Research

REACTIONS OF HORSES TO WILDLIFE AND LIVESTOCK GUARDING DOGS

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1. Introduction

A combination of natural habitat loss (Cimatti et al., 2021) and the ongoing recovery of large carnivores in Europe (Chapron et al., 2014) brings challenges for coexistence with predators such as the grey wolf *(Canis lupus)* in human-dominated landscapes. Measures to protect livestock from attack, including the use of livestock guarding dogs (LGDs) and electric fences (Bruns et al., 2020), tend to focus on smaller species such as sheep and goats, with less attention paid to horses. This may be because wolves most often kill small stock (see Freitas et al., 2021 in *CDPnews* issue 23) or because it is assumed that horses have sufficient anti-predator responses (DBBW, 2021a).

Nevertheless, between 2012 and 2016, an average of 645 horses per year were compensated for losses attributed to wolves across the European Union (Linnell and Cretois, 2018). Free-ranging ponies constitute an important prey for wolves in NW Iberia (see Freitas and Álvares, 2021 in *CDPnews* issue 23). Furthermore, attacks on horses have increased significantly in some countries. For example, in Slovenia 14 attacks on horses were recorded in 2016/17 rising to 50 attacks in 2018/2019 (Dušanka Jordan, personal communication).

In the federal state of Lower Saxony, Germany, with confirmed presence of 35 wolf packs, five pairs and thrtee solitary animals in 2020/21 (DBBW, 2021b), attacks have been recorded on foals, ponies and yearling horses, which were mostly kept without any protection measures (Niedersächsisches Ministerium, 2021). This has intensified the debate regarding the possibility of some wolf packs specialising on hunting particular types of livestock, namely horses. As a result, the German Equestrian Federation has called for further measures to reduce attacks by wolves on horses and other livestock (Deutsche Reiterliche Vereinigung (FN), 2020).

The value of horses is thought to differ from that of other livestock due to factors including their emotive value, monetary value, role as a signal of social status and their perception in politics (Grönemann, 2015). Diverse stakeholder groups are involved to a greater or lesser extent in the debate about the return of wolves, including breeders, farmers, horse owners, professional riders and their sponsors, hunters, conservationists and state and local authorities and organisations), thus there is a need for sustainable solutions for conflict-reduced coexistence with wolves. Furthermore, horse keepers and owners fear that wolf presence and attacks may trigger fear reactions in horses leading to flight responses, escapes from pastures and road accidents (Grönemann, 2015).

Probably because experiments in the field are challenging, research on anti-predator responses of ponies and horses is rare (but see the observations of Lema et al. in this issue). Few researchers have addressed the reactions of domestic horses towards predator stimuli. Christensen and Rundgren (2008) reported that predator odour (from wolf fur), associated with a sudden auditory stimulus, increased the level of vigilance of individually tested horses. Recent studies on two groups of different breeds found that horses increased their alertness, gaits and grouping in response to predator vocalisations (Janczarek et al., 2020).

Protection measures for small livestock cannot be readily adopted for horses without prior assessment to avoid risk of injury. For example, guidelines for horse fences (BMELV, 2009) were drafted before wolves returned to Germany and their suggestions do not necessarily meet requirements for protection from wolves (Reinhardt et al., 2012). According to these recommendations, the lowest bar or wire of fences for horses should be at least 40 cm above the ground (BMELV, 2009) to avoid the risk of leg injuries if horses kick or roll under the fence, but this allows wolves to crawl under the fence. Several possible solutions have been proposed, such as the attachment of lower wires outside fences (DLG, 2020) or the use of low injury risk materials. Their effectiveness needs to be validated (see Schütte, 2021 in *CDPnews* issue 23).

Currently, scientific studies on damage prevention measures for the equine sector are limited. Electric fences are usually recommended (DLG, 2020; NABU Niedersachsen, 2020; Schütte, 2021), although alternatives could include the use of LGDs (NABU, 2015; see also Lagos and Blanco, 2021 in *CDPnews* issue 23). LGDs are used to protect livestock from predation worldwide (Rigg, 2001) and effectively reduce depredation on sheep, goats, cattle and other species of domestic animals (Gehring et al., 2010).

