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LIVESTOCK GUARDING DOGS IN EUROPE:
paying attention to the context is important when managing complex human-wolf-dog relationships

AN INNOVATIVE APPROACH
to mitigate the conflict between large carnivore conservation and local communities

Article

THE CANOVIS PROJECT:

STUDYING INTERNAL AND EXTERNAL FACTORS THAT MAY INFLUENCE LIVESTOCK GUARDING DOGS' EFFICIENCY AGAINST WOLF PREDATION

PRELIMINARY RESULTS AND DISCUSSION

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1. Introduction

The wolf's return to the Alps has led to many changes in the pastoral practises due to the need for damage prevention measures. The most effective non-lethal tool is the livestock guarding dog (LGD) (Gehring et al., 2010), preferably in combination with shepherds and night-time enclosures (Espuno, 2004). For millennia, LGDs have been the keystone for the protection of small domestic animals against large predators throughout Eurasia, and are being reintroduced in areas that wolves are recolonizing, like the Alps. However, in the southern part of the French Alps wolf damage remain a chronic problem, and may even be increasing (MEDDE and MAAF, 2013), despite nearly all flocks are guarded by LGDs. Data suggest we are facing the limit of LGDs' efficacy in the present French pastoral system, especially in flocks with frequent attacks.

In the early 1980's, LGD researchers assumed that dogs' working abilities were based on three essential traits: attentiveness to the flock, trustworthiness and protectiveness (for more details see Coppinger and Coppinger 1982; Coppinger et al., 1983). Unfortunately, very few studies were conducted to understand how LGDs protect a flock and how their efficacy could be improved. Data are lacking because wolf attacks on livestock are difficult to observe. They are unpredictable and occur mostly during the night or on heavily vegetated terrain. Consequently, the effectiveness of LGDs has commonly been evaluated through indirect methods like questionnaires (Gehring et al., 2010). Nevertheless, these kind of studies are not free from confounding factors (e.g. density of predators, vulnerability of livestock, husbandry system, behavioural variability of LGDs and breeds, experience of the shepherds, or the existence of predator control programs) (Gehring et al., 2010). Census of losses gathered from livestock owners may also be unreliable (Green and Woodruff, 1983), and questionnaires do not provide information about how LGDs interact with wolves to protect a herd.

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Thanks to a set of military-grade thermal (night-vision) binoculars (Matis type) with recording capabilities, provided by the Sagem Society, 20 night interactions between LGDs and wolves were videotaped in 2000 and 2004, in the National Park of Mercantour (NPM) (Maritime Alps). This new technology provided us a first time view of how LGDs and wolves interact on alpine pasture (for more details see Landry, 2013). Although those images provided valuable information, the number of dogs, wolves and locations was insufficient to draw any conclusion. Fortunately, we had the opportunity to conduct further observations, resulting in the implementation of a new project named "CanOvis", designed to study night-time interactions between LGDs and wolves.

The main objective of the CanOvis project is to study the LGDs' innate and learned abilities to protect flocks. Furthermore we want to know how internal (e.g. age, sex, physical conditions) and external factors (e.g. social structure of the group of LGDs, density of predators, shepherding) influence their effectiveness. To achieve this goal, we plan to record: a) interactions between LGDs and wildlife, focusing on wolves (mainly during the night); b) LGD and flock movements, to study LGDs spatial distribution relative to the herd; c) LGD vocalisations, to study their effect on other LGDs and wolves. We will also study the practical knowledge of shepherds about predation and protection.

In the summer of 2013 we set up a pilot study to test the equipment (e.g. GPS collars), logistics and the sampling protocols. During this testing period we collected night-time footage of LGD-wolf interactions that we present in this article. The results are preliminary but suggest the need to select LGDs for alpine pastures based on new criteria, as well as the need to refine their training, monitoring and management in the herds.

