


## Article

# Spatiotemporal Activity and Farmers' Perception of the Red Fox in a Regional Reserve of Central Italy: A Case Study

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**Simple Summary:** The Regional Reserve “Calanchi di Atri” is a WWF-protected area included in the Italian Farmers-Nature Project, which identifies natural vulnerabilities that require protection and improvement measures. In this area, both wild animals and farmers coexist; therefore, it is important to know the activity of predators to mitigate human–wildlife conflicts and preserve both predators and livestock. To this end, the activity of the red fox was monitored over a one-year period. The study depicted the spatial and temporal patterns of this predator, which was found not particularly harmful to livestock, as reported by local farmers.

**Abstract:** In line with the Italian “Farmers-Nature Project” aimed at reducing conflicts between wild predators and livestock farmers, the spatiotemporal activity of the red fox was monitored in a protected area of central Italy over a one-year period. In parallel, farmers living in the study area were asked to participate in an interview about their perception of the red fox and its predatory activity towards livestock. Analysis of data obtained by camera trapping revealed that a higher number of red fox sightings was recorded in February and March in relation to the search for food, while a lower number was recorded in July when food is more abundant. Red fox primarily moves at night, with a peak of activity between 9 and 10 p.m., staying around an area close to the den. Interviews with farmers revealed a generally positive view of the red fox, as its predation on livestock was rare, suggesting that the fox can find sufficient food resources in the environment.

**Keywords:** *Vulpes vulpes*; wildlife monitoring; camera trapping; human–wildlife conflict; livestock predation



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## 1. Introduction

The red fox (*Vulpes vulpes*) is the widest-distributed member of the order Carnivora, with a worldwide geographical range that covers nearly 70 million km<sup>2</sup>. Red fox populations are spread across the entire northern hemisphere from the Arctic Circle to North America, Europe, North Africa, part of Asia and Australia [1,2]. The red fox is a generalist and opportunistic species [3], with an impressive ability to adapt to changes in the ecosystem [4]. Due to its incredible flexibility and the consequent high number of individuals, the red fox excels in a broad spectrum of environments and has far-reaching

effects (both positive and negative) on ecosystems, economies, and societies [5]. Its adaptability is evident through the partitioning strategy [6], as it has been observed to modify its resource usage across spatial, temporal, and trophic levels when competing with various species [7–10]. Due to its high ecological flexibility, the red fox broadly influences and provides a unique perspective on ecosystems' health. As an omnivore, it regulates prey populations, contributes to ecosystem sanitation by removing carcasses and animal waste [11], and aids seed dispersal by consuming fruits and vegetables, thereby enhancing germination chances [12–14]. In urban environments, the occurrence of the red fox indicates incorrect or negligent waste removal and can aid in the prevention of other opportunistic predators, such as wolves [15], approaching human populations.