To contribute to this topic by increasing knowledge of horse reactions to the presence of wolves and the possibility of using LGDs to protect them, we implemented two case studies. The aim of the first study was to obtain information about the reactions of horses kept in pastures under semi-natural conditions to wolves, as well as to other wildlife and domestic animals. We also evaluated the usefulness of monitoring groups of horses via GPS in combination with camera trapping. The second study aimed to evaluate the potential of protecting horses with LGDs by analysing the reactions of a group of horses towards guarding dogs. We evaluated whether a social bond, which forms the basis for protective behaviour in LGDs (Coppinger et al., 1983), can be established with horses.

2. Study areas

Both studies were implemented in the 2018/2019 wolf monitoring year. The first study was conducted in the rural district of Celle, Lower Saxony (Fig. 1). The landscape was characterised by alder forests,

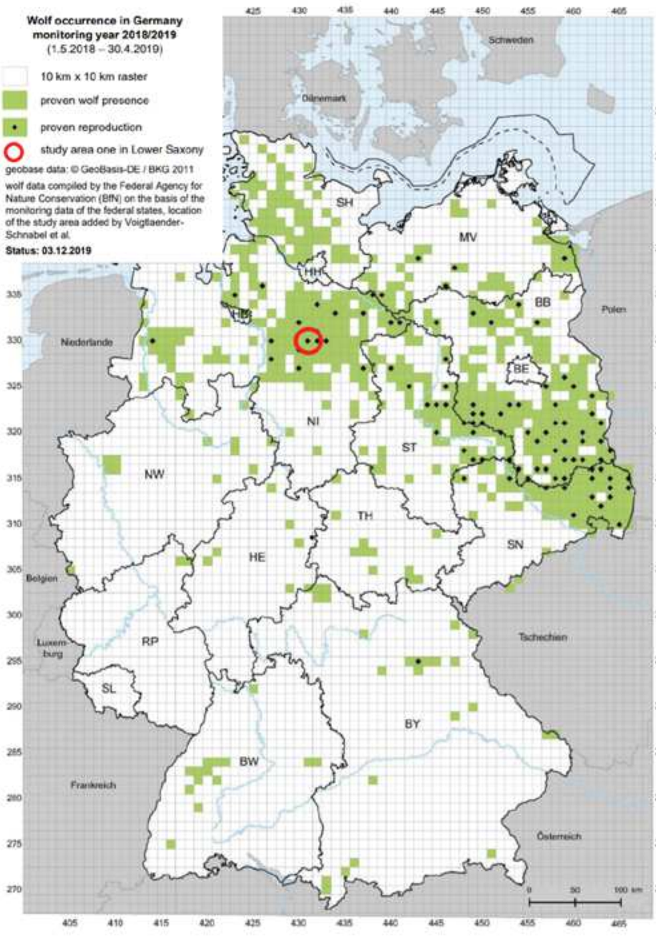

Fig. 1 Location of the Lower Saxony study area showing wolf occurrence in Germany in the 2018/19 monitoring year.

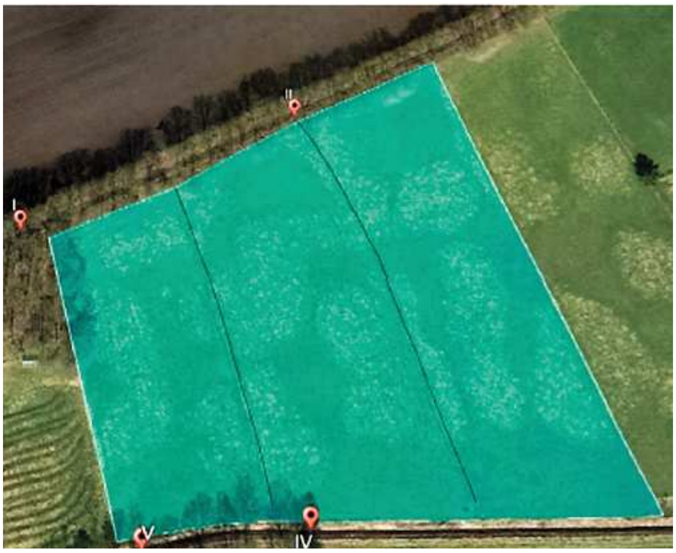

Fig. 2 Group 1 pasture indicating the positions of wildlife cameras.

Fig. 3 Group 2 pasture indicating the positions of wildlife cameras.

