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## Observations on the vocation of the protection dog of Abruzzo's pastoral civilisation to defend the flock from predators

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## Abstract

This study aimed to assess the effectiveness of a group of livestock guardian dogs (LGDs) in independently protecting a sheep flock in the absence of the shepherd, while also evaluating the absence of aggressive behavior toward humans. The focus was on the Maremma-Abruzzese sheepdog, a breed historically selected by Abruzzese pastoral communities for its guarding abilities.

Fieldwork was conducted over three autumn and winter seasons (2017–2020), totaling 258 observation days. The flock, consisting of approximately 300 sheep, was enclosed within an electrified fence and guarded by three LGDs. Observations took place during twilight, nighttime, and early morning hours, always without human supervision. Monitored variables included vocalizations (208 in total), behavioral responses to human or vehicle presence, and autonomous nighttime positioning patterns. Results demonstrated that the dogs effectively protected the flock, exhibiting strong motivation to defend, well-balanced behavioral responses, itinerant territoriality, and the ability to develop independent antipredator strategies. Vocalizations were distributed primarily at night (75), at twilight (53), and in combinations involving night, twilight, and dawn. Five distinct spatial positioning patterns (A, B, C, D, E) were identified, adopted spontaneously by the dogs to ensure coverage and surveillance of the area. Importantly, no aggressive behaviors toward passing humans were recorded, confirming the dogs' suitability for working in shared human-animal environments. These findings support the role of the Maremma-Abruzzese sheepdog as a highly effective autonomous livestock guardian, whose behavioral traits are the result of centuries of selective breeding for pastoral purposes.

**Keywords:** Maremma-Abruzzese sheepdog, Abruzzo, anti-predatory strategies, ethology, predators, breeders

## Riassunto

Questo studio ha avuto l'obiettivo di valutare l'efficacia di un gruppo di cani da protezione del bestiame nel difendere un gregge in autonomia, in assenza del pastore, e di verificare l'assenza di comportamenti aggressivi nei confronti delle persone. La ricerca si è concentrata sulla razza Maremmano-Abruzzese, tradizionalmente selezionata dalla civiltà pastorale abruzzese per la custodia degli ovini. L'indagine si è svolta nel corso di tre stagioni autunnali e invernali (2017-2020), per un totale di 258 giornate di osservazione. Il gregge, composto da circa 300 pecore, era custodito da tre cani all'interno di un recinto elettrificato. Le osservazioni si sono concentrate nelle ore crepuscolari, notturne e del primo mattino, sempre in assenza del pastore. Sono stati monitorati comportamenti vocali (208 vocalizzazioni totali), reazioni a stimoli esterni (passaggio di persone e veicoli) e posizionamenti autonomi notturni dei cani. I risultati confermano che i cani hanno protetto efficacemente il gregge, mostrando forte motivazione alla difesa, capacità di elaborare strategie antipredatorie indipendenti e un buon equilibrio comportamentale. Le vocalizzazioni si sono distribuite principalmente nelle ore notturne (75), al crepuscolo (53) e in combinazioni tra notte, crepuscolo e alba. Sono stati individuati cinque schemi di posizionamento (A, B, C, D, E), adottati spontaneamente dai cani per garantire la sorveglianza dell'area. Importante è anche la totale assenza di aggressività verso le persone, a conferma dell'idoneità di questi soggetti a operare in contesti condivisi con l'uomo. Lo studio dimostra che il cane da pastore Maremmano-Abruzzese è un ausilio altamente efficace per la protezione degli ovini, in grado di operare con autonomia e affidabilità anche in assenza del pastore.

**Parole chiave:** cane da pecora abruzzese, Abruzzo, strategie antipredatorie, etologia, predatori, allevatori

## Introduction

Shepherds have always seen the wolf (*Canis lupus*) as a constant and real danger to their activity. Sometimes the activity of predators on livestock has triggered a real conflict with man with no holds barred (Young and Goldman, 1944; Cluff and Murray, 1995; Piscopo et al., 2021). Among the many strategies to counter predator activity, e.g. poison, leghold traps, snares and firearms (Boitani, 1995; Browne-Núñez et al., 2015), at the shepherd's side there has always been a valid and effective ally: the 'sheepdog' (*Canis lupus familiaris*), a descendant of the wolf, but its direct adversary (Andelt, 1992; Fritts, 2003). The man-dog partnership has been an essential element of pastoral civilisation: there was no flock without a shepherd, no shepherd without dogs in Abruzzo, where the wolf has always been present. This union has made possible over time the selection of dog breeds with different characteristics selected for defence or for livestock management. The culmination of this association was reached during the periods of transhumance: seasonal migration of flocks, herds and shepherds who moved, on foot, from the pastures located in hilly or mountainous areas (in the summer season) to those on the plains (in the winter season) along the natural routes of the 'tratturi', wide grassy tracks (Breber, 1993; Guacci, 2013; Breber, 2017).

In the region of Abruzzo (South of Italy), rich in breeders, sheep and wolves, a particular dog breed has been selected and 'specialised' in the protection of herds: this is what is historically called the 'Mastino abruzzese' or 'Abruzzese sheep dog'. Nowadays the official ENCI (Ente Nazionale Cinofilia Italiana) nomenclature defines it as the Maremmano Abruzzese sheepdog. This dog breed presents itself as a large, strong and well-structured animal, which was born and lives among the herds and considers the cattle, the grazing area and the shelters where the animals are housed as

its 'territory', defending them with great effectiveness as it considers them its 'property' (Breber, 2017). A dog with such a structured and well-defined build is considered typical of the breed – a reflection of its functionality. This functionality is essential when breeding a working dog. In fact, today the main selection criterion is the preservation of both the breed and the pastoral culture that has shaped it, to the point of making it almost perfect (Cavallini, 1991; Giuliani, 1997; Giannelli, 2002).

The Abruzzese sheepdog has obtained official recognition as a cultural heritage from the Abruzzo Region only recently; with Regional Law No. 21 of 9 July 2016, in which it is defined as an 'irreplaceable element in the eco-friendly herding activity of Abruzzo's pastoral tradition'. Even though today the phenomenon of transhumant herding has been considerably reduced compared to the past, it nevertheless maintains its millennia-old cultural connotations (Colapietra, 1972; Di Giustino, 2016).

In this paper we document some behavioural aspects related to the Abruzzese sheep dog effectiveness in protecting livestock. We made behavioural observations on a group of three protection dogs guarding a flock of about 300 Bergamasque sheep over three winter seasons from 2017 to 2020 near the city of Teramo, in Abruzzo.

The flock was led out to pasture by the herdsman from dawn until dusk, and from dusk until dawn it was kept within an electrified enclosure and entrusted to the custody of the three protection dogs. The herder practiced a nomadic grazing system, in which the flock remained in a given area for a few days, grazing around the temporary enclosure. When the availability of fresh pasture was exhausted, the enclosure was dismantled and relocated to a new grazing area. Each time the enclosure was relocated, the new position was georeferenced, thus documenting the various stopovers made by the flock during the transhumant grazing period. All flock stop-

overs took place within the designated study area located near the city of Teramo.

