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Coordinated scientific design and protocols to study the relationship between predators, prey and human activities

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**Project LIFE18 NAT/IT/000972 - LIFE WolfAlps EU
“Coordinated Actions to Improve Wolf-Human Coexistence
at the Alpine Population Level”**

Action A4

Technical Report

**COORDINATED SCIENTIFIC DESIGN AND PROTOCOLS
TO STUDY THE RELATIONSHIP BETWEEN PREDATORS,
PREY AND HUMAN ACTIVITIES**

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1. Introduction

Perceived or actual wolf (*Canis lupus*) impact on livestock and wild prey is a widespread source of conflict that hinders the acceptability of wolf presence in the landscape throughout the Northern hemisphere, and particularly in the European countryside (Linnell and Boitani 2012, Mech 2017, Bautista et al. 2019, Kuijper et al. 2019). Breeders, especially of sheep (*Ovis* spp.) but increasingly of cows (*Bos* spp.) and other domestic animals, often feel their activity is incompatible or unfairly challenging and stressful in the presence of wolves, particularly when the latter are granted the status of a protected species (Dressel et al. 2015, Zahl-Thanem et al. 2020, Meuret et al. 2021). Hunters, for their part, are concerned that wolves and other large predators such as the Eurasian lynx (*Lynx lynx*) might impact the populations of wild ungulates to such an extent that the hunting of large game will soon no longer be a viable activity (Bisi et al. 2010, Lühtrath and Schraml 2015).

However, little is known about the direct and indirect effects of predation on the behaviour of prey in space and time in systems characterised by strong anthropogenic impacts (Kuijper et al. 2016) such as the complex human-wolf-wild prey-livestock systems of southern and central Europe. For instance, presence of hunters, human hikers, livestock and livestock guarding dogs (LGDs, *Canis lupus familiaris*) might impact the daily rhythm of activity of wild ungulates to a greater extent than wolf presence (Whitehouse-Tedd et al. 2020, Smith et al. 2020). The presence of livestock in night enclosures might influence wolf use of space and hence impact the antipredator use of space by wild prey. Availability of livestock as prey for wolves might reduce the predator's impact on wild ungulate populations, and vice-versa (Meriggi and Lovari 1996, Kaartinen et al. 2009, Imbert et al. 2016). The presence of alternative predators, including humans, as well as relative hunting pressure, might lead to complex spatio-temporal strategies by prey to minimise predation risk (Atwood et al. 2009, Thaker et al. 2011, Muhly et al. 2011, Lone et al. 2014). And recently, during the Covid-19 emergency, wild ungulates and other species experienced novel periods of human absence in the environment followed by the return of high human pressure due to a rebound in local tourism. Better understanding these complex interactions between wolves, wild and domestic prey and human activities in their holistic, ecosystemic dimension is necessary to produce tools to inform decision-making for the sustainable development of human activities and land management. Such an approach takes into account the long-term conservation of wildlife species, in accordance with the needs and indications put forward in the Agenda 2030 of the United Nations.

2. Objectives

The objective of this study is to quantify behavioural responses in space and time by large ungulate prey (≥ 10 kg) to perceived predation risk from wolves and humans, while also accounting for the presence of alternative prey (domestic and wild) and alternative predators (lynx and LGDs), in 4 different sites across the Alps. This study will also characterise wolf diet and the body condition of human-hunted, road-killed and wolf-killed prey to obtain preliminary indications that can guide future studies on other possible effects of wolves on wild and domestic prey.

It is important to note that this study will not focus on wolf impact on prey abundance or population growth rate because of the timeframe of the LIFE WolfAlps EU project (2019-2024, 5 years) relative to the time required to adequately tackle this question in the case of large ungulates (≥ 10 years). Adult female survival in such species exhibits a consistent pattern of high survivorship and low yearly variation, and is the vital rate having the greatest impact on the growth rate of non-hunted populations (Gaillard et al. 2000, Eberhardt 2002). As a consequence, quantifying the impact of wolf predation on the growth rate of populations of large ungulates requires tracking the survival of many marked adult female prey over the long term (≥ 10 years). Spatio-temporal responses by large ungulate prey to perceived predation risk, in contrast, can be assessed over a shorter timeframe and are likely to produce results in this 3-year study conducted in the framework of the LIFE WolfAlps EU project.

Looking beyond the LIFE WolfAlps EU timeframe, this study is expected to be the founding stone of a long-term joint research programme aimed at defining a set of intensively monitored sites that will become references in the study of the complex interactions involving wolves, LGDs, wild and domestic ungulates, other predators and human activities in south and central Europe. This programme would go beyond the study of spatio-temporal patterns in the wolf-ungulate-human system to also dwell into ungulate demography. The ultimate goal is to acquire knowledge that will guide management and the sustainable development of human activities to improve the coexistence of humans and domestic and wild animals in the mountainous landscapes of the continent.

3. Hypotheses

This study will be based on the landscape of fear framework, which predicts that prey adapt their behaviour and use of resources in time and space to avoid or minimise the risk of predation (Laundré et al. 2001, Brown and Kotler 2004, Hernandez and Laundré 2005, Kuijper et al. 2013, Kohl et al. 2018, Gaynor et al. 2019). Prey are hypothesised to perceive humans (and not just hunters) and LGDs as potential predators or at least as a source of disturbance to be avoided (Stankowich 2008, Marchand et al. 2014, Whitehouse-Tedd et al. 2020). Alternative wild and domestic prey can be considered as potential competitors that might also impact the use of space of a given prey species. The presence of multiple predators and prey may lead to several contrasting hypotheses which take into account the potential impact of human hunting and disturbances (Kuijper et al. 2016):

- H1: **risk enhancement**, where avoiding one predator or source of disturbance in space and time increases prey exposure to another predator or source of disturbance (Sih et al. 1998). In the context of this study, large ungulate prey avoiding humans or competitors might increase their exposure to wolves, lynx, LGDs and/or hunters, or vice-versa (e.g., Atwood et al. 2009, Lone et al. 2014, 2016).
- H2: **risk reduction**, where presence of one predator or source of disturbance leads prey to adopt an antipredator strategy in space and time that also reduces the risk of predation from the alternative predator (Sih et al. 1998). In this study, large ungulate prey might preferentially use areas that represent refuges against all types of predators (humans, LGDs, wolves and lynx).
- H3: **human shield**, where prey do not perceive humans as predators but rather select areas strongly impacted by human presence that act as refuges in space and time against natural predators (e.g., Berger 2007, Muhly et al. 2011, Atickem et al. 2014). Here large ungulate prey might converge to the proximity of humans and their infrastructure, which are generally avoided by wolves and other predators, particularly at night.

Selection or avoidance of areas due to perceived risk of predation can be expected to vary depending on the configuration of the habitat (Schmidt and Kuijper 2015), the escape mode of prey (Wirsiing et al. 2010) and the hunting mode of the predator (e.g., Thaker et al. 2011, Lone et al. 2014). In our study, for instance, roe deer (*Capreolus capreolus*) are expected to be less able to fend off an attack from wild predators than red deer (*Cervus elaphus*), which are larger and stronger. Predation risk induced by wolves and dogs (both LGDs and hunting dogs), which are cursorial predators, might lead prey to select

closed and dense habitat, if available, which might prove ineffective in avoiding predation from stalk-and-ambush hunters such as lynx and possibly humans.

Similarly, spatial responses by prey may vary depending on their perception of how predation risk varies over time, from diel (e.g., Sonnichsen et al. 2013, Marchand et al. 2014, Kohl et al. 2018) to daily (e.g., Courbin et al. 2016, Chassagneux et al. 2019) and seasonal patterns (e.g., during the hunting season, Sonnichsen et al. 2013, Lone et al. 2015). In our study, for instance, wolves, lynx and LGDs are expected to be generally active at night, whereas humans operate mostly during the day and only hunt during the hunting season. Prey can also be expected to adjust how long they remain in resource patches as a function of perceived predation risk (Brown and Kotler 2004).

Consequently, given that prey may adopt different strategies of space use depending on the temporal dynamics of perceived predation risk, support for the hypotheses described above might also vary in time (e.g., H1 might only be supported at night time, or H3 might only be supported during the hunting season). Different hypotheses might thus only be mutually exclusive at a given temporal scale (e.g., at night during the hunting season). This aspect will be accounted for in the analyses (see section 6.6 below).

4. Study design

This study will be based on the comparison of four sites across the Alps: one in France, two in Italy, and one in Slovenia. These sites differ in terms of presence and density of both predators and prey: the study site in France and one in Italy are characterised by the presence of established wolf packs and a relatively high abundance of both domestic prey (sheep) and wild ungulates. The site in Slovenia is characterised by the presence of newly-established wolf packs and the additional presence of lynx as a main predator (as of 2020). The second site in Italy is devoid of an established wolf pack and has a relatively low density of roe deer, but is characterised by a relatively high density of red deer. Hunting or management culling of large ungulates by humans occurs at all sites, but with varying intensity in space and time (a full description of each site is given in Annexes 1 to 4).

Given these differences among sites, this study will adopt a “natural experiment” approach, in which each site is considered as an independent replicate of the large mammal, multi-predator, multi-prey system of the Alps that is then submitted to different treatments: wolf presence or absence, varying hunting regimes, varying presence and density of livestock and large ungulates, and varying presence

and density of alternative predators such as lynx and LDGs. We will use three different approaches to study the wolf-prey-human system depending on the similarities and differences between the 4 study sites. Firstly, we will capture and equip wolves and roe deer with GPS collars in the French, Slovenian and Italian Maritime Alps sites to evaluate the hypotheses described above at various spatial (i.e., location of an individual's home range within the landscape and use of space by the individual within its home range) and temporal scales (e.g., seasons, day and night). Secondly, we will deploy an array of camera traps in the French and the two Italian sites to evaluate our hypotheses at a coarser spatial and temporal scale to better account for the full range of the interacting, large mammalian predators and prey present at these sites. Thirdly, we will sample and analyse wolf scats from three sites (French, Slovenian and Italian Maritime Alps sites), in which the predator is present, to describe the predator's diet, while also sampling ungulate carcasses across all sites to identify cause of death and the body condition of prey. Finally, we will characterise hunting pressure and location according to the level of hunter participation in each site. A full description of materials and methods is provided below.

5. Study areas

Four core areas have been identified for the study (Fig. 1):

- 1 site in Slovenia, in South-Eastern Alps (Julian Alps), where wolf packs and prey are present (description in Annex 1);
- 1 site in Italy, in the South-Western Alps (Maritime Alps), where wolf packs and prey are present (description in Annex 2);
- 1 other site in Italy, in Stelvio National Park in central Alps, where wolf packs are not present and prey are present (description in Annex 3); and
- 1 site in France, also in the South-Western Alps, where wolf packs and prey are present (description in Annex 4).

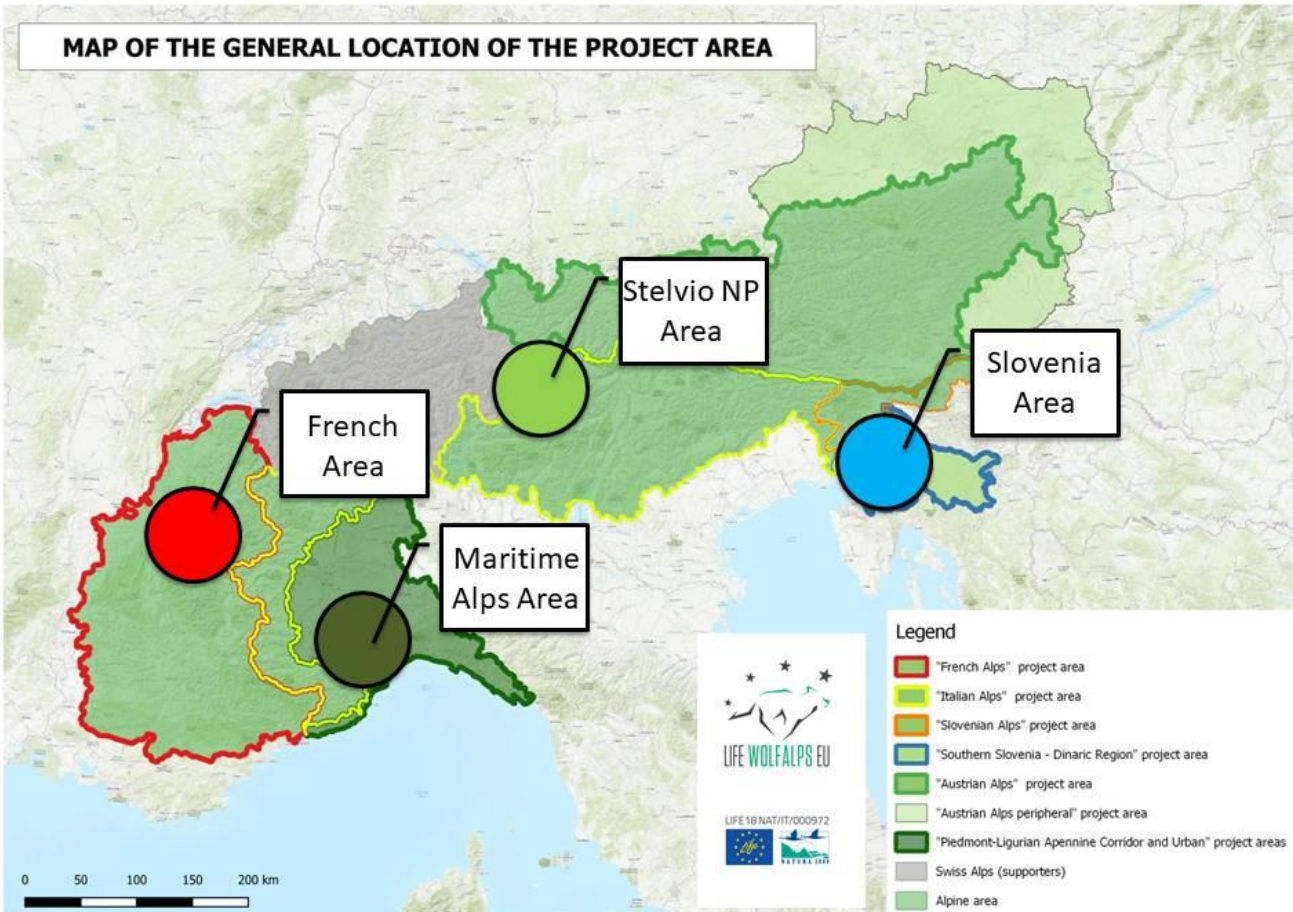


Figure 1. Location of the four sites in which a coordinated study will be conducted on the interactions between predators, prey and humans in the framework of the LIFE WolfAlps EU project, actions A4-C3.