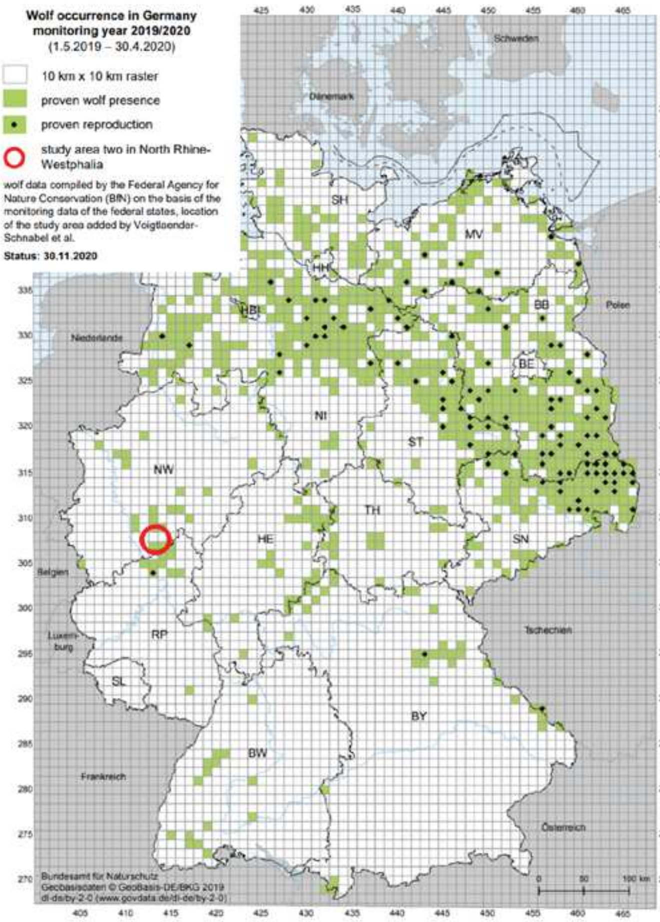

Fig. 4 Location of the North Rhine-Westphalia study area showing wolf occurrence in Germany in the 2019/20 monitoring year.

meadows and moor. Two horse groups were placed in two different pastures, 460 m apart from each other. Group 1's pasture was about 2.39 ha, surrounded by small forests (on two sides), pasture and farmland (Fig. 2). In addition, a dirt road bypassed one side of the pasture behind adjacent bushes. Group 2's pasture was about 1.25 ha, surrounded by forests, farmland and grassland (Fig. 3). Wildlife in this area was rich in deer, raccoons, foxes and rabbits. The study area was located near the territory of the 'Osterholzer Moor' wolf pack, which consisted of two adults and five pups (Landesjägerschaft Niedersachsen, 2021).

The second study was implemented in the Rhine-Sieg district of North Rhine-Westphalia (Fig. 4). It was conducted on private land where three Arabian stallions were kept year-round in an open stall in a 1.3 ha pasture surrounded by fields, meadows and forests. The property was located in the 'Wahnbachtal' water protection area, which restricted use of pastures in winter. The area was located in the 'Oberbergisches Land' wolf area near the 'Leuscheid' wolf territory, where one pair of wolves was documented during the study (DBBW, 2021c).

3. Methodology

3.1 Study 1: Reactions of horses to wildlife

Data on horse–wildlife interactions were obtained from analysis of the movement behaviour of seven horses in two groups (Table 1). Group 1 comprised four mares, each with a 5-months old foal. For this group, hay was available *ad libitum* in the pasture throughout the trial period. In addition, mares were fed with concentrated feed each morning. Group 2 comprised three 2-year-old mares in a second pasture. All horses were familiar with the pastures, having either grown up on the farm or lived there for

Table 1 Details of horses included in Study 1.