The aim of this study was to assess in the field the vocation of this dog breed for livestock protection and to study the intraspecific behavioural dynamics between the dogs and the predators present in the area (wolves and feral dogs). Furthermore, the study aimed to analyse the behaviour of the protection dogs in relation to the morphology of the territory, in order to document their effectiveness as a strategy for mitigating human-predator conflict, as well as the dogs' reactions to people and vehicles passing near the herd, to investigate the psychological balance of these dogs. By assessing the dogs at work with livestock and during interactions with possible dangers through direct observations, their functionality and effectiveness can be established, to select the best subjects or detect unsuitable dogs, so that the existing nucleus of dogs can be improved, and the defence system made more effective (Guadagno et al., 2023).

## Materials and methods

### *Study area*

The study area was located south-west of the city of Teramo (42,65875° N, 13,70294° E) and consists of a hilly environment with altitudes varying between 200 and 500 metres above sea level.

The soil is characterised by a strong clay component that in some places gives rise to small gully formations. From an environmental point of view, the territory is a mosaic, with natural areas and cultivated areas. The natural areas are mostly characterised by two basic components: 'wooden' areas and riparian vegetation. The areas covered by arboreal-arbustive vegetation are characterised by high scrubs slowly evolving towards a compact and highly intricate woodland, practically impenetrable by man. From an ecological point of view,

the areas located at the margin between the various environments are of particular interest. These ecotonal areas constitute systems in which the characteristics of the bordering environments merge revealing considerable dynamism and are extremely important for wildlife as they provide wildlife with places to rest and move around without being seen (Wildlife & Farming handbook). In this study area, large hilly zones are used for agriculture and are therefore open landscapes where wildlife is more easily observed, compared to small woodlands and scrubby areas that offer better concealment. Among the plant species present in the area are the stone pine (*Pinus pinea*), the maritime pine (*Pinus pinaster*), the white poplar (*Populus alba*), the downy oak (*Quercus pubescens*), the Turkey oak (*Quercus cerris*), the wild cherry (*Corylus avellana*), the blackthorn (*Prunus spinosa*), the dog rose (*Rosa canina*), the bramble (*Rubus ulmifolius*), and the Spanish broom (*Spartium junceum*). The area, which covers over 100 km<sup>2</sup>, has a high level of anthropisation both for the widespread presence of housing and urban agglomerations, as well as for intense human activity on the territory. The latter takes the form of various activities: agriculture (arable and tree crops), livestock breeding (especially sheep), tourism (agritourisms and B&Bs), hunting (mainly wild boar *Sus scrofa*) (Gallizia et al., 2018).

The study, which spanned three winters, was conducted in a very specific area where there was the simultaneous presence of a wolf pack (*Canis lupus italicus*) (Fig. 1) and a group of about twenty feral dogs (whose number varied during the breeding season) (Fig. 2) in contiguous areas. These feral dogs were observed preying on both wild animals and livestock. Continuous monitoring of these two predators enabled the creation of a predation risk map, on which the flock under study spent its winters. Three areas with different levels of danger were created: a green area with low danger, a yellow area with moderate danger,

and a red area with high danger. The danger level was calculated based on the core areas primarily occupied by the predators, while the areas where the flock stayed depended on the availability of grazing areas each year.

### Field methods

The field study took place over 258 days divided as follows: from 15 December 2017 to 15 March 2018 for a total of 91 days, from 13 November 2018 to 4 December 2018 and from 23 January 2019 to 10 March 2019 for a total of 69 days, from 20 November 2019 to 23 December 2019 and from 2 January 2020 to 5 March 2020 for a total of 98 days. The present study was conducted exclusively through direct observation sessions carried out during dawn, dusk and night (in the latter case using night vision equipment). Data on the vocalisation activity of the protection dogs were also recorded during the observation sessions. Vocalizations were documented as part of the dog's communication system. Despite contextual limitations and the multiple possible functions of vocal behavior (e.g., alert, territoriality, threat response, intraspecific interaction), data were collected on the frequency of vocalizations, mainly expressed through barking during observation sessions. The crepuscular observation sessions were primarily aimed at assessing the dogs' ability to autonomously choose night-time positioning in defence of the flock. During each observation session, the positioning of the dogs, their reaction to people passing near the flock, and their vocalization activity were evaluated. After grazing, the flock was led into the electrified pen around 4 p.m. and returned to the pasture the following morning after 9 a.m.. Each day was divided into three direct observation shifts: sunrise from 5 a.m. to 8 a.m., twilight from 4:30 p.m. to 7:30 p.m., and night from 9 p.m. to midnight. During these observation shifts, the herd was always kept with-





**Figure 1.** Apennine wolf (*C. lupus italicus*) pups photographed in the study area.



**Figure 2.** Individuals of the feral dog nucleus photographed in the study area.

in the electrified containment enclosure and was guarded exclusively by livestock guardian dogs. As an observational method, we used continuous ad libitum sampling (Bateson & Martin, 2021), made possible by the constant presence of researchers during the observation sessions.

The flock was guarded by three dogs, one female and two males: a young male about 2 years old, an adult female about 3 years old, and an adult male about 4 years old. None

were neutered. The dogs came from a pastoral selection. During the day in the presence of the shepherd, the dogs played a supportive role while the sheep were grazing, remaining vigilant to control any dangers. At night the sheep were kept inside an electrified enclosure and the three dogs were kept outside the enclosure and entrusted with the care of the flock from dusk to dawn while the shepherd was absent. The electrified enclosure consisted of a 200-meter-long net, 120 cm in height.



The fenced area was 2,500 square meters. The three dogs were fed commercial dry food (kibble). Direct observations were conducted using non-invasive methods, with the aid of a Bushnell Equinox 6 x 50 mm digital night viewer, a Konus Konuspot - 80 20- 60 x 80 spotting scope, a Nikon Monarch 5 10x42 binoculars, an Olympus DPS 1 10x50 binoculars, a Nikon d3300 camera, a Nikon d810 camera, a Nikon AF-S DX 55 - 200 mm f/4 - 5 telephoto lens. 6 G VR, a Sigma 150 - 600 mm f/5 - 6.3 DG OS telephoto lens. HSM S, a Sony ICD- PX240 sound recorder with a Karma DMC 943 microphone. The GPS positions of the herd were recorded via a mobile phone app called 'Conota' (<https://conota.app>), the phone used was a Samsung Galaxy Grand Neo and maps were

themselves, focusing their protection more on the areas where danger could more easily arise, particularly where dense vegetation was present (Fig. 3).

