LIFE18 NAT/IT/000972 PROJECT - LIFE WolfAlps EU

"Coordinated Actions to Improve Wolf-Human Coexistence

at the Alpine Population Level"

Action C1

Transboundary study: Differences among livestock depredations events within territories of Italian-French crossborder packs

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Table of contents

1. Introduction

In the Western Alps wolf packs settled in the early 1990s (Landry, 2013; Benhamou, 2014; Marucco and Avanzinelli, 2018).

The return of the wolf in the Alps, after 100 years of absence, has seen an increase of social conflicts with some stakeholders, mostly because of livestock depredation (Bautista et al., 2019; Kuijper et al., 2019; Bruns, 2020) and due to the loss of traditional livestock-guarding knowledge (Fourli, 1999; Reinhardt et al., 2012; Boitani and Linnel, 2015). These conflicts strongly influence peoples' attitudes towards wolves, leading to persecution and even complete eradication in many countries (Fritts et al., 2003). Therefore, it is important to collect data on conflicts between wolves and humans and to try to ease the problem. It is important to determine the risk factors predisposing farms to wolf depredation to enable more effective defence against wolf attacks.

On the Italian side of the Western Alps (Regione Piemonte), the wolf has been monitored over the years from the beginning of its return in the framework of different Projects: Progetto Lupo Piemonte (https://www.centrograndicarnivori.it/progetti/progetto-lupo-piemonte), Life Wolfalps Project and Life Wolfalps Project EU (https://www.lifewolfalps.eu/). Since 1999, different studies have been conducted to evaluate the impact of the wolf on the mountain husbandry and the efficacy of the protection systems (https://www.centrograndicarnivori.it/media/200babbb.pdf; Dalmasso and Orlando, 2009; Menzano et al., 2018). In Cuneo province, we observed that, after an initial strong impact of the wolf on livestock in the first phase of recolonization process where few wolf packs caused several attacks with a high number of victims (4,189 victims officially reported in the period 1999-2009, with packs increase from 2 to 14; Menzano et al., 2018), the abandonment of wild and semi-wild grazing and the adoption of protection measures lead to a decrease in the number of victims, attacks and in the number of victims per attack, despite the increase in the number of wolf packs (4,523 victims in the period 2010-2019, with packs increase from 14 to 32; Menzano, 2020). The attack chronicity (i.e., the number of attacks on the same pasture) changed from a rate of 54.1% of farms with one attack and 45.9% with more than 2 attacks in the period 2002-2004 to a rate of 72.5% of farms with one attack and 27.5% with more than 2 attacks in the period 2018-2020 (Menzano and Di Blasio, not published data). Sheep and goats resulted to be the domestic species most vulnerable to wolf attacks but also the most protected by the use of at least one protection measure (Menzano et al., 2018).

On the French side, the wolf has officially come back in 1992 through Italy, in the Parc National du Mercantour, which has been in charge of the first monitoring of the species (1993-1996). Then, following the progression of the species on the territory, the steering of the actions has been held at the national level by the Ministry of the Environment and the Ministry of Agriculture, via the Prefects. A series of national action plans and LIFE projects followed to ensure both the maintenance of pastoral activities and the conservation of the wolf. The decentralised services of the state, at the regional (DREAL, DRAAF) and departmental (DDT) levels, assist in the implementation of state policy under the authority of the Prefect in charge of the Wolf National

Plan. OFB is in charge of the monitoring of the wolf at the national level through the Loup-Lynx Network in which the PNM participates since 1995 by collecting signs of the species' presence. DRAAF coordinates the herd protective measures allocation, DDT is in charge of the damage compensation at the departmental level and centralises the data via the national GEOLOUP database whose data are reliable since 2004. OFB realises most of the damage reports (PNM does them in its territory by its own means). So, wolf management tasks are divided between different public state services, on which the PNM depends to have information that it does not acquire directly. In order to assess the efficiency of the protective measures, some studies have been funded by the Ministry of Environment at the national scale (Roincé et al., 2016, Boisseaux et al., 2019). At the PNM scale, no study has been led to evaluate the factors that could influence the depredation level. However, the damage reports are realised by casual workers recruited by the Park, so number of attack trends are well known. From 1999 to 2012, the number of attacks and victims by attacks have followed an upward trend with a peak of 531 attacks for 1,631 victims, but since 2013 the trend has reverse to attain 438 attacks for 1,051 victims in 2023 (Canut, 2024), with slight fluctuations around 400 attacks on average these last 10 years. Regarding the number of packs in the PNM, in 2012, one pack has been added to the previous 8 ones defined in 2011. However, the situation has changed over the last 12 years. The latest analysis of wolf genetic samples collected from 2017 to 2023 counts at least 16 wolf packs in the PNM territory, with 4 packs that should be considered with caution (Laudic, 2024). It is important to keep in mind that since 2015 the number of attacks occurring during the day exceeds the number of attacks at night in the Alpes-Maritimes, and so in the PNM (Fressard, 2021).In the PNM, most of the breeders have at least 2 protective measures, more often 3, but no study has crossed parameters to assess if the implementation of the protective measures could have an impact on the numbers of attacks.

Apart from the size of the herds, which seems to be higher on average in France than elsewhere in Europe (Boisseaux et al., 2019), the latest studies on wolf predation have tended to show the multiplicity of factors that influence the effectiveness of the prevention measures (Plisson, 2011; Roincé et al., 2016 ; Borelli and Landry, 2020; Kaatinen et al., 2009). For this reason, it is reasonable to work at small scale, and moreover across borders, since the pastoral practices are not the same between countries just like the management of the species: France authorising the shoot of wolf except in National Parks core area and National Natural Reserves, with a threshold of 19% of the assessed annual population, while wolf removal is not allowed in Italy.

Although wolf livestock depredation has a clearly different impact on the Italian or French side of the Maritime Alps, to date no study has been carried out to understand the factors responsible for this difference. Several factors affect livestock depredation and therefore predation risk, such the spatial distribution of carnivores and livestock and their numbers, the quality of livestock husbandry, the environmental factors such as vegetation cover, topography or weather and the correct use of prevention systems (Treves et al., 2004; Kolowski and Holekamp, 2006; Kaartinen et al., 2009; Valeix et al., 2012; Imbert et al., 2016) but also wolf and pack behaviour (Borelli and Landry, 2021).

A specific and preliminary study on wolf livestock depredations in the areas occupied by Italian-French transboundary packs is necessary to evaluate how the use of preventive systems, the correct management of the livestock, the flock size and the environmental factors could affect the number of wolf attacks and victims. Knowing which factors determine higher risk of wolf depredation to alpine farms may provide insights for efficient strategies to reduce livestock and wolf losses.

2. Objectives

The aim of the study was to establish if the use of preventive systems, the typology of livestock husbandry, and wolf packs characteristics affect livestock depredations (attacks and victims) in areas occupied by transboundary packs of the Parc National du Mercantour (PNM-France) and the Aree Protette Alpi Marittime (APAM-Italy). Understanding the main factors causing livestock depredations is essential to plan specific interventions to reduce the impact of the predator on mountain livestock farming.

Our main goal was to evaluate how different variables (livestock characteristics, preventive methods used, and wolf presence) are related to depredation events in transboundary packs.

3. Study design and methods

This study compares 3 areas of transboundary (France-Italy) wolf packs and considers two different periods: a past situation (with data collected previously the LIFE WolfAlps EU project, during years 2004 and 2010) and recent situation (with data collected in the field in 2022 and 2023 in the framework of the LIFE WolfAlps EU project), thus reflecting the evolution of the husbandry practices and of the wolf population in the years.

For each study area and for each year investigated, we collected data on depredation events (number of attacks, number of victims for each attack, weather conditions, georeferenced location of the depredation events), husbandry practices (shepherd presence, use of prevention systems), and wolf presence (minimum number of wolves present and wolf minimum area of presence).

Since the majority of depredations occurred between June and September in Italy (Menzano, 2018) and between July and October in France (Canut, 2022) and most available data on husbandry practices are for the summer grazing period, we restricted the analysis to the period 1st June-31th October of each year.

Data are preliminary used to collect indications if the same transboundary wolf pack could have a different depredation impact on mountain livestock in the 2 countries, and which are the factors connected to the different impact. We compared past and recent data.