Group	Horse	Breed	Age	State of health
1	B	Holsteiner	16	healthy
1	C	Hanoverian	11	mild ataxia
1	D	Hanoverian	6	healthy
1	E	Hanoverian	17	mild osteoarthritis
2	F	Hanoverian	2	healthy
2	G	Pony	2	healthy
2	H	Hanoverian	2	healthy

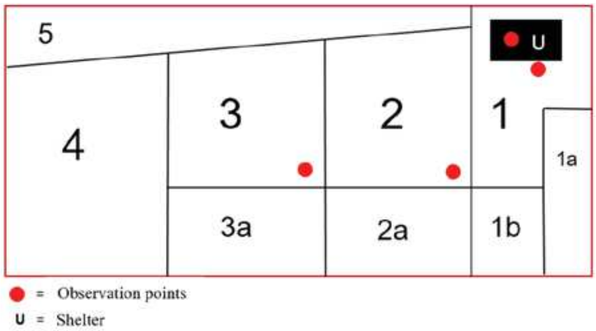

Fig. 5 Diagram showing the five meadows and subdivisions in Study 2.

Table 2 Details of Arabian stallions and livestock guarding dogs in Study 2.

Species	ID	Year of birth	Sex	Kinship
horse	P1	2009	male	no
	P2	2012	male	no
	P3	2013	male	no
dog	dm1	2015	male	parents of m2 and f2
	df1	2016	female	
	dm2	2017	male	offspring of m1 and f1 (different litters)
	df2	2018	female	

several years. They were warmbloods, including one pony, and the farm veterinarians considered them to be in good condition and health, except two which had slight movement constraints due to mild forms of ataxia and osteoarthritis (Table 1).

The mares in both groups were equipped with GPS devices (GPS Lap Timer BT-Q1000eX) and, over a period of six weeks from 20th August to 30th September 2018, their movements were recorded every night from 18:00 (sunset c.20:00) to 08:00 (sunrise c.06:00) as wolf attacks on livestock are known to take place primarily during the night (Boitani, 1992). Longitude, latitude and moving speed were recorded once per second for each horse. Foals were not fitted with GPS devices as previous research has demonstrated that foals < 6 months of age mostly follow their mothers (Berger, 1986).

Around each pasture we positioned five camera traps (SecaCam Raptor, SecaCam HomeVista, Wild-Blick) at a maximum distance of 10 m from the fence and oriented towards the pasture. They were attached to tree trunks or fence posts 73–116 cm above the ground. Cameras were set to picture mode from 20th August to 10th September, taking four pictures followed by a 30-second break after each trigger. To check whether video mode enhanced the likelihood of documenting wolves, they were then switched to record 15 seconds of video at each trigger until the end of the trial. The ten cameras operated for 41 days resulting in a sampling effort of 410 trap nights. Detected animals were categorised as 'carnivores' or 'other animals'.

Horse moving distance, speed, position and distances within the group were matched with animals recorded by camera traps resulting in a total of 19 assessment nights. Movements were categorised according to speed: fast (> 12 km/h), slow (< 12 km/h) or close to zero (< 0.129 km/h) (Zierman, 2006) and later associated with the presence of animals recorded by the cameras. Horses were considered to have reacted to animals whenever they showed fast movements within a 10-minute time frame from five minutes before to five minutes after animals were registered by a camera trap. 'Speed concerted' were intervals[1] with at least one horse showing speed movements (> 12 km/h); including either the speed movement of one horse, two, three or all horses of a group.

3.2 Study 1: Reactions of horses to wildlife

The second study examined social interactions between LGDs and horses, based on analysis of affiliative and agonistic behaviours shown by horses towards dogs. Since 2016, three Arabian stallions (male, uncastrated) had been protected by two Šarplaninac (Yugoslavian Shepherd Dogs) (dm1 and df1). The dogs had pups in 2017 (dm2) and 2018 (df2) which were raised from a young age in close proximity to

[1] An interval was defined as the timespan when a defined movement category starts until it ends, e.g. starts when speed movement is > 12 km/h and ends when speed is < 12 km/h.

the horses. To promote the socialisation of dm1 and df1 with the stallions, they were first kept in a separate area next to the horses. After two to three weeks, horses and dogs were put together in an area of 1.3 ha.

During the observation period, the area was divided into five meadows of different sizes (Table 2, Fig. 3), only the first three of which were open for grazing. The other two meadows could be entered by the dogs but not by the horses. Area 1 had a shelter for horses and dogs, a paddock, two hay feeding stations and a watering trough. Areas 1a, 1b, 2a and 3a were separated from the other sections by mobile fences and electric nets and were not accessible to the horses. Section 1a was a nature conservation area. Sections 1b, 2a and 3a were used as a separation area for LGD dm2 during the feeding time of other dogs.