At certain stopovers, the flock enclosure was situated close to well-travelled roads. These circumstances provided opportunities to record the dogs' responses to human presence, with the aim of evaluating their behavioral equilibrium and confirming their suitability for work in anthropized contexts. Data were collected using ad libitum sampling, recording any behavior perceived as relevant at the moment of observation (Martin & Bateson, 1993 / 2007). The events considered were as follows: passage of people on bicycles, passage of people on foot, passage of people with ag-

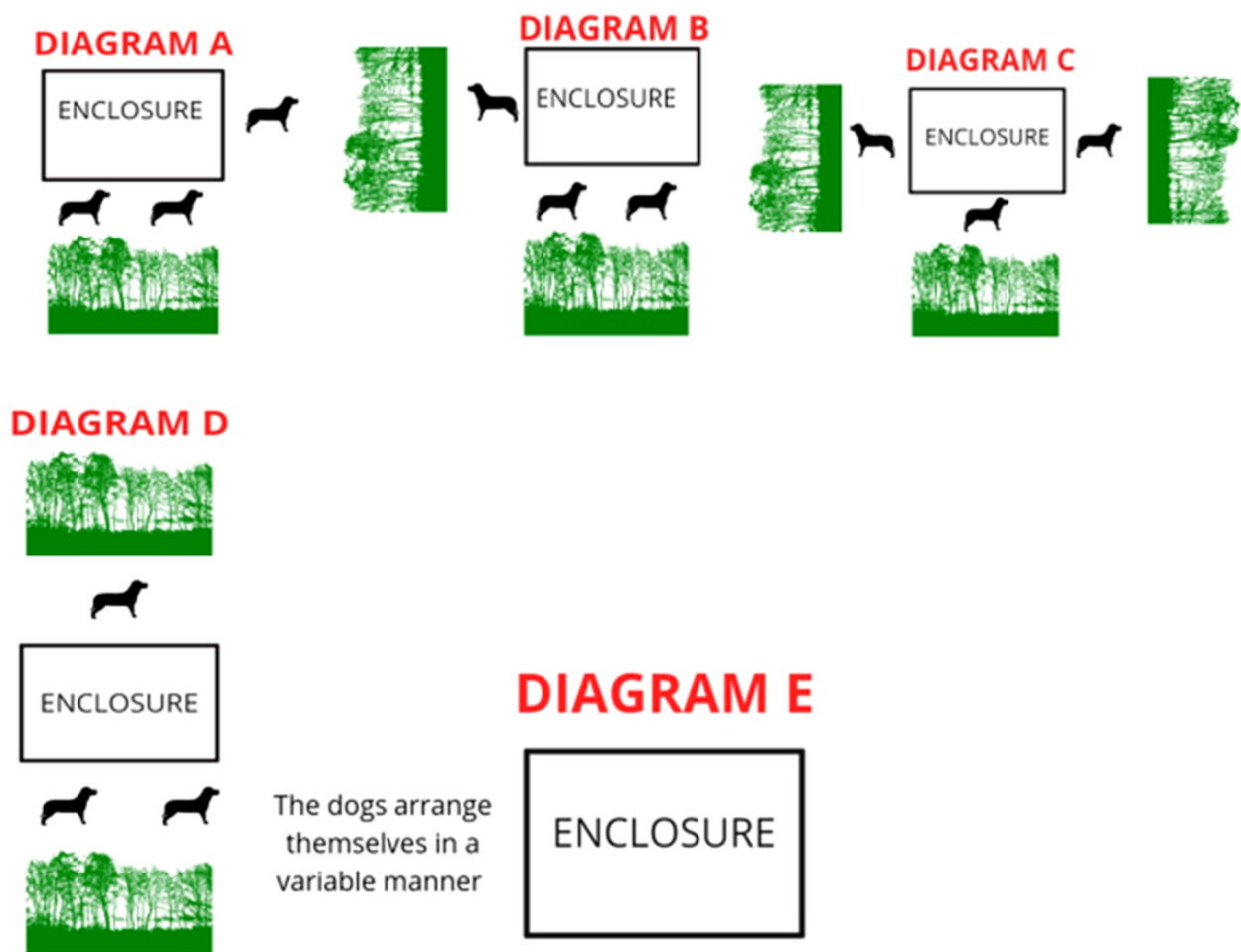


**Figure 3.** Dogs positioned around the flock once the herding shepherd had departed.

created with the aid of Google Earth. The nighttime resting locations of the herd were taken into consideration to evaluate the level of risk associated with each site in relation to the proximity of core areas of wolves and feral dogs. Temperature and weather conditions were obtained from the 3B Meteo website (<https://www.3bmeteo.com>).

The researchers positioned themselves at no less than 200 meters from the herd in order to avoid interfering with the activity of the dogs, while still maintaining adequate visibility and an effective auditory range during observation shifts. Once the shepherd had left at dusk, the dogs autonomously positioned

themselves around the flock, focusing their protection more on the areas where danger could more easily arise, particularly where dense vegetation was present. At certain stopovers, the flock enclosure was situated close to well-travelled roads. These circumstances provided opportunities to record the dogs' responses to human presence, with the aim of evaluating their behavioral equilibrium and confirming their suitability for work in anthropized contexts. Data were collected using ad libitum sampling, recording any behavior perceived as relevant at the moment of observation (Martin & Bateson, 1993 / 2007). The events considered were as follows: passage of people on bicycles, passage of people on foot, passage of people with agricultural vehicles, workers by the roadside, people on foot with dogs, and passage of people riding scooters. All considered events occurred at a minimum distance of approximately 50 meters from at least one of the dogs. It was assessed whether the dogs displayed aggressive or non-aggressive behavior towards people in the vicinity of the flock. Regarding vocalizations, only the dogs' barks were considered. The barks considered in this study are interpreted as alert signals and territorial marking behaviors, indicating the presence of livestock guardian dogs in that specific time and space. Under the conditions and context of the study, it was not possible to