For each study area, we considered the following data:

- livestock characteristics:
  - flock size
  - presence of the shepherd
  - prevention methods in use when animals were attacked (enclosure in electrified fences, presence of livestock guarding dogs, presence of a shepherd)
- depredation events (we define "attack" as an event resulting in at least 1 kill, we consider only events attributed to wolves following appraisal from an expert)
  - number of attacks per pasture
  - number of killed animals per pasture
  - predation month and time of the day
  - weather conditions during the depredation event
- wolf presence
  - transboundary wolf pack size estimation and location

4. Study area

Three areas have been selected for the study (Figure 1). All three areas are occupied by transboundary packs, which have been monitored by both Italian and French researchers since wolves returned in the early 1990s (Marucco and Avanzinelli, 2018; Wolf Alpine Group, 2018). The minimum pack areas of presence are obtained from monitoring activities both in Italy and in France. Around each minimum area of presence of the transboundary packs, we considered a buffer zone of 5 km. These areas (Figure 1) partially include territories of the Aree Protette Alpi Marittime (APAM-Italy) and Parc National du Mercantour (PNM-France), and they are:

1. Bassa Stura/Isola
2. Sabbione/Roya
3. Pesio/Tende

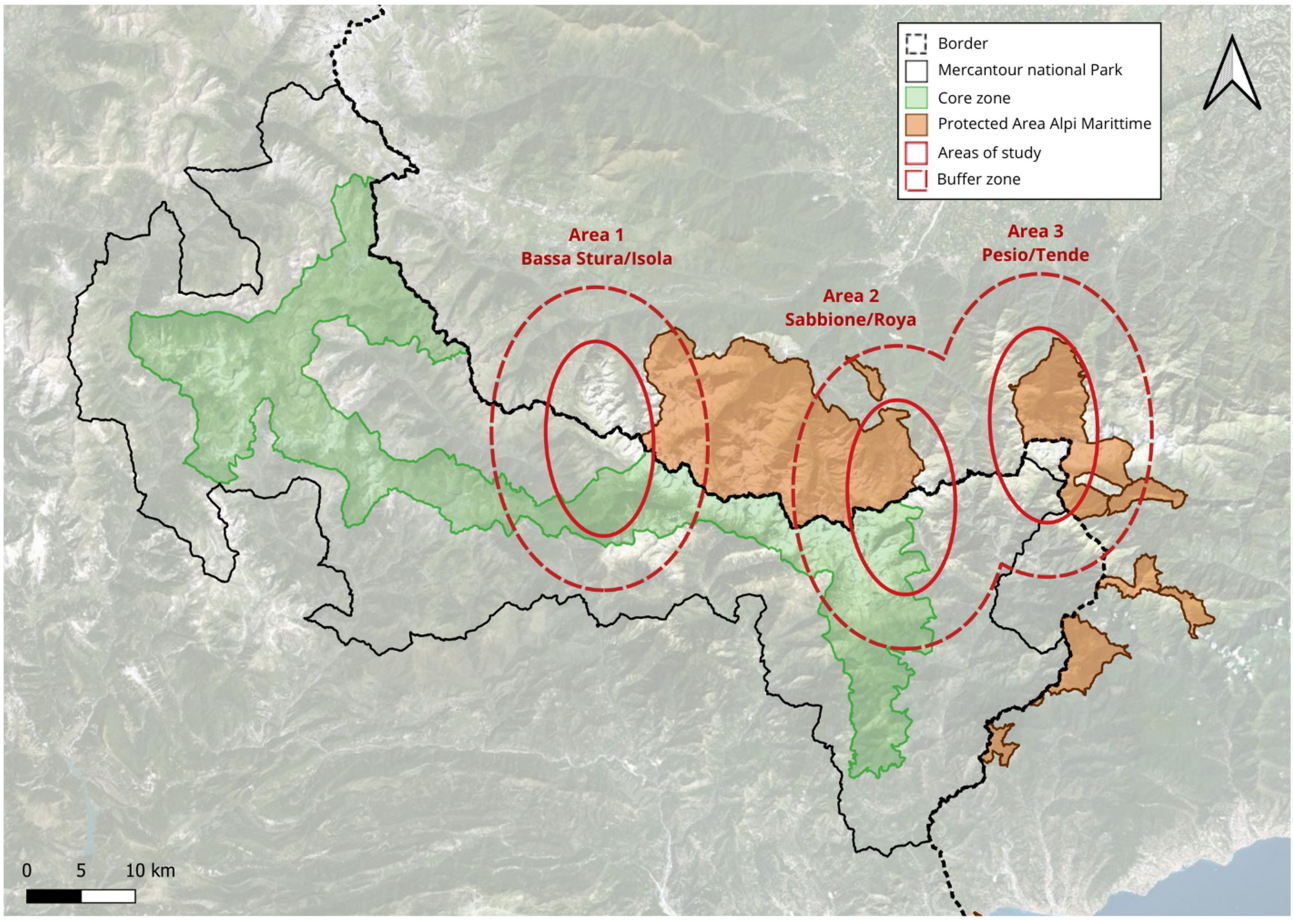

Figure 1. Location of the 3 study sites (delimited by solid lines), around each minimum area of presence of the transboundary packs, we considered a buffer zone of 5 km (delimited by dotted lines).

Six species of wild ungulates coexist within the Parks areas: chamois (*Rupicapra rupicapra*), mouflon (*Ovis musimon*), ibex (*Capra ibex*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*). The livestock in the study areas is mainly composed of small stock (goats and sheep) and cattle. This study takes in consideration only small livestock because at this stage and in this area, compared to sheep, attacks on cattle are rather rare. On both side, during the day, flocks are generally let out to graze, reportedly under the surveillance of herders/shepherds and/or guarding dogs (mainly belonging to Great Pyrenees and to Maremmano-Abruzzese Sheepdog breeds), with grazing between early morning and sunset. At night, the livestock is typically accommodated in electrified enclosures. The structure of enclosure may vary among shepherds (e.g., height, number of nets, etc.) which influences its overall quality. The use of alternative protection methods is relatively rare in these areas. The details of each livestock management is considered in the study.

4.1 Overview of Sheep Breeding

In France, and in PNM in particular, the sheep population is estimated at around 220,000, distributed in around 230 sheep breeders mainly for meat consumption. Dairy farmers are a minority. The mean number of sheep flock in the PNM is estimated around 1,200 heads. The majority of livestock farmers living in the Roya valley are local breeders who occupy different pastures at different altitudes in the same valley throughout the year. It is the case of the breeders working in Areas 2 and 3 (Figure 1). By contrast, breeders in the valleys west of the Vésubie are transhumant (Area 1), meaning that outside the alpine grazing period, they live in other departments with their sheep and only return to their pasture between June and October. In summer, farmers can either look after their flocks themselves, or hire a shepherd to look after their animals in the mountain pastures. In most cases, the farmer's LGD are made available to the shepherd to protect sheep, so shepherds are not the owners. The average number of LGD per flock is 5 (1-14). The shepherd usually has his own shepherd dogs. In the morning, the shepherd takes the sheep out of the electrified enclosures in which they are locked up at night, and releases them for the day under the watchful eye of the shepherd and LGD. The day alternates between grazing and resting. The shepherd may sometimes leave his flock under the sole care of LGD, particularly during resting time and maintenance activities in the pasture. At the end of the day, the shepherd takes his sheep back to the night fence. In most cases, the shepherd has a hut nearby, although not all areas have one. In this case, the shepherd can sleep in a tent or have a cabin a little further away from the flock. Shepherd representatives asked for work condition improvement to match French work rules which clarify the minimum required for them to work.

In Italy, in the Piemonte Region, the size and number of sedentary herds of small ruminants is growing, whereas, an opposite situation is observed in mountain pastures (Menzano, 2015). In Piemonte, in 2024 the sheep population is estimated at around 125,000, with an average flock size between 100-500. In the 3 study areas, there are mainly local breeders who pool their flocks together and give it in guard to a common-unique guardian, so as to reduce the management costs. Sometimes this guardian is an extra-communitary operator, hired only for the pasture season, whose habits and capacity in managing flocks and LGDs can be not so careful, sometimes leading for example to a lack of LGD care. The presence of transhumant shepherds is occasional (only few in the 3 study areas, with one flock with a maximum of 1,830 sheep in 2022). Usually, sheep are bred in plain/bottom valley stables during the winter. A part of them, mainly meat breeds, are then moved from May to October (mean period 145±55 days; Menzano, 2015) to the Alpine pastures where they may utilise several shepherds' huts at increasing elevation to follow the seasons. No stables are present in the Italian study areas and also mountain huts for shepherd recovery are very rare. Often, farmers have to stay overnight in emergency facilities such as containers or caravans or have to travel long distances, therefore unable to intervene promptly at night in case of need (Menzano, 2015). Shepherds are used to build oversized enclosures to allow livestock to feed during night, when it is cooler and animals are more willing to eat, and to reduce a close contact between flock and predators and frightening situations that could lead livestock to break down the fence. Shepherds enclose animals as soon as it gets dark and open them in the

early morning. During the day the shepherd is commonly present with livestock, also in case of LGD presence (he is obliged by the Italian law), but he could be engaged in Alpine pasture maintenance activities and, so, not always fully attentive to what is happening. The use of LGD is increasing in the Italian Alps because, when dogs are adult and well trained, they have a high economic return for the breeder. After an initial investment in terms of time and cost, their maintenance is relatively low (Landry et al., 2005; Vercauteren et al., 2008) and their use could be also economically supported by EC programs (European Union's Common Agricultural Policy). The use of LGDs is increasing in the Italian Alps as they offer a high economic return when well-trained and mature, although they need proper training and integration to avoid causing problems.