In each site and as indicated above (page 2), a team of researchers and technicians will compose the Scientific Committee of the study. Several workshops have been conducted and will continue to be organised by its members both at the local (national) and overall (international) level to discuss planning and implementation of the study. Moreover, additional meetings between researchers, technicians and stakeholders in each study area have and will continue to take place to refine study design through a participatory approach.

6. Materials and Methods

6.1. Capture and collaring of wolves and roe deer

All procedures and manipulations of both wolves and roe deer will strictly adhere to national guidelines and recommendations on animal welfare, capturing and immobilising. All collars will be equipped with activity and mortality sensors, and a drop-off mechanism.

Wolf captures will be conducted primarily during the snow-free months. Study sites will be intensely prospected prior to setting up the trap line to identify trails recurrently used by wolves and maximise the probability of capturing them while minimising the capture of non-targeted animals (dogs, foxes, badgers etc.). Two or more wolves from at least one wolf pack will be captured using rubber-padded foothold traps made of steel or equivalent gear (USGS 2011, Cattet 2017). Traps will be equipped with an alert device to inform field personnel of a capture or will be inspected at least once a day. Captured non-target animals will be inspected and released in the absence of injuries. Captured wolves will be immobilised prior to manipulation. Injured animals, whether wolves or others, will receive treatment on site by a qualified veterinarian. If injuries are too severe, euthanasia will be performed by a qualified veterinarian.

GPS collars for wolves will be programmed to acquire one location every 30 minutes from dusk until dawn during about one and a half months in winter (December to February) and spring (March to May). During daytime and for the remainder of these two seasons, at least 2 locations will be taken daily. During summer (June to August) and autumn (September to November), when sheep herds become more readily available to wolf predation and when the hunting season for ungulates occurs, wolf collars will be programmed to acquire one location every 30 minutes daily for a month in each season. For the remainder of these two seasons, locations will also be taken at least 2 times per day. This scheduling of wolf collars represents a compromise between battery life, which should last at least a year, and the frequency of locations.

Roe deer will be captured using box traps in winter (December to March) and/or vertical nets and beat drives during the rest of the year (ONC 1993). Ideally, at least 10 collared roe deer will be present in each study site. If box-traps are used, they will be equipped with an alert device to inform field personnel of a capture or will be inspected at least once a day. Captured non-target animals will be inspected and released in the absence of injuries. Injured animals will receive treatment on site by a

qualified veterinarian or expert staff with capture permission. If injuries are too severe, euthanasia will be performed by a qualified veterinarian or hunting ranger of the area in question. GPS collars for roe deer will be programmed as described above for wolves. Collars put on roe deer will be equipped with drop-off and battery life is expected to last up to 2 years.

6.2. Camera traps

Alongside the use of GPS collars, variation in habitat selection and activity patterns of prey species will be investigated using camera traps (e.g., Bowkett et al. 2007). These devices will also be used to build occupancy models (see section 6.6.2 below) to assess the co-occurrence of different species of predators and prey. In Stelvio National Park (SNP) study site, 50 camera trap locations have already been identified following a random tessellation sampling design (where a random point is identified within each grid cell) and monitored since 2019 (Fig. 2). This approach, which will also be implemented in the French and Italian Maritime Alps sites, guarantees full coverage of the study area, and therefore the representativeness of habitat features, while also ensuring the properties of random sampling.

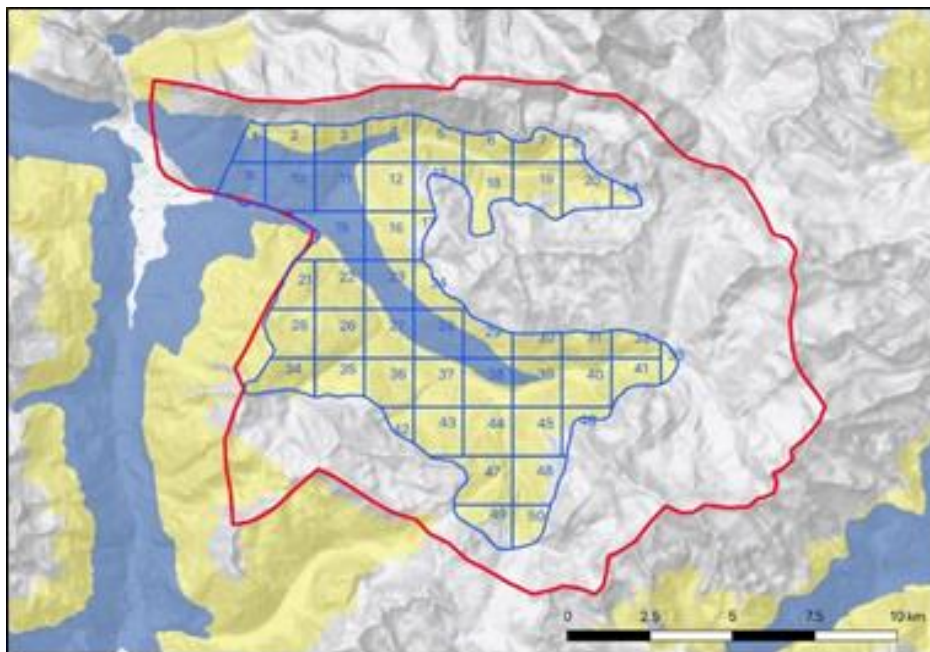


Figure 2. Random tessellation sampling design for camera traps adopted at the Valfurva study site in Stelvio National Park to investigate habitat selection by prey.

Trap cameras will be deployed every year in the French and the two Italian sites, if possible over the entire year, or at least between late spring and the end of autumn (May-November), to include the ungulate hunting or management culling season. An area of about 100 km² in each study site –

corresponding as precisely as possible to the territory of the wolf pack under study, if present – will be divided into a grid of cell size = 1.5×1.5 km. As mentioned above, trap cameras will be placed in each cell following a random tessellation sampling design. Cameras will be installed on trees or on poles (when in alpine meadows) at about 50 cm from the ground, and will be checked every 3 weeks for battery status and SD cards. All devices will be set in photo mode with high sensitivity, no delay and trigger speed as short as possible. Camera trap events (i.e., detection of individual(s) of the target species) will be considered independent when they are at least 5 minutes apart from each other. Yet within the 5-min time frame, events can be considered independent whenever a different individual is recognised in a photo. A detailed description of how to use camera trapping for wildlife research can be found in Rovero and Zimmermann (2016).

A key assumption in studies using camera traps is that detection probability is consistent across camera sites. Detection probability may be influenced by a number of factors, including animal size, which cannot be controlled for, and by the environmental features around each camera site (e.g., Bowkett et al. 2007). To quantify detection probability, at each camera location we will collect information on: 1) canopy cover (measured with a spherical densiometer), 2) visibility (measured using a chessboard-like panel and counting the number of visible cells at $-45^\circ/0^\circ/+45^\circ$ and 0 cm/130 cm at 13 m in front of the camera), and 3) exact exposure (using a compass).

The ability of camera trap data to track variations in habitat selection will be evaluated against GPS data by means of resource selection functions. For the French and Italian Maritime Alps sites, this will be performed using the wolf and roe deer GPS data described above. In the case of SNP, this will be done using data from GPS-collared red deer. While binomial models (i.e., used/available) can be used for GPS data, different analytical techniques are required for data from camera traps. Given that the number of events recorded per camera are counts, a Poisson/negative binomial conditional distribution is likely to be needed when fitting generalised linear models (GLMs) to the data. In addition, different buffer sizes around the camera site may be employed to associate cameras with information on environmental variables (e.g., open/closed areas, type of forest etc.), and different buffers can be subsequently compared in different models, to select for optimal buffer size. The final dataset thus contains the following information (Table 1): camera ID, time unit used for analysis (e.g., month), number of animals of the target species recorded in the time unit, effort (number of days a given camera was working in the time unit), period of day (day/dawn and dusk/night, depending on the species), camera type, spatial coordinates, environmental characteristics of the camera trap

location (e.g., elevation, open areas etc.) within a given buffer size, and variables collected to control for detection probability at the trapping site. From such a dataset, a global model for the analysis of habitat selection using camera trap may thus be of the form:

$$Y_i = NB(\mu_i, k)$$

$$E[Y_i] = \mu_i$$

$$\text{var}[Y_i] = \mu_i + k \times \mu_i^2$$

$$\log(\mu_i) = \beta_0 + \beta_1 X_1 + \dots + \beta_n X_n + \log(D_{\text{work}_i}) + b_i$$

where Y_i is the number of photographs of the species of interest for trap camera i (i.e., the response variable), NB is the expected distribution of the response variable (negative binomial) with mean μ_i and shape parameter k , $E[Y_i]$ is the expected mean of the response variable, $\text{var}[Y_i]$ is the variance of the negative binomial distribution, X_1 to X_n represent all the covariables of interest to be included in the linear predictor, β_n are the associated coefficients of each covariable, $\log(D_{\text{work}})$ is the offset that accounts for sampling effort, and b_i is the random intercept that accounts for the correlation that stems from repeated sampling of the same site. The model also allows to include spatial correlation, if needed.

Table 1. Example of a dataset used to build models for the analysis of habitat selection and occupancy using camera traps.

	ID_cam	month	num_deer	working_days	daynight	Camera_type	Latitude	Longitude	Altitude
1	FT100	6	3	19	DAY	Cuddeback	46.719	10.565	1933
2	FT100	7	3	31	DAY	Cuddeback	46.719	10.565	1933
3	FT100	8	8	31	DAY	Cuddeback	46.719	10.565	1933
4	FT100	9	10	30	DAY	Cuddeback	46.719	10.565	1933
5	FT100	10	6	25	DAY	Cuddeback	46.719	10.565	1933
6	FT105	6	6	17	DAY	Cuddeback	46.694	10.608	2238
7	FT105	7	2	31	DAY	Cuddeback	46.694	10.608	2238
8	FT105	8	5	31	DAY	Cuddeback	46.694	10.608	2238
9	FT105	9	15	30	DAY	Cuddeback	46.694	10.608	2238
10	FT105	10	11	23	DAY	Cuddeback	46.694	10.608	2238

Camera trap data will also be used to assess activity patterns of prey species (Ridout and Linkie 2009). Time data extracted from still images collected in any given time frame/at any given location and converted into radians. Activity density will then be estimated by fitting a circular normal distribution to the data using a von Mises kernel (Ridout and Kinkie 2009). To estimate uncertainty, 1000 non-parametric bootstrap samples will be generated with replacement from the original dataset, and the same kernel function will be applied iteratively. Activity patterns with and without presence of wolves can then be compared using the Wald test.

6.3. Wolf scat and ungulate carcasses

Wolf scat will be collected opportunistically and/or following transects at all study sites, and visually analysed to determine the prey species that were consumed and gain insights on wolf diet, following the approach described by Reynolds and Aebischer (1991). Accuracy of scat sampling should be considered to allow comparison among study sites (Marucco et al. 2008). Further indications on methods can be found in Palmegiani et al. (2013) and Newsome et al. (2016).

Samples will be washed and filtered through a 0.5 mm meshed sieve. Undigested prey remains, fruit and grasses will then be oven-dried at 50 °C for 24 h. Prey remains will be identified by comparison with a reference collection of mammal hair. When necessary, the microscopic characteristics of hair (*cortex* and *medulla*) will be compared to published atlases. Alternatively to the visual analysis of scats, metabarcoding methods can also be used.

Ungulate carcasses are expected to be of different origins: road kill, hunted by humans, predated by wolves, predated by an alternative predator (lynx, LGDs) or death by natural causes other than predation. A common datasheet will be used to gather information on each carcass (species, sex, age, location etc.). Carcasses from road kill or resulting from predation of alternative predators will be found and sampled opportunistically and/or following transects in each study site. Access to carcasses from hunting by humans will be negotiated with hunters collaborating in the project. Wolf-kill carcasses will be found and sampled either opportunistically and/or following transects, or thanks to cluster analysis of the locations of GPS-collared wolves (Webb et al. 2008). Finally, carcasses might also be found following the death of GPS-collared ungulates. In winter, when appropriate, snow depth will be measured manually with the aid of a pole at the site of the carcass.

Samples will be taken from carcasses to assess the body condition of the deceased animal through the analysis of marrow lipid content (Neiland 1970, Ratcliffe 1980, Krofel et al. 2014). If available, the thigh bone (femur) will be extracted in cases, when the composition of bone marrow is not yet compromised (i.e., if the decomposition process has not started yet). Other long bones will be collected if available and/or if the femur is absent. Sex and age of the carcass will be determined when possible, as well as the estimated date of the animal's death and the date of carcass discovery and extraction of the femoral bone. The bone should not have been exposed to adverse weather conditions for more than 2 or 3 days during the snow-free seasons, although this period can be reasonably extended to five days, if the bone is still covered with flesh or if it is found lying in the protective shadows of the forest. This period can be further prolonged in winter (up to 10 days), if the carcass is found lying frozen in the snow. Extracted bones will be packed air-tightly and frozen. Measurement of bone marrow content should take place as soon as possible, and two or three months later at the latest. Bone marrow extracted from femur (a 4-cm long segment cut out of the middle of the diaphysis) will be dried in an oven at 60-65°C until it reaches a constant weight (for at least three days), and weighed before and after drying. Dried samples will be stored in air-tight glass jars with silica gel to prevent condensation while cooling. Proportion of fat content in the bone marrow will be calculated according to Neiland (1970).

6.4. Livestock, alternative predators, wild prey and non-hunter human presence and use of space

The distribution and abundance of livestock and LGDs, when present within the wolf territory under study (or within an equivalent area in the absence of a permanent wolf presence), will be obtained through direct field observations, or from information provided by breeders or publicly available. Lynx presence in the Slovenian site will be obtained through GPS locations of radio-collared individuals, data from camera traps (if present in the study area) and by other signs of presence reported from the field (e.g., direct observations, tracks, scats etc.). LGDs and sheep might also be equipped with GPS collars to provide data on their use of the landscape in space and time. The presence and abundance of alternative wild prey [wild boar (*Sus scrofa*), red deer, chamois (*Rupicapra rupicapra*), Alpine ibex (*Capra ibex*) etc.] will be obtained from camera traps and/or hunting bags.

Non-hunter human spatio-temporal use of the wolf territory (or equivalent area) under study will be obtained through a variety of methods, including field observations, personal GPS trackers carried by

people, online applications such as Strava®, road and trail configuration obtained from maps and classified satellite imagery, and trap cameras.

6.5. Hunters' use of space and spatial coordinates of hunted animals

Hunters' use of space will be obtained through a variety of methods, as described above for non-hunter humans and depending on the level of implication of hunters in each study site. Data collected will focus on the animals successfully hunted, including species, age and sex, time, body measurements, and the coordinates of where the animal was killed. If possible and again according to the level of engagement of hunters in each study site, we will quantify hunting effort (i.e., how many days of hunting per hunter per prey) and include it as a covariate in our resource selection analyses (see section 6.7.1 below).