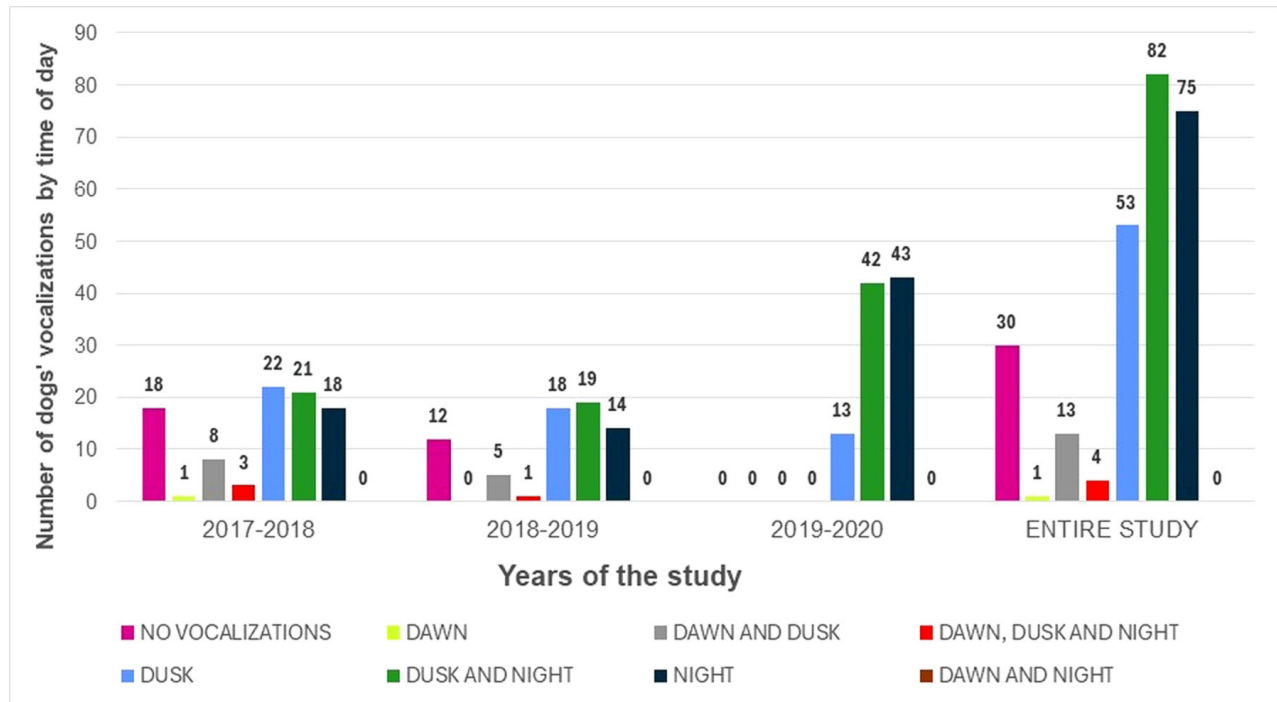


**Figure 4.** Disposition of dogs based on the surrounding territory; the green represents dense vegetation.

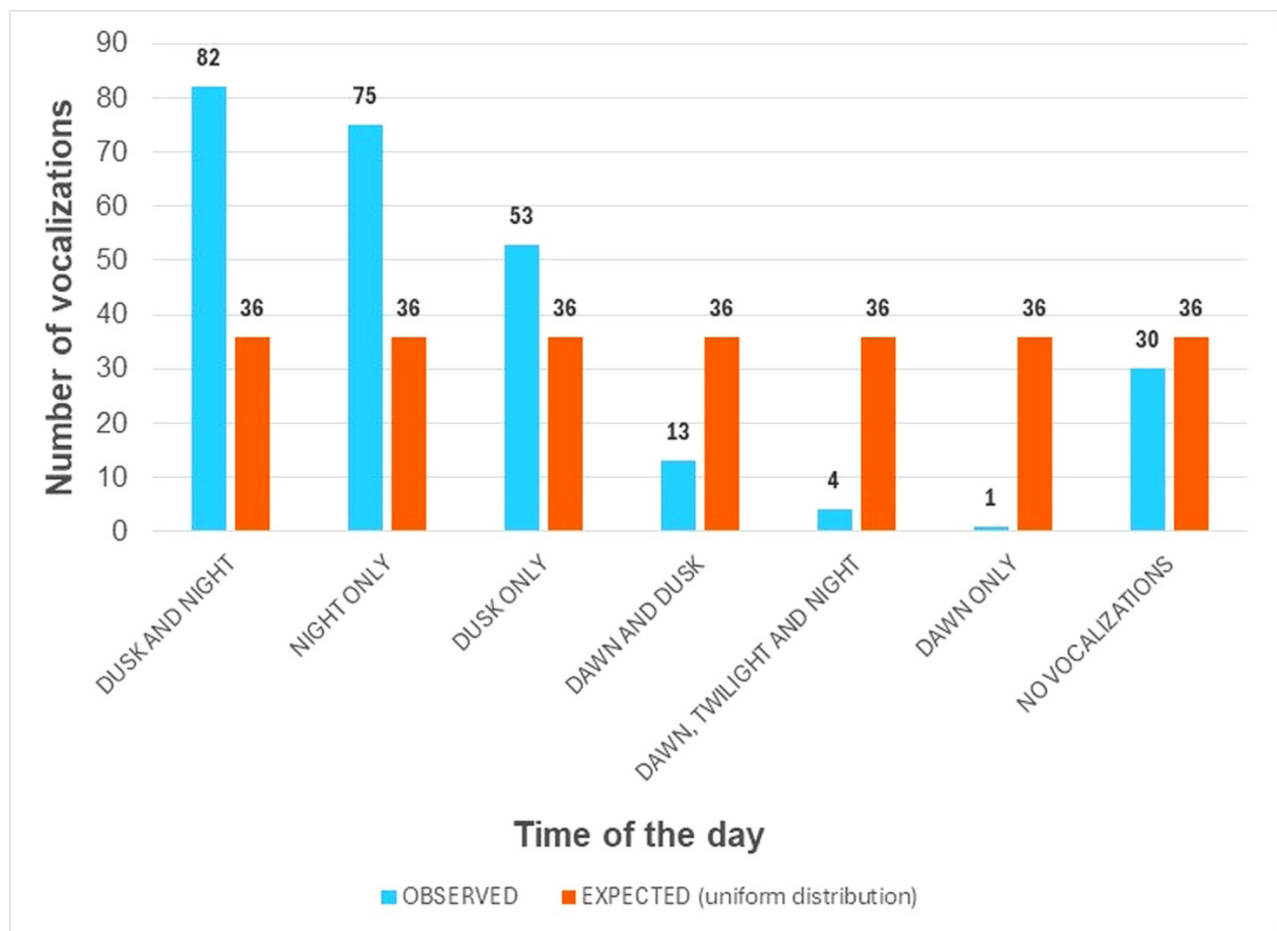
clearly determine the distance of the potential threat during periods of low visibility, and thus the precise meaning of the barking—except in cases where, after the herd had been secured inside the enclosure, the dogs circled around it while barking, as a form of territorial marking. The observations of feral dogs and wolves were made by the researchers and the herding shepherd, as there was constant exchange of information with the latter.

During the grazing period, the dogs still monitored the flock, some positioning themselves in the middle of the flock and others at the edges, interposing themselves between the grazing animals and the areas of reduced visibility so that they could easily monitor the flock and intervene promptly to signal or counter potential danger. After the shepherd departed at dusk, the dogs autonomously po-

sitioned themselves, prioritizing surveillance in areas with a higher likelihood of threat emergence, particularly those characterized by dense vegetation. Five positioning patterns were identified, labeled A, B, C, D, and E, which are described below. In pattern A, dense vegetation was present on one of the four sides of the sheep pen, and two dogs positioned themselves along that side. In pattern B, dense vegetation was present on two adjacent sides of the pen, with two dogs positioned along the longer side of the rectangle near the underbrush, and one dog positioned along the shorter side, also facing the underbrush. In pattern C, the underbrush was present on three of the four sides of the rectangle, and three dogs positioned themselves, each along one of the sides with the densest vegetation. In pattern D, the underbrush was pres-



**Figure 5.** Number of dog vocalizations by time of day (dawn, dusk, night, and combinations thereof) across three study years and the overall study period.



**Figure 6.** Chi-Square test: observed vs. expected dog vocalizations during flock defense.



ent on two non-adjacent sides of the rectangle, with two dogs positioned along one side with denser vegetation and one dog along the other side with underbrush. In pattern E, no underbrush was present, and the dogs positioned themselves variably (Fig. 4).

### *Data analysis*

The collected data were entered into a Microsoft Excel spreadsheet (Microsoft Corp., Redmond, WA, USA) and used to generate descriptive graphs and chi-square tests. We used a chi-square goodness-of-fit test to compare the observed frequency of dog vocalizations across six temporal categories (dawn, twilight, night, and combinations thereof) against a uniform distribution. The null hypothesis assumed an equal probability of vocalizations across all categories. To test whether the dogs' reactions to the passage of people near the flock were evenly distributed, a chi-square goodness-of-fit test was conducted comparing the observed frequencies of "no reaction" and "barking while remaining with the flock" against a uniform distribution. The distribution of the dogs' positioning patterns (A-E) was tested against a uniform expectation using a chi-square goodness-of-fit test, with five categories and  $df = 4$ . Geographic data and spatial visualizations were created using Google Earth Pro which was employed to generate maps.

