Demeter A, Spassov N (1993) *Canis aureus* Linnaeus. 1758 - Schakal. Goldschakal. In: Stubbe M, Krapp F (eds) *Handbuch der Säugetiere Europas*, Volume 5/1: Raubsäuger I Canidae, Ursidae, Procyonidae, Mustelidae 1. Aula-Verlag, Wiesbaden, pp 107–138
- Dinets V, Eligulashvili B (2016) Striped hyaenas (*Hyaena hyaena*) in grey wolf (*Canis lupus*) packs: cooperation, commensalism or singular aberration? *Zool Middle East* 62(1):85–87
- Dorning J, Harris S (2019) Understanding the intricacy of canid social systems: Structure and temporal stability of red fox (*Vulpes vulpes*) groups. *PLoS One* 14:9. <https://doi.org/10.1371/journal.pone.0220792>
- Gabryś J, Kij B, Kochan J, Bugno-Poniewierska M (2021) Interspecific hybrids of animals in nature, breeding and science – a review. *Ann Anim Sci* 21(2):403–415. <https://doi.org/10.2478/aoas-2020-0082>
- Galov A, Fabbri E, Caniglia R, Arbanasić H, Lapalombella S, Florijančić T, ... & Randi E (2015) First evidence of hybridization between golden jackal (*Canis aureus*) and domestic dog (*Canis familiaris*) as revealed by genetic markers. *R Soc Open Sci* 2(12):150450
- Ghaskadbi P, Das J, Mahadev V, Habib B (2021) First record of mixed species association between dholes and a wolf from Satpura Tiger Reserve, India. *Canid Biology & Conservation, IUCN/SSC Canid Specialist Group*, ISSN 1478–2677
- Giannatos G, Marinos Y, Maragou P, Catsadorakis G (2005) The status of the golden jackal (*Canis aureus* L.) in Greece. *Belg J Zool* 135(2):145–149
- Hatlauf J, Hackländer K (2016) Preliminary results for golden jackal (*Canis aureus*) survey in Austria. *Beiträge Zur Jagd- Und Wildforschung* 41(2016):295–306
- Hatlauf J, Bayer K, Trouwborst A, Hackländer K (2021) New rules or old concepts? The golden jackal (*Canis aureus*) and its legal status in Central Europe. *Eur J Wildl Res* 67:25
- Hatlauf J, Böcker F (2022) Recommendations for the documentation and assessment of golden jackal (*Canis aureus*) records in Europe. *BOKU-Berichte zur Wildtierforschung und Wildbewirtschaftung* 27. Hrsg.: Institut für Wildbiologie und Jagdwirtschaft (IWJ) Universität für Bodenkultur Wien. ISBN 978–3–900932–94–7.
- Hatlauf J, Böcker F, Wirk L, Collet S, Schley L, Szabó L, Hackländer K, Heltai M (2021) (2020) Jackal in hide: detection dogs show first success in the quest for golden jackal (*Canis aureus*) scats. *Mammal Res* 66:227–236
- Iossa G, Soulsbury CD, Baker PJ, Harris S (2008) Body Mass, territory size, and life-history tactics in a socially monogamous canid, the red fox *Vulpes vulpes*. *J Mammal* 89(6):1481–1490
- Krofel M, Giannatos G, Ćirović D, Stoyanov S, Newsome TM (2017) Golden jackal expansion in Europe: a case of mesopredator release triggered by continent-wide wolf persecution? *Hystrix* 28(1):9–15
- Lanszki J, Heltai M, Szabó L (2006) Feeding habits and trophic niche overlap between sympatric golden jackal (*Canis aureus*) and red fox (*Vulpes vulpes*) in the Pannonian ecoregion (Hungary). *Can J Zool* 84:1647–1656
- Lanszki J, Schally G, Heltai M, Ranc N (2018) Golden jackal expansion in Europe: first telemetry evidence of a natal dispersal. *Mamm Biol* 88:81–84