4.2 Work Conditions for Shepherds

There are notable differences between the two countries in terms of work conditions for shepherds. In France, labor regulations establish minimum working conditions. The PNM conducted a census of shepherd huts in 2018 to plan their restoration. While some huts can be in poor condition, all pastures are equipped with at least one shelter or cabin for shepherds. Both breeders and shepherds are advocating for better working conditions to improve their sleeping and resting facilities. In Italy, work conditions are more challenging, particularly for small-scale sheep owners. There are issues such as a lack of housing and access roads to pastures, difficulties in finding skilled labor, and competition from larger lowland breeders supported by the EU Common Agricultural Policy. This makes farming less profitable and harder to maintain, especially with the added costs of protecting livestock from predators.

4.3 Daily Management of Sheep Flocks

In general, the day-to-day management of sheep flocks is similar in both France and Italy. However, large flocks are often managed by groups of farmers (GAEC, GP), meaning that outside the summer grazing period, each farmer's sheep live separately. The mixing of different flocks during the summer grazing season can complicate guarding efforts, especially when the sheep are unfamiliar with each other and the breeds differ. This situation may also force dogs from different packs to coexist, leading to relationship difficulties. Small flocks (over 200 heads) are often dairy ewes for cheese production, but this is a minority and not relevant to our study areas.

5. Results

5.1 Data collection

5.1.1. Depredation events and damage prevention methods

We used 2 different sets of data:

1. data collected in France and in Italy in 2004 and 2010 (Source of data in Table 1).

In Italy: data on depredation events were collected by the Progetto Lupo Piemontet or by the Public Veterinary Service and data on the use of prevention systems were obtained by a declaration of the shepherd (data collected within a specific questionnaire during the evaluation of the depredation event).

In France: data on depredation events were collected in a national database (Géoprédateur) managed by the DREAL (Regional Service). Damage reports are validated by departmental service (DDTM06). Data on the use of prevention systems were found in the archives of the DDTM06 (in "cahier de paturage" and in the DDTM 06 files recording breeders who have contracted state aid for the implementation of protection measures).

Table 1. Italian and French sources for the collection of the data of interest related to years 2004 and 2010.

Type of data collected	Data source	
	Italy	**France**
Depredation events	Progetto Lupo Piemonte or Public Veterinary Service	DREAL (Geoprédateur) DDTM 06
Livestock characteristics	Progetto Lupo Piemonte or Public Veterinary Service or interview to the breeders conducted in the framework of the Progetto Lupo Piemonte	DDTM 06 (cahier de pâturage), archived files
Wolf presence	Progetto Lupo Piemonte	OFB

2. Data collected in France and in Italy in 2022 and 2023 in the framework of the LIFE WolfAlps EU Project (LWA EU).
   In Italy: the main research team was composed of a full time master student from the University of Torino (DBIOS), Park Rangers (APAM) and the veterinary coordinator (APAM). This team was in charge of collecting all the data needed, in collaboration with the local WPIU. The WPIU, as far as possible in collaboration with the research team, collected detailed data on each depredation event and on every connected variable directly in the field based on a common datasheet.
   In France: the official data sheets filled by the damage inspector (recruited by the PNM) were the main source of information about circumstances of depredation events and herd husbandry information which are based on the breeder statement. The DDTM06 studied the damage reports, if the wolf cannot be dismissed, damages are paid to the breeder. In parallel, the PNM-LWA EU team was composed of the technical coordinator and technicians recruited as a WPIU. They have conducted detailed studies in the highly attacked pasture in the area 1. They were assisted in each valley (Tinée and Roya) by the person in charge of the damage reports and pastoral mediators.

The correctness of the depredation event was confirmed by trained staff (defined before) after visiting the location and interviewing the livestock owner reporting the loss. Only attacks attributed to wolves were included in the dataset. All the depredation events were georeferenced.

We considered three main methods of protecting grazing animals:

1. the presence of shepherds guarding the herd during the day and closing the animals into a night pen to protect them from predators;
2. the use of electrified fences to surround a pasture to prevent large carnivores from reaching animals by night, and eventually by day for grazing animals;
3. the use of livestock guarding dogs-LGD (Maremmano-Abruzzese Sheepdog, Montagne des Pyrénées, Anatolian shepherd) that are brought up within the herd of grazing animals to create a bond between the dogs and the animals they are protecting.

5.1.2. Wolf presence

OFB is in charge of the monitoring of the wolf at the national level through the Loup-Lynx Network in which the PNM participates since 1995 by collecting signs of the species' presence. Reports on the wolf presence in France are regularly produced by OFB, taking into account also the Mercantour National park study area (https://www.loupfrance.fr/).

Centro Grandi Carnivori (CGC), defined by the Regione Piemonte and set at the Ente di Gestione Aree Protette Alpi Marittime, is in charge of the coordination of the wolf monitoring in Piemonte, Italy, through the Wolf Network since 1999. The study area of the Alpi Marittime has been systematically studied since 1999 and many reports are available to document the details of the wolf presence in this site (https://www.centrograndicarnivori.it/download#Report).

Moreover, since 2001 there has been an effort to combine the wolf data from France and Italy in order to monitor the wolf alpine population as a whole, over the boundaries, and document transboundary packs. In this framework, the Wolf Alpine Group (WAG) was established in 2001, with the main Institutions in charge of wolf monitoring from the different countries. Within this group, transboundary packs have been constantly documented, and reported (WAG 2001, 2004, 2008, 2010, 2015 - https://www.centrograndicarnivori.it/download#Report). More recently the WAG monitored the expansion of the wolf population, and of the transboundary packs, in the framework of the LIFE WolfAlps EU project, and continued to document the entire population over 7 countries, as well as the transboundary packs (WAG 2023, https://www.lifewolfalps.eu/wp-content/uploads/2023/05/C4_Deliverable_WAG_2020_2022_updated.pdf).

The study area in Figure 1 interested 3 packs which have been documented as transboundary since 2000 by the WAG. The details of the documentation of the transboundary packs are in the reports cited above.

5.2 Descriptive results

5.2.1. Number of attacks in regional areas

The 3 study areas do not present a significant difference in the number of depredation events (Table 2), so we can consider that the three French-Italian areas are under the same depredation pressure by wolf in each transboundary pack. If there are differences between the two countries, we have to determine what could explain them. Our hypothesis is that other aspects have to be considered such as management of the livestock, the use of prevention systems or habitat characteristics.

Table 2. Total number of attacks recorded in the 3 study areas by the 3 transboundary packs.

	Italy+France			
Transboundary Area	**1**	**2**	**3**	**Total**
Total number of attacks	**89**	**88**	**84**	**261**

5.2.2. Location, distribution and number of attacks in each country

The locations of the attacks distributed in the 3 areas are presented in Figures 2 to 4, with a general overview of the study area (Figure 2) and a focus of regional areas with the Area 1 (Bassa Stura/Isola) in the Tinée and Stura valleys (Figure 3) and the areas 2 (Sabbione/Roya) and 3 (Pesio/Tende) in the Roya, Sabbione and Chiusa Pesio valleys (Figure 4).