2. Materials and Methods

The study area is located in the southern French Alps (Alpes Maritimes department) where frequent wolf damage is recorded. In 2013, 2,416 head of livestock, mainly sheep, resulted in producer compensation, which constitutes 39% of wolf-damage compensation in the whole country (Yoann Poncin Bressan, DREAL Rhône-Alpes, pers. comm.). This region represents a typical alpine landscape with forests (e.g. *Larix decidua*), meadows and heaths. On southern slopes, the forest edge can reach up to 2400 metres. Its location near the sea and a rapid elevation on a few kilometres make this territory extremely rich in plant and animal communities (Muséum National d'Histoire Naturelle 2003-2013). The study was conducted in the MNP. Five species of wild ungulate inhabited the area:

red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), mouflon (*Ovis aries musimon*) and chamois (*Rupicapra rupicapra*).

We selected three flocks (Fig. 1), which graze on pastoral units (PU, alpine pastures where a particular sheep flock grazes during the summer season) based on three criteria: the past and current pressure of wolf attacks (high and low), the PU's accessibility and the willingness of the sheep owners to participate in the project. Two PUs had high wolf pressure. One of the flocks grazes in the core area of the MNP where no shooting permits (to defend the flock or cull a wolf) are issued (MEDDE and MAAF, 2013). The number of sheep per flock ranged from 1,750 to 2,500 head and altitudes range from 1,500 to 2,550 MASL*. One PU had two flocks at the beginning of the grazing period (500 and 2,000), and then was gathered in one herd at the end of the summer (due to frequent wolf predation on the small herd). All flocks were protected by LGDs, mainly Great Pyrenees (GP) or crossbreds (GP x Maremma sheep dog). One of them had 11 LGDs and the other two had 4 LGDs each.

The sheep were observed during their night-time bedding, penned or free, from a distance of 100 to 700 m. Observations lasted from one hour before sunset until sunrise. We used a long-range infrared binocular designed for the army (SAFRAN/Sagem) connected to a video recorder. Everything emits thermal radiation and those of animals are infrared. The warmer the object is, the brighter it appears on the screen (Fig. 2). Therefore, animals are easily detectable, even at a distance of more than 3,000 m (but not necessarily identifiable). In our study, the practical distance for video analysis was 700 m. This equipment does not allow sound recording (e.g. LGDs vocalizations).

We also fitted LGDs with GPS collars (I-gotU GT-120) during the night-time surveillance. Since wolf chasings by LGD last an average of 5 seconds to 2 minutes (Landry, 2013), we adjusted the GPS collars accordingly with a threshold speed of 10 km/hour. A point was recorded each 10 seconds (primary interval) under this speed limit (maximum displacement of 20 m) and each 2 seconds after that (secondary interval). The GPS autonomy was around 20 hours and so we fitted the dogs with the GPS collars every evening and removed them the next morning to charge the battery during the day.

Fig. 1. Location of the three UP in the National Park of Mercantour (Maritime Alps).

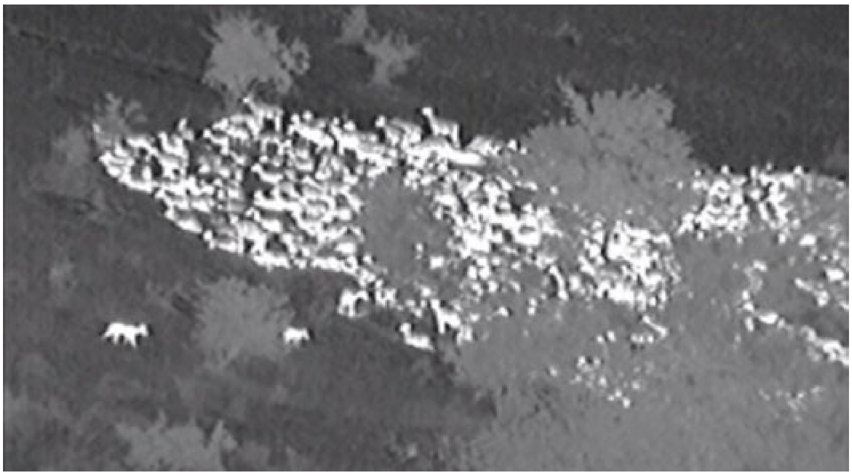

Fig. 2. The back of the sheep is more insulated and appears darker in comparison to the two wolves, on the left lower section of the image, that are less insulated due to their short fur. Photo: CanOvis/NPM.