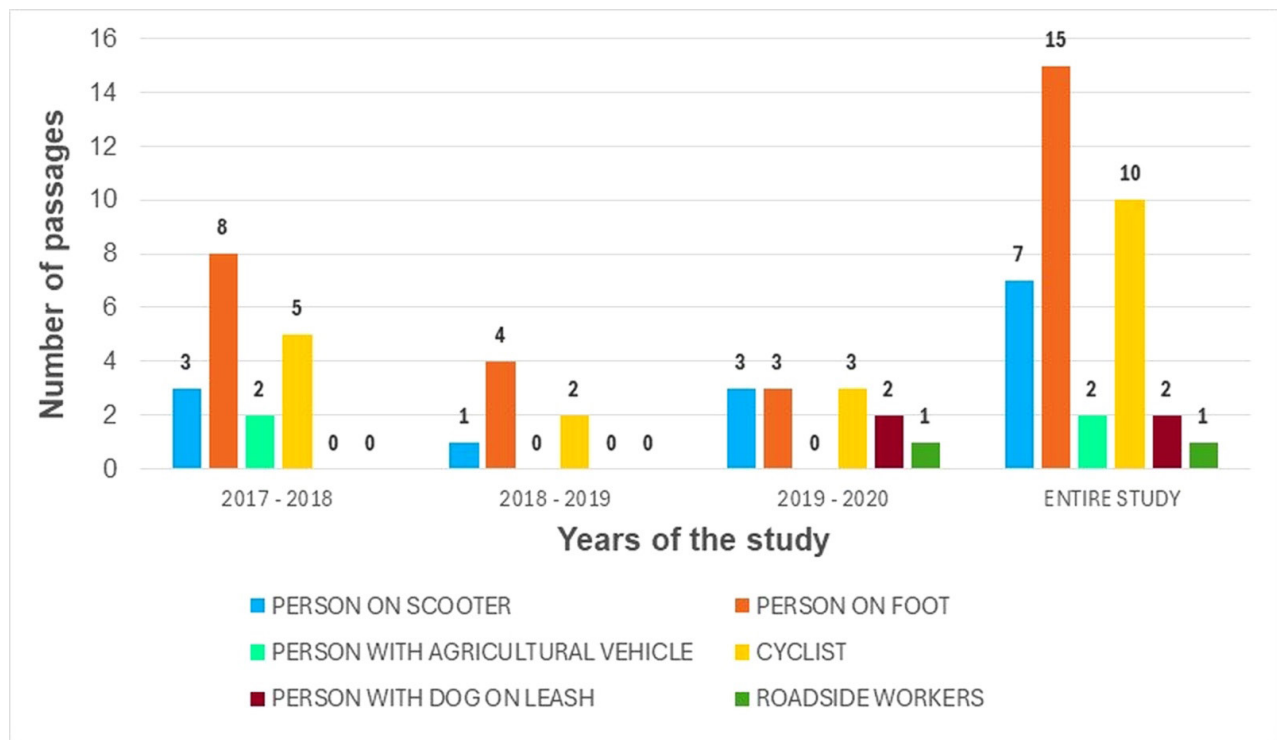
## **Results**

During the 258 days of observation, a total of 208 vocalizations by the livestock guardian dogs (LGDs) were recorded. The distribution by time period was as follows: 82 vocalizations occurred both at twilight and during the night, 75 only at night, 53 only at twilight, 13 both at dawn and twilight, 4 at dawn, twilight, and night, and 1 only at dawn. In 30 cases, no vocalizations were recorded (Fig. 5). Consec-

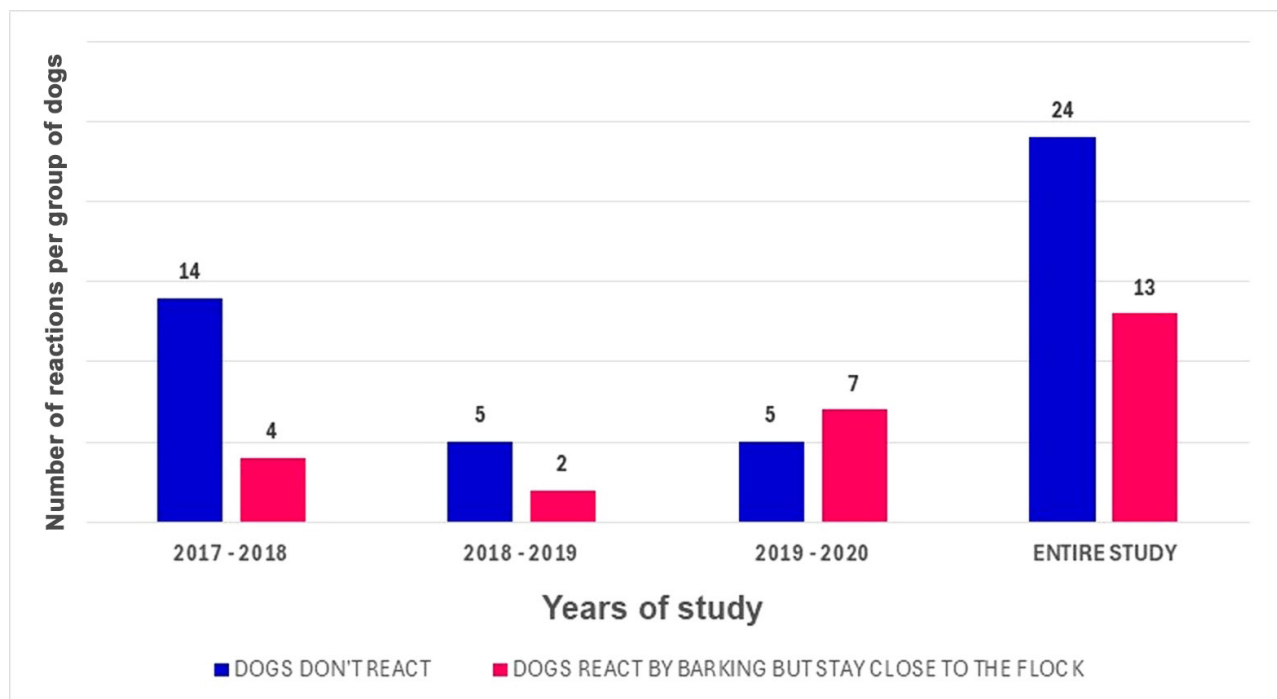
utive barking episodes within the same event were considered a single vocalization. The number of individual barks was not recorded, as it was not relevant to the study's aims. Vocalizations clearly directed at people passing near the flock were included. In most cases, it was not possible to determine the specific target or trigger of the vocalizations, particularly at night when visibility was limited. Therefore, we could not assess whether the barking was in response to an actual threat or served other functions such as territorial marking. A chi-square goodness-of-fit test was used to evaluate whether the distribution of vocalizations differed significantly among the time categories. The result showed a significant deviation from uniformity ( $\chi^2 = 182.73$ ,  $df = 6$ ,  $p < 0.001$ ), indicating a non-random distribution with vocalizations more concentrated during twilight and night hours (Fig. 6).

One of the aspects taken into consideration was the dogs' reaction to the passage of people near the flock, a relevant factor given the high degree of anthropisation in the study area. Over the three years of observation, we recorded 37 such events: 15 involved people on foot, 10 on bicycles, 7 on scooters, 2 with agricultural vehicles, 2 with dogs on leashes, and 1 involving roadside workers (Fig. 7). In none of these cases did the dogs show aggressive or playful behavior, nor did they abandon the flock to approach or interact with people. This behavior is particularly relevant in a region with a strong tourism vocation, as it demonstrates the dogs' ability to remain focused on their protective role while avoiding potential conflicts with humans.