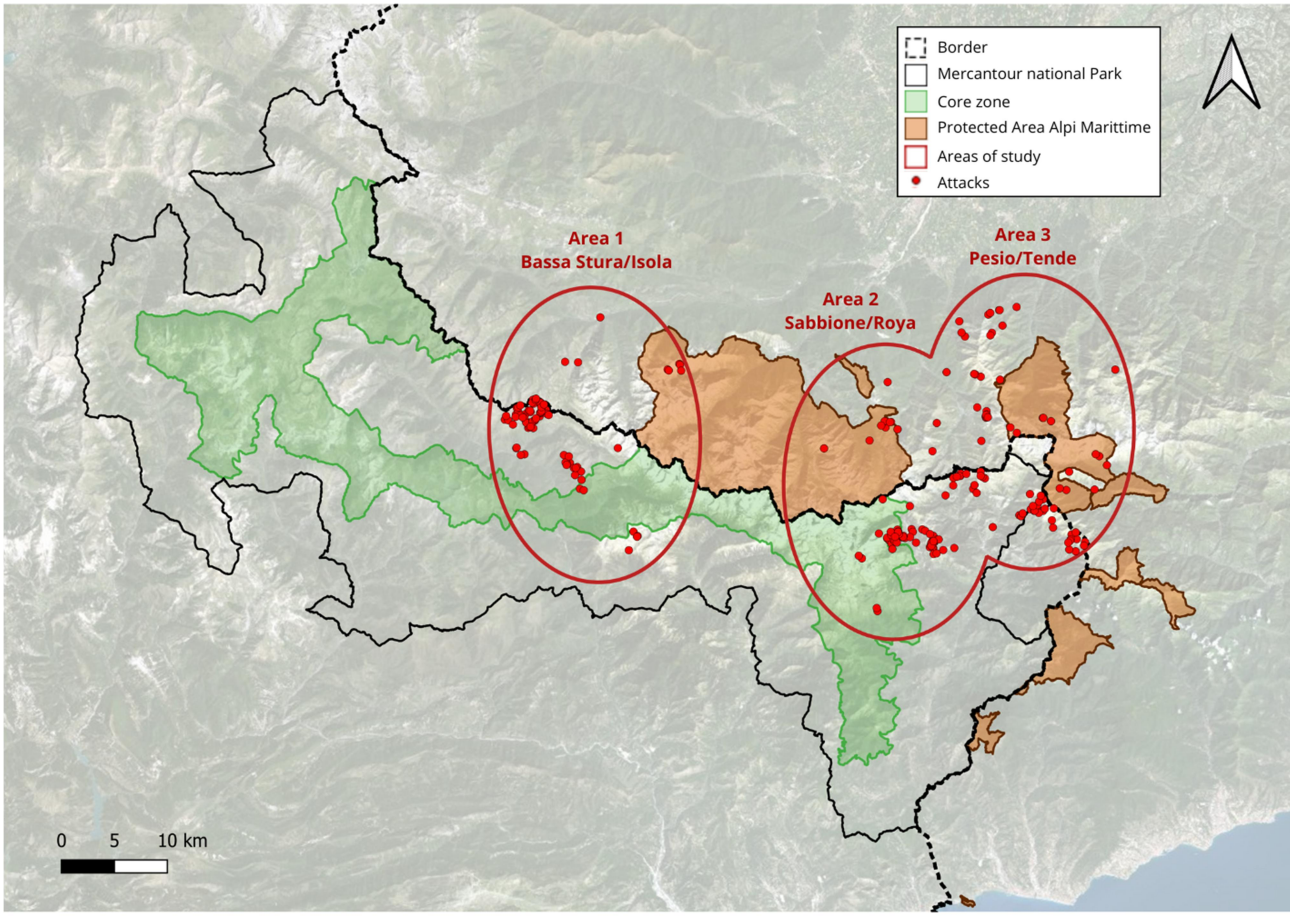

Figure 2. Location of attacks recorded during the study period on the 3 study sites delimited according to the presence of transboundary packs between France and Italy.

The number of pastures concerned by attacks were equivalent on both sides (Table 3) in area 1 and 2. But there were more pastures affected by attacks in Italy than in France in area 3 (Table 3).

Although the number of pastures concerned by attacks are rather the same, the attack distribution and number are different in each country.

Table 3. Total number of pastures concerned by attacks in France and in Italy in each area.

	Nb of pastures in France	Nb of pastures in Italy
AREA 1	**7**	**7**
AREA 2	**8**	**7**
AREA 3	**9**	**15**

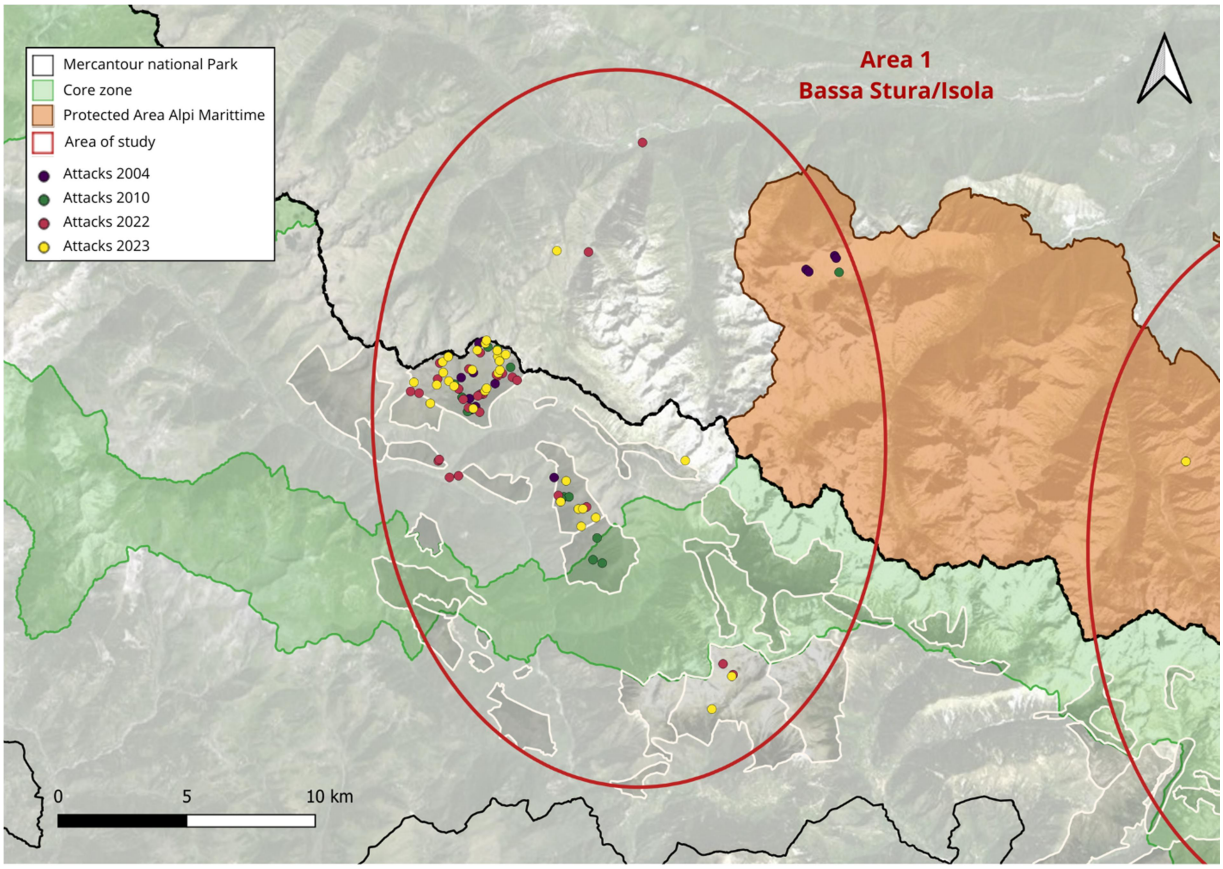

Figure 3. Location of attacks recorded during the study period on the Area 1: Bassa Stura/Isola study site (one colour by year of attack), with Mercantour national Park pastures delimited with white border.

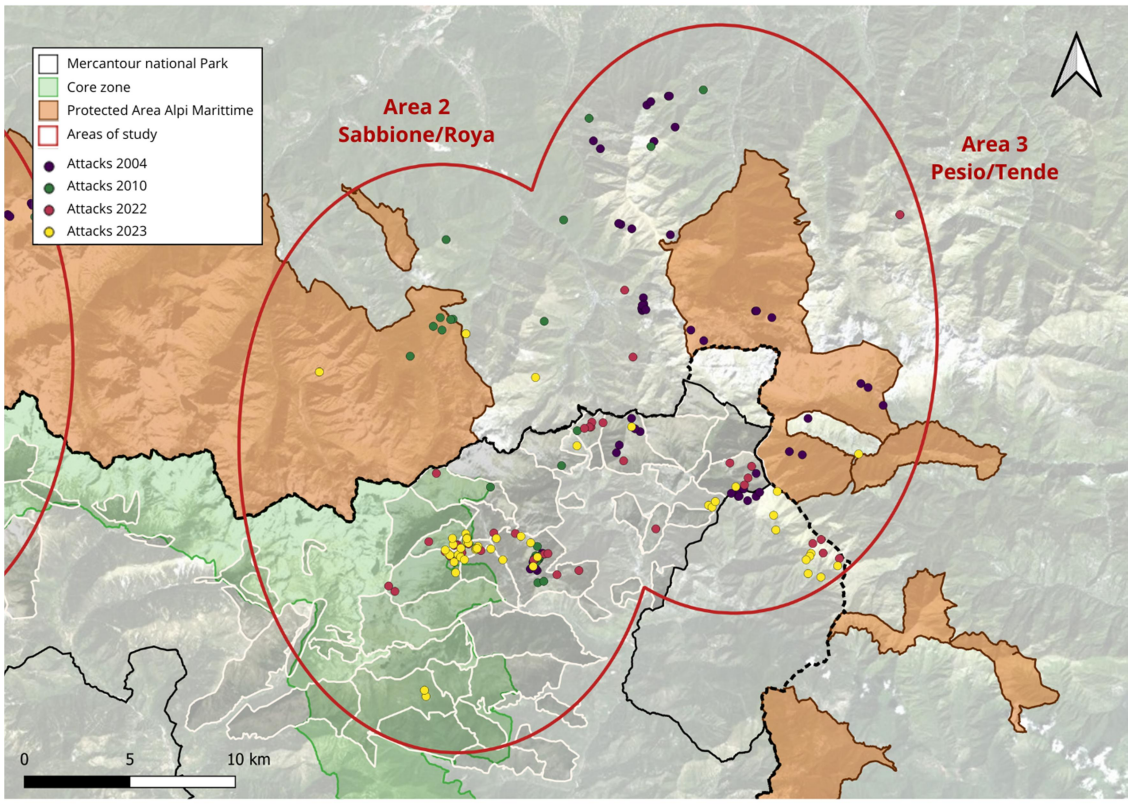

Fig. 4 – Location of attacks recorded during the study period on the Area 2: Sabbione/Roya (left) and Area 3: Pesio/Tende (right) study sites (one colour by year of attack) with Mercantour national Park pastures delimited with white border.