* Meters above sea level.

3. Preliminary Results

We observed flocks during five working sessions for a total of 23 nights (3-7 nights per session) of surveillance. We recorded 9 events involving wolves (of which 3 were attempted attacks) (Table 1), at least 23 with other wildlife (7 with red foxes *Vulpes vulpes*, 3 with chamois *Rupicapra rupicapra*, 3 with red deer *Cervus elaphus*, >10 with *Lepus ssp*) and 2 events with stray dogs. Additionally, we recorded more than 10 hours of wolf footage.

LGDs' responses towards wolves ranged from no reaction, barking, social or close contacts (33% of the events) to chasing (Table 1). One dog fitted with a GPS collar reached a speed of >40 km/h during a chase (which was also filmed). The length of the pursuits varied from

Table 1. Synthesis of the night interactions between LGDs and wolves on three PUs in the National Park of Mercantour during the summer of 2013.

PU, altitude, flock size, damage reports/nr. losses	Nr. of LGDs	Date and nr. of events	Wolves' behaviours	LGDs' reactions
		30.07-02.08		
Entraunes 1,500-2,000 MASL 1,750 head 13 attacks/ /15 head lost	4	1	2 wolves attempt an attack on the flock confined to an electric fence.	A LGD raises its head.
		2	a. Two wolves approach a LGD (the flock is located at 50 m). One* (high posture) smells the dog (shoulders, back and head). Contact during 38 sec. Retreats for 5 m, returns (no contact), leaves again. d. Returns after 35 sec. Sniffs the ground around the dog during 30 sec. No contact. Leaves. g. Wolves escaping.	b. LGD stays still, no movement. High posture. Turns head to the opposite side. c. LGD orients itself towards the two wolves. High posture (hackles raised). e. No reaction. f. Two LGDs** standing close to the flock chase the wolves (82 sec. after the last encounter). A third dog joins the group. h. Long chase >1 km.
		3	2 wolves roaming around the flock.	No reaction.

* The other stays 5–10 m away from the LGD.

** The LGD sniffed by the wolf showed the same posture towards the two LGDs.

PU, altitude, flock size, damage reports/nr. losses	Nr. of LGDs	Date and nr. of events	Wolves' behaviours	LGDs' reactions
		25-29.08		
Millefonts 1,900-2,300 MASL	3	4*	1 wolf spent 3 nights in the vicinity of the flock (10 hours of recordings).	Different responses of the LGDs: from no reaction to chasing (>1 km).
2,000 head 6 attacks/13 head lost		5	a. A wolf carefully approaches the flock (not surrounded by a fence), attacks, captures a sheep by the neck, 4 other attempts to catch other sheep. The attack lasts 50 sec. No sheep were wounded. c. The wolf escapes.	b. LGDs bark. Seem to search for the source of the flock disturbance. Chase the wolf.
		6	A wolf carefully approaches the flock (not surrounded by a fence) and attacks. Makes 2 attempts to catch a sheep. The attack lasts 15 sec. The wolf escapes.	LGDs bark. Chase the wolf.
		7	A wolf approaches the flock, walks alongside the flock, lies down during 45 sec. at 20 m, stands up and continues to walk alongside the flock. Leaves. The occurrence lasts 152 sec.	No reaction. A LGD barks. The wolf was already approaching the flock.
		8	a. 2 wolves feeding on a lamb. c. The 2 wolves approach the LGDs →bow behaviour. e. The 2 wolves return to feed on the carcass.	b. A LGD approaches and sniffs the ground. d. The LGD chases off the two wolves. f. The LGD leaves the area sniffing the ground.
		9-13.08		
Longon 2,000-2,550 MASL	8	9	1 wolf passes by the flock at 300 m. Feeds on a lamb killed during the day.	No reaction.
2,000-2,500 head 12 attacks/32 head lost		10	a. 4 wolves pass by the flock at 300 m (at the same place, during the same night). Feed on the lamb. Social interactions between the presumably two parents (double marking). Leave the carcass. c. The four wolves chase the LGDs. Stop to drink in a stream.	b. A LGD chases the four wolves. Then it suddenly flees before the wolves chase it. Another LGD, which was joining the first one is also escaping.
		11	Two wolves pass by the flock at a distance of 200 m.	No reaction.**
14 – 21.09		12	Two wolves return to the rendezvous site passing by the flock at a distance of 200 m. One wolf is carrying food in its mouth. The other is limping. Marking behaviour from the latter.	No reaction.
11 – 16.10	11		The pack has changed its rendezvous site, presumably after a hunter discovered it. The pack was filmed 2 km from the flock.	