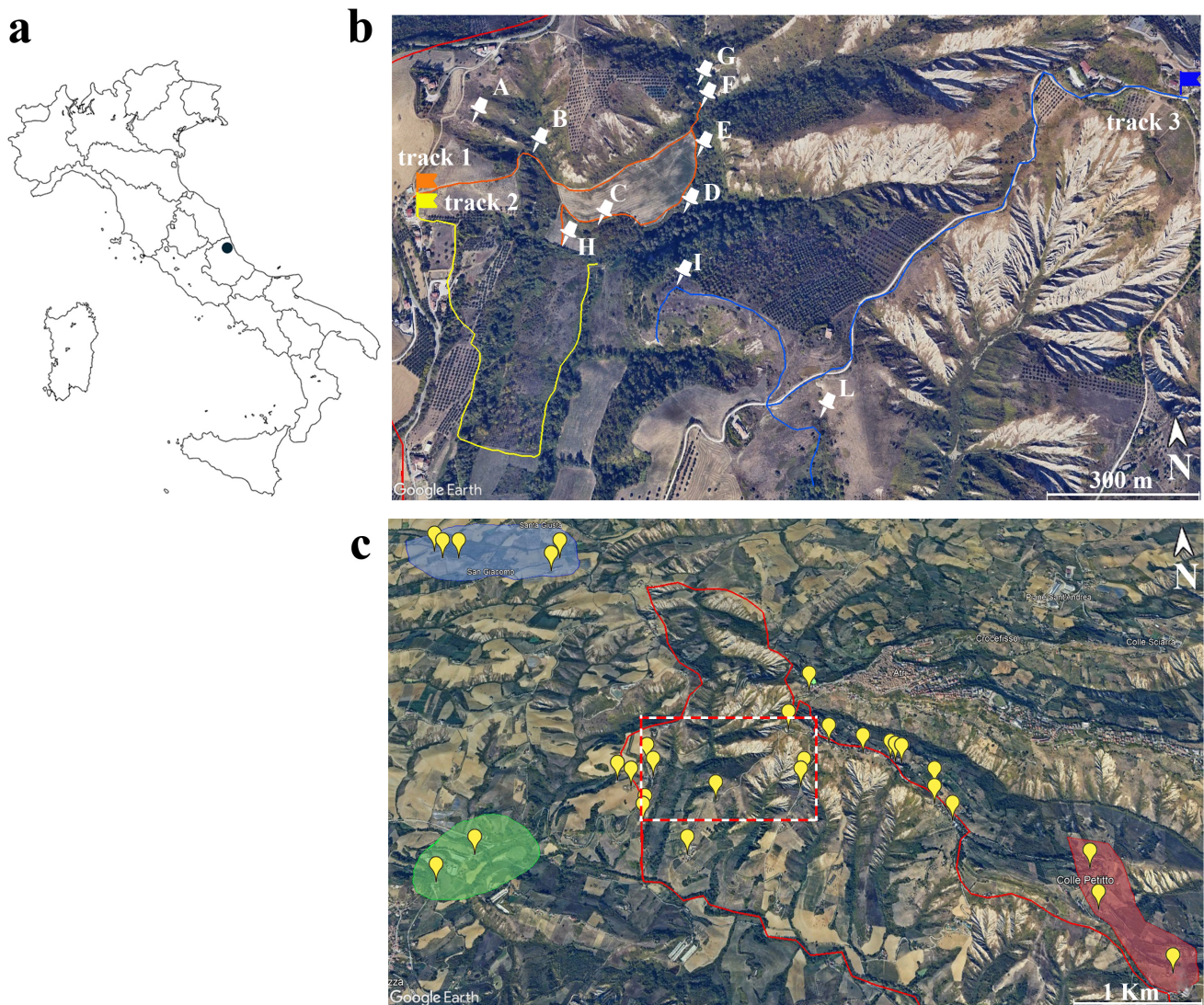
The red fox is known to cause significant damage to livestock and crops, impacting farmers' income and livelihoods [16]. Its presence in agricultural areas often leads to conflicts, as it may prey on small animals or raid poultry. The relationship between red fox and agricultural practices makes it an important subject for research, particularly to understand its behaviour, impacts, and potential management strategies. Therefore, studying red fox activity and farmers' perception can help develop more effective solutions to mitigate the damage caused by this predator, while balancing ecological demands.

We focused our study on the red fox inhabiting the Regional Reserve 'Calanchi di Atri' in Central Italy, a protected area which includes a diverse range of ecosystems as well as local farming communities. To assess possible conflicts between humans and the red fox, this study comprised (i) a spatiotemporal analysis of the fox activity, using camera trapping and indirect observation, and (ii) a ten-question survey assessing farmers' perceptions of the red fox. This investigation is part of the ongoing "Farmers-Nature Project" (PAN), which aims to develop and refine defence strategies to protect the livestock sector from predator activity [17] and, at the same time, mitigate human-wildlife conflict.