During stopovers when the flock was located near the road, we evaluated the dogs' behavioral response to the presence of people in the vicinity. In these conditions, the dogs remained passive in 24 instances, while in 13 cases they barked but did not move away from the flock, maintaining a protective position (Fig. 8). In 26 stopovers, the flock was positioned too far from the road to reliably observe the dogs' reaction to human pas-



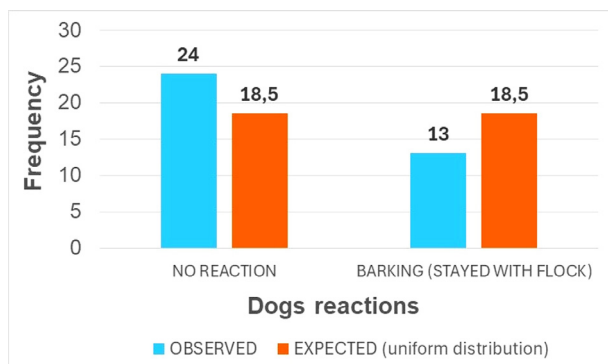
**Figure 7.** Number of people passing near the flock, categorized by type (scooter, on foot, agricultural vehicle, cyclist, person with dog on leash, roadside workers) across three study years and the entire study period.



**Figure 8.** Dogs' reaction to people passing near the flock.

sage. This trend, although not statistically significant, supports the observation that the dogs were able to remain vigilant without dis-

playing aggression or abandoning their position, highlighting their behavioral balance in human-influenced environments.

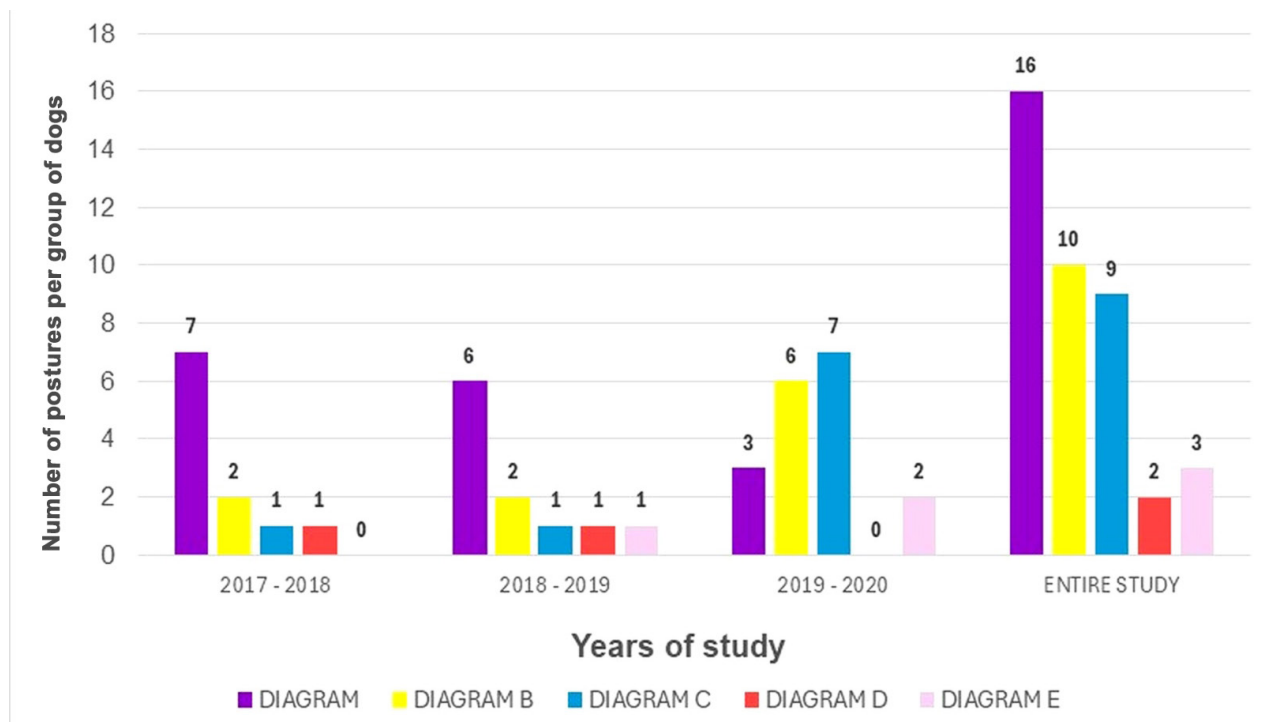


**Figure 9.** Chi-square test: Observed and expected frequencies of dog reactions to people passing near the flock.

Unlike other dog breeds commonly used in livestock farming that require verbal or gestural commands from the shepherd (like border collie or Australian shepherd), this breed demonstrated full autonomy in carrying out its protective role (Lamberini et al., 2012; Bigi et al., 2018). This independence was observed both when predators were potentially nearby and during routine relocations of the flock. In the presence of potential threats, dogs au-

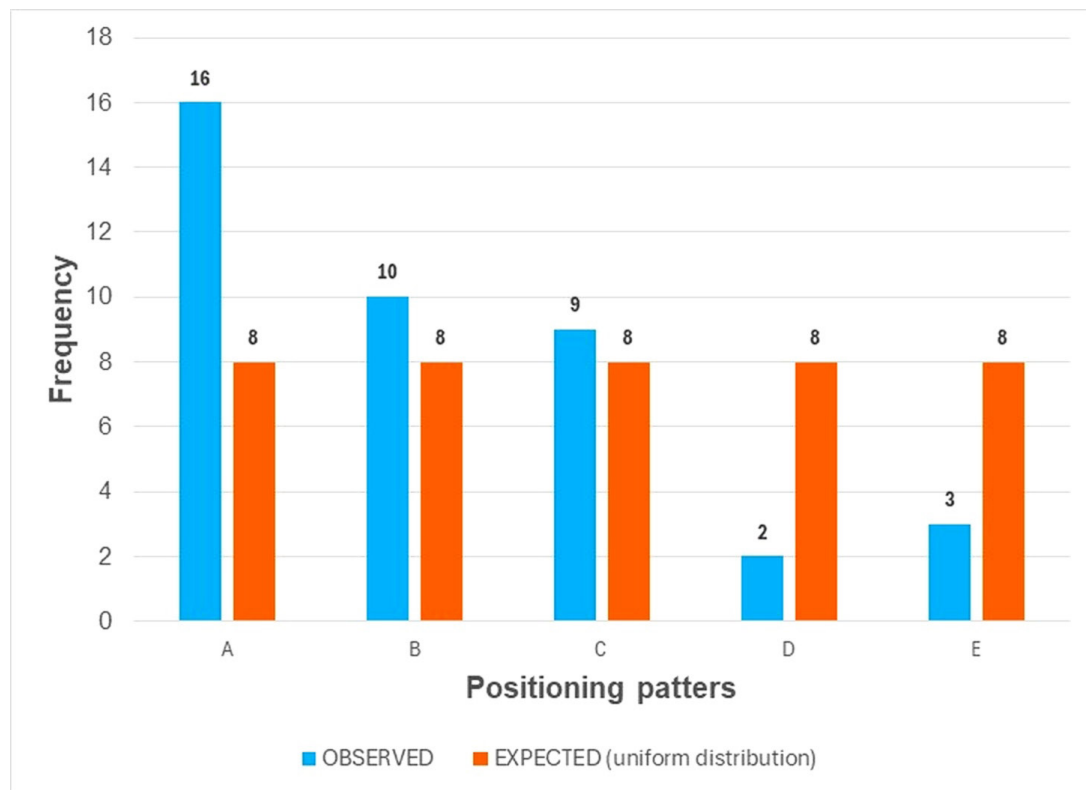
tonomously positioned themselves between the flock and the perceived source of danger, without shepherd intervention. Similarly, when the flock was moved to a new resting or grazing site, and the shepherd departed, the dogs initiated a consistent sequence of behaviors: they marked the perimeter of the electrified enclosure with urine and feces, and then positioned themselves based on the specific morphological and vegetational characteristics of the terrain. This behavior was observed daily, particularly at dusk.