In area 1 (Bassa Stura/ Isola) the number of wolf attacks is significantly higher in the French portion compared to the Italian side. Moreover, in France, attacks gathered in only a few pastures, and the great majority of the attacks occurred only in one pasture at the border (Figure 3). Indeed, in area 1, this one French breeder contributed to 66.25% of the total number of attacks (n=53) from 2004 to 2023, and contributed to 59.55% of the total number of attacks (n=89) if both countries are considered. This indicates that attacks are particularly concentrated on this specific French breeder (Table 4 and Figure 3).

Area 2 (Sabbione/Roya) presents a similar pattern to Area 1, with a higher number of attacks in France compared to Italy.
In France the concentration of the attacks are related to a limited number of pastures (Table 3 and Figure 4).
Specifically, from 2004 to 2023, two breeders accounted for 56.36% of the attacks (43 out of 73) among the 10 breeders in the area. Conversely, in Italy, the distribution of attacks is more evenly spread across breeders, with 4 to 7 breeders experiencing 15 attacks in total; however, one breeder alone accounted for 40% of these attacks (6 out of 15), as shown in Table 4 and Figure 4.

Area 3 (Pesio/Tende) is characterised by a broader distribution of attack locations, especially in Italy. In France, attacks are concentrated along the eastern border, with the majority occurring outside the PNM (Table 3, Figure 4). In France, the 44 attacks were more evenly distributed among the 10 breeders, though one breeder accounted for 27.2% of the attacks (12 out of 44). In Italy, the distribution is similarly uniform, with 10 to 14 breeders affected by 40 attacks in total, although one breeder was impacted by 25% of these attacks (10 out of 40), as indicated in Table 4 and Figure 4.

This number of attacks should be related to the total number of sheep actually present in the two zones, but we don't have this data at this time.

The number of attacks is more than three times higher in France than in Italy. Indeed, in the 4 years of the study, considering the 3 study areas, there were 64 (24.5%) reported cases of wolf attack on sheep farms in Italy and 197 (75.5%) in France (Table 4). In addition, in Italy, in all the 3 study areas, a decrease of depredation events was recorded from 2004 to 2023. In France there is an opposite trend of increase, with more attacks in 2022 and 2023 than during the first two years considered (Figure 5).

Table 4. Number of depredation events occurred in each study area in Italy and France in 2004, 2010, 2022 and 2023.

Depredation events

	Italian areas				**French areas**			
	Area 1	**Area 2**	**Area 3**	**Tot**	**Area1**	**Area2**	**Area 3**	**Tot**
n. of pastures	7	7	15	**29**	7	8	9	**24**
2004	5	/	32	**37**	10	7	14	**31**
2010	1	9	3	**13**	13	9	1	**23**
2022	3	3	4	**10**	26	24	15	**65**
2023	/	3	1	**4**	31	33	14	**78**
2004-2023	**9**	**15**	**40**	**64**	**80**	**73**	**44**	**197**

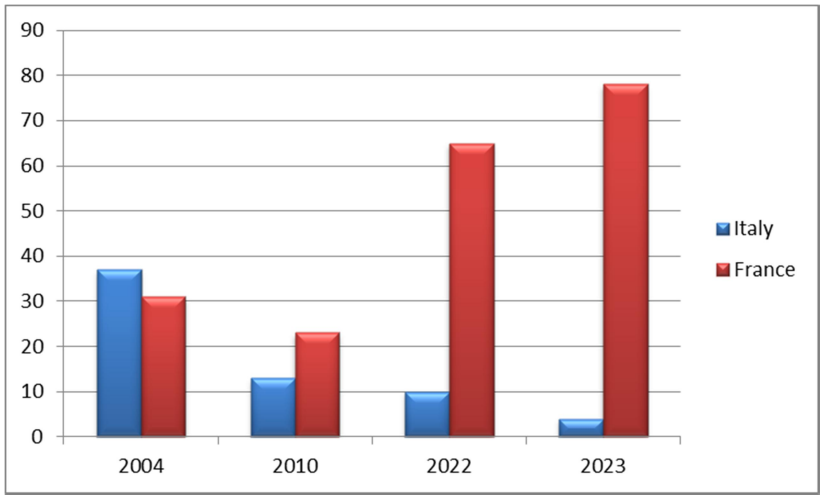

Figure 5. Total number of depredation events in the study areas in Italy and France in 2004, 2010, 2022 and 2023.

In the same way, we also observed a decrease in the **number of victims** in Italy (from 53 in 2004 to 16 in 2023) and a fluctuation of the number of victims between the years in France (Table 5 and Figure 6).

Table 5. Number of killed sheep/goats during the study period, in the 3 study areas.

Number of killed livestock (sheep and goats)

	Italian areas				French areas			
	1	**2**	**3**	**Tot**	**1**	**2**	**3**	**Tot**
2004	6	0	47	**53**	89	13	48	**150**
2010	2	12	11	**25**	84	31	1	**116**
2022	8	6	14	**28**	88	60	24	**172**
2023	0	15	1	**16**	106	86	40	**232**
TOTAL 2004-2023	**16**	**33**	**73**	**122**	**367**	**190**	**113**	**670**

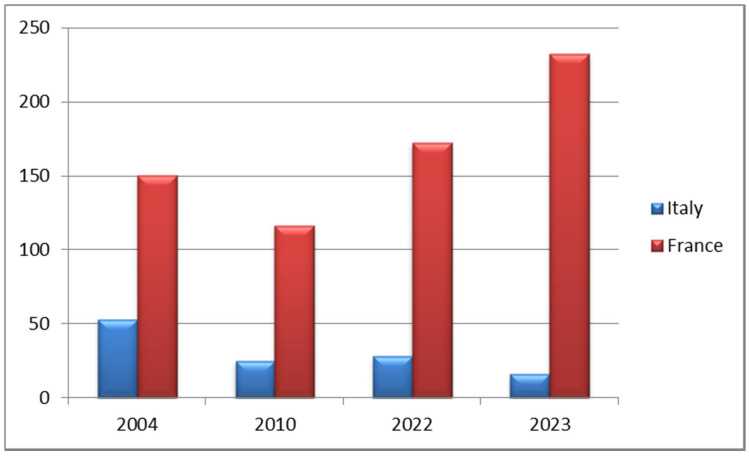

Figure 6. Number of killed sheep/goats during the study period from 2004 to 2023, in the 3 study areas of Italy and France, respectively represented with the blue and red colours.

In summary, the number of depredation events and the number of sheep killed increased over time in France, whereas both parameters have decreased in Italy (Table 4 and 5, Figures 5 and 6). Additionally, attacks in France are concentrated in a smaller number of pastures compared to the more dispersed pattern observed in Italy.

5.2.3. Attacks frequency

In Italy, the majority of affected farms (63.6%) experienced only a single depredation event. Six pastures (18.2%) experienced two depredation events, primarily in 2004 and 2022. One farm (3%) was attacked exclusively in 2004, while five farms (15.2%) suffered more than four attacks—four in 2004 and one in 2010, with the highest number being 10 attacks on a single farm in 2004, resulting in a total of 14 victims (Figure 7).

In contrast, in France, the majority of the most affected farms (46.5%) experienced more than four depredation events, with an increase in frequency over the four years. The most impacted farm recorded 21 attacks in 2023, resulting in a total of 64 victims (Figure 6). Eleven farms (25.6%) experienced a single depredation event, occurring across all four years, while five farms (11.6%) were attacked three times.

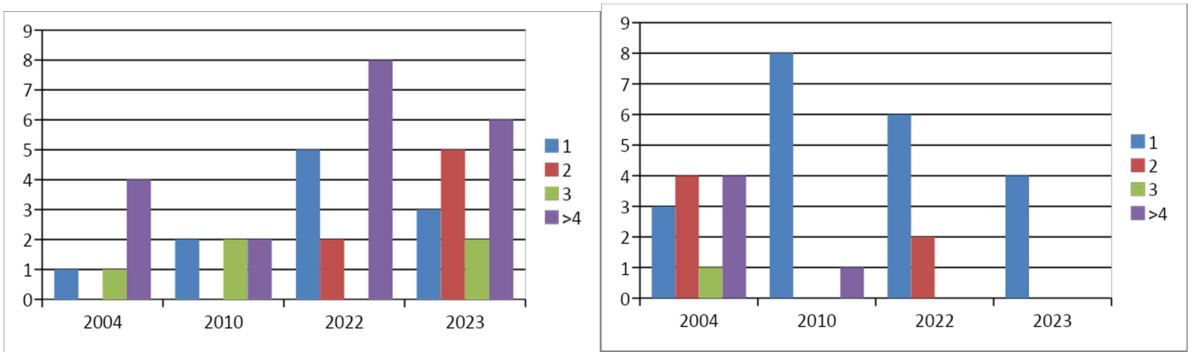

Figure 7: Number of attacks recorded in the 3 study areas, during the 4 years of the study, in France (on the left) and in Italy (on the right).