## 2. Materials and Methods

### 2.1. Study Area

The Regional Reserve "Calanchi di Atri" (42°34' N, 13°57' E) is located in the Northern part of the Abruzzo region, between the Gran Sasso National Park and the Adriatic coast, in the Atri municipality (Figure 1a). The Reserve was established in 1995, and in 1999, it became a WWF Oasis. Its surface extends approximately 600 hectares, with an elevation ranging from 104 to 468 m above sea level [18]. Particularly relevant is the presence of badlands (calanchi in Italian), areas of clayey-sandy terrain which, following strong water erosion, take on tormented and unstable shapes that significantly impact the reserve geomorphology. Numerous plants live in extremely unfavourable conditions, such as high sodium concentration in the substrate, elevated height of the walls, exposure to sun-drenched slopes, lack of organic matter in the soil, and frequent landslides. Fauna is rich and diverse due to the great variety of ecosystems created by forests, meadows, badlands, and waterways. The red fox represents one of the main predators; its competitors are the grey wolf (*Canis lupus italicus*) and the beech marten (*Martes foina*). Within the reserve and at its borders, there are small farms mainly devoted to raising livestock, such as chickens, hens, rabbits, and ducks. Few farmers also cultivate crops on a small to medium scale [18]. Limited information was available on the red fox population inhabiting the reserve and interactions with local farming practices, mainly related to livestock predation and occasional sightings.



**Figure 1.** Maps of the study area. (a) In the map of Italy, the location of the Regional Reserve Calanchi di Atri is indicated by a black dot. (b) Detailed view of the study area, showing the locations of camera traps A–L (white markers). The three tracks connecting camera traps are represented in different colours. (c) Locations where interviews were conducted (yellow markers). The reserve is delimited by a red line, the survey areas outside the reserve are indicated by colours, and the area where camera traps are located (shown in panel (b)) is indicated by a red-and-white dotted rectangle. Maps were generated using Google Earth Pro 7.3.

## 2.2. Camera Trapping and Data Analysis

Ten CW-200W01, 2MP CMOS sensor camera traps were positioned to monitor the territory (Figure 1b). Three planned tracks connected all camera trap sites. The specific position of camera traps and tracks was chosen on sites selected after experimenting with several locations and routes near farms within the reserve, according to the PAN project. This selection was based on observations of footprints and markings that provide evidence to be visited by wildlife. Camera traps, marked from A to L, were installed at the main access points to pastures and livestock shelters, such as trails and scrublands adjacent to meadows used by livestock. They were placed on shrubs at the site, at a height that allows easy documentation of red fox activity and at elevations ranging between 166 and 265 m above sea level (the lowest were H and D and the highest were A and L). The geo-localization of the three tracks' starts (indicated by a flag in Figure 1b) and lengths are the following:

Track 1, 42°34'29" N, 13°57'58" E—1925 m (one way);  
Track 2, 42°34'28" N, 13°56'51" E—1270 m (one way);  
Track 3, 42°34'27" N, 13°56'51" E—775 m (one way).

Camera traps were set up to turn on at 6:30 p.m. CEST (UCT + 1 during winter and spring, UCT + 2 during summer and autumn; we referred to the equinoxes and solstices to define start and end of the seasons) and turn off at 8:00 a.m. CEST. The intense anthropogenic activity did not allow the use of camera traps during daylight hours, as the frequent passage of farmers, domestic animals and visitors to the reserve largely exceeded the number of sightings (however very rare or absent) of the studied species. Videos were routinely collected every 10 days. On these rounds of video gathering, the three tracks were travelled, and additional indirect observations (e.g., markings, footprints) were recorded.

A total of 7200 videos were recorded and visually analysed. For each video, the collected data included the following: camera trap location and coordinates, date and time of recording, observed animal species, the number of individuals for each species, sex (when visible), age category (young or adult), activity type (e.g., exploration, feeding, hunting, interaction, marking, nursing, transition, resting, vocalisation, mating), and any additional notes. All the collected data were listed in an Excel file for analysis and elaboration. Information on the red fox was filtered, resulting in 1641 total observations regardless of the type of activity performed. This value was taken as 100% and used to calculate the percentages for the different time slots. The same procedure was applied to extract data on grey wolves, resulting in 253 total observations. A graph on the red fox's marking activity was elaborated by using the 48 recorded observations of this behaviour.

### 2.3. Questionary Survey

A specific survey was designed to investigate the perception of the red fox by farmers residing in the study area and its borders (Figure 1c), who may have had interactions with foxes. The targets of the questionnaire survey were primarily farmers with small livestock (i.e., hens, ducks, chickens, rabbits, geese) living in or near the border of the reserve area. To recruit as many subjects as possible who met the desired criteria (ownership of small farm animals), the snowball sampling technique was used. Sampling targeted all farms within the reserve. Given the small size of the study area, interviews with farmers from three additional areas surrounding the reserve boundary were included to broaden the survey, resulting in a total of thirty interviews.