Based on these observations, we identified five recurring positioning patterns corresponding to different environmental configurations in the resting areas. The dogs adopted pattern A 16 times, pattern B 10 times, pattern C 9 times, pattern D 2 times, and pattern E 3 times (where no dense vegetation was present and the dogs chose freely which side to defend) (Fig. 10). If all patterns were equally likely, each would be expected to occur eight times. A chi-square goodness-of-fit test indicated a significant deviation from uniformity ( $\chi^2 = 16.25$ ,  $df = 4$ ,  $p < 0.01$ ), with pattern A



**Figure 10.** Positioning of dogs during shepherd-free hours.





**Figure 11.** Chi-square test: observed and expected frequencies of livestock guardian dog (LGD) positioning patterns (A–E) during flock surveillance.

being chosen disproportionately often (Fig. 11). This suggests that the dogs actively selected positioning strategies most suited to the protection of the flock, particularly favoring defensive positions near dense underbrush or other features that could conceal predators. These results further highlight the dogs' ability to assess environmental risk and act independently to ensure flock safety.

During positioning, the dogs remained oriented toward the bush or away from the flock, in order to maintain a clear view of their surroundings and to prevent ambushes from predators approaching from behind. These areas are where predators emerge to transit through open fields or approach the flock undisturbed.

The final aspect we wanted to assess was the actual defense function of this group of dogs in protecting the flock. During the first winter (2017 – 2018) the flock made eleven stops within the study area, 2 of which in the low-risk area, 1 in the moderate-risk area and 8 in

the high-risk area.

During the second winter (2018 – 2019) the flock made eleven stops within the study area too, of which 1 in the low-risk area, six in the moderate-risk area and 4 in the high-risk area. During the third winter (2019 – 2020) the flock made eighteen stops within the study area, of which 3 in the low-risk area, 7 in the moderate-risk area and 8 in the high-risk area (Fig. 12). Over the three-year study period, 20 out of 40 total stopovers (50%) occurred in areas classified as high risk, where the likelihood of predator presence was highest.

During the three years of monitoring, a total of 14 predator encounters near the flock were recorded: 9 involving wolves and 5 involving feral dogs. Specifically, during the winter of 2017–2018, 9 events were observed (5 involving wolves and 4 involving feral dogs); during 2018–2019, 4 events occurred (3 involving wolves and 1 involving feral dogs); and in 2019–2020, only one wolf encounter was recorded. In all cases, the livestock guardian



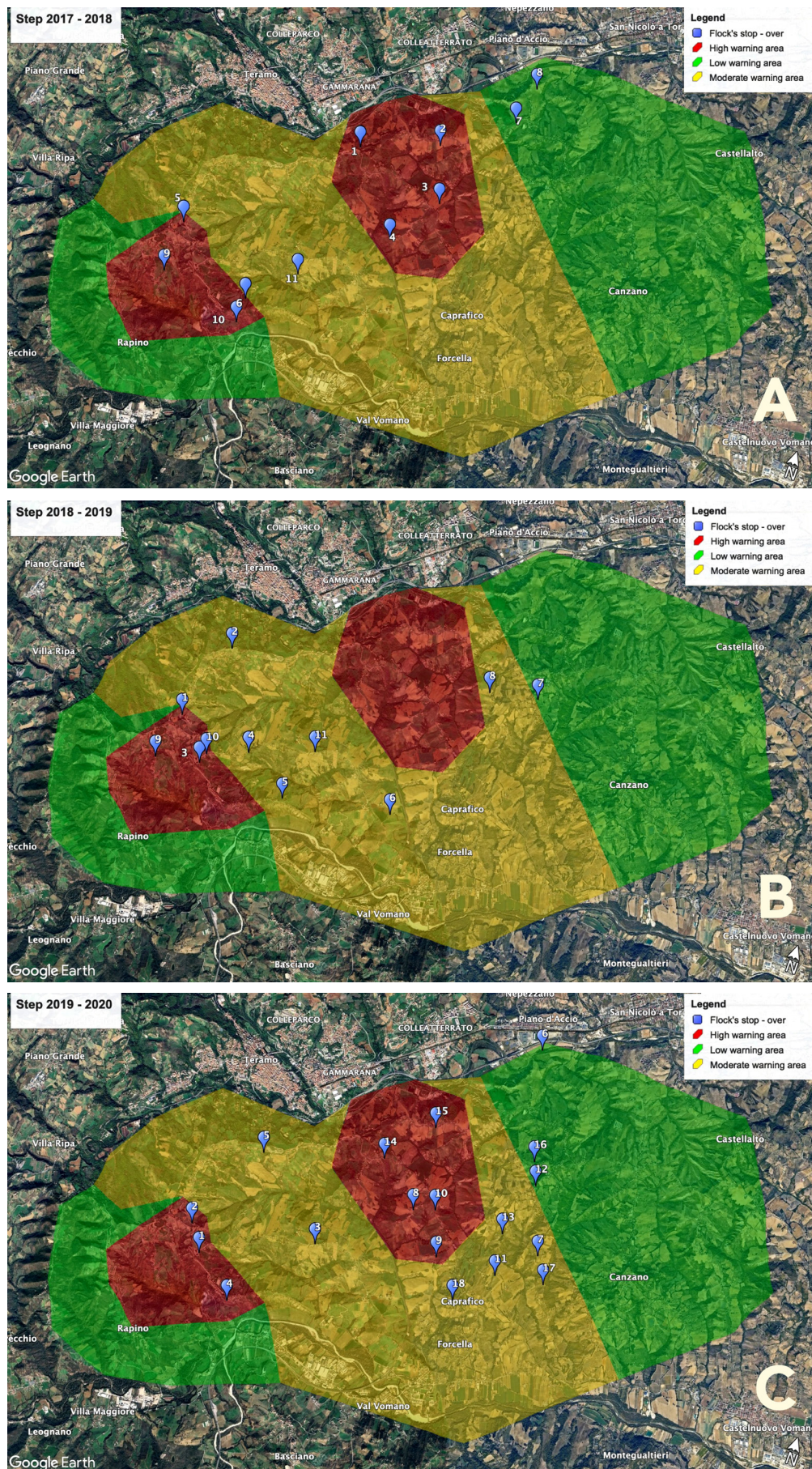


Figure 12. Flock stops during the study years.



dogs reacted autonomously, without instructions from the shepherd, and successfully repelled the threat. No livestock losses were recorded following these events (Fig. 14).