*A presumably young wolf spent three nights around the flock interacting with the flock and the dogs. We have recorded 10 hours of video material on this wolf. To simplify the table, we summed all the interaction in one event.

** It's interesting to note that just before the appearance of the wolves, the LGDs and herding dogs were barking very loud after which the herding dogs began to howl. Suddenly all the dogs stopped vocalizing.

a few hundred meters to more than one kilometre (Fig. 3). Prior to or during long chases (n=3), the wolf being chased seemed to wait for the LGDs instead of running away. In one case, the wolf being chased stopped and watched the LGD running by, even though 2 minutes before it was confronted by it and displayed a fearful aggressive behaviour (with low posture, ears back, tail under the belly, mouth wide open) (Fig. 4).

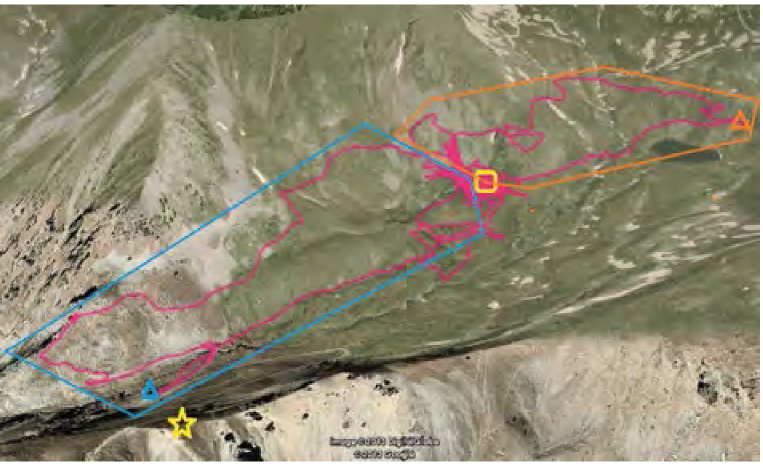

Fig. 3. Routes of one LGD chasing a wolf (pink lines). The blue polygon encloses a chase anti-clockwise initiated in the shepherd hut (yellow square), where the flock was bedded, ending at the blue triangle. The orange polygon encloses a second chase, clockwise from the shepherd hut, ending at the orange triangle. Image from Google earth.

Fig. 4. A wolf (on the right of the image) facing a LGD (on the left). Photo: CanOvis/NPM.

In two separate events, a LGD did not chase away two wolves which were standing nearby. In the first occasion, one wolf approached the LGD and sniffed it (Table 1). In the other event, the LGD sniffed the ground and approached two wolves feeding on a sheep carcass. The wolves then approached the LGD and attacked. The LGD defended itself by chasing them away. After that the wolves returned to feed on the carcass, while the LGD retreated sniffing the ground. On two PUs, wolves and LGDs were seen in proximity of each other (less than 100 meters apart) near the shepherd's hut (less than 100 meters away), without interacting.