6.6. Habitat configuration

The configuration of the habitat in study sites will be obtained from classified satellite imagery (Landsat, Sentinel) and/or from open source data such as CORINE Land Cover. Other layers such as Natura 2000 sites, administrative boundaries (e.g., hunting districts) and the location of artificial feeding sites for ungulates will also be obtained when relevant to the study sites. Topography will be acquired through digital elevation models. Snow accumulation will be obtained from the pan-European High-Resolution Snow & Ice products (HR-S&I) data at 20 m spatial resolution.

6.7. Statistical analyses

6.7.1. Resource selection functions

We will build resource selection functions (RSF) (Manly et al. 2002, Hebblewhite and Merrill 2008, Courbin et al. 2013) using GPS data to evaluate our hypotheses for roe deer at three of our study sites (France, Slovenia and Italian Maritime Alps) and at two spatio-temporal scales [i.e., the location of the animal's home range relative to the pack's territory and the animal's use of space within the home range, which corresponds respectively to the second and third order of habitat selection in the classification proposed by (Johnson 1980)]. RSFs evaluate selection or avoidance of habitat features while controlling for the availability of these features. To account for temporal variability in resource selection and responses to predation risk, we will build separate RSFs for each season, and for day and night and dawn and dusk (or alternatively, we will include a diel time variable in the model). Following

Courbin et al. (2013), our RSFs will compare resource covariates at GPS locations with an equal or superior number of random locations drawn within 95% minimum convex polygon (MCP) for wolves and within the 100% MCP of each individual prey. RSF parameters will be estimated using a generalised linear mixed model (GLMM). A random intercept for each individual will be included in the model to account for the non-independence of observations of a given roe deer and the unbalanced sampling design. Mixed-effects RSF models for roe deer will then have the following general form:

$$w(\mathbf{x})_s = \exp(\beta_0 + \beta_1 \times \text{Pred. risk wolves} + \beta_2 \times \text{Pred. risk humans} + \beta_x \times \text{Habitat covariates} + \dots + \beta_y \times \text{Interactions} + \gamma_i)$$

where $w(\mathbf{x})$ is the relative probability of use for roe deer for season s , β_n is the estimated coefficient for covariate x_n , and γ_i is the random intercept for each individual roe deer i . Additional covariates such as presence of alternative predators and alternative prey, or hunting effort if available, will be included as covariates in the model. We will evaluate the robustness of our models using k-fold cross-validation (Boyce et al. 2002).

Two indexes of predation risk will be tested: in the case of wolves, the first will be based on the intensity of wolf use of space (i.e., within their territory) and will be built as a Brownian bridge movement model (Horne et al. 2007) or as movement-based kernel density estimation (Benhamou 2011). The assumption here is that predation risk for prey is greater in areas that are intensively used by wolves. However, because previous studies have shown that this risk is not necessarily related to the intensity of wolf use of space (Hebblewhite et al. 2005, Kauffman et al. 2007), we will also build and test a second index of predation risk based on the locations of wolf-killed carcasses. Similarly, for predation risk from humans, one index will be based on general human use of the landscape in space and time, while the second will be based on the locations of hunted animals.

6.7.2. Occupancy models

We will build occupancy models (MacKenzie et al. 2002) using data from camera traps to evaluate our hypotheses for all prey species (roe deer, red deer, chamois, etc.) at three of our study sites (France and the two Italian sites). Occupancy models provide the probability ψ that a given species is present within a defined area while correcting for detection probability $p < 1$. Both probabilities can be related to covariates such as habitat configuration and the occurrence of other species (Rota et al. 2016, Devarajan et al. 2020) through generalised linear models (GLMs) so that:

$$\text{logit}(\Psi_{ij}) = \alpha_{\Psi_i} + \beta_{\Psi_{i1}} \times \text{Predator occurrence} + \beta_{\Psi_{i2}} \times \text{Competitor occurrence} + \dots + \beta_{\Psi_{ix}} \times \text{Habitat covariates}$$

and

$$\text{logit}(p_{ijk}) = \alpha_{p_i} + \beta_{p_{i1}} \times \text{Covariates}$$

where i is the species, j is the camera trap site, K is the sampling occasion and β_n is the estimated coefficient for covariate x_n .

7. Expected management implications

The effects of predation pressure on the abundance, distribution and behaviour of wild prey have been poorly documented in highly anthropogenic landscapes (Kuijper et al. 2016) such as the complex agropastoral systems of southern and central Europe. This has direct implications for hunting management and the acceptability of wolf presence in the landscape (Martin et al. 2020). Some stakeholders believe that wolves invariably negatively impact the abundance of hunted wild ungulates (Martin et al. 2020, Ericsson and Heberlein 2003), including the adult component of the population. Under certain conditions, such as in the case of isolated populations of prey or during severe winters, this is certainly possible (Mech and Peterson 2003). But before having any noticeable impact on the abundance of adult females and hence on the growth rate of a population of large ungulate, predators are firstly expected to impact the use of space of prey, which are not passive agents but actively engage in antipredator behaviour (e.g., Chassagneux et al. 2019, Atwood et al. 2009, Berger 2007, Hernandez and Laundré 2005). Use of space by prey is also bound to be impacted by other factors (hunting pressure, tourism, Covid-19 restrictions, seasonal presence of livestock and LGDs etc.). Therefore, potential perception by hunters that there is less game available in their hunting district might not necessarily be due to a decrease in the abundance of game, but rather the result of changes in prey distribution due to predation risk and other factors. If predator impact is indeed on abundance, then hunters will likely need to adapt their hunting bags. But if predator impact is mostly on prey use of space, then hunters might need to adapt where, when and how they hunt. Although these two effects are not mutually exclusive, they clearly imply different management strategies depending on which predation effect is the most prevalent for each game species of interest.

In addition, if support is found for hypothesis H2 and refuge areas against all types of predation risk are identified in the landscape, these key locations will warrant special protection under plans for

sustainable management. Hence, by investigating the complex spatio-temporal dynamics of the predator-prey-human system, this study will lead to results that are likely to inform sustainable development, further wolf-human coexistence and lay the foundations for long-term studies of wolf impact on prey abundance.

8. References

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ANNEX 1 – Slovenian study site: Julian Alps

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Site location

The South-Eastern Alps that span into Slovenia are represented by three mountain ranges in the north and north-west of the country: the Julian Alps, the Karavanke Alps and the Kamniško-Savinjske Alps. Adjacent are pre-alpine areas to the south-west and the Pohorje massif to the north-east.

The Julian Alps are the vastest and highest mountain massif in Slovenia, culminating at 2864 m a.s.l. at Mount Triglav. The massif is characterised by a diverse assortment of deep valleys and mountain passes interspersed by many glacial lakes remnant of the last Ice Age. The geomorphology of the area is mostly karstic, which is why the landscape is characterised by countless caves, chasms, waterfalls and mountain gorges. Waters from Julian Alps feed two distinct river basins, the Adriatic Sea and the Black Sea. Two major rivers of Slovenia have their source in the Julian Alps: the Soča and the Sava. The Triglav National Park was established in the area in 1981. Many other protected sites or points with special natural value or protection are located in the study area, as well as Natura 2000 sites.

The study site (46,25263 N; 14,01098 E) at its maximum will comprise the area of three wolf packs (Fig. I.1), measuring roughly 1270 km² altogether (550, 350 and 370 km² for respective wolf territories). The border of pack territories was deduced from the locations of a GPS-collared wolf, genetic analysis of wolf scats and urine collected through snow-tracking, and saliva obtained from cases of livestock depredation – always taking into account landscape morphology and the linear configuration of the landscape.

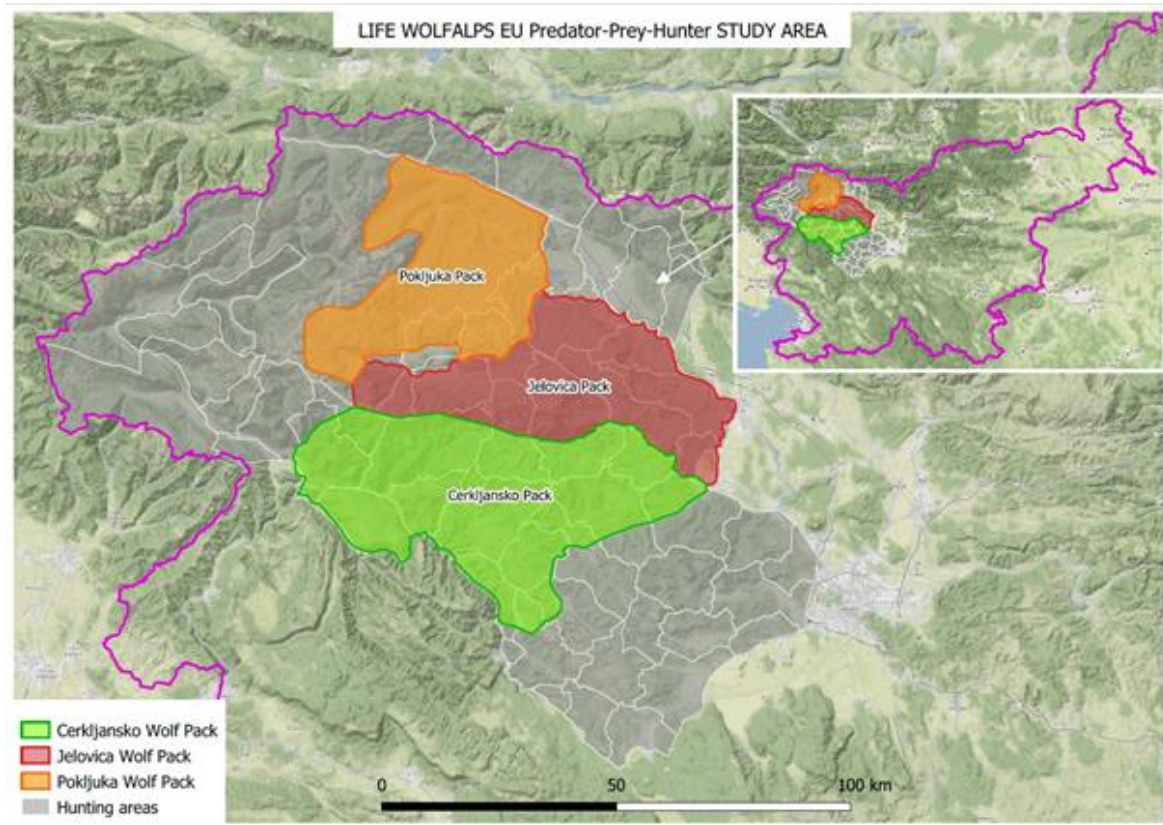


Figure I.1. Approximate contours of the LIFE WolfAlps EU A4-C3 study area in Slovenia. It consists of the area used by three alpine wolf packs in North-Western Slovenia: the Pokljuka and Jelovica packs in Julian Alps and the Cerkljansko pack in pre-alpine area.

Habitat configuration

The topography of the Julian Alps and the adjacent pre-alpine area is very diverse and characterised by high peaks and steep slopes exposed to erosion and karstic processes. Limestone is the prevalent type of rock, while the presence of glaciers strongly impacted the landscape during the Ice Ages. An extremely dynamic geological past is one factor that explains the great diversity of plant and animal species in the area, in which many relic, endemic and protected species are found.

Precipitation is on the average frequent and abundant, mostly in spring and autumn, and the least during winter. In the heart of Julian Alps there is around 2800-3000 mm of precipitation annually, in the lowlands between 1300-1500 mm. Two high Alpine plateaus characterise the study area, Jelovica and Pokljuka, where forests are mostly comprised of spruce (*Picea abies*) and the average annual temperature amounts to 3 or 4°C. There are also wetlands to be found in the high plateaus of Pokljuka, where the continental climate of most of the area shifts towards the characteristics of a mountain

climate. The interlacement of both climates is characterised by frequent temperature inversions and noticeable temperature oscillations.

The vast majority of the study area is covered by forests (Fig. I.2) that cover more than three-quarters of the total surface (77,8% of the study area). Meadows cover 14,3% of the area, agricultural lands 3,1% and 2,2% of the surface are human settlements.

Forests are commonly mountainous and alpine beech forest, alpine spruce forests and alpine dwarf-pine forests. They belong most frequently to the plant communities of *Anemone trifoliata* – *Fagetum*, *Blechno* – *Fagetum*, *Castaneo sativae* – *Fagetum*, *Ranunculo platanifoliae* – *Fagetum*, *Homogyno sylvestris* – *Fagetum*. Plant community *Rhodothamno* – *Rhododendretum hirsuti* is present (among others) on the upper timberline. In some parts, tree composition can be heavily changed in favour of spruce.

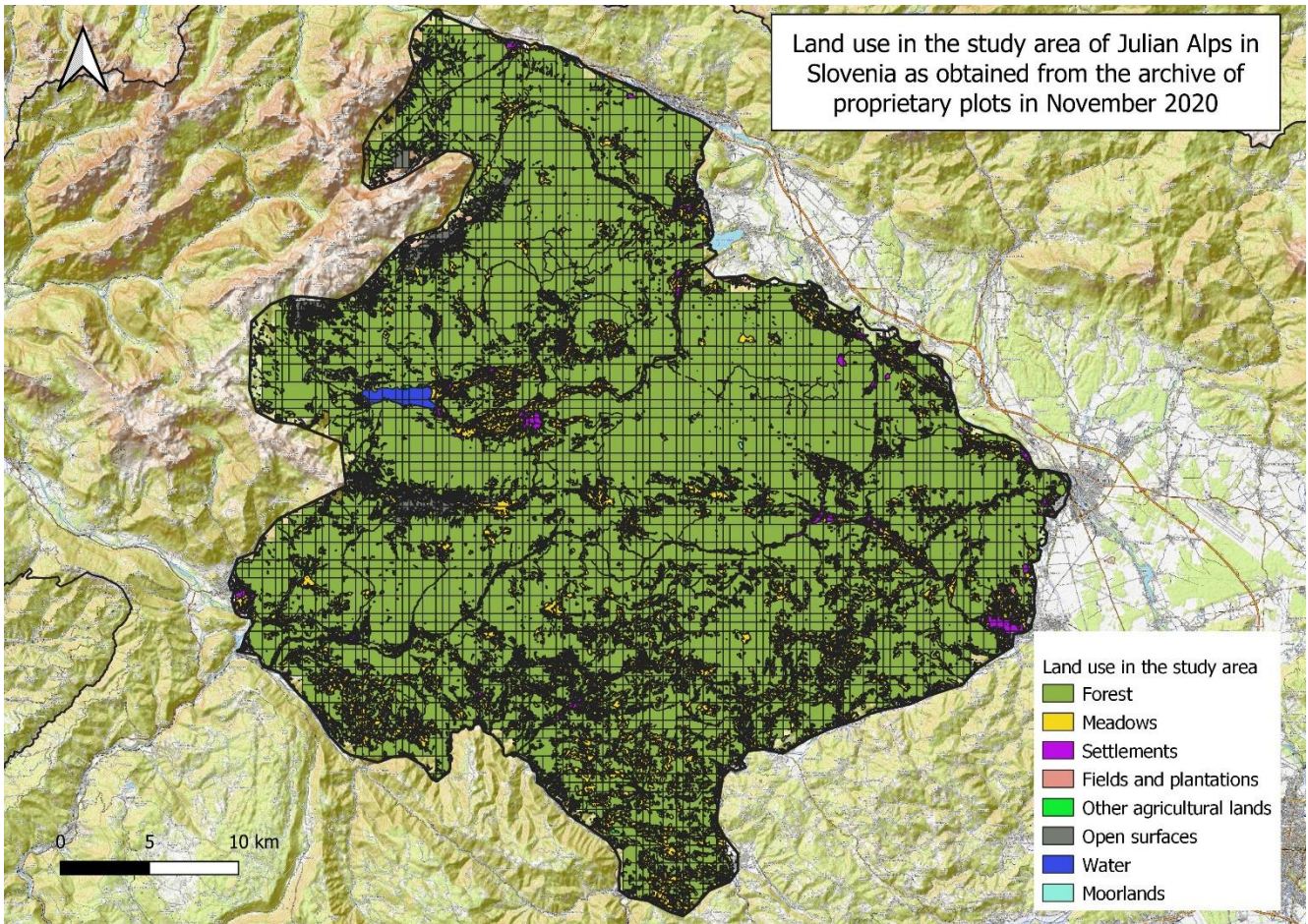


Figure I.2. Land use in the LIFE WolfAlps EU A4-C3 study area in Slovenia, as calculated from data obtained from the Ministry of Agriculture, Forestry and Food of Slovenia in November 2020.