5.2.4. Periodicity (day/night) of the attacks and preventive measures in place

No or one preventive measure was used respectively in 16 (25%) and in 25 (39.1%) reported Italian depredation cases. The other 21 Italian depredation events (32.8%) occurred with the use of 2 or 3 prevention systems. In 2 (3.1%) cases, the Italian reports contained no information about the use of preventive measures (Table 6).

In France, at least one preventive measure was in place during a wolf depredation and in most of the reported cases 2 or 3 systems were present (91.4%). In 14 (7.1%) cases, the French reports contained no information about the use of preventive measures (Table 6).

Table 6 - Number of preventive measures in place considering wolf attacks occurred in each year of investigation.

Preventive	2004		2010		2022		2023	
measures in place	Italy	France	Italy	France	Italy	France	Italy	France
0	14	/	2	/	/	/	/	/
1	10	/	11	/	3	1	1	2
2	11	21	/	22	5	55	2	68
3	/	/	/	/	2	9	1	5
NA	2	10	/	1	/	/	/	3
TOT	37	31	13	23	10	65	4	78

In France, there has been a clear shift in the timing of attacks from night to day. While the attacks occurred predominantly by night in 2004 and 2010, 70% of attacks over the past two years have occurred during daylight hours. In Italy, this shift is less pronounced; with the exception of 2022, daytime attacks have consistently outnumbered nighttime attacks.

If attacks occurred during the day, the electrified fence used by night has no utility since sheep graze outside this preventive system. That's why attacks occurring during the day and those occurring during the night have been described separately in regards to the preventive measures in place. In general (Table 7 and 8, Figure 8), in France 75.5% of the attacks occurred during the day when in 85.8% of cases both shepherd and LGD (ranging from 1 to 14) were present, in the other cases no data was available. In 31.1% of attacks the weather was sunny, in 46.6% it was foggy or rainy and in 22.3% no data on the weather conditions were available. In Italy, 58.2% of the attacks occurred during the day when at least a shepherd or a LGD were present (83.9% of the cases). In 29.0% of attacks the weather was sunny, in 54.8% it was foggy or rainy and in 16.1% no data were available.

Table 7. Occurrence of attacks by night and by day in France and Italy from 2004 to 2023.

	Italy		France	
	night	day	night	day
2004	11	17	17	14
2010	3	9	14	9
2022	8	2	9	55
2023	1	3	8	70
2004-2023	**23**	**32**	**48**	**148**

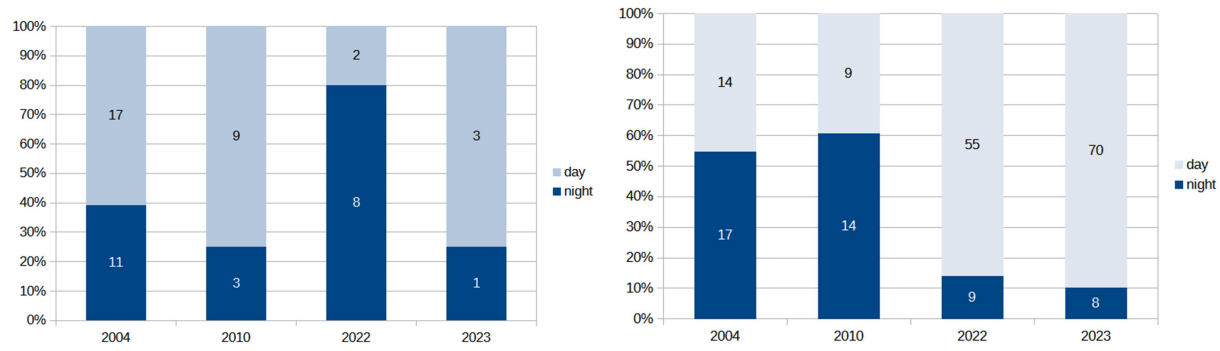

Figure 8. Frequency of occurrence of attacks during day and night in Italy (on the left) and in France (on the right)

Table 8 - Frequency of occurrence of attacks during day and night in Italy and in France, with different weather conditions.

weather	DAY ATTACKS		NIGHT ATTACKS	
	Italy (%)	France (%)	Italy (%)	France (%)
good	29.0	31.1	30.4	16.7
foggy-rainy	54.8	46.6	30.4	16.7
NA	16.1	22.3	39.2	66.6

In France, in 2004, 14 attacks occurred during the day. Sheep were protected in 12 cases by LGD and shepherd. No information was available for the 2 others. For the 17 attacks occurring during the night, no information was available for any of the protective measures in 8 cases, and in the 9 last cases, sheep were protected by the shepherd and LGD.

In 2010, 9 attacks occurred during the day. Except for one attack without any data available about protective measures, sheep were always protected by LGD and the shepherd. For the 14 attacks occurring during the night, no data is available about the use of electrified fences, but all flock that were attacked were protected by LGD and the shepherd too.

No data about weather conditions were collected in 2004 and 2010.

I**n 2022**, 55 attacks occurred during the day: 47 attacks occurred when the flocks were usually grazing (37 of which with bad weather). When grazing, all sheep flocks were supervised by LGD and shepherd. There were 8 other cases of attacks by day which occurred on sheep or rams which were kept apart from the flock in grazing pens or sanitary pens. During the 9 night attacks, all flocks were protected with the 3 preventive measures LGD-shepherd-fence.

In 2023, 70 attacks occurred during the day during grazing (32 of which with bad weather), in 60 cases, flocks were protected by LGD and shepherd and for 10 attacks, no information was available on the preventive measures in use. Of the 8 attacks occurring during the night, in 6 cases flocks were protected by 3 preventive measures (LGD, shepherd and electrified pen) and in 2 cases only by LGD and shepherd.

To summarise, in France, when data is available, flocks were protected **by at least 2 protective** measures during the attack, whatever the year considered. However no data is available on the correct use of the protection measure at the time of the attack.

In Italy, in 2004, there were 9 attacks with no information about the periodicity (day or night). Seventeen occurred during the day (10 of which with bad weather): 5 with no preventive measures in place, 3 with only the shepherd, 2 with only LGD, 6 with LGD and shepherd, in a case we don't have data available. Eleven attacks occurred during the night (5 of which with bad weather). None pasture was equipped with an electrified fence, 4 with no preventive measures at all, 4 with only LGD, 2 with only shepherd, 1 with LGD and shepherd.

In 2010, 9 occurred during the day (7 of which with bad weather): no pastures were equipped with an electrified fence, 8 with only the shepherd, and 1 with LGD and shepherd. Three attacks occurred by night: 1 with no preventive measure, 1 with only the shepherd and 1 with only LGD.

In 2022, 2 attacks occurred during the day, 1 with only shepherds, 1 with LGD and shepherd. Eight attacks occurred during the night, 2 with only shepherd, 2 with LGD and shepherd, 1 with fence and shepherd, 1 with LGD and fence, 2 with all 3 preventive measures.

In 2023, 3 attacks occurred during the day, 1 with only the shepherd, 2 with LGD and shepherd. The only attack occurred during the night has all 3 preventive measures in place.

No data about weather conditions were collected in Italy in 2022 and 2023.

To summarise in Italy, the attacked flocks were rarely protected by the use of a combination of the 3 preventive measures, above all in 2004.

5.2.5. Periodicity (month) of attacks

Considering the distribution of the attacks during the examined months, they occurred mainly during July and September, with a peak in August while the number of victims was higher in August in Italy and in September in France (Figures 9 and 10).

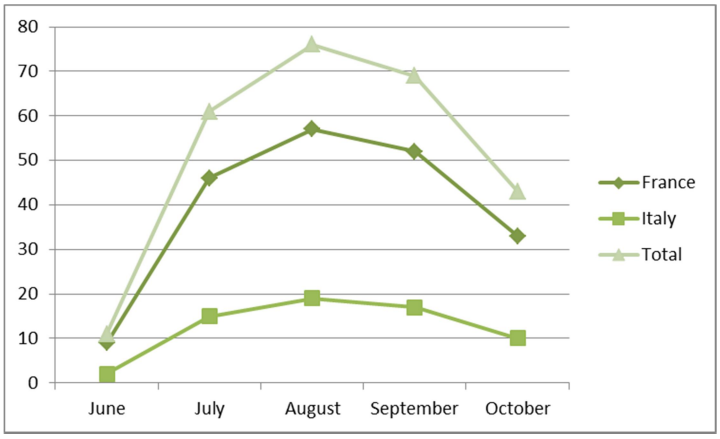

Figure 9. Distribution of events of wolf attacks from June to October, considering the 3 study areas and the 4 years examined.