Responses of LGDs towards other wildlife ranged from no reaction (especially towards hares, including *Lepus timidus* and *Lepus europaeus*), to barking with a short approach (<100 m) (*Lepus ssp*, red deer), and chasing (chamois and red fox), although always shorter than in the case of wolves. The LGDs' responses to stray dogs included chasing and social interactions (a neighbouring LGD male managed to enter the flock to reach a receptive female despite the presence of three other male LGDs).

Barking by LGDs did not prevent a wolf from attacking the flock during the first videotaped attack. During the second attack, on the following night, the wolf stopped the attack after LGDs barked; but LGDs were closer than the previous night.

4. Discussion

Thanks to the infrared binoculars, we were able to collect a remarkable set of images of interactions among LGDs and wildlife near flocks of sheep on summer pastures. We observed wildlife and especially wolves during all sessions. Wolves were observed passing by the flock, feeding on freshly killed sheep or attempting to attack sheep, despite the presence of LGDs. Wolves were apparently unafraid of LGDs. Although wolves were chased by LGDs or had agonistic encounters, these experiences did not prevent them from returning the same or following nights. Moreover, we recorded several occurrences in which a single LGD faced a wolf and exaggerated its behaviours instead of attacking, allowing enough time for the wolf to escape. Thus, the LGDs observed (either naive or experienced with wolf encounters) seemed to be very cautious around wolves. These results, which corroborate those of the previous study (Landry, 2013), strongly suggest that LGDs (or at least the dogs we observed) may be considered as a primary repellent (Shivik et al., 2003), namely they disrupt a predator's behaviour (Coppinger et al., 1988), but do not permanently modify their behaviour as a secondary repellent could do, through associative learning. Therefore, it is likely that wolves become habituated to LGDs, suggesting that no long-term avoidance learning occurs (Landry, 2013). It also seems that both LGDs and wolves evaluate the risk of an escalating confrontation. If LGDs play only the role of a primary repellent, the risk (i.e. to be wounded) for the wolves remains low. Therefore, the protection of the flock depends primarily on the physical ability of the LGD to consistently disrupt predatory behaviour night after night or to win a fight. This ability (to win an all-out contest) was called resource holding potential (RHP) by Parker (1974) to distinguish physical fighting ability from the motivation to persist in a fight. Therefore, the probability to win a fight depends not only on physical components, but also on motivational aspects (Parker, 1974), which depend on the value of the resource as well as the perceived prowess and motivation of the opponent (Barlow et al., 1986). Daring (which equals aggressiveness to Hurd, 2006) was proposed as a third variable, which plays an important role in determining fight outcome (Barlow et al., 1986). Daring (or aggressiveness) is the readiness to risk an encounter, to enter, or to dare to escalate an aggressive interaction (Barlow et al., 1986; Hurd, 2006). These factors (RHP, motivation and aggressiveness), which were first applied to fish, might be useful on other species like guarding dogs, to be employed as a toll to improve protection abilities. Based on behavioural models, these factors affect the choice of whether and when to escalate a confrontation (Hurd, 2006). Animals with higher RHP may escalate more as they have less to fear in a physical fight (Hurd, 2006). Individuals with higher subjective resource values may define winning as very important and more readily escalate an aggressive interaction (Hurd, 2006). Yet, it is difficult to know how valuable this resource (flock, sheep) is for a LGD and if it is correlated to the strength of the social bond to it (which is thought to be the first step of the protection success, Coppinger et al., 1988). LGDs traditionally used in Eurasia are taller than wolves, giving them theoretically higher RHP. Aggressiveness may be more important than the RHP and motivation to win a fight, at least in some species (Hurd, 2006). Therefore, the LGDs' aggressiveness may be a selective criterion as already pointed out by Green and Woodruff (1990) and rarely used in western countries. Daring (aggressiveness) appears to be an inherent property (Liinamo et al., 2007) and is a component of the temperament (or personality) of an individual (Barlow et al., 1986). Therefore, temperament may play a major role in flock protection, which corroborates the findings of McGrew and Blakesley (1982), who observed that LGDs with a clumsy or shy temperament were more often challenged by coyotes in contrast to aggressive/bold individuals. Moreover, aggressiveness is independent of the effect of RHP and resource value (Hurd, 2006). Thus, selecting aggression among LGDs may be beneficial for the protection of the herd. Yet, in touristic areas like the Alps, it will be essential to ensure aggressiveness is maximal towards predators while it is minimal regarding humans. Selecting aggressiveness against predators may also increase aggression towards companion or hunting dogs, which will lead inevitably to conflicts with hikers and hunters. The level of LGD aggressiveness towards predators varies among breeds and bloodlines suggesting an input of artificial selection. For example, eastern LGDs, like the Karakachan from Bulgaria, are known to be more aggressive (and territorial?) towards intruders (Sedefchev, 2005). According to Sedefchev (2005), the success of the LGD is its readiness to confront and fight, which seems not to be the case with GP. Compared to other breed, GPs are known to be less aggressive towards humans and dogs (Green and Woodruff, 1988) and therefore were recommended for touristic areas (Andelt, 1992; Hansen and Bakken, 1999; Landry, 2004). It was assumed that wolves would avoid LGDs, because the first instinct of a predator is not to feed, but to avoid hazard (e.g. Coppinger and Coppinger, 1993), and that their presence would interrupt their predatory sequences (e.g. Coppinger and Schneider, 1995). Thus, the lack of readiness to escalate might indicate that the LGD is not a real obstacle and that the wolf's success is just a question of time (the balance of costs and benefits is in its favour). In areas where LGD traditions were lost, the developmental environment in the sheep culture might not be similar enough to the ancestral one to elicit the proper behaviour from the dogs – if indeed they have any of those genes left because of selective breeding during recent years (Coppinger and Coppinger, 2005).