The entire area was surrounded by a wooden fence with two battens at 30 cm and 100 cm above the ground. Additionally, an electrified wire to prevent wolves crawling underneath the fence was attached 10 cm above the ground outside the wooden fence. Electric nets were only used to separate the dogs from each other and were out of reach of the horses. Fences were connected to the power network at night.

Behavioural observations were conducted for a total of 46 hours over seven separate days, from November 2019 to January 2020. Different locations were chosen for observations due to the influence of the weather on horse movements between shelter and meadows (Fig. 5). The first observation day included a period from 09:00 to 12:00 for the horses to habituate to the observer. During subsequent observations, sampling was initiated when the horses ignored the presence of the observer. Continuous, all occurrence behaviour sampling (Altmann, 1974), was implemented simultaneously for all animals in the group by the same observer from 09:00 to 12:00 and 13:00 to 17:00. An ethogram describing affiliative and agonistic behaviours was adapted from McDonnell and Haviland (1995) and used to register horse behaviour towards the dogs (Table 3). A separate recording sheet was used for each observation period.

We also recorded submissive behaviour of dogs towards horses. In case of aggression by livestock, LGDs should retreat, lay down and look away (AGRIDEA, 2010). Dog behaviour unrelated to horses, such as barking and running to fences, was noted along with the reaction of the horses to such behaviour, but was not analysed statistically as the sample size was too small.

3.3 Data analysis

Data were analysed with R and SPSS software. GPS data were analysed using a newly developed R script. Some data were not normally distributed (Shapiro-Wilk test). Correlations between parameters and comparisons of means were analysed with a Generalised Linear Model (GLM), allowing multivariate calculation of non-parametric data. The dependent variable is tested against several predictors to determine which is the most significant. Frequency distributions of the behaviours shown by each horse towards LGDs were analysed with chi-square tests and binomial tests. The level of significance was set to $p < 0.05$ and all tests were two-sided.

Table 3 Ethogram of horse social behaviours towards livestock guarding dogs (McDonnell and Haviland, 1995).

Affiliative behaviours	Behaviour components
1. social play	1.1 play fighting (head/neck/chest nip)
	1.2 running
2. rest/feeding together	2.1 feeding together
	2.2 rest standing
	2.3 rest sleeping
3. vigilance/social behaviour	3.1 attentive ears and looking in the dog's direction
	3.2 neighing
	3.3 following dogs
4. comfort/investigation	4.1 allogrooming
	4.2 olfactory investigation

Agonistic behaviours	Behaviour components
1. threat	1.1 ears laid back/pinned
	1.2 kick threat
2. avoidance	2.1 facing away
	2.2 leaving
3. attack	3.1 kick
	3.2 biting
	3.3 bite threat/chasing
4. impose/posturing	4.1 strike
	4.2 arched neck threat
	4.3 squeal

Table 4 Animal species detected and horse reactions.

Species	Number of records	Number of 'fast movements'
Carnivores		
marten	40	6 (23%)
fox	33	6 (23%)
domestic cat	28	2 (8%)
badger	21	4 (14%)
domestic dog	12	2 (8%)
raccoon dog	8	1 (4%)
raptor	3	0
raccoon	1	0
dog or wolf	1	0
polecat	1	0
other animals		
rabbit	55	2 (8%)
deer	13	2 (8%)
unidentified small animal	6	1 (4%)
small bird	5	0
bat	1	0
TOTAL	**228**	**26**

4. Results

4.1 Study 1: Reactions of horses to wildlife

A total of 228 animal occurrences were identified from camera trap images: 158 at the Group 1 pasture and 70 at the Group 2 pasture. Most occurrences were of carnivores (martens, foxes, badgers and various other wildlife species as well as cats and dogs) or herbivores (rabbits, deer). No definite record of a wolf was obtained from the cameras (Table 4). Group 1 horses showed fast movements (including *speed concerted*) in 15 occurrences (9.5%) compared to 11 occurrences (15.7%) for Group 2. No significant difference was found in the number of movement reactions to 'carnivores' versus 'other animals'.