Each interview was held in person and in an anonymous format. To ensure anonymity, a random number was assigned to each interviewee and the interviewee's location was not specified. Verbal informed consent was obtained, facilitated by the strong relationships established through prior research activities between the research team and the farmers.

The survey consisted of the following ten questions:

Q1: Do you think the red fox is a harmful animal?

Q2: Is the red fox present in the area you live in?

Q3: What kinds of small farm animals do you possess or have you possessed?

Q4: How many?

Q5: Do you use a night shelter, or do you leave them free during the night?

Q6: Have you ever received predation from the red fox?

Q7: Do you think that by using appropriate equipment the problem could be solved?

Q8: Have you ever used equipment or structures to defend from the red fox?

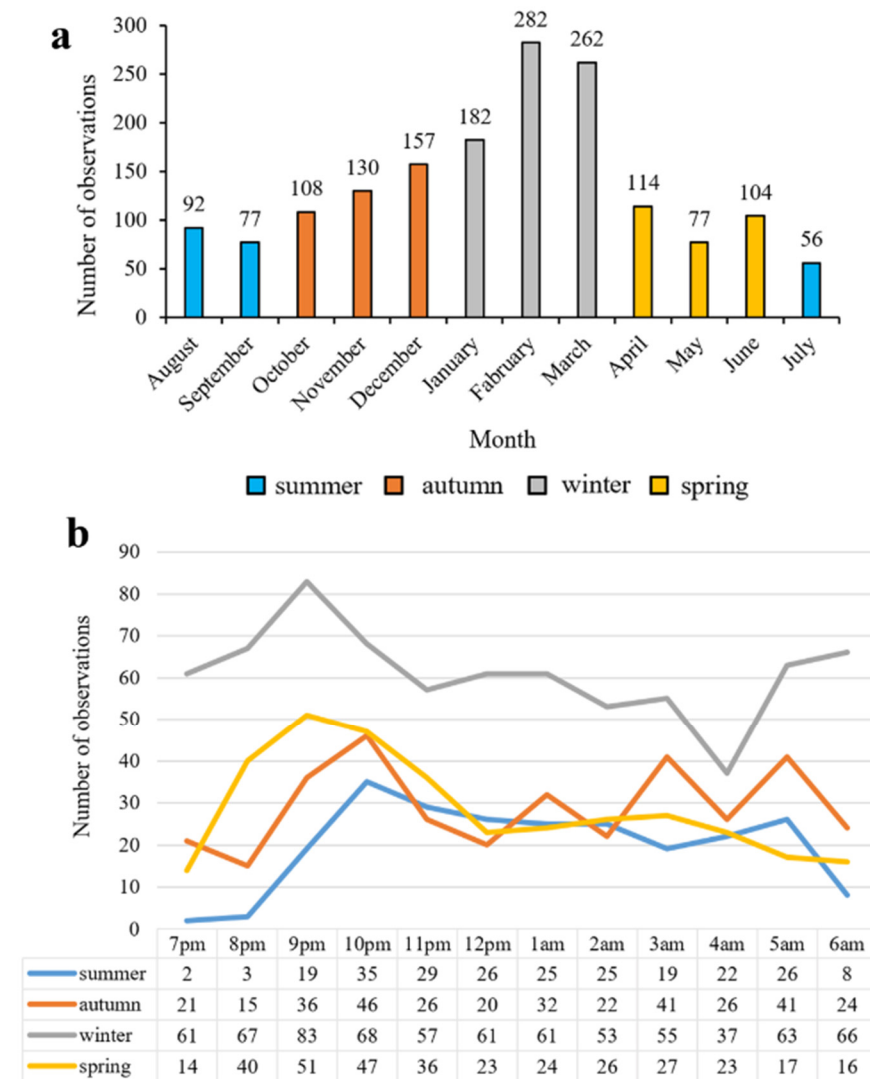
Q9: Did you find them effective?

Q10: Do you think it is possible to live peacefully with the red fox?