Our preliminary results and those of Landry (2013) demonstrate that LGD barks alone often do not modify wolves' on-going behaviours (60% of the cases in Landry, 2013), which corroborate the findings of Linhart et al. (1979) and McGrew and Blakesley (1982) on coyotes, and the ideas of Sedefchev (2005) regarding wolves. Because barking is easy to pinpoint (Coppinger and Feinstein, 1991), they might give valuable information to the wolves about the LGDs' location, the number of individuals, their distance and maybe even temperament (McGrew and Blakesley, 1982). Nevertheless, LGDs' barks can attract other LGDs even if they are not able to observe the scene (Landry, 2013). These observations suggest that LGDs vocalisations might transmit information. Indeed, the length of the barks and their frequency vary according to the context (e.g. type of intruder and threat), which suggests a function of communication (Yin, 2002; Yin and McCowan, 2004; Maros et al., 2008). Therefore, the effect of LGDs vocalisation on both LGDs and wolves will be studied in our project.

Fig. 5. During day-time, flocks scatter on large areas, which makes them difficult to protect. Photo: CanOvis/NPM.

We have regularly observed LGDs leaving the flock in the early morning to defecate and urinate before returning. LGDs and wolves can also defecate on the same spot. In our PUs, these scent "markings" did not prevent wolves from passing by or from attacking the flock, which supports the findings of Linhart et al. (1979) and McGrew and Blakesley (1982) on coyotes. Moreover, a recent study using a "biofence" made of non-native wolves faeces, urine and scratch marks showed ambiguous results as wolves regularly crossed the "forbidden" invisible line (Ausband, 2010). Therefore, LGDs markings should not be considered effective in preventing attacks as it is sometimes claimed.

MacNulty and colleagues (2009) demonstrated adult wolf predatory performance declines with age and that an increasing proportion of senescent individuals in the wolf population depresses the rate of prey offtake. Moreover, the performance weakening is correlated to the physical condition (Gurven et al., 2006). As an analogy to these results, the same may happen with the LGDs protecting a flock of sheep. Thus, the maintenance of the LGD, its age (which are RHP components), and the age structure of the LGDs' group are also key factors in protecting skills. But the latter will be ineffective if the females' heats are out of control. The energy to protect the flock is wasted on courting females and fighting males. In our case, a strange male LGD managed to reach a female in heat in the middle of the flock despite the presence of three males, probably because they were wounded during a fight at the beginning of the evening.