Analysis of the GPS data showed when horses reacted to animal occurrence they moved significantly slower (mean speed animal occurrence: 1.28 km/h) than the average speed of horses without documented animal occurrence (mean speed no animal occurrence: 17.2 km/h) in fast movement (GLM $N=64$, $t=2.574$, $p=0.013$). In general, analysis of the distance between individual horses revealed that, in slow movements, horse pairs were significantly closer to each other (mean distance slow movement: 22.7 m) than in speed concerted movements (mean distance speed movements: 30.6 m) (GLM $N=153$, $t=5.755$, $p<0.001$). The distance between moving horses during speed concerted intervals decreased when they reacted to animals (mean distance animal occurrence: 26.5 m) (GLM $N=84$, $t=5.919$, $p<0.001$). At very slow speeds (<0.126 km/h), the distance between horses within each group varied greatly (distance very low movement speed: 6.6–24.8 m).

4.2 Study 2: Reactions of horses to LGDs

A total of 493 behaviours were recorded comprising affiliative (71%) and agonistic (29%) reactions of horses towards LGDs. Although the frequency of the two categories differed between horses, all three showed significantly more affiliative behaviours (binomial test for P1: $N=154$, $p<0.001$; P2: $N=144$, $p<0.001$; P3: $N=195$, $p=0.015$). All three horses showed 'vigilance/social behaviour' significantly more often (62%) than 'rest/feeding together' (29%), 'comfort/affection' (5%) or 'social play' (4%) (chi-square test: $N=350$, $X2=303.55$, $df=3$, $p<0.001$) (Fig. 6). When data for all three horses were combined, 'attentive ears and looking in the dog's direction' (56%) was significantly more often shown than the other affiliative behaviour components (chi-square test: $N=350$; $X2=855{,}95$, $df=8$, $p<0.001$) (Fig. 7).

The distribution of agonistic behaviour was similar for horses P1 and P2. In contrast, P3 showed significantly more agonistic reactions towards the dogs, especially 'threat' (chi-square test: $N=114$, $X2=11.558$, $df=2$, $p<0.003$) and 'posturing' (binomial test: $N=18$, $p<0.001$) (Fig. 8). Overall, 'ears laid back/pinned' was significantly more often exhibited towards LGDs than any other agonistic behaviour (chi-square test: $N=143$, $X2=313$, $df=7$, $p<0.001$) (Fig. 9).

LGDs reacted by immediately retreating when horses showed agonistic behaviour ($n=104$). Horses displayed the behaviour 'ears laid back/pinned' in a total of 86 instances and 'kick threats' in 18 instances. In 100% of such cases, LGDs retreated from the horses (Fig. 10).

In several situations when LGDs ran to fences and barked, horses showed the affiliative behaviour 'vigilance/social behaviour'. In particular, they showed 'attentive ears & looking in the dog's direction. In three situations of play-fighting between horses, LGDs reacted by running towards the horses and barking, which caused the horses to stop their

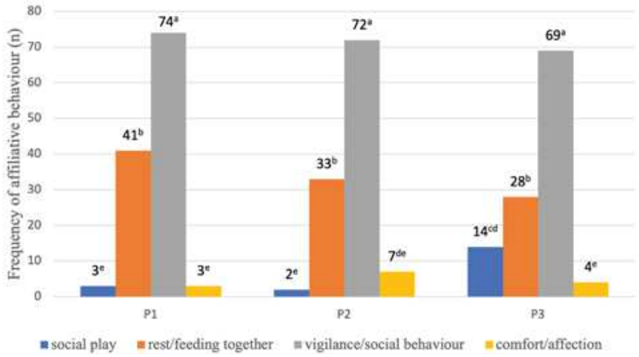

Fig. 6 Frequency of occurrence of affiliative behaviour shown by three horses (P1, P2 and P3) towards LGDs. Letters (a, b, c, d, e) show significant differences.

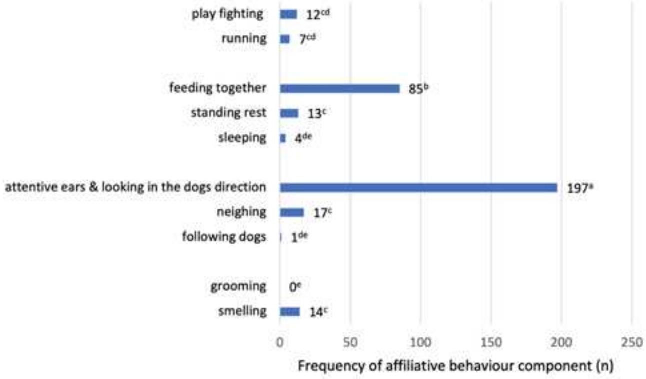

Fig. 7 Frequency of occurrence of affiliative behaviour components shown towards LGDs by three horses combined. Letters (a, b, c, d, e) show significant differences.