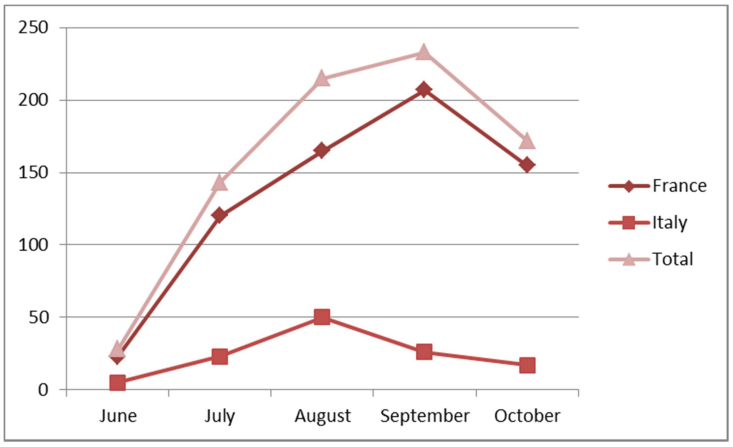

Figure 10. Distribution of victims of wolf attacks from June to October, considering the 3 study areas and the 4 years examined.

5.2.6. Flock size

In the study areas, the size of the flocks in France is larger than the Italian ones (W = 10,446, p-value < 0.005; Table 9). Considering the flocks that suffered depredations**, the most numerous were in France** (W = 9,361, p-value < 0.005). The mean number of animals was always higher in France than in Italy whatever the years (Table 9; Kruskal-Wallis chi-squared = 9.0943, df = 3, p-value = 0.02). On the whole, French flocks averaged 1,227 ± 525 (with 69 cases of depredations on flocks with more than 1,500 animals), while Italian flocks averaged 380 ± 276.8 head (with only one case of depredation on a flock with more than 1,500 head).

Except in 2004 (many data unavailable) the difference in flock size between France and Italy was the most important in Area 1 (Bassa Stura/ Isola), where the size of the flock is 2 to 6 times larger in France than in Italy. In Areas 2 and 3, this difference is less pronounced with fluctuation from one year to another, even if on average the size of the flock is larger in France than in Italy.

Table 9. Mean number (min-max) of flock size during the depredation events, in the 3 study areas, in Italy and in France. * *Some flock sizes have to be considered with caution since information is not always available and could only represent the size of one flock*.

Mean number of flock size during depredation events

	Italian areas			French areas		
	Area 1	**Area 2**	**Area 3**	**Area 1**	**Area 2**	**Area 3**
2004	329 (328-329)	/	438 (23-720)	*400**	NA	955 (889-1,075)
2010	664	308 (17-488)	177 (20-310)	1,293 (467-1,918)	2,065 (2,061-2,067)	828
2022	242 (2-347)	275 (112-357)	540 (107-1,830)	1,455 (333-1,581)	850 (33-1,306)	963 (175-1,736)
2023	-	244 (90-325)	257	1,488 (672-1,806)	1,000 (190-1,300)	1,449 (685-1,650)
mean number of flock size in each area	337	289	424	1,424	1,090	1,112

In Italy, most of the flocks are composed of 100-500 sheep (Pace, 2004) and this group represents also the most depredated (67.2% of attacks; Figure 11); there was only a depredated flock with more than 1,000 heads (in total 1,830 sheep).

In France, most of the attacks occurred in flocks with a size superior to 1,000 head (Table 10). In France, 109 depredated flocks were composed of more than 1,000 sheep (in particular, in 2010, the 2 breeders who had between 1,900 and 2,067 heads totalized 90% of the attacks).

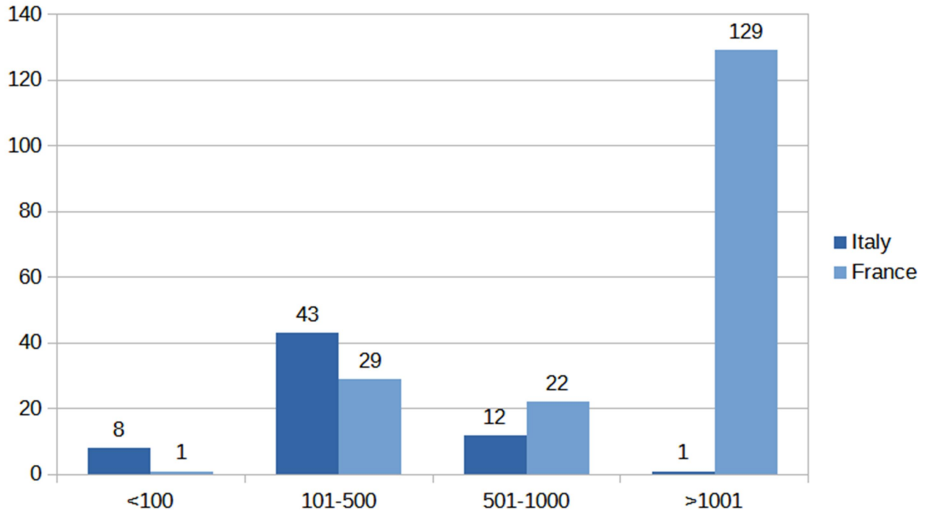

Figure 11. Number of sheep/goats in flocks who suffered depredation events in France and in Italy.

Table 10. Number of sheep/goats in flocks who suffered depredation events in the 4 years of the study (/ = data not available).

flock head	2004		2010		2022		2023	
	Italy	France	Italy	France	Italy	France	Italy	France
<100	4	/	2	0	1	1	1	0
101-500	22	1	10	3	8	14	3	11
501-1000	11	9	1	5	/	1	/	7
>1001	/	5	/	15	1	49	/	60
NA	/	16	/	/	/	/	/	/

6. Discussion

This study focuses on how prevention systems are applied in 3 territories of transboundary wolf packs in France and Italy. The two countries share the presence of 3 transboundary wolf packs, but with different results in terms of frequency of attacks on livestock and number of victims within those territories. The number of depredation events did not differ significantly among the 3 study areas, allowing for comparisons.. However, variations emerged when examining the temporal trends, the spatial distribution of attacks, the number of victims and the presence of preventative measures employed in each country. As highlighted by several authors (Landry, 2017; Plisson, 2011; Kaartinen, 2009), the vulnerability of a pastoral system to wolf predation is influenced by a complex range of factors. These include pastoral-specific factors (such as the type of protective measures used, the number of sheep in a herd, etc.), circumstantial factors (such as weather conditions and the time of day), environmental factors (such as habitat features and terrain roughness), and wolf-specific factors (such as proximity to rendezvous sites and the size of wolf packs).

Unfortunately, many of these factors were not adequately documented or included in the context of this study, limiting our ability to provide a comprehensive analysis of the factors contributing to wolf depredation.For instance, gathering detailed information about pastures that were not subject to wolf attacks—particularly in earlier years—proved challenging. The difficulty in obtaining such data was compounded by the lack of historical records in the archives of pastoral services from both Italy and France. For instance, it remains unclear whether wolves attacked certain pastures in 2004 or 2010 simply because these were the only available grazing areas. Nevertheless, our preliminary descriptive results can provide valuable insights into the dynamics of wolf depredation events on livestock, especially from the perspective of two different countries' management situations..

Temporal and Spatial Trends in Depredation Events

One of the key findings of the study is the contrasting temporal trends in depredation events between the two countries. Considering the three transboundary packs' territories, in France, the number of depredation events and the number of sheep killed increased over the 4 analysed years (Figure 5 and 6). This is in contrast to Italy, where both parameters showed a decrease over the same period. This opposite trend may be linked to different aspects, for example linked to the management practices or the limits and the efficiency in using mitigation measures. Additionally, in France, attacks were concentrated in a smaller number of pastures, repetitive and localised with intense predation pressure on few flocks, and therefore suggesting the incapacity in solving chronic and predictable attacks over one single pasture. In Italy, instead, depredations were more widely dispersed across the landscape, which might reflect more effective preventive measures applied across the overall area.

Frequency of Depredation Events

The scale and intensity of attacks also differed between the two countries. In Italy, the majority of the affected farms (63.6%) experienced only one depredation event, suggesting that many farmers may face isolated incidents rather than chronic depredation pressure. On the other hand, in France, 46.5% of the most affected farms experienced more than four depredation events, with a notable increase in frequency over the four years. This suggests that few farmers in France face a more persistent and consistent problem with wolf attacks, requiring the strong need of intervention in finding ad-hoc prevention strategies solutions, like in Italy. In fact, chronic wolf attacks represent a significant problem only in France, while in Italy it has been solved over the years with best practices implementation of prevention strategies. This is crucial to decrease human-wolf conflict and lead to financial stability for farmers.

Preventive Measures and Their Use

The study further reveals significant differences in the application of preventive measures between the two countries. In Italy, preventive measures were less frequently employed during the attacks, with 25% of reported depredation cases occurring without any preventive measures at that time, and 39.1% of cases with only one preventive system in place, demonstrating the need for the use of a correct implementation of the preventive measure. In contrast, in France, preventive measures were almost universally applied, with 91.4% of cases involving two or more systems of protection. However, it is questionable if the prevention measures were actually in place at the time and place of the single attack. More data should be collected to actually evaluate the use of the preventive measure at the specific site and time of the attack both in France and Italy, to correctly evaluate their efficiency and efficacy. What is clearly evident in Italy is the increase in the use of preventive systems during the years which can be attributed to a consistent increase in farmers' trust in their effectiveness.