We videotaped particular wolves staying nearby flocks (roaming, marking), attempting attacks (without being successful), and interacting with LGDs. Based on behaviours and phenotypes of such wolves, we speculate they could be young wolves learning how to hunt and testing LGDs. Consequently, if these first encounters are not associated with negative consequences, we hypothesize they will learn that LGDs and shepherds are not a danger and will perceive sheep as an available resource. This knowledge may then be passed to the next generation through associative learning. Thus, more aggressive LGDs may be necessary to teach young wolves that encounters with LGDs have severe consequences.

To date, observations suggest that shepherds are not perceived as a threat for wolves. For example, during encounters shepherds can only yell or throw stones with minimal observed effects. Even if they could get the permission to use a gun (MEDDE and MAAF, 2013), the majority of them do not ask for such a permit or leave the gun in the hut. Wolf flight distance when approached by a shepherd is typically less than 100 m to as little as 30 m (J-M Landry, unpub. data). Recently, shepherds reported being challenged by a wolf while trying to recuperate a recently wounded lamb. Such emerging testimonies might be correlated to an increase in day-time attacks (which reached 52% of all attacks in 2013 in the Alpes Maritime Department, P Merlot, DDTM 06, pers. comm.).

A shepherd's daily job is to lead, care for, gather the flock for night-time bedding and feed the LGDs, as well as to monitor and adapt to available forage on summer pastures. Some shepherds continually follow the flock, while others observe from a distance to have a better overview. A herd of 1,500-2,000 head of sheep can easily scatter and occupy a large area (Fig. 5). Oftentimes, the topography is rough and heavily vegetated, leaving the flock out of view and more vulnerable to wolf predation.

5. Conclusions

The efficacy of LGDs protecting a flock depends on several internal and external factors. The way of managing the group of LGDs (e.g. neutering selected individuals) is the first step and can be easily applied if clear rules are ascertained (e.g. to respect an "age pyramid" of experience within the LGDs' group, which experienced dogs are the most representative, to take into account agonistic interactions between dogs) But it is not always obvious for sheep owners or shepherds, especially for those who have little experience with LGDs. The selection of inborn abilities like protecting a flock, RHP, motivation and aggressiveness (or "daring" temperament) may be serious criteria to consider, as would be their capacity to learn from external events (e.g. social learning) and internal experiences (e.g. own experiences). The population of the main "breed" (GP) used in France went through a severe bottleneck due to the disappearance of large predators. Since then, selection was based on phenotypic criteria and even docility rather than on protective behaviours. Currently, unreliable LGD selection is implemented on the new alpine LGD populations (nearly 1,400 dogs).

As wolves are able to develop strategies to approach a flock without being detected (Boitani, 1982) or to attract LGDs to one side, while others attack on the other side (Coppinger and Coppinger, 1978), the success of the LGDs depends not only on internal factors (RHP, motivation and aggressiveness), but also on external factors (e.g. size of the flock, topography, weather). Therefore to make a selection, we need solid criteria independent of these external factors (e.g. predator density and age structure, wild prey availability, PU topography) or subjectivity, which may bias the results. The only way to discover these criteria is to study LGDs protection skills by observing how they react to wolves and how the latter counter-respond. Because wolf attacks occurred mainly during night, the use of a set of thermal (night-vision) binoculars is obligatory to study interactions between LGDs and wolves, which is one of the main objectives of the on-going CanOvis project.

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References

Andelt WF (1992) Effectiveness of livestock guarding dogs for reducing predation on domestic sheep. Wildl. Soc. Bull. 20, 55-62.

Barlow GW, Rogers W, Fraley N (1986) Do Midas cichlids win through prowess or daring? It depends. Behav. Ecol. Sociobiol. 19, 1–8.

Ausband D (2010) Pilot study report for using a biofence to manipulate wolf pack movements in central Idaho. Montana Cooperative Wildlife research unit. Wolf project. 14 p.