Wolf presence

Three wolf packs are present in the chosen study area (Fig.I.1) according to the results of the previous season of national wolf conservation status monitoring in Slovenia (Bartol et al. 2020).

a) Pokljuka pack 2019; Wolf pack status: new pack – first litter.

The pack is formed by a male wolf that originates from the Lessinia area in Italy. He is a descendant of the wolf Slavc that immigrated to Lessinia in 2012 from Slovenia. The female wolf is also an immigrant, but of unknown origin. They had a first litter of five pups during the 2019/20 monitoring season, of which one female yearling was shot in the area of Jelovica pack in January 2020. In 2019, seven wolves were photo-trapped together on one photo-trap. During that season, we genetically detected six different wolves, one of which was shot.

b) Jelovica pack 2019; Wolf pack status: new pack – second litter.

A pair of wolves had their first litter here in 2019. The breeding male originates from the Vremšica pack in the Dinarics (south of the study area; 2016 litter) and breeding female from the Trnovski gozd pack (north of the highway Ljubljana-Trieste; 2016 litter). The pack had another litter in 2020 (detected via provoked howling) which genetic sampling identified as one female and three male pups. Through genetic sampling we detected six different wolves in the pack's territory, with one mortality being detected.

c) Cerkljansko pack; Wolf pack status: unknown.

The wolf pair had their first litter in 2019. The breeding male originates from the CRO/SLO pack Gomance (2015 litter) located in the border area of Slovenia and Croatia in the Dinarics. The breeding female originates from Trnovski gozd pack (2016 litter). Five offspring have been detected during the 2019/20 monitoring season. At the end of 2019, the breeding male and one male pup were shot. We also detected one case of dispersal: a male pup dispersed to the Gotenica pack located in the Dinaric area.

Wolf conservation status in Slovenia and monitoring techniques

Referral to the Appendix to Annex II of the Grant Agreement

Wolves that live in Slovenia represent the very NW part of the Dinaric-Balkan population that extends towards Greece to the south and Bulgaria to the east, and is estimated at 3900 individuals (Kaczensky et al. 2013). Contrary to many other European countries, wolves never disappeared from the Slovenian territory. During the decades of systematic wolf persecution in the 18th and 19th centuries, wolves survived in the most remote parts of the Dinaric mountains. Following strict protection of the wolf in 1993, a third period began when the population started to grow in the Dinaric Mountains and recolonise some of its historic habitats.

Systematic wolf monitoring based on telemetry studies, molecular analysis of non-invasive genetic samples, capture-recapture modelling and systematic wolf litter detection via provoked howling began in 2010. In the 2010/11 season, Slovenia's wolf population was estimated at between 34 and 42 individuals living in seven packs. From then on, the expansion and growth of the wolf population in Slovenia is well documented (Bartol et al. 2020). The last available estimate of population size comes from the monitoring season 2019/2020. It was estimated that there are between 121 and 150 wolves (average = 131 individuals, Fig. I.3) in Slovenia, forming 16 packs, including 4 transboundary packs along the border with Croatia. As a result, the conservation status of the wolf in Slovenia is defined as favourable (Bartol et al. 2019, 2020).

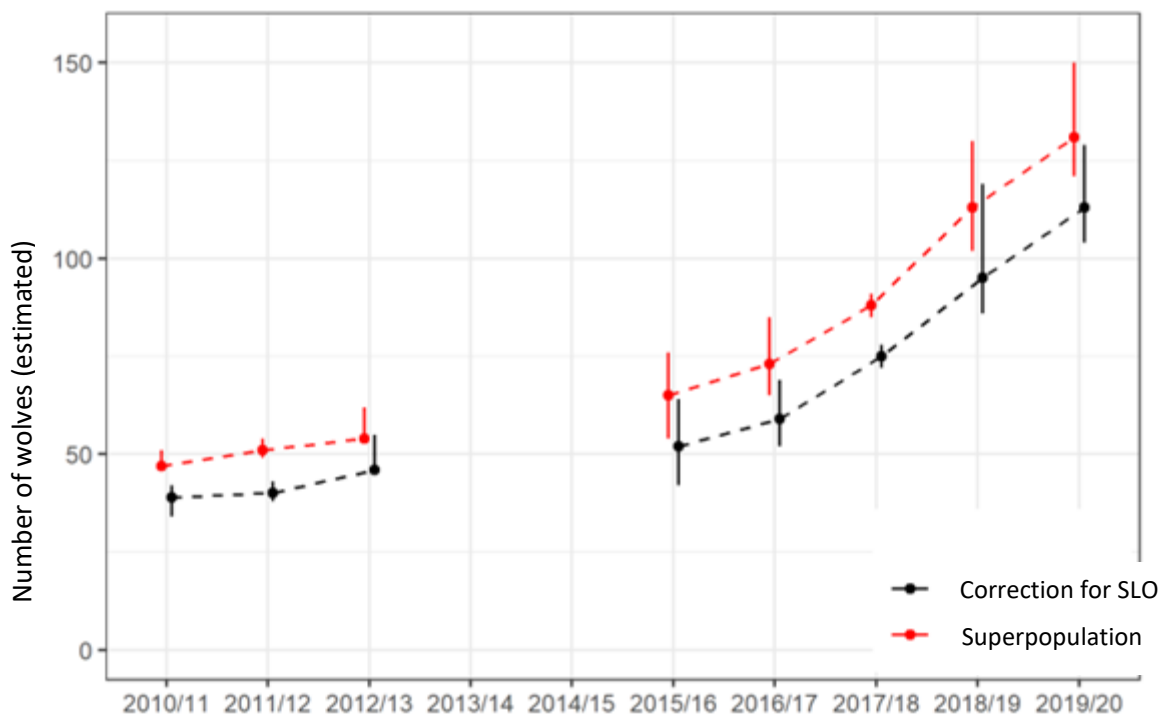


Figure I.3. Multi-year dynamics of the wolf population in Slovenia. The points are estimates of mean population size, while the vertical lines indicate the 95% confidence interval.

Since the beginning of the wolf expansion wave, wolf pack presence was limited to the southern and western parts of Slovenia – the Dinaric region. When the systematic monitoring started in 2010 there were just sporadic occurrences of single animals in the pre-alpine and alpine regions of the country - as a result of the expansion of Dinaric wolf population. The first pack in the Alpine Convention area was established in 2012 (Potočnik et al. 2014) and until 2018 two to three packs were detected annually in the area (Bartol et al. 2018). But in monitoring seasons 2018/2019 and 2019/2020 there was a swift increase in the spatial expansion of the alpine wolf population in Slovenia. First, three new packs were detected in the alpine and pre-alpine regions during the 2019/20 wolf- howling session, and confirmed later by genetic evidence (Fig. I.4). The presence of three newly established wolf packs was detected in the 19/20 season, forming a group of 5 packs in the Alpine Convention area in Slovenia (Bartol et al. 2020). During the last two monitoring seasons, the situation significantly changed in the Alpine part of the wolf presence area, as this season all three newly established packs in that area had litters. Although one of the three packs lost its breeding male and so it is very likely that it will disintegrate, we can expect the dynamics of wolf distribution in the Slovenian Alps to accelerate.

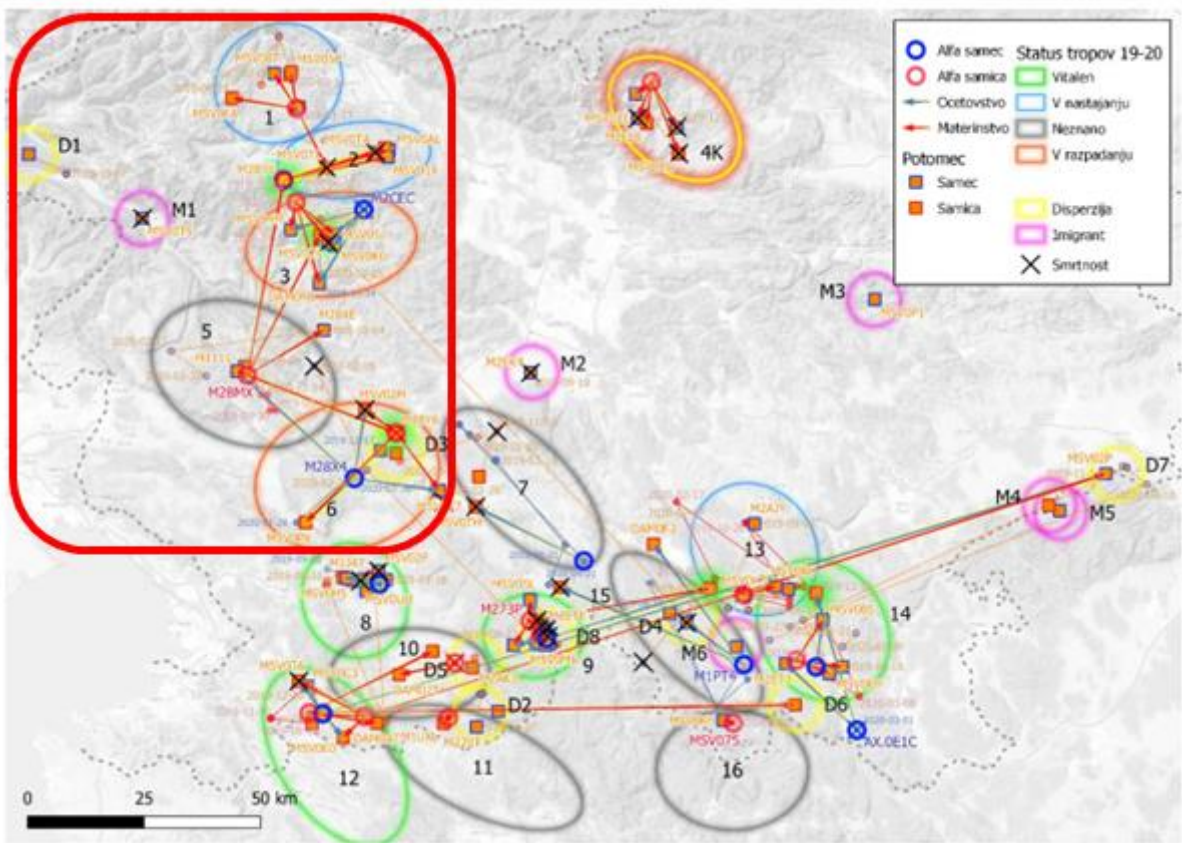


Fig. I.4. Wolf population monitoring season 2019/20 in Slovenia: the five wolf packs detected in the Alpine Convention area in Slovenia are highlighted in the red box. The figure also shows the family connection (pedigree) of wolves in the sampling season 2019/20, presumed pack territories, and tagged disperses / immigrants. Pack territories are made on the basis of the locations of members of each pack, but are of a purely indicative nature.

Wolf telemetry studies are an important component in monitoring the status of the wolf population. They provide important knowledge on spatial distribution, structure variation and expansions in a wolf population. They also provide information on their basic and applied ecology and act as important tool/information in human dimension issues and conservation management. There has been over 30 years of experience in endangered carnivores telemetry studies in Slovenia, including on the Eurasian lynx, brown bears, wolves, wildcats and golden jackals. The Animal Ecology Research Group at the Biotechnical faculty is one of the most experienced and highly qualified in the field, having successfully radio-collared and studied over 50 individuals of mammals. The invasiveness of the capture/handling/telemetry methods and associated risks for studied individuals are minimised by detailed protocols and the involvement of experts. They strictly follow scientific ethics as well as national legislation on nature protection, and animal health and welfare. Accordingly, we have applied for and obtained the permission to capture, handle and conduct telemetry studies of wolves in the

entire territory of Slovenia (Permission Nr. 35601 – 115/2017-4). The permit, issued by the Slovenian Ministry for Environment and Spatial Planning (31/01/2018), validates all the procedures and protocols used. Considering the status of wolves in Slovenia, as presented above, and the protocols we apply in telemetry studies, we confirm that methods used do not pose any considerable risk for wolf population in any part of Slovenia (Alpine or Dinaric) and that the methods used outperform alternative methods.

Wild ungulate presence

There are 24 species of game¹ in Slovenia, but main target species for the wolf prey in the study area represent five species of ungulates, namely red deer, roe deer, chamois, mouflon and wild boar.

The spatial distribution and abundance of most species of wild ungulates (ruminants and wild boar) have been increasing throughout Europe in recent decades, which also applies to wild ungulates in Slovenia. The area of distribution and local density of individual species of ungulates in Slovenia depend on differences in size, geographical presence, shape and fragmentation of population areas of individual species. Roe deer are present almost all over the country. The second most prevalent species in the country in terms of distribution is the wild boar. Even though the species lives in fairly fragmented areas in Slovenia, population patches occur almost all over the country. The population of red deer has expanded spatially in the last 20 years and the population range occurs in much larger fragments compared to wild boar. Presence of chamois is mainly concentrated in the alpine and pre-alpine areas, while outside these areas the species shows a pronounced meta-population type of distribution. Mouflon is a non-indigenous species that inhabits forests in the hills and highlands. For the most part, the species occurs near human settlements.