The management of LGD is similar in both countries. There is currently no centralized structure which takes care of the LGD breeding procedure in the study areas . Breeders are used to exchange their LGD puppies according to their relationship network and knowledge of the work of their respective dogs. The number of LGD used by each breeder varies on the basis of various factors (e.g. herd size, breeder experience, ...) but often LGD large packs might create conflicts with tourists.

The most common preventive measures used in both countries included the deployment of LGD, electric fences, and the presence of shepherds. with a higher simultaneous presence of the 3 measures in France suggesting a more proactive approach to addressing wolf predation. This difference may be attributed to varying governmental policies, funding availability, or farmer awareness and engagement with conservation programs in the two countries.

There are, furthermore, two fundamental differences in the management systems between the French and Italian study areas

The first one regards wolf management: in the Italian side of the study areas legal permits for the culling of wolves have not yet been applied, while on the French side they have been since 2005. The French government now authorises an annual threshold (19% of the estimated annual population) of wolf shooting in the vicinity of attacked flocks. These shots are authorised only outside the park's core area, and concerned the majority of the pastures studied in the French side of the areas. It is difficult to evaluate the influence of wolf shots over other protection measures, as wolf culling can have an additional effect which has not been measured in this descriptive study. .

The second one concerns the funds dedicated to prevention: in France, preventive measures are funded by the Ministry of Environment through their decentralised service at 100% in the National Park and at 80% outside the National Parks. Besides they need to have at least 2 preventive measures to get damage compensation. That encourages breeders to equip their pasture with them. However, there is not a constant external assistance to improve and evaluate the efficacy of the prevention measures in place. In Italy, the preventive measure distribution is managed at regional scale and the rules can be different according to the region in charge. From the 2014 in Piemonte Region prevention systems are supported by FEASR, but funds are dedicated only to professional breeders and they have to comply with well defined rules, so only a little percentage of breeders apply for funds. In particular, the majority of the breeders in Italian study area of the Alpi Marittime have been constantly equipped with preventive measures, and assisted in the correct implementation of the measures over the years, thanks to the work of the Progetto Lupo Piemonte until 2012, and to the LIFE WolfAlps and LIFE WolfAlps EU projects from 2014 to 2024. Hence, the breeders in the Italian area of interest of this study have been fully assisted through the years considered. The absence of chronic attacks on farmers in the Italian study area show the efficacy of ad-hoc preventive measures solutions implemented over the years, and the constant work of full-time dedicated veterinarians from the cited projects to help the breeders find solutions. Infact, in the Italian dataset, the absence of preventive measures reported in some cases, are indicated for the exact time and place of the attack. This incentivized the single farmers to actually improve to have a constant and efficient use of the measures all the time, resulting in the overall decrease of number of attacks and victims for the Italian side of the study area, in the sparse distribution of attacks, and in the high frequency of only single events of attacks in a farm (Figure 5 and 6).

Moreover, the study area is characterised by the presence of both sheep and cattle farming, especially in the Roya, Sabbione, and Pesio valleys in both countries. In particular, there are more cattle breeders in the Italian side of the border compared to the French side, specifically in areas 2 and 3. These cattle pastures could exert a "buffer effect," potentially influencing the frequency and nature of wolf attacks on sheep, as wolves may target sheep flocks, which are more numerous and might be easier to depredate. Interestingly, reports of wolf depredation on cattle in the Piemonte region of Italy are relatively low, as documented by Menzano et al. (2023).

This factor further complicates our understanding of the dynamics between wolf livestock depredations and the efficacy of preventive measures and pasture management strategies, suggesting that many factors should be taken into account to understand the system, beyond simple availability of prey and predators.

Weather Conditions and Daytime Attacks

Both in Italy and in France, wolf attacks on livestock occurred primarily during the daytime, which may reflect the wolves' behavioral adaptations to human activity patterns or the highest vulnerability of flocks during daylight hours with respect to the night when livestock is better protected. If we look at the pattern of attacks from 2004 to 2023, electrified fences result to be an efficient preventive measure which wolves seem to have learned to avoid since a shift toward attacks occurring by day is observed during these 10 last years. During the day, breeders can only count for the 2 others preventive measures: shepherd and LGD. During the day the animals are free to graze, spread over a larger area, and, especially for very large herds and during bad weather, it becomes difficult to control what is happening and prevent wolf attacks. New strategies of prevention and management of flocks should be implemented in such cases.

Weather conditions also appear to influence the timing and frequency of wolf attacks. In France, 31.1% of attacks occurred under sunny weather, whereas in Italy, 29% of attacks were during sunny conditions. However, in both countries, the weather conditions during attacks were often foggy or rainy (46.6% in France and 54.8% in Italy), which may create more favourable conditions for wolf predation by limiting visibility and making it more difficult for shepherds or LGDs to detect and deter attacks.

Flock Size and Susceptibility to Attacks

The relationship between flock size and depredation events is another important factor. French flocks in the study area are much larger than their Italian counterparts, and larger flocks tend to experience more frequent and more severe attacks. This is particularly evident in cases where flocks exceed 1,000 sheep, which are more commonly found on the french side. In 2010, for example, two French breeders with flocks of 1,900 to 2,067 sheep accounted for 90% of the attacks, with continuous chronic attacks not solved over the years, especially on the single farmer present in the French study area of Isola 2000 (Figure 3) . In Italy, however, most flocks affected by depredations are smaller, with the majority comprising between 100-500 sheep, and all chronic cases of attacks on single pastures have been solved with ad-hoc solutions. This difference in flock size and ability to solve chronic attacks cases on single pastures likely contributes to the disparity in depredation events from the Italian and French side of the transboundary packs areas, as larger flocks may serve as greater attraction to the wolf, or have a higher vulnerability) and be more difficult to protect (Kaartinen et al., 2009).

In the future, to further develop this first pilot study on transboundary packs' depredations, it will be interesting to measure the characteristics of the total number of flocks and pastures in the study areas, including both attacked and non-attacked flocks. In fact, the number of attacks should ideally be analysed taking into consideration the total number of sheep and cattle available to wolves, allowing for a more accurate understanding of the vulnerability of different herds to predation.

The Influence of Seasonality

Both countries exhibited a peak in wolf depredation events during the month of September, coinciding with the post-weaning season for wolves (Oftedal and Gittleman, 1989; Iliopoulos et al., 2009; Nowak et al., 2005). During this season, a pack must meet the higher nutritional intake requirements of the pups (Fritts et al., 2003; Oftedal and Gittleman, 1989). In addition, young wolves learn and develop hunting techniques that cause them to attack and injure more animals than is necessary (Packard, 2003; K. Schanze, Fachstelle Wolf, personal communication, 2021). Furthermore, in September we also observe the greater frequency of rainy and foggy days, and the lower tourist presence in the mountain which favours the wolves to approach a flock.

This seasonal pattern suggests that both farmers and wildlife managers in both countries need to prioritise preventive measures during these peak months when wolf attacks are more likely to occur.

7. Conclusions

This study offers the first descriptive but valuable insights into the differences among livestock depredations events within territories of Italian-French crossborder packs, and it acknowledges the significant gaps in the data that needs to be further investigated in the future for a more comprehensive understanding of the system. The findings presented should be seen as part of a larger, ongoing investigation into the complex dynamics between wolves and pastoral systems. Future research, incorporating a broader set of variables, will be essential for understanding why certain mountain pastures and management approaches are more vulnerable to predation than others, especially to solve important chronic depredation cases on single pastures, which should not be present anymore over the years. Such studies will be crucial for developing more effective management strategies to mitigate livestock losses while fostering coexistence between wolves and pastoral communities.

In conclusion, the implementation of protection systems against wolf attacks on domestic livestock, such as LGD, electric fences, and improved herding practices, are important and fundamental for decreasing depredations.

However, further research is needed to better evaluate the effective use of the prevention measures at the time and place of the attack, which then will allow us to better understand the factors that contribute to the risk of predation in different pasture environments.

Key variables such as farming characteristics, landscape variables, wolf pack dynamics, and environmental conditions need to be measured in greater detail at the time of the attack, and considered in relation to pastures who do not experience wolf attacks nearby. A more comprehensive understanding of these factors will allow for the development of more targeted and adaptive protection strategies, ultimately leading to more effective and sustainable coexistence between livestock farming and wolf populations.

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9. ACRONYMS

APAM: Aree Protette Alpi Marittime

DDT: Direction Départementale des Territoires

DDTM 06: Direction Départementale des Territoires et de la Mer des Alpes Maritimes

DRAAF: Direction Régionale de l'Alimentation, l 'Agriculture et de la Forêt

DREAL AuRA: Direction Régionale de l'Environnement, de l'Aménagement et du Logement Auvergne Rhône Alpes

OFB: Office Français de la Biodiversité