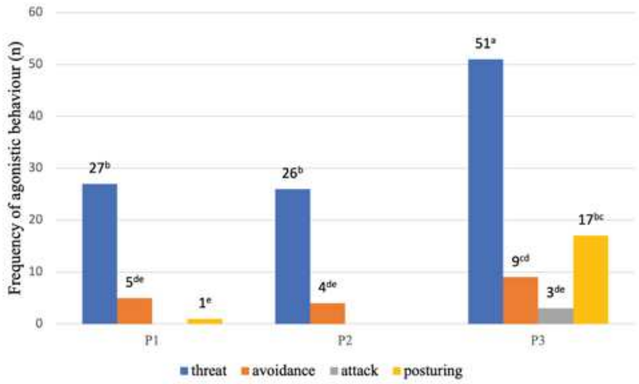

Fig. 8 Frequency of occurrence of agonistic behaviours shown by three horses (P1, P2 and P3) towards LGDs. Letters (a, b, c, d, e) show significant differences.

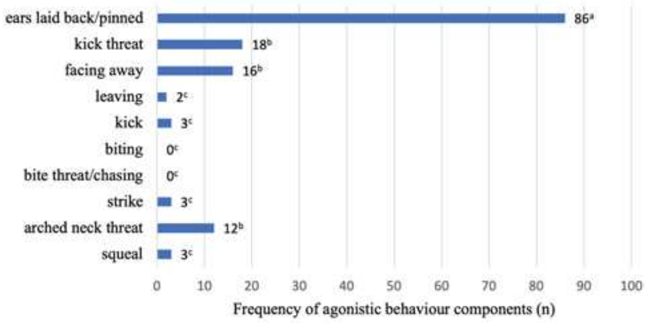

Fig. 9 Frequency of occurrence of agonistic behaviour components shown towards LGDs by three horses combined. Letters (a, b, c, d, e) show significant differences.

Fig. 10 A horse, disturbed from rest by the approach of a LGD, warns the dog to keep its distance with threatening facial expressions. The dog immediately retreats. *(Photo: B. Greiner)*

encounters and to threaten the dogs with agonistic behaviour. In one case, horse P3 injured dog df1 by kicking.

5. Discussion

5.1 Study 1: Reactions of horses to wildlife

Prior to the study, intensive investigations of wolf presence in the observation areas were done in 2017 and 2018. However, severe drought in the summer of 2018/2019 caused wolves to leave the area. Therefore, due to the lack of wolf detections by camera traps, conclusions for horse behaviour towards wolves cannot be drawn. Nevertheless, this study provides a first insight into reactions of horses towards other species and GPS monitoring allowed analysis of group structures between speed concerted intervals and slow movements of horses. The average speed of horses associated with wildlife presence was significantly slower than their average speed without wildlife occurrence, which suggests that the presence of wildlife does not cause fleeing but may lead to more alert reactions. Horses may have slowed down to inspect animals. It is important to mention that the camera traps only monitored a certain part of the pastures and may not have detected all wildlife occurrences.

Since the presence of wildlife was only recorded by camera traps, it is not clear if the horses reacted to visual, olfactory or auditory stimuli or to a combination of these stimuli. Horses are polyphasic, being active during day and night (Murphy et al., 2009). Their eyes are well adapted to recognising movement and shapes in very dark environments (Hanggi and Ingersoll, 2009). Their sound-localisation acuity is less developed than that of some other mammals, which could be due to their evolutionary history (e.g. visual capabilities are more relevant in open plains) (Heffner and Heffner, 1984).

Christensen and Rundgren (2008) demonstrated that predator odour increased vigilant behaviour in horses, but fear reactions were only seen after a sudden auditory stimulus. Horses appear to react with flight behaviour to a combination of at least two predator stimuli, which may pay in natural settings, as flight reactions demand more energy (Christensen and Rundgren, 2008). In contrast, in a recent study, auditory stimuli of predators (grey wolf, Arabian leopard and golden jackal) alone caused alertness, faster movements and grouping in horses (Janzcarek et al., 2020). It remains unclear whether the number, type or strength of predator cues plays the main role in eliciting flight responses in horses.