### 3. Results

#### 3.1. Temporal and Spatial Patterns of the Red Fox

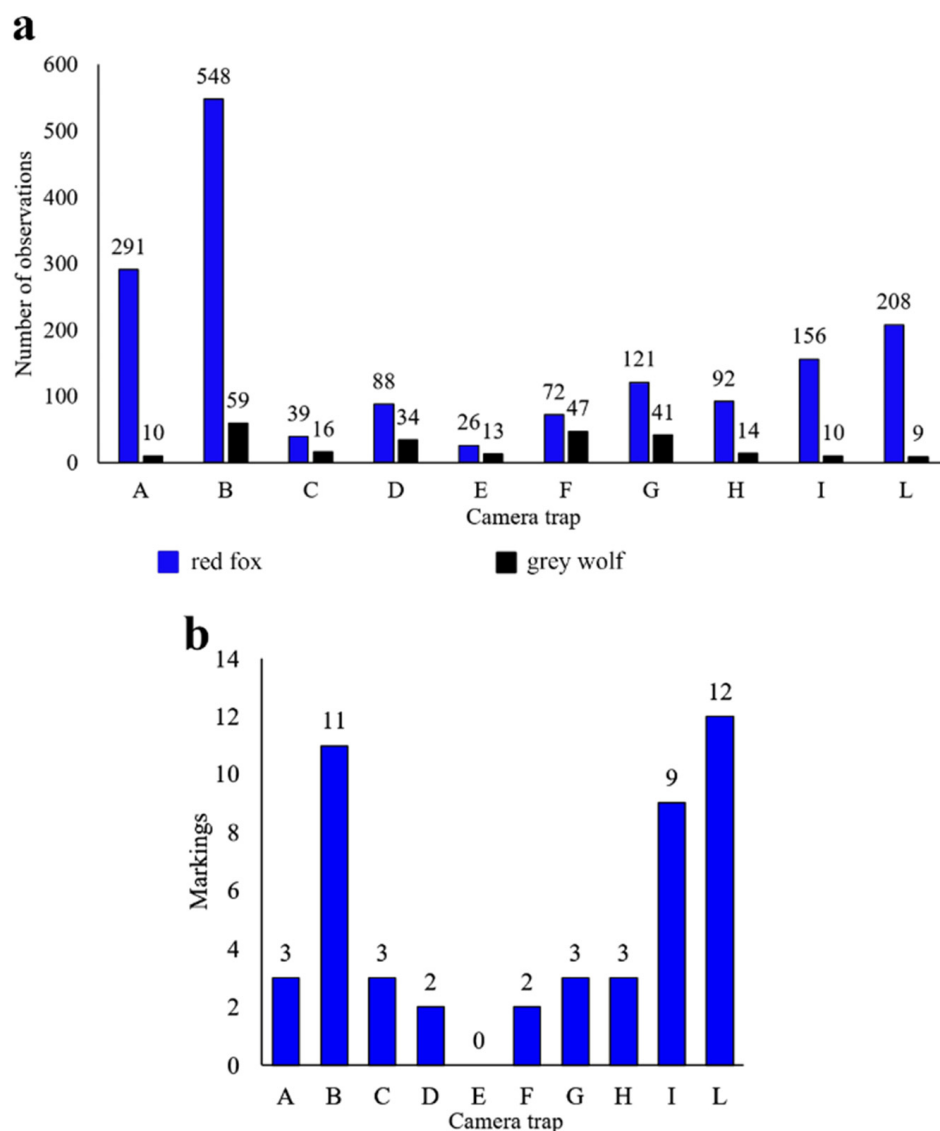
Videos recorded by camera traps throughout one year, from August 2022 to July 2023, provided evidence that the red fox is a common inhabitant of the area. The red fox was found to be the most active in winter (43.7% of the 1641 total number of videos containing the red fox) and the least active in summer (14.6%). On a monthly basis, the most active period was February (17.2%), followed by March (15.9%) and January (11.1%). Drops in activity were recorded in July (3.4%), May (4.7%), and September (4.7%) (Figure 2a).