All five species of ungulates are permanently present in the study area. For the appropriate long-term presence of carnivores and ungulates, it is necessary, when adopting game management plans, to also take into account the presence of large carnivores² (bear, wolf and lynx). Appropriate adaptation of the management of prey species ensures a sufficient alimentary base for large carnivores, maintains

¹ The game species in Slovenia are: red deer, fallow deer, roe deer, chamois, alpine ibex, mouflon, wild boar, brown hare, alpine marmot, edible dormouse, nutria, muskrat, fox, raccoon dog, jackal, pine marten, stone marten, badger, grey partridge, common pheasant, mallard duck, jay, magpie and hooded crow.

² Large carnivores are protected and are managed by the Ministry of the Environment and Spatial planning.

the tolerance of hunters to the presence of large carnivores and enables long-term conservation of large carnivores and sustainable management of prey species.

The impact of wolves on these ungulate populations varies greatly across environments and depends on a number of environmental factors. In some population fragments, predators' influence appears a principal cause of prey mortality. In others, predators seem to have a less pronounced or negligible impact. In the chosen study area, three wolf packs have formed since 2019. As there have been no permanent wolf packs in the area before, a greater impact on prey species is expected. Lynx predation is also expected, especially on roe deer, mouflon and chamois, as there are ongoing lynx translocations into the area.

The permanent presence and densities³ of the five species of ungulates (red deer, roe deer, chamois, mouflon, wild boar) are presented below:

1. Roe deer (*Capreolus capreolus*)

As a territorial species, roe deer inhabits almost all habitat types and is widespread throughout Slovenia. Roe deer are constantly present in the study area, but differences in density occur between larger forest complexes (Pokljuka and Jelovica), where roe deer densities are lower, and the more fragmented landscape of the high Alpine plateaus, where roe deer densities are higher. Roe deer population in the project area is viable and stable.

2. Red deer (*Cervus elaphus*)

The trend for red deer indicates spatial expansion of the population. The hunting bag in the last five years has actually been the largest in the last 20 years⁴. Given the spatial distribution of red deer and a slight increase in abundance, a healthy and stable population has also been formed in the study area in Slovenian Alps.

³ The density of each ungulate species is modelled through the withdrawal trends, together with the use of ecological and other indicators.

⁴ Source: Annual harvest data, Slovenia Forest Service, Večna pot 2, Ljubljana.

3. Chamois (*Rupicapra rupicapra*)

Chamois is a species that inhabits open rocky areas above the forest line. Generally, chamois stay above the forest line in summer and descend to lower altitudes in winter. Many chamois, however, remain on high mountain pastures all year round. In smaller fragments, chamois is present also in hilly pre-alpine and Dinaric areas in Slovenia. In the study area, chamois habitat is represented mainly by steeper slopes on forested terrains in midlands, areas in which wolves are expected to prey on chamois. There are relatively high densities of chamois in the study area compared to the rest of the country, the population being stable and viable. Chamois in the highlands are not expected to be affected by wolf predation.

4. Mouflon (*Ovis aemon musimon*)

Mouflon is a non-native game species in Slovenia. It was introduced in the 1960s and 1970s. For the most part, its occurrence coincides with human settlements. Individual colonies or local populations became established in or in the vicinity of release sites. Local populations also became established in the midland forests in the study area, where mouflon is regularly present. Wolf predation is expected to be the most prominent in this case, considering that the mouflon is a non-native species.

5. Wild boar (*Sus scrofa*)

The wild boar, as an extremely adaptable species, is widespread almost all over Slovenia, except in the highlands. Our study area represents a sub-optimal habitat for the wild boar, which is indeed reflected by relatively low densities of the species. In the last 10 years, only a slightly increasing population trend has been detected on the basis of hunting quotas.

Presence of other large predators

a) Eurasian lynx (*Lynx lynx*)

Historically, Eurasian lynx was widespread throughout the Alps (Breitenmoser 1998) and Slovenia, including the Julian Alps, where it disappeared during the 19th century (Kos 1927). The species was then absent in Slovenia for about one hundred years, until a reintroduction project took place in the Dinaric Mountains in Kočevsko in 1973. The population quickly expanded and the first lynx in the study area in Julian Alps were recorded in the mid-1980s on the Jelovica plateau and in the Trenta and Soča valleys

(Čop 1994). At first (from 1985), lynx removal in the alpine region was unrestrained in order to prevent lynx expansion out of the Dinaric Mountains. This zonation was abandoned in 1990 and in 1992 lynx became protected along the borders with Austria and Italy to promote transboundary connectivity. Lynx presence was regularly reported in this area. However, almost all of the recorded animals were males and no successful reproduction was reported (Čop 1994). Between 1995-2009 lynx were still present in the Julian Alps, especially around the Soča valley and Bohinj, although the population was reported to be declining (Koren et al. 2006, Kos et al. 2012). Afterwards, lynx apparently disappeared from the region with the last reliable record being from 2014 near Bohinj when a male was killed in a vehicle collision (ZGS 2015). Since then, only occasional unconfirmed records are available and lynx is considered to be likely absent (Krofel et al. 2021). The situation changed in 2020/21 with the translocation of Carpathian lynx into the area as part of a reinforcement project (LIFE Lynx, LIFE16 NAT/SI/000634). In 2020, one of the translocated lynx from Slovakia (male 'Maks') dispersed from Snežnik in the Dinaric Mountains to the Julian Alps and Karavanks until Kranjska gora, but then returned the same way back to the Dinaric Mountains. In spring 2021, translocation of 5 lynx was carried out to the study area on the Pokljuka and Jelovica plateaus (LIFE Lynx project). We therefore expect permanent lynx presence in the area in the next few years.

b) Brown bear (*Ursus arctos arctos*)

Historically, the brown bear was widespread throughout the Alps (Breitenmoser 1998) and in Slovenia, including in the Julian Alps, where they appear to have been permanently present until the late 19th century (Simonič 1994, Švigelj 1961). Afterwards, bears were recorded in the study area only sporadically, although relatively regularly throughout the first half of the 20th century (Simonič 1994, Švigelj 1961). In 1966, bear hunting became regulated in the Dinaric mountains, whereas bears dispersing outside of this area were not protected until 1992 (Simonič 1994, Kryštufek and Griffiths 2003). After 1992, only moderate harvest was allowed in north-western Slovenia, which led to expansion towards the Alpine region, but in the late 1990s further expansion was halted due to increased culling in response to increased damage to livestock (Kryštufek and Griffiths 2003; Jerina and Adamič 2008). Since then, bear population throughout Slovenia gradually increased despite relatively high culling quotas, which were lower in the Alpine region to promote expansion towards Italy and Austria. The last genetic survey in 2015 showed that bears in Slovenian Alps are still few (41-57 bears, 95% CI), but that the population more than doubled since the previous genetic survey in 2007 (Skrbinšek et al. 2019). Due to male-biased dispersal typical for this species, the majority of bears in

the Alps are males and characterised by large home ranges (Krofel et al. 2010). Sex ratio has nevertheless improved in the last years (60% M vs. 40% F in 2015), and the reproductive area with permanent presence of females is now reaching the southern slopes of the Julian Alps (Skrbinšek et al. 2019).

Livestock presence and prevention systems in use

The most frequently depredated livestock by wolves are sheep (the livestock category “sheep” in this Annex refers to both sheep and goats altogether, but with goats representing only a very small share in the category). In the period 2015-2019, the highest number of sheep present in the study area was about 7400 heads per municipality (Fig. I.5).

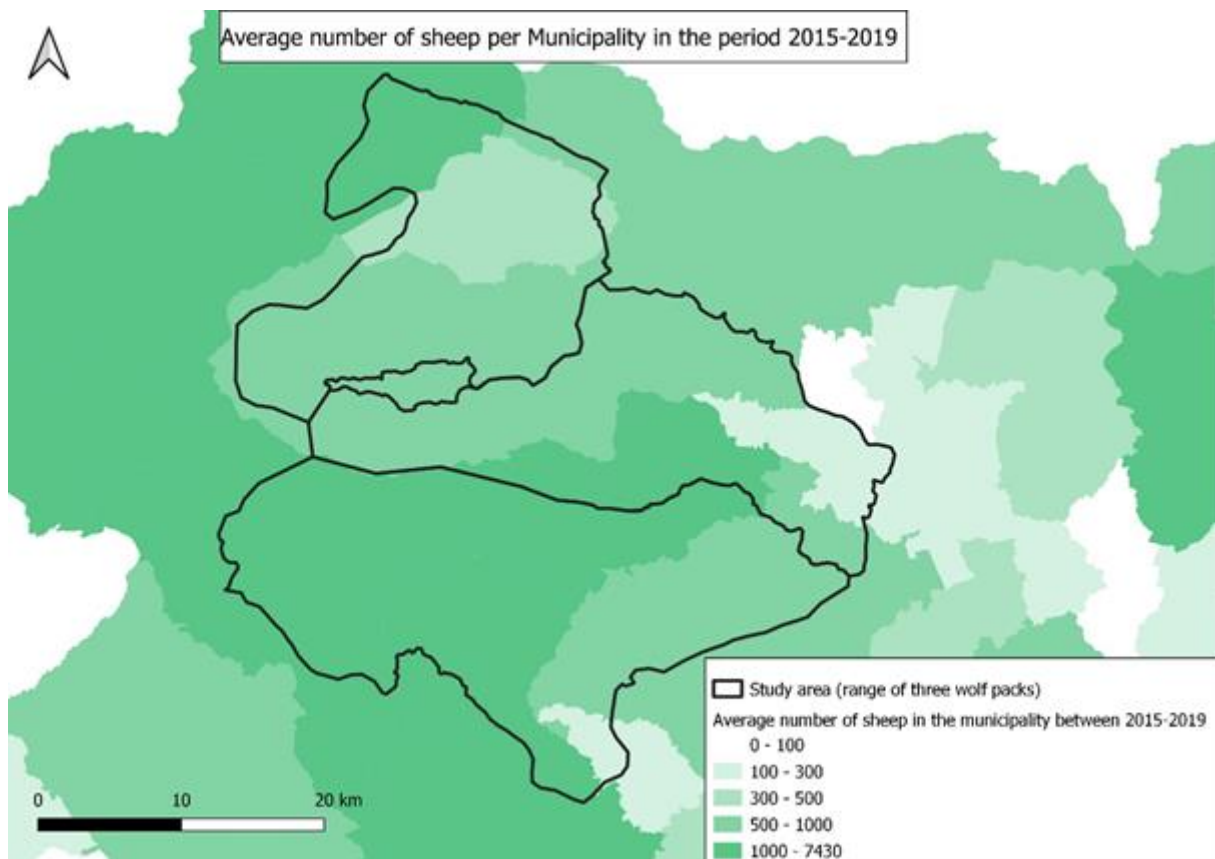


Figure I.5. Average number of sheep per municipality in the period 2015-2019 in the LIFE WolfAlps EU A4-C3 study area in Slovenia (outlined in black). Total numbers did not exceed 7500 sheep.

Sheep breeders in the study area are mostly “small farmers”, as here the average number of sheep per single livestock husbandry is low to medium compared to other parts of Slovenia. In the period 2015-2019, the average number of sheep per hectare of available pasture in a single municipality in the study

area did not exceed 0.8 head/ha. In all but one municipality in the study area, less than half the number of sheep belonged to husbandries comprised of more than 50 heads of sheep. The vast majority of sheep breeders in the area own sheep herds of less than 50 heads and only a couple of them own a herd of more than 150 sheep. As for the average in each municipality, the number of sheep per single husbandry unit did not exceed 64 sheep (Fig. I.6).

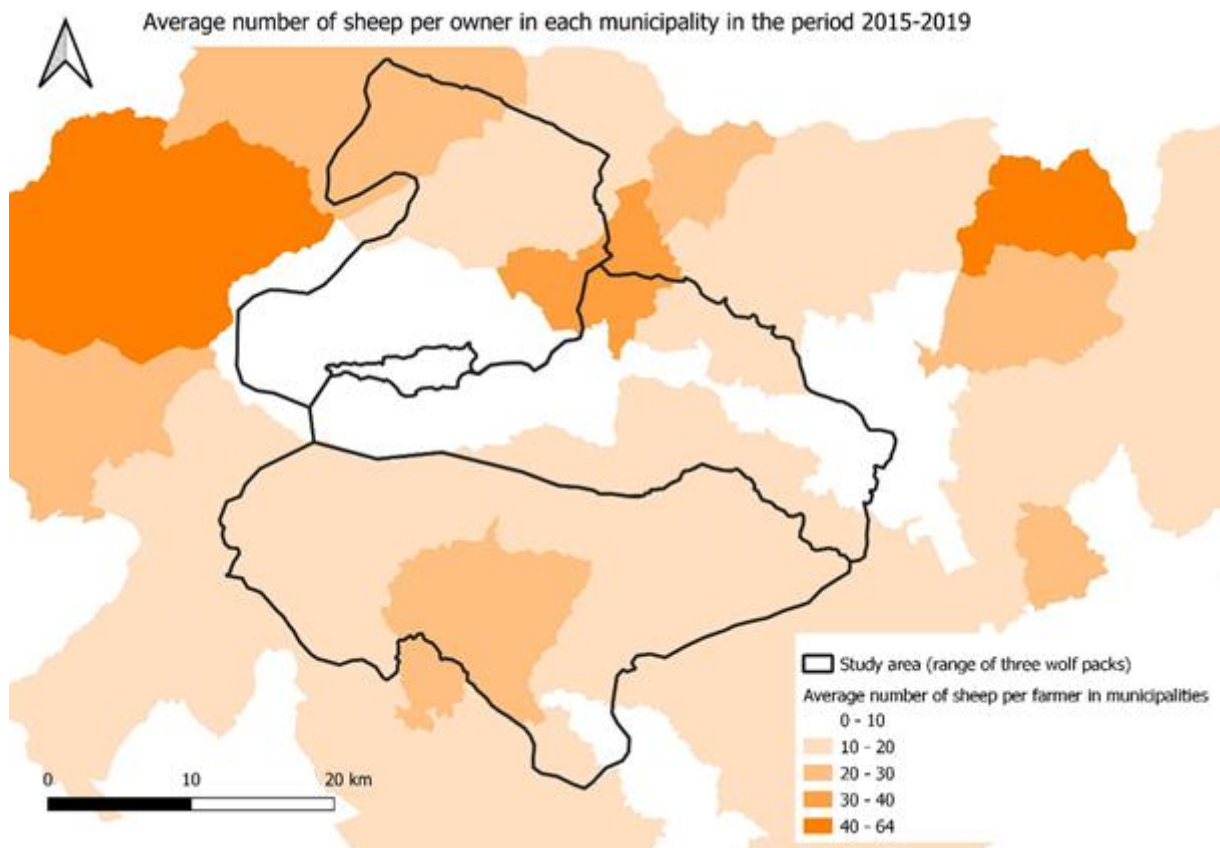


Figure I.6. Average number of sheep per single livestock husbandry unit in each municipality in the LIFE WolfAlps EU A4-C3 study area in Slovenia (outlined in black) between 2015 and 2019.