In our study, only smaller predators were documented. The fact that horses showed faster movements in only 11% of animal occurrences might be related to the horses' excellent vision during the night, which enables them to evaluate the potential danger of wildlife very well. Another reason could be the learned response to certain wildlife odours. In mammals, the response to predator smell is innate, but odour perception also depends on learning (Nielsen, 2017). The horses in the present study may have learned to recognise the odour of non-threatening species.

The breed and size of horse groups seem to influence their reaction to certain predator stimuli (Janzcarek et al., 2020). Differences in reaction to fearfulness tests are also related to horse breed (Budzy ska et al., 2018). Warmblood breeds such as Holsteins were less reactive than Thoroughbreds in fearfulness tests (Janiszewska et al., 2004), which may explain the mild response to wildlife occurrences of the horses in the present study. Holsteins and Hanoverian are characterised as uncomplicated, enthusiastic, strong-nerved and reliable.

However, it should be noted that the recording of a *slow average speed during wildlife occurrence* may have been influenced by the recording period, which was from five minutes before to five minutes after the first movement in connection with wildlife occurrence set in. We assumed that any wildlife captured by cameras was in the immediate vicinity of the pastures during this 10-minute period.

Analysis of the distance between members of a group indicates that the horses in the present study reduced their individual distance in alert situations and moved closer together, as reported for other predator responses (Rees, 2017). Reducing the distance to conspecifics in threatening situations reduces the risk of being attacked (Duranton and Gaunet, 2016). In a previous case study, different formation strategies were shown in Koniks (circular herd formation) and Arabians (linear group formation) (Janczarek et al., 2020). Further analysis of GPS data might show whether similar formation strategies were used by the horses in the present study. To validate the results from the first study, further research on horse groups with different sizes and compositions and the application of network analysis is needed (Rubenstein, 2015).

5.2 Study 2: Reactions of horses to LGDs

The study was conducted with a small group of male horses. These stallions showed more affiliative than agonistic behaviour towards LGDs. This leads to the conclusion that horses and LGDs can be socialised and bonding between the two species is possible. Furthermore, horses were more alert when LGDs barked and ran to fences. Therefore, we suggest that horses may recognise dog behaviour as an indicator of potential danger. However, our sample size of such observations was small and this conclusion needs to be treated with caution until further studies replicate our findings.

Agonistic behaviour shown by horses towards LGDs, such as 'ears laid back/pinned' and 'kick threat', led to immediate retreat by the dogs. It can be assumed that dogs have learned how to identify threats by horses. Further agonistic behaviour such as attack ('kicking') was shown only in connection with fights between stallions. The dogs started to bark and ran between the horses while the horses were play-fighting, which in one case resulted in injury of a dog. Dogs intervene in play and aggressive encounters of their conspecifics (Wars et al., 2009), similar to horses which also intervene in the conflict of others to reduce the level of aggression within the group and to establish social bonds (Schneider and Krueger, 2012). Behavioural analogies appear to exist between dogs and horses which may facilitate communication between species and assist horses to develop strong bonds with dogs (Maglieri et al., 2020). The observed interspecies intervention behaviour of LGDs during horse play-fighting also suggests that the dogs in our study established some level of social bond with the horses. Analysis of intervention behaviour between two different species (e.g. Landry et al., 2020) is highly interesting in itself and may enhance understanding of interactions between LGDs and livestock, including horses.

Further studies are needed to enlarge the data set and to consider different horse and dog groups, husbandry systems, social structures within horse groups, different dog and horse breeds and ages as important factors. Moreover, training strategies for bonding LGDs with horses must be evaluated in detail to avoid potential injuries to pups.

Acknowledgements

Permission for the observational study was provided by the local animal welfare board: Nds. Landesamt für Verbraucherschutz und Lebensmittelsicherheit (LAVES), Dezernat 33 – Tierschutzdienst, Postfach 3949, 26029 Oldenburg. We thank Kurt Krüger for his help with fitting GPS devices and setting up software for GPS data analysis. We thank the owners of the animals and properties for their support and also NABU Niedersachsen for providing accommodations and logistic support. We also thank the editors of *CDPnews* for their help with improving this article.

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