**Figure 2.** Temporal pattern of the red fox activity. (a) Monthly activity of the red fox. For each period, the total number of observations (i.e., the number of camera trap videos in which the red fox was recorded) is shown. (b) Comparison of nocturnal activity of the red fox in different seasons. The total number of observations for each time slot is reported in the table. Seasons are indicated by different colours.

It is known that the red fox moves preferentially during the night, using vegetative cover to avoid predators and sun radiation during the day [19,20]. Our analysis revealed that the red fox activity remained consistent throughout the night, with peaks occurring between 9 and 10 p.m. Instead, a small drop in activity was observed at around 4:00 a.m. (Figure 2b).

Regarding the spatial pattern, the comparison between records of the red fox and the grey wolf revealed that the patterns of activity of the two species were much more diverse: a larger number of observations of the red fox activity was obtained at the camera traps located in A, B, I, and L sites, while the grey wolf was mainly registered by camera traps B, D, F, and G (Figure 3a). Data relating to the red fox's marking behaviour, which registered peaks at sites B, I, and L (Figure 3b), confirmed the results from the camera traps.



**Figure 3.** Spatial pattern of the red fox. (a) Comparison of the red fox and grey wolf activities registered by different camera traps throughout one year. For each camera trap, the total number of the red fox and grey wolf records is indicated. (b) Number of videos capturing the red fox's marking behaviour at the different camera trap locations.

### 3.2. Farmers' Perception of the Red Fox

Farmers involved in the questionnaire survey owned or had owned small farm animals). Almost all owned hens and one-third raised chickens, while a smaller proportion raised ducks and rabbits (Table 1). Most of the interviewed farmers (67% of the interviewees) reported having between 10 and 20 animals, and 29 out of 30 interviewees protected their livestock using night shelters.

**Table 1.** Dataset reporting results of the interviews with farmers living within or on the edges of the reserve area. Questions Q1–Q10 are reported in Section 2.

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
1	no	yes	Hens	5	Night shelter	yes	yes	no		yes
2	no	yes	Hens	4	Night shelter	yes	yes	no		yes
3	yes	yes	Hens	23	Night shelter	no	yes	yes	yes	yes
4	no	yes	Hens, ducks	50	Night shelter	yes	yes	no		yes
5	no	yes	Chickens, hens	20	Night shelter	yes	yes	no		yes
6	no	yes	Chickens, hens, rabbits, ducks	10	Night shelter	yes	yes	yes	yes	yes
7	no	yes	Chickens, hens, rabbits, ducks	20	Night shelter	yes	yes	no		yes
8	yes	yes	Chickens, hens, rabbits	30	Night shelter	yes	yes	no		yes
9	no	yes	Hens, ducks	20	Night shelter	yes	yes	no		yes
10	yes	yes	Hens	15	Night shelter	yes	yes	no		yes
11	no	yes	Hens	10	Night shelter	no	yes	yes	yes	yes
12	no	yes	Hens	10	Night shelter	yes	yes	no		yes
13	no	yes	Chickens, hens, ducks	15	Night shelter	yes	yes	no		yes
14	no	yes	Hens	8	Night shelter	yes	yes	no		yes
15	no	yes	Chickens, hens, rabbits, ducks	20	Night shelter	yes	no	no		yes
16	no	yes	Chickens, hens, ducks	20	Night shelter	yes	yes	no		yes
17	no	yes	Hens	20	Night shelter	yes	yes	no		yes
18	no	yes	Hens	6	Night shelter	no	yes	yes	yes	yes
19	no	yes	Hens	15	Night shelter	yes	yes	no		yes
20	no	yes	Hens	30	Night shelter	yes	yes	no		yes
21	no	yes	Rabbits	20	Night shelter	no	yes	no		yes
22	no	yes	Hens	10	Night shelter	yes	yes	no		yes
23	no	yes	Hens	15	Night shelter	yes	yes	yes	yes	yes
24	no	yes	Chickens, hens, rabbits	23	Night shelter	yes	yes	no		yes
25	no	yes	Hens	15	Night shelter	yes	yes	no		yes
26	no	yes	Hens	20	Night shelter	yes	yes	no		yes
27	no	yes	Chickens, hens	30	Night shelter	yes	yes	no		yes
28	no	yes	Hens	15	Night shelter	yes	yes	no		yes
29	no	yes	Chickens, hens	10	Free during the night	yes	yes	no		yes
30	no	yes	Hens	15	Night shelter	yes	yes	no		yes

The survey showed an overall positive perception of the red fox by the farmers. Although 87% of farmers had experienced predation by the red fox, 90% of them did not see it as a harmful animal. In addition, farmers' opinions on equipment and facilities for protection against red fox predation were positive. However, only 17% used equipment or structures to defend farm animals from predation. Responses to the final question of the survey underscore the positive perception farmers have toward the red fox: 100% of subjects believe it is possible to live peacefully with it.