Given that forest covers 78% of the surface in the study area, pasture lands are not abundant. On average, up to 13 km² (ranging from 0 to 13) of pastures were used for sheep grazing per single agricultural administrative unit during 2015-2019 (Fig. I.7).

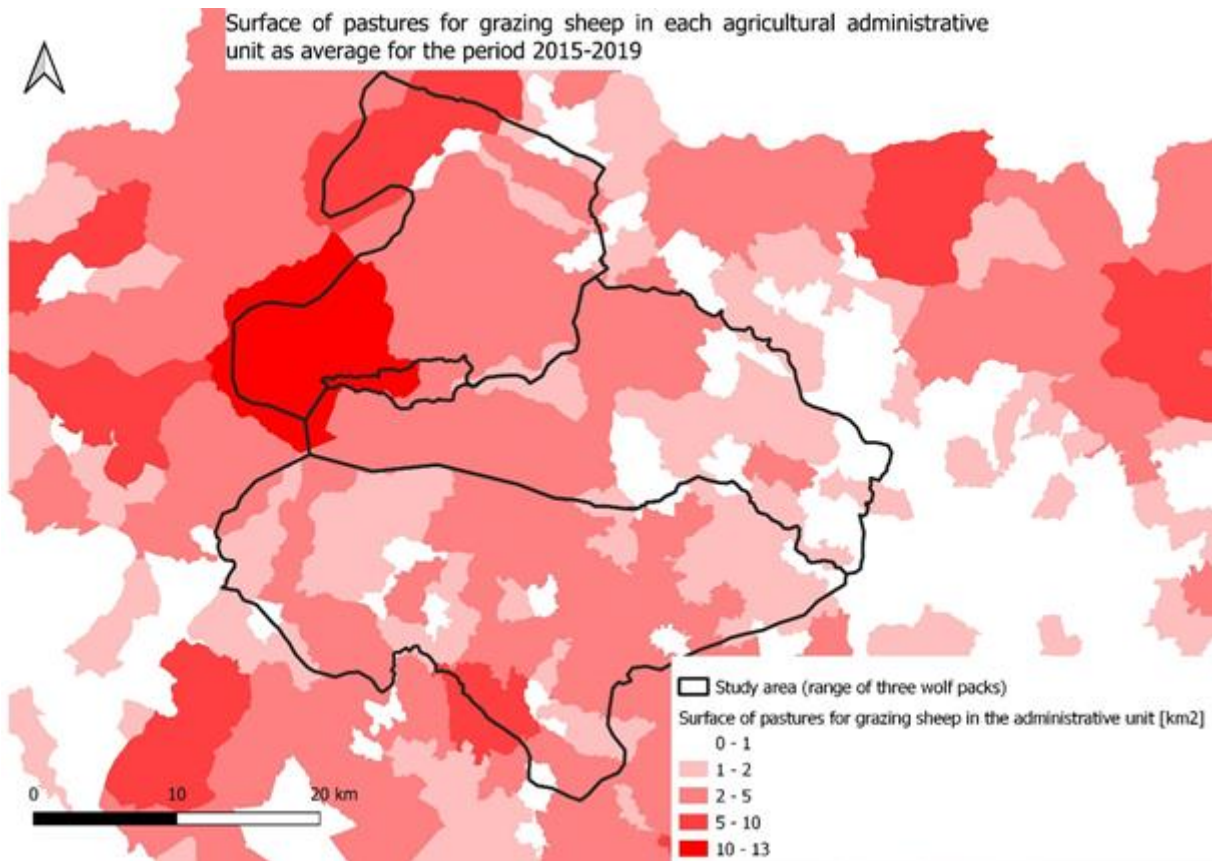


Figure I.7. The amount of pastures (in km²) used for sheep grazing in the period 2015-2019 per agricultural administrative unit. The LIFE WolfAlps EU A4-C3 study area in Slovenia is outlined in black.

In the years 2019 and 2020, there were 63 events recorded (and compensated) in the chosen study area, when wolves were recognised to have caused damage on human property. Out of these, 51 attacks happened in 2019, and only 12 attacks in 2020. The majority of damage cases were depredations on sheep (i.e. sheep and goats; N=50; 79,4%), 6 damage cases were on cattle (9,5%), 4 cases on horse and 1 on donkey.

In the alpine and pre-alpine study area, where the wolf has permanently settled now after a period of long absence, preventive measures against depredation are unsuitable and inadequate, as fencing is intended only for grazing in the absence of large carnivores, and not for preventing large carnivore depredation on livestock. Pasture fencing is designed to keep livestock on pasture, so farmers are mostly equipped with either wire fences without electricity or electric fences with a few wires, which do not prevent wolves from passing under the fence.

Currently, five sheep breeders have decided to upgrade their existing system in the study area. They now protect their livestock either with high electro-nets or with permanent night enclosures with the

addition of two electric wires. In the coming years, more farmers are expected to use efficient protective measures against wolf attacks.

The use of livestock guarding dogs is very rare in this area. In the frame of the LIFE DINALP BEAR project, one LGD of the Tornjak breed was used in the area of Cerkljansko pack.

Hunting regime

Wildlife management in Slovenia is based on transparent and sustainable planning, thus all the measures are prepared for ecologically delineated areas and in cooperation with all stakeholders⁵. In game management, hunters and hunting organisations play a very important role. The Slovenian Forest Service (which is under the auspices of the Ministry of Agriculture, Forestry and Food) is the competent wildlife management institution and annually prepared (from now on every two years) a proposal of short-term (from now on biannual) management plans. These are further validated through the public debate, stakeholders' involvement and contribution of the Institute of the Republic of Slovenia for Nature Conservation, and agricultural holdings operating in neighbouring countries. The guidelines set up in two-year management plans must be in line with the ten-year forest- and hunting management plans.

The methods and implementation of hunting are regulated by law. Hunters are obliged to hunt in accordance with regulations and in accordance with the legally defined hunting periods. The implementation of game management plans is supervised by hunting inspectors, who also work within the Inspectorate for Agriculture, Forestry, Hunting and Fisheries. The Inspectorate monitors compliance with legal provisions, the implementation of concession contracts and game management plans, and the work of hunting guards.

There are 411 hunting grounds and 12 special-purpose hunting grounds in Slovenia, which are grouped into regional associations for the purpose of sustainable game management. Hunting grounds are managed by legal entities registered for hunting activities (hunting associations encompassing over 20.000 hunters), acting in the public interest, having public authority and performing public service, but established on the basis of a voluntary decision of their members in accordance with the legislation on associations. The umbrella organisation is the Hunting Association of Slovenia, which unites all

⁵ <https://www.gov.si/en/policies/agriculture-forestry-and-food/hunting/>

hunting associations and others, whose activities are related to game, hunting and nature protection. The Slovenian Forest Service performs a public service in the field of game management, while managers of hunting grounds and hunting grounds with special purpose perform certain tasks under the conditions of public service. Special-purpose hunting grounds in Slovenia were established in areas that are particularly important for the nature protection and are organised as legal entities under public law (Slovenian Forest Service - SFS, Triglav National Park, Public Protocol Institute).

Hunting on roe deer is carried out in the following periods: 1st May to 31st October for adult males, yearling males and females; and 1st September to 31st December for adult females and offspring of both sexes. Hunting is carried out by stalking in combination with hunting by waiting (from high-stands) and during the daytime (from morning to dusk). Hunting at night is strictly prohibited.

Also in case of red deer, hunting is carried out in accordance with the prescribed hunting periods, which determine hunting by categories: adult males from 16th August to 31st December; adult females and offspring of both sexes from 1st September to 31st December; yearlings of both sexes from 1st July to 31st December. Red deer hunting is carried out by stalking in combination with hunting by waiting (from high stands), in late autumn and in winter also in drive hunts. Hunting is carried out only during the day (from morning to dusk). Some exceptions can occur by means of individually issued and time-limited culling decision due to local increase in damage to agriculture and forestry, which also allows nocturnal deer hunting.

The sustainable game management described above for Slovenia also applies to the chosen study area. The regional association of hunting ground managers of Gorenjska includes 40 hunting associations and 2 special-purpose hunting grounds. Besides, the study area is partly located in the area of Triglav National Park, which is the only national park in the country (TNP; covers 840 km², 4% of the surface of Slovenia). It is divided into three protection zones. In the first protection zone, also called the central area of TNP (area of 314,88 km², 36% of TNP) there is a permanent ban on hunting.

Land management and other human activities

Beside prevalent forests, the agricultural land is the second most important land management type in the area. Nowadays, agricultural areas remain mostly in the valleys of the main water streams and on pastures above the upper timberline, somewhere also grouped around the mountain villages. Livestock breeding is the main type; breeding of cattle for cheese and milk being the most common, alongside

with the sheep breeding for meat. Crop production is mainly oriented to the needs of own household or local food chains. Corn silage and barley are common crops on fields. Forest pasturing can be found in some parts.

The area is a highly-prized destination for hikers, mountaineers, cyclists, campers and all sorts of other tourists that enjoy the mountains, lakes and mountain rivers (sports on wild waters, lake-bathing, hunting tourism, winter sports etc.). As indicated above, part of the study area covers the territory of the Triglav National Park. Summer and winter tourism is one of the most important sources of revenue for the inhabitants of the area. Four large skiing centres (downhill and cross-country) are located within the study area, one even hosting World Cup competitions (biathlon).

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ANNEX 2 – Italian study site 1: Maritime Alps

Authors: F. Marucco, D. Airaudo and A. Menzano

Site location

The Maritime Alps are a mountain range in the south-western part of the Alps. They form the border between the French region of Provence-Alpes-Côte-d'Azur and the Italian regions of Piedmont and Liguria (Fig. II.1). They are the southernmost part of the Alps. Administratively the range interested by the study site is within the Italian province of Cuneo. The mountains are drained by the rivers Stura, Pesio and Ellero and other tributaries of the Tanaro and Po.

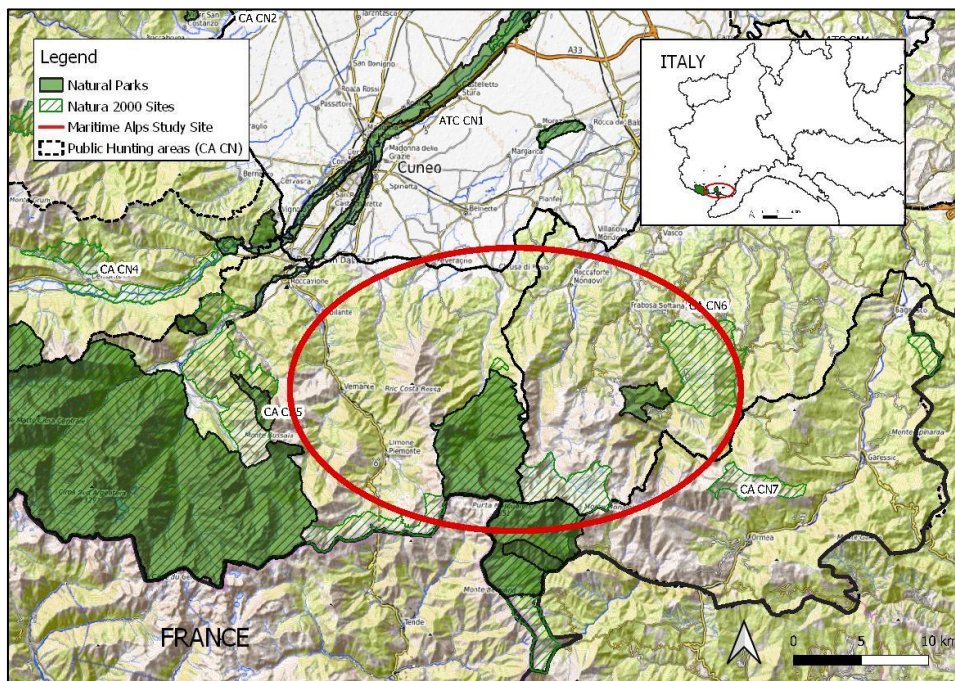


Figure II.1. Location of the LIFE WolfAlps EU A4-C3 study area in the Italian Maritime Alps (in red) in the north-west of Italy.

The study site for Action C3 of the LIFE WolfAlps EU project is centred in the Pesio Valley, but also encompasses parts of the Ellero and Vermenagna valleys (Fig. II.1). Part of the study site is within the Marguareis Natural Park (PNM), one of the first regional parks of the area, defined in 1978 with the aim to conserve its important natural resources while favouring low-impact sustainable socio-economic local development and eco-touristic fruition. This area corresponds roughly to the territory of the “Pesio Valley” wolf pack, the first settled pack in the Italian Alps in 1996 and further described in detail below. The area extends over 600 km² in the Cuneo Province of the Piedmont region. The area

is a complex combination of sedimentary and metamorphic deposits that have generated a high diversity of habitats, which have a flora characterised by a very high number of endemic species in relation to their small geographical extension. This area is in fact considered one of the most important centres of biodiversity of the Alps and a Mediterranean hotspot of biodiversity. The area is also divided into 2 public hunting districts (CACN 5 and 6) which are described in details below.

Habitat configuration

The study site covers a wide area of the piedmontese side of the Maritime-Ligurian Alps. Its central territory is known as Piccole Dolomiti (Small Dolomites), which is characterised by the presence of a very large complex of karstic caves underground. Altitude at the study site ranges between 600 and 2651 m a.s.l.. A wide percentage of the area consists of woodland (mainly beech, deciduous forests, and woods of silver fir *Abies alba* and European larch *Larix decidua*), whose development was favoured by the monks of the Certosa of Pesio. Overall forests cover about 60% of the surface, while vegetated open areas and rocky areas represent another 30% (Fig.II.2).The peculiar climate of the area, which shows both Alpine and Mediterranean features, as well as its karstic geology, sustains a very remarkable vegetal biodiversity. In the protected area indeed about 1500 different plant species have been recorded. A well-developed network of waymarked footpaths is available within the area, that is also crossed by the southernmost part of the GTA, a long-distance hiking trail which runs across the piedmontese Alps. Mountain tourism is well developed, and three important ski resort areas are present in the study area.