- Lapini L, Ferri M, Villa M (2022) Diffusione di *Canis aureus* in Italia: aggiornamento 2022. L'espansione in Italia centrale è accelerata dall'incontro col lupo? <https://www.habitatonline.eu/2022/03/diffusione-di-canis-aureus-in-italia-aggiornamento-2022-lespaansione-in-italia-centrale-e-accelerata-dallincontro-col-lupo/>
- Linderoth P, Johann F, Handschuh M, Bauch T, Elliger A, Dalüge G, Herbst C, Pegel M, Arnold J (2020) Schwarzwildproblematik im Umfeld von Schutzgebieten. Raum-Zeit-Verhalten und Aktivität von Wildschweinen (*Sus scrofa*) in Gebieten mit Jagdruhezonen. Projektbericht, Wildforschungsstelle Baden-Württemberg beim LAZBW, Aulendorf
- Loveridge AJ, Macdonald DW (2002) Habitat ecology of two sympatric species of jackals in Zimbabwe. *J Mammal* 83(2):599–607
- Macdonald DW (1979) The flexible social system of the golden jackal, *Canis aureus*. *Behav Ecol Sociobiol* 5:17–38. <https://doi.org/10.1007/BF00302692>
- Macdonald DW, Campbell LAD, Kamler JF, Marino J, Werhahn G, Sillero-Zubiri C (2019) Monogamy: cause, consequence, or corollary of success in wild canids? *Front Ecol Evol* 7:341. <https://doi.org/10.3389/fevo.2019.00341>
- Möckel R, Podany M (2015) Weitere Nachweise des Goldschakals *Canis aureus* in Deutschland. *Säugetierkd. Inform.* 10, H.50:97–104
- Moura AE, Tsingarska E, Dąbrowski MJ, Czarnomska SD, Jedrzejewska B, Pilot M (2014) Unregulated hunting and genetic recovery from a severe population decline: the cautionary case of Bulgarian wolves. *Conserv Genet* 15(2):405–417
- Pecorella S, De Luca M, Fonda F, Viviano A, Candelotto M, Candotto S, Mori E, Banea O (2023) First record of allonursing in golden jackal (*Canis aureus*, L. 1758): a case of double breeding and communal denning within the same social unit. *Eur J Wildl Res* 69:43. <https://doi.org/10.1007/s10344-023-01671-5>
- Rutkowski R, Krofel M, Giannatos G, Ćirović D, Männil P, Volokh AM, Lanszki J, Heltai M, Szabó L, Banea OC, Yavruyan E, Hayrapetyan V, Kopaliani N, Miliou A, Tryfonopoulos GA, Lymbekakis P, Penezić A, Pakeltyté G, Suchecka E, Bogdanowicz W (2015) A European concern? Genetic Structure and Expansion of Golden Jackals (*Canis aureus*) in Europe and the Caucasus. *PLoS One* 10:11. <https://doi.org/10.1371/journal.pone.0141236>
- Scheinin S, Yom-Tov Y, Motro U, Geffen E (2006) Behavioural responses of red foxes to an increase in the presence of golden jackals: a field experiment. *Anim Behav* 71:577–584
- Stensland E, Angerbjörn A, Berggren P (2003) Mixed species groups in mammals. *Mammal Rev* 33:205–223
- Tillmann JE (2020) Der Goldschakal in Deutschland. *Naturschutz Und Landschaftsplanung* 52(09):2020

- Torretta E, Riboldi L, Costa E, Delfoco C, Frignani E, Meriggi A (2021) Niche partitioning between sympatric wild canids: the case of the golden jackal (*Canis aureus*) and the red fox (*Vulpes vulpes*) in north-eastern Italy. *BMC Ecol Evol* 21:129
- Wurster DHH, Benirschke K (1968) Comparative cytogenetic studies in the order carnivora. *Chromosoma* 24(3) Springer-Verlag: 336–382. <https://doi.org/10.1007/BF00336201>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.