## Discussion

The present study aimed to evaluate whether a small nucleus of livestock guardian dogs (LGDs) could autonomously and effectively protect a flock under real-world grazing conditions, where human disturbance and predator presence (wolves and feral dogs) are part of the environment. Overall, the behavioral observations, supported by statistical results, provide solid support for the hypothesis that this breed exhibits high suitability and efficiency in flock protection.

The chi-square analysis on vocalization timing ( $\chi^2 = 182.73$ ,  $df = 6$ ,  $p < 0.001$ ) demonstrates that LGD vocal activity is significantly concentrated during twilight and night hours. This aligns with numerous ecological studies showing that wildlife is primarily crepuscular or nocturnal especially in areas with a strong human presence, with peaks in hunting-related movements at dusk and night (Ciucci et al., 1997; Theuerkauf et al. 2003; Gaynor et al. 2018). This also shows how these dogs are very alert especially when there may be the greatest danger to the herd.

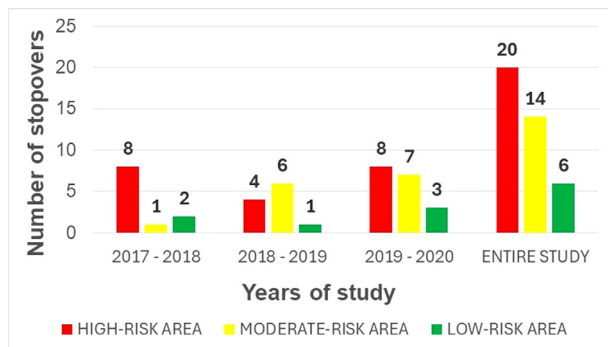
The significant non-uniform distribution of positioning patterns ( $\chi^2 = 16.25$ ,  $df = 4$ ,  $p < 0.01$ ) indicates that dogs consistently selected pattern A—positioning along sides with dense vegetation—far more frequently than expected by chance. This suggests a deliberate strategic placement, likely aimed at improving visibility and intercepting predators that use vegetated cover to approach the flock. The dogs' orientation toward bush or dense cover corroborates this hypothesis and reflects a predictive, risk-based behavior. Dogs rarely responded aggressively to human passage near the flock; instead, they displayed a balanced vigilance, with most

reactions being passive vocalizations while maintaining flock protection. The chi-square result ( $\chi^2 = 3.27$ ,  $df = 1$ ,  $p = 0.07$ ) indicates a non-significant trend toward more passive responses, reinforcing the notion of stable, non-aggressive behavior in populated areas. This behavioral equilibrium is essential in heavily utilized regions such as Abruzzo with significant tourism and human presence.

The flock spent a considerable proportion of stops in moderate to high-risk areas, based on field-assessed predator presence; long-standing stopovers took place in areas frequented by wolves and feral dogs. Despite this, no predation events or livestock losses were recorded across three winters, even though 14 predator encounters were documented (9 wolves, 5 feral dogs; 2017–2020). In all such instances, the LGDs responded autonomously and effectively, successfully deterring threats without shepherd intervention. This ancient breed requires no training from humans to perform its tasks, and its efficiency can be attributed to centuries of adaptation, its natural abilities, and, in part, the imitation of adult specimens by younger dogs in learning the defence strategies for the animals under their care (Coppinger et al., 1983).

This study provides a detailed account of the behaviors and spatial strategies adopted by a small nucleus of livestock guardian dogs (LGDs) under specific environmental and management conditions. The results suggest that, within this particular context, the dogs demonstrated effective deterrent behavior and a capacity for strategic positioning in response to potential predator threats. However, given the limited sample size (three dogs) and the homogeneity of the observed group, caution must be exercised when attempting to generalize these findings to the entire breed or to other ecological and management settings. Numerous variables may influence the effectiveness of LGDs, including but not limited to the sex and age of the animals, the number of individuals deployed, the size of the flock, environmental characteristics, and



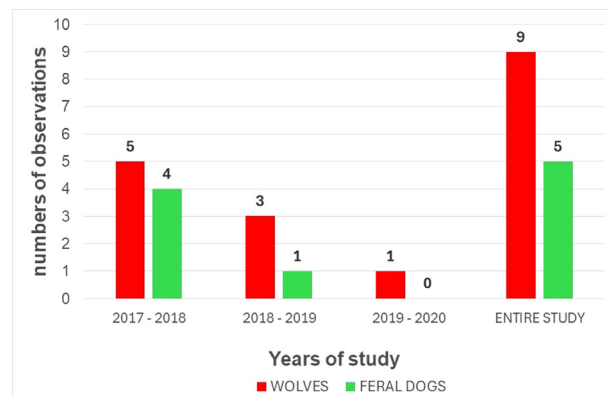


**Figure 13.** Number of flock stopovers by risk category and year.

the dogs' genetics and experience. Future research should aim to systematically investigate these factors, ideally through comparative studies across different contexts and larger, more diverse samples. Such studies would help clarify the extent to which the observed behaviors are representative of the breed and identify the conditions under which LGDs are most effective in flock protection. In conclusion, while our observations provide valuable insights into the functioning of LGDs in a real-world setting, further research is necessary to deepen our understanding of the variables that contribute to their success and to inform evidence-based guidelines for their deployment in livestock management.

A key limitation of this study is that observations were conducted on a single group of three livestock guardian dogs (LGDs), working together and potentially related, although their degree of kinship was not verified. This aspect restricts the generalizability of the findings, as the behaviors observed may reflect specific group dynamics rather than broader behavioral patterns applicable to other LGD groups. Ideally, future research should include independent observations across multiple groups, with varied compositions and unrelated individuals, to strengthen the reliability and applicability of the results.

Despite this limitation, the present study provides valuable insights into the cooperative behavior of livestock guardian dogs—an increasingly relevant category of working ani-



**Figure 14.** Number of observations of wolves and feral dogs in proximity to the flock.

mals in the context of managing coexistence between large carnivores, such as wolves, and livestock farming. Understanding group dynamics, coordination, and responses to potential threats is essential for improving the effectiveness of these dogs in their protective role, and for informing more sustainable, evidence-based strategies to mitigate human-wildlife conflict.

Our results add to the growing body of literature highlighting the utility of LGDs in livestock protection, particularly in settings where predators are active during low-light hours and human presence is moderate to intense. The breed's ability to work autonomously, responding adaptively to ecological and anthropogenic cues, suggests potential for improved livestock management strategies that rely less on direct human control.

Future studies could explore comparative performance across different LGD breeds or lineages, the impact of learning dynamics within multi-age LGD groups, such as whether younger dogs learn effective positioning from older ones and a longitudinal monitoring of flock outcomes under LGD supervision across different predator landscapes and management regimes.

In conclusion, within the specific environmental and management context of this study, the LGDs displayed consistent, adaptive defensive behaviors that aligned with theoretical

expectations of risk-based vigilance. Their vocalizations corresponded with predator activity peaks, their spatial positioning was strategically oriented toward threat corridors, and they maintained a non-aggressive posture in interaction with humans. While constrained by sample size and setting, these findings illustrate the potential of this LGD breed—and carefully selected individuals—for robust, autonomous flock protection in real-world grazing systems.

### Author Contributions

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