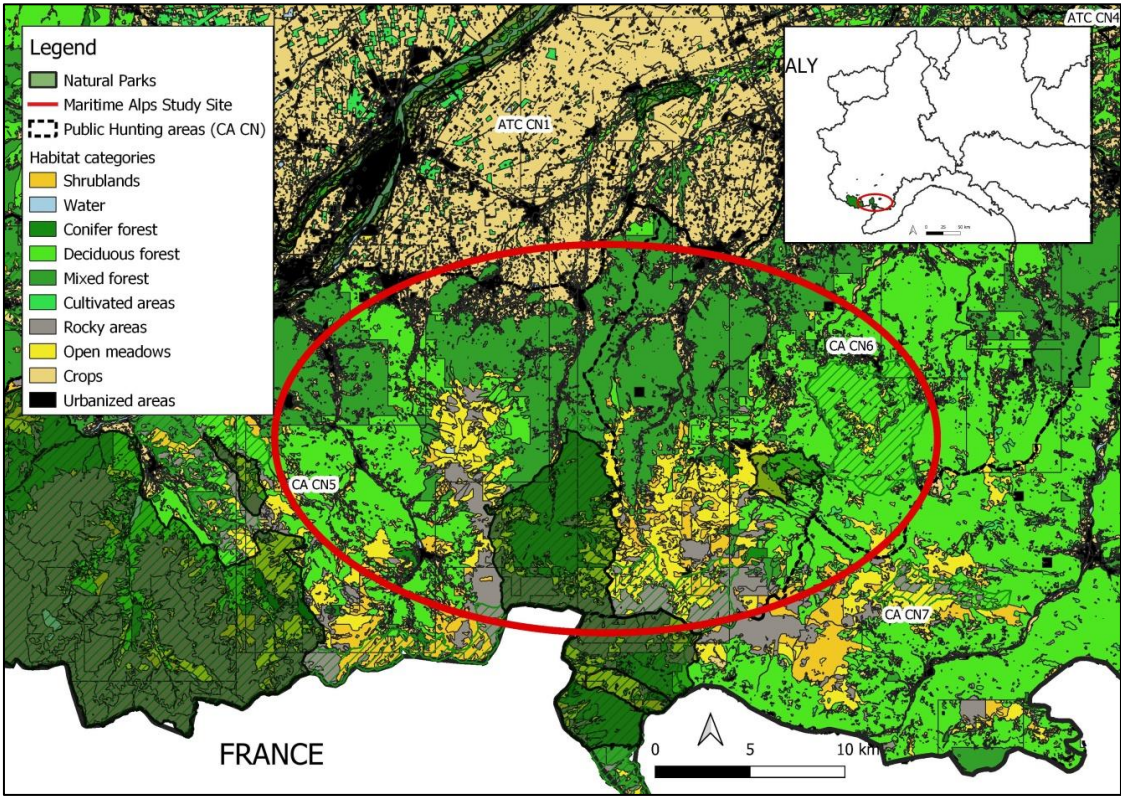


Figure II.2. Habitat configuration of the LIFE WolfAlps EU A4-C3 study area in the Italian Maritime Alps (in red) in north-west Italy.

Wolf presence and diet

The study area has a high density of wolf packs. The presence of wolves in the study area dates back to mid-1990s, when the first pack settled in the Pesio Valley in 1996, which was the first documented pack of wolves in the Italian Alps after the disappearance of the species during the 19th century. This wolf pack (The Pesio Valley pack) has been widely monitored since 1996 up to 2021. In the first years it ranged over a vast territory of up to 450 km², but in the last few years the size of the pack’s territory has decreased due to the higher pack density in the area (Fig. II.3). Complete pedigrees of the Pesio Valley wolf pack have been reconstructed every year since 1998 (Fig. II.4), as well as of adjacent packs (Fig. II.4), so that social dynamics, immigration and dispersals events have been directly evaluated. Survival rates in the area estimated through capture-recapture estimates (Marucco et al. 2009) revealed that young wolves had lower apparent survival than adults. Many intensive studies have been conducted in the area over the years, including via the radio-collaring of 3 wolves (Marucco et al. 2010, Marucco et al. 2018).

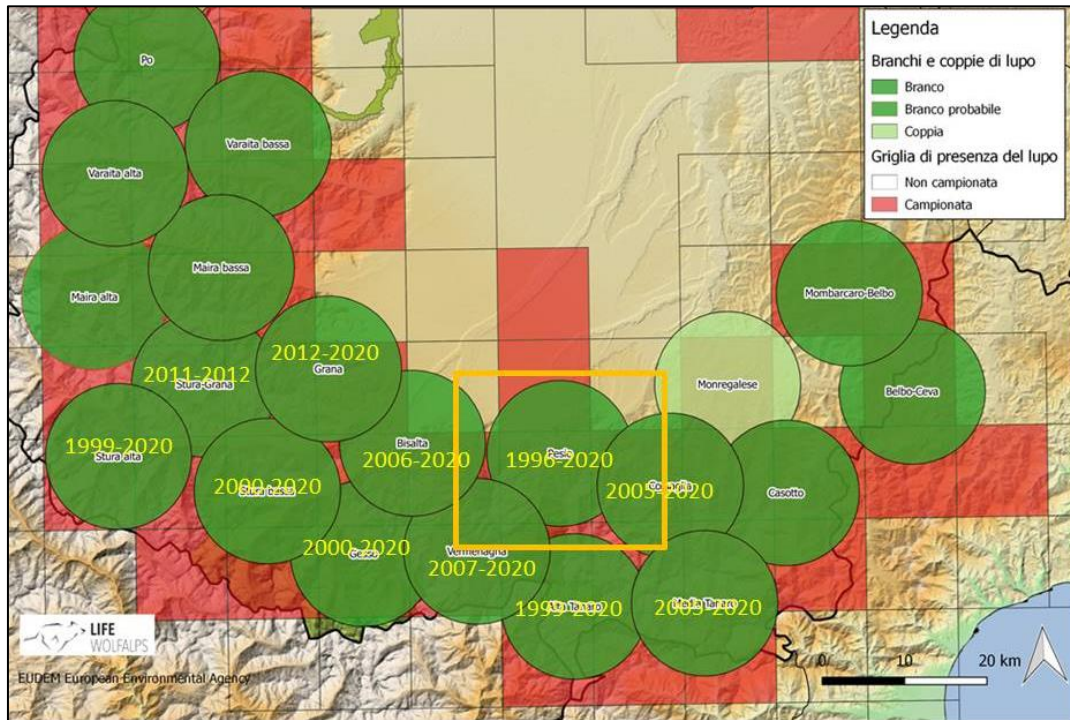


Figure II.3. Pack density in the LIFE WolfAlps EU A4-C3 study area in the Italian Maritime Alps in 2017-2018 from Marucco et al. 2018. In the yellow square the Valle Pesio pack is indicated, and for each pack the years of presence of the pack.

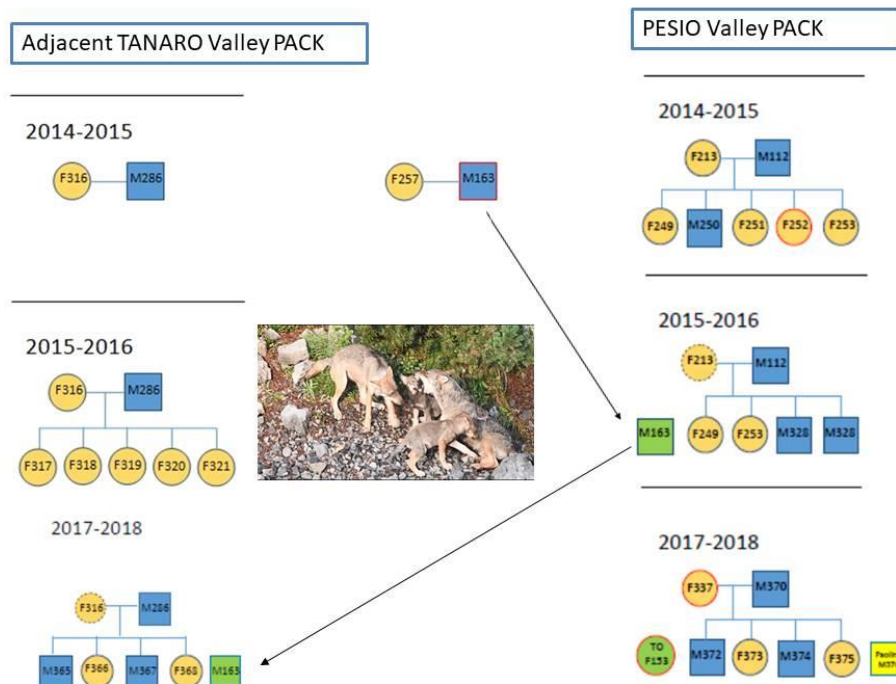


Figure II.4. Example of pedigrees of the PESIO Valley pack in 2014-2016, and of the adjacent pack from Marucco et al. 2018. In yellow a radio-collared wolf.

Diet analysis on the Valle Pesio wolf pack and on adjacent packs have been conducted for the first 13 years (Marucco et al. 2008, Marucco et al. 2010), indicating that in the study area the main species consumed by wolves were roe deer and wild boar (Fig. II.5). Occurrence of species in wolf diets varied over the years, among adjacent packs, and between seasons (Fig. II.5, Marucco et al. 2010). During a study on diet selection of the Valle Pesio pack in the first years, however, the most consumed species was red deer (less abundant), whereas roe deer, which was more abundant, was used as available (Marucco et al. 2008).

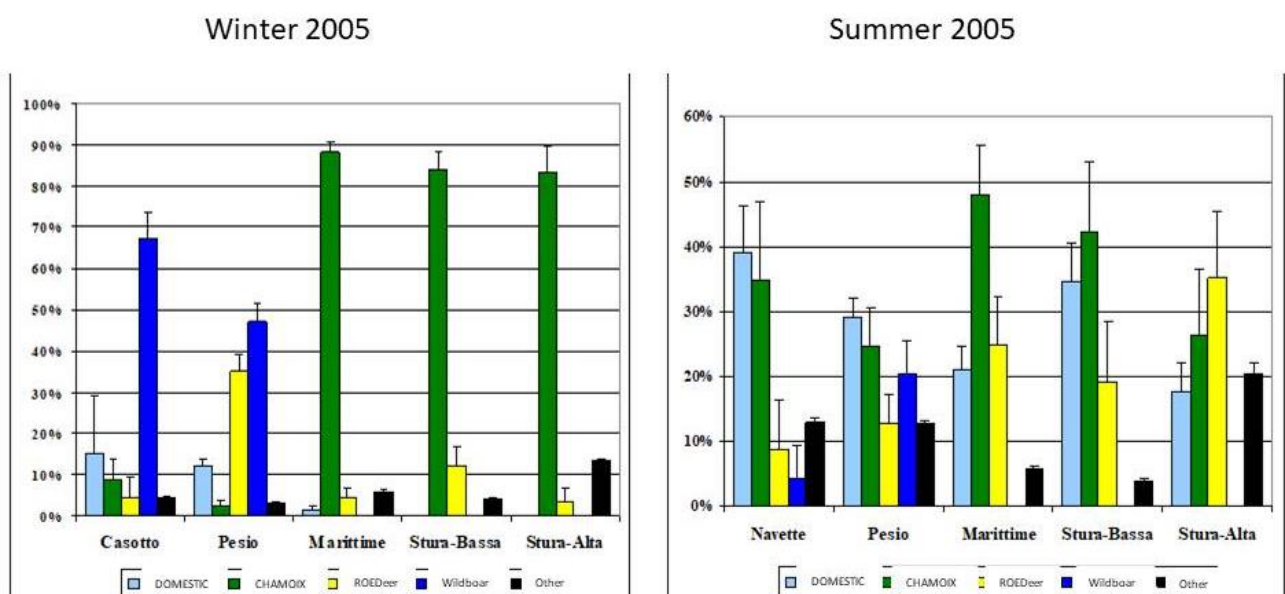


Fig. II.5. Relative abundance (%) of wild and domestic ungulates and other prey in the scats of Valle Pesio wolf pack and adjacent packs in winter and summer 2005. Data obtained from Marucco et al. 2010.

Wild ungulate presence

Five species of wild ungulates populate the Maritime Alps: roe and red deer, wild boar, chamois and ibex. In the study site however ibex is marginal, present only in the extreme west part of the area and in low numbers. Insufficient data are available on the relative abundance of the four species. But raw data from hunting night counts show an increase in the abundance of red deer since 2001, concomitant with an apparent decrease in the abundance of roe deer. Wild boar and chamois do not show important trends.

Livestock presence and preventions systems in use

The study site is characterised by the presence of local herds of sheep and cows that during the summer months use the mountain pastures (June to October). The area is also characterised by an historical wolf presence (almost 30 years), and despite a high level of livestock depredation at the beginning of the recolonization in the nineties, today 100% of sheep and cow breeders of the area use livestock guarding dogs and electric fencing at night, and are present within day and night in pastures to protect their herds against wolf predation and manage them at the best. Number of attacks and victims due to livestock depredations dropped over the years (Menzano 2015, Menzano et al. 2018).

An intensive and very detailed study has been conducted in the study area during summer 2017, in the framework of the first project LIFE WolfAlps. A deep evaluation on the use of prevention systems by alpine breeders has been conducted in 3 different areas of wolf presence, one of these being the area of the Pesio Valley wolf pack (Fig. II.6). All farmers in the study area have been contacted by operators to collect data on the species and number of livestock bred, on the type of management, on the use of prevention systems and on the number of depredation events occurred during the summer (Colombo et al. 2018). In Fig. II.6 the pasture area of each farmer and the localisation of depredation events are represented.

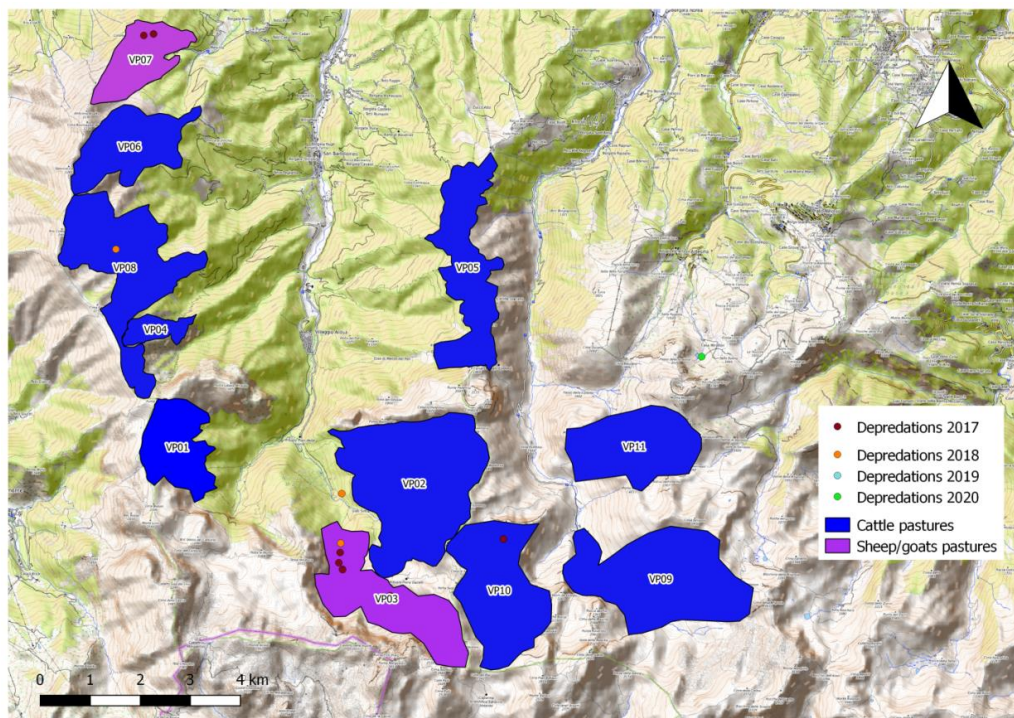


Figure II.6. Pesio Valley pasture areas and the localisation of wolf depredation events.