#### 4. Discussion

The information gathered by camera trapping provided an overview of the fox's activities within the relatively small natural reserve Calanchi of Atri. From a temporal perspective, the red fox is more active in winter than in summer, preferentially moving at night, between 9 and 10 p.m. Among factors that may explain the seasonal differences in activity, temperatures, food availability, and breeding period appear to be the most important. Spikes in activity in winter may be mainly due to the pre-mating period, as well as the increased need to search for food. The greater food availability typical of spring and summer—during which the red fox was shown to increase invertebrates and plant consumption [21]—may significantly reduce the need to travel for hunting-related reasons. In addition, throughout the whole summer, red fox parental couples must care for their

litter born at the end of spring until their young's independence is reached at the beginning of autumn [22]. This significantly reduces adult individual's home range, limited to the area around the den. The intensified activity of the grey wolf during spring and summer, which corresponds to its reproductive period [23], may also contribute to the decrease in red fox movements.

The highest number of red fox observations was recorded by camera traps located near dense vegetation in areas where the grey wolf was less commonly present. This suggests that environmental conditions and the presence of other predators influence the spatial use of the territory by the red fox. In addition, the increased presence of markings, typically placed within or at the edges of the animal's territory—an area “that is consistently defended against conspecifics to secure resources like food or den sites” [24]—indicates possible proximity of locations B, I, and L to red fox's dens.

The red fox represents a potential concern for farmers, particularly those raising free-range chickens or other vulnerable small animals. However, interviews with farmers living within or near the protected area revealed that the red fox is not seen as a significant issue, and very few farmers used equipment or structures to defend farm animals from predation. Therefore, farmers' perception of the red fox was generally positive as livestock predation was rare, suggesting that this predator can obtain adequate food resources from its natural environment. Furthermore, talking to farmers revealed their appreciation for the ecosystem services provided by red foxes, particularly their role as scavengers [25] and in controlling certain pest species (e.g., rodents) [26]. Consistent with other studies on farmers' perception of wildlife in similar contexts [27,28], farmers recognized the benefits of scavenging and regarded red foxes as non-harmful species, in contrast to other predators such as wolves. When asked whether peaceful coexistence with the red fox is possible, some interviewees noted that they implemented protective strategies against crop damage caused by wild boars (*Sus scrofa*). Farmers clarified that fox predation is much rarer than crop destruction by wild boars.

The infrequent predation of livestock by red foxes in the area, the substantial and more significant product losses caused by wild boar activity, and an understanding of the red fox's essential role in the ecosystem are the key factors contributing to the positive perception of red foxes in the study area. This vision offers an optimistic perspective on wildlife conservation, at least from the livestock sector's point of view. Comments indicating that agricultural damage caused by wild boars poses a greater threat to farm productivity highlight the potential for targeted actions to address human-wildlife conflicts more effectively in the study area while fostering a more balanced approach to coexisting with species like the red fox.

## 5. Conclusions

The investigation into the spatiotemporal activity of the red fox and farmers' perception in the Natural Reserve Calanchi of Atri revealed two key findings. First, this study highlighted some habits of this predator, which is predominantly nocturnal and more active in winter due to increased food searching, moving preferentially near areas with dense vegetation close to its den. Second, it provided insights into how farmers perceive the red fox in terms of its impact on livestock. Although the red fox inhabits areas where livestock farming occurs, its activity rarely disturbs farmers, as predation events are infrequent. These findings may thus be useful for guiding future actions to promote coexistence, mitigate conflicts, and ensure both wildlife conservation and the sustainability of agricultural livelihoods.

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