Boitani L (1982) Wolf management in intensively used areas of Italy. In: Harrington FH, Paquet PC, editors. Wolves of the World: Perspectives of behavior, ecology, and conservation. Noyes Publications, Park Ridge, New Jersey, USA, pp. 158-172.

Coppinger R, Coppinger L (1978) Livestock guarding dogs. Hampshire college, Amherst Ma, USA.

Coppinger R, Coppinger L (2005) Livestock Guarding Dogs: from the Transhumance to Pre-Zygotic Selection. Carnivore Damage Prevention News 8, 2-9.

Coppinger R, Coppinger L, Langeloh G, Gettler L, Lorenz J (1988) A decade of use of livestock guarding dogs. In: Crabb AC, Marsh RE, editors. 13th Proceedings of the Vertebrate Pest Conference. University of California, Davis, USA, pp. 209-214.

Coppinger L, Coppinger R (1982) Livestock-guarding dogs that wear sheep's clothing. Smithsonian 1, 65-73.

Coppinger R, Lorenz J, Glendinning J, Pinardi P (1983) Attentiveness of guarding dogs for reducing predation on domestic sheep. Journal of Range Management 36, 275-279.

Coppinger R, Coppinger L, Langeloh G, Gettler L, Lorenz J (1988) A decade of use of livestock guarding dogs. In: Crabb AC, Marsh RE, editors. 13th proceedings of the Vertebrate Pest Conference. University of California, Davis, USA, pp. 209-214.

Espuno N (2004). Impact du loup (Canis lupus) sur les ongulés sauvages et les ongulés domestiques dans le massif du Mercantour. Thèse de doctorat, Université Montpellier II, 221 p.

Gehring TM, VerCauteren KC, Landry J-M (2010) Livestock protection dogs in the 21st century: is an ancient tool relevant to modern conservation challenges? BioScience 60, 299–308.

Green JS, Woodruff RA (1983) The use of three breeds of dogs to protect rangeland sheep from predators. Applied Animal Ethology 11, 141-161.

Hansen I, Bakken M (1999) Livestock-guarding dogs in Norway: Part I. Interactions. J. Range Manage. 52, 2-6.

Hurd PL (2006) Resource holding potential, subjective resource value, and game theoretical models of aggressiveness signalling. Journal of Theoretical Biology 241, 639–648.

Landry J-M (2013) Analyses comportementales des interactions entre des chiens de protection et des loups dans le parc national du Mercantour. Rapport pour le Ministère de l'Agriculture et de l'Agroalimentaire et de la pêche, 60 p.

Linhart SB, Sterner RT, Carrigan TC, Henne DR (1979) Komondor guard dogs reduce sheep losses to coyotes: a preliminary evaluation. Journal of Range Management 32, 238-241.

Maros K, Pongrácz P, Bárdos G, Molnár C, Faragó T, Miklósi Á (2008) Dogs can discriminate barks from different situations. Applied Animal Behaviour Science 114, 159-167.

McGrew JS, Blackesley CS (1982) How Komondor dogs reduce sheep losses to coyotes. Journal of Range Management 35, 693-696.

Muséum National d'Histoire Naturelle (Ed.) (2003–2013) Inventaire national du Patrimoine naturelle. Available: http://inpn.mnhn.fr.

Parker GA (1974) Assessment strategy and the evolution of animal conflicts. Journal of theoretical Biology 47, 223-243.

Ministère de l'Ecologie, du Développement Durable et de l'Energie, Ministère de l'Agriculture, de l'Agroalimentaire et de la Fôret (MEDDE, MAAF) (Eds.) (2013) Plan d'action national loup 2013-2017. 68 p.

Sedefchev S (2005) The Karakachan Dog: Continuation of an Old Bulgarian Tradition. Carnivore Damage Prevention News 8, 14-19.

Yin S (2002) A new perspective on barking in dogs (Canis familiaris). Journal of Comparative Psychology 116, 189-193.

Yin S, McCowan B (2004) Barking in domestic dogs: context specificity and individual identification. Animal Behaviour 68, 343 – 365.