Breeders do not always report predatory events because not all have adhered to the insurance system that compensates in case of wolf attack, so the data on depredation are not always complete. During the study, the ongoing relationship between project operators and farmers allowed for an accurate collection of this data concerning the years 2015, 2016 and 2017, but this is not the case for 2018, 2019 and 2020 (Fig II.6).

Livestock presence

Eleven farmers were present in the study area. Most of them bred cattle (81,8%), mainly for meat production (Piemontese breed). The other 2 farmers bred sheep and goats for milk or meat production (Table II.1). These farmers are likely to still be present in the area today.

Table II.1. Farmers and livestock in the Pesio Valley study area.

Alpine ID	Bred species	Number	Type of production
VP01	Cattle	190	Milk
VP02	Cattle	180	Milk
VP03	Sheep-Goat	395	Meat
VP04	Cattle	44	Meat
VP05	Cattle	210	Meat
VP06	Cattle	150	Meat
VP07	Sheep-Goat	150	Milk
VP08	Cattle	210	Meat
VP09	Cattle	250	Meat
VP10	Cattle	300	Meat
VP11	Cattle	250	Meat

Preventions systems in use

From a management point of view, it is very important to avoid behaviours that could increase the risk of wolf depredation, such as allowing births in alpine pastures, bringing to pasture young animals that cannot follow adults in their movements, not protecting livestock at night, not staying with the livestock on pastures etc.

During the study period, livestock management choices were not always appropriate: in 6 occasions (54,5%) the farmers brought to the alpine pasture animals younger than six months and in 6 cases births took place at the pasture, even though the farmer or an assistant was always present during the pasture time at daytime and always closed the animals into electrified fences during the night.

Different prevention systems are used in Piedmont according to the species to be protected. In the case of cattle, the main aim is to keep the herd cohesive and prevent some animals from becoming isolated and more exposed to the risk of being depredated. The farmers in the study area usually used a single electrified wire (height of about 90-100 cm) to protect cattle, but this fence is not effective in avoiding the exit of calves and is used above all to delimit the grazing area. A better protection is obtained using more than one electrified wire, placed at different heights. In the case of sheep and goats, the farmers usually used electrified nets of at least 120 cm in height. The type of electrified fences used by each farmer is reported in table II.2. Five farmers (45,4%) had at least 2 livestock guarding dogs (LGD: Maremmano-Abruzzese Shepherd) to protect cattle or sheep and goats (Table II.2).

Table II.2. Prevention and management systems used by farmers in Pesio Valley against depredation by wolves.

Alpine ID	Bred species	Animals younger than 6 months	Births during the pasture period	Electrified fences	LGD
VP01	Cattle			3 wires	
VP02	Cattle		x	1 wire	3
VP03	Sheep-Goat		x	net (h. 120 cm)	2
VP04	Cattle	x		1 wire	
VP05	Cattle	x	x	1 wire	
VP06	Cattle	x	x	1 wire	
VP07	Sheep-Goat	x		net (h. 120 cm)	3
VP08	Cattle		x	1 wire	
VP09	Cattle	x		1 wire	5
VP10	Cattle	x	x	1 wire	
VP11	Cattle			1 wire	2

Hunting regime

General national and regional overview

Law n°157 approved in 1992 (L157/92) regulates the whole hunting activity in Italy. For the purposes of this annex, only the parts that directly impact the hunting of wild ungulates will be analysed. First of all, the law says that Regions and Counties must write a “Piano Faunistico-venatorio” (PFV, wildlife hunting plan), where the administrative authorities fix the management objectives for their territories. This law establishes that ungulates (except wild boar) can be hunted only with driven hunts based on selective hunting plans (SHP). The total number of animals that can be killed are a percentage of the estimated population or a percentage of the minimum certain population derived from census operations. Also, the SHP subdivides this number in age classes and sex according the population structure of the species. L157/92 defines the hunting periods for all the species of wild ungulates, but these periods can be modified according to article n° 11-quaterdecies of the law n° 248 approved in the 2005. Additionally, L157/92 states that the territories of alpine regions are divided in two faunal zones: Zona Alpi (Alpine zone), ZA, and Zona di Pianura (Flat land Zone), ZP, even though it devolves to the Regional authorities the definition of the zone boundaries. Furthermore, these two faunal zones are divided into smaller areas called Ambiti Territoriali di Caccia (Hunting Territorial Domains), ATC, for the ZP, and Comprensori Alpini (Alpine Domains), CA, for the ZA. Finally, the law declares that on a given percentage of the regional area, private hunting grounds are possible through the institution of two types of private game reserves: Aziende Agrituristiche Venatorie (Game and Agritouristic Reserve), AATV, and Aziende Faunistico Venatorie (Game and Faunal Reserve), AFV.

Hunting activity In Piedmont region is regulated by the Regional law n°5 approved in 2018 (Lr5/2018). In many aspects, this law reaffirms what the National law states but adapts some concepts of the L157/92 law to the regional contest. The Lr5/2018, at the article n° 21, establishes that all the data collected during the hunting or wildlife management activities must be inserted in a database called Portale Osservatorio Faunistico regionale (Regional Wildlife Observatory Portal), POF. This database exist from 2004, but only as of 2018 did it become the official collecting point of the wildlife management data. The regional law establishes that game activity, wildlife control plans, wildlife censuses, wildlife carcasses and wildlife collisions with vehicles must be logged in the POF. Today only the game activity part is completely operational. Qualified technicians that work for CA or ATC compute data in the database. Biometric information, date and place of the shot are also available in the

database. Concerning the localisation of the shot, in the first version of the POF only municipality and locality were registered. After an upgrade, the system stored the location of the event using the lower-left corner cell coordinates of a regional 1 km² grid that does not match the European reference grid. In the latest version, the technician can put a dot in a map canvas and the POF registers the geographic coordinates of the point automatically. In addition, for wild ruminants and wild boar, the regional council promulgated two different guidelines for regulating the hunting activity of these animals (Ruminants Guidelines and Wild boar Guidelines respectively). For wild ruminants the guidelines state that every ATC or CA that wishes to hunt these species must write a programmatic document (Organizzazione e Gestione degli Ungulati Ruminanti, OGUR: Ruminant Ungulate Management and Organisation) where all aspects of the management are explained. In this document there is a subdivision of the CA/ATC territory into hunting districts for better organisation of the hunting activity and a more precise definition of management targets. This document is approved by the regional council and is valid for five years. After this period, the CA/ATC updates this document and at this moment can change the boundaries of hunting districts to better organise the hunting management. For wild boar the guidelines are simpler and it does not provide any management document or any hunting district. The two guidelines explain how and when the censuses must be carried out and how a driven hunting plan is elaborated. Finally, in the Piedmont region, the driven hunter must carry any animal killed during the driven hunt to a check-point where a qualified technician collects biometric data, the date of the kill and the location (municipality, locality and often geographic coordinate) to insert them in the POF.

Hunting regime in the study site

In Marguareis Natural Park hunting is not allowed. However, wild boar are occasionally removed using capture cages with the aim to reduce their impact on local crops. Those removals are organised and supervised by the staff of the national park. In the remainder of the study site, there are 2 Public Hunting Districts (Fig. II.7). The main one is the CA CN5 (Fig. II.7), which lies on the southern part of the ZA and intersects some protected areas. Inside the CA CN5, a private game reserve, called AFV “Fontana Cappa”, is present. The alpine domain occupies a total surface of about 70 900 ha (709 km²) with a public hunting ground of about 36 560 ha (365 km²) (Fig II.7). The hunting ground is divided in hunting districts: 4 for roe deer, 2 for chamois and none for wild boar.

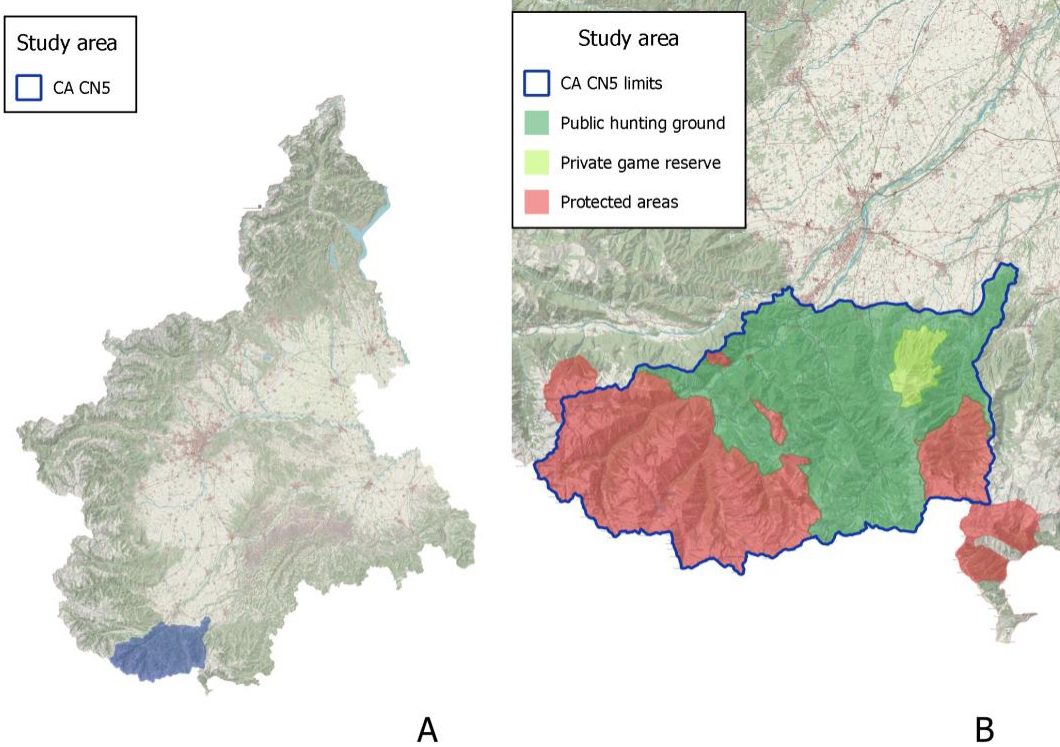


Figure II.7. The study area and the CA CN5: location (A) and administrative organisation of the territory (B).

In fact, taking into account only large mammals, roe deer, red deer, fallow deer, chamois, mouflon and wild boar can be hunted in the Piedmont territory, but in CA CN5, hunters can shoot only roe deer, chamois and wild boar. The districts changed over the time according to the upgraded management plan and organising targets of OGUR (Fig. II.8).

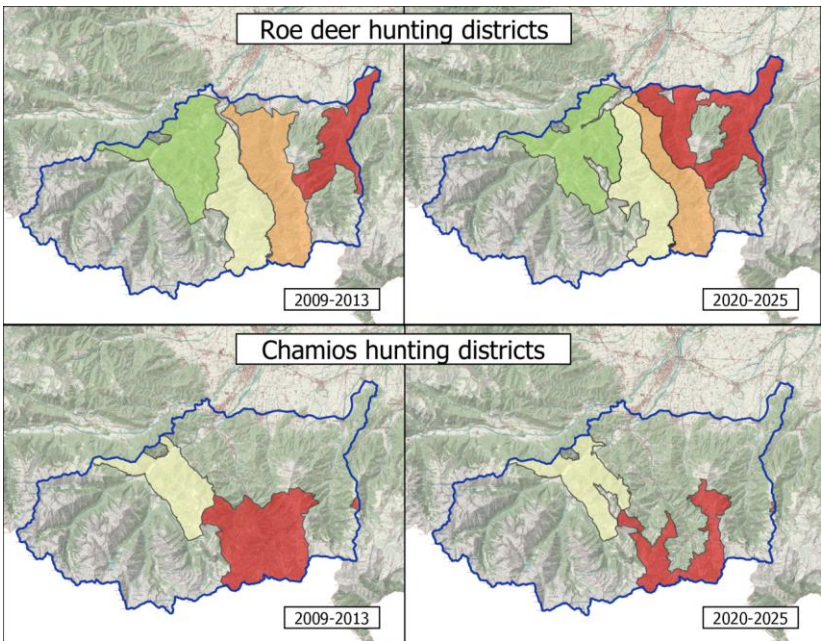


Figure II.8. An example of the changes in the hunting districts in Piedmont.

CA CN5 and available data of interest for the present study

The CA TO5 uses the POF from the year 2004, so the time series is at currently 16 years’ long. For the years 2005 and 2015, data are missing, but they could be easily recollected by contacting the CA. Table II.3 reports the total amount of data, the number of non-georeferenced data, the “gridded” data and the georeferenced data by species and year. Fig. II.9 shows the number of hunted roe deer in CA CN5 from 2014 to 2019, and in the adjacent CA CN4.

Table II.3. Total amount of hunting data by species and year within the CA CN5.

year	Chamois				Roe deer				Wild boar			
	total	no coord.	grid coord.	geo coord.	total	no coord.	grid coord.	geo coord.	total	no coord.	grid coord.	geo coord.
2004	42	42	0	0	44	44	0	0	163	163	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0
2006	58	2	56	0	49	0	49	0	136	0	136	0
2007	72	0	72	0	96	0	96	0	272	4	268	0
2008	69	3	66	0	145	0	145	0	367	0	367	0
2009	59	0	59	0	123	0	123	0	106	1	105	0
2010	58	0	58	0	141	0	141	0	236	0	236	0
2011	71	1	70	0	146	2	144	0	167	1	166	0
2012	72	1	71	0	183	1	182	0	268	0	268	0
2013	66	0	66	0	170	0	170	0	210	1	209	0
2014	87	0	87	0	230	1	229	0	317	3	314	0
2015	0	0	0	0	0	0	0	0	0	0	0	0
2016	77	0	0	77	242	0	0	242	263	0	2	263
2017	84	0	4	80	246	0	3	241	508	0	0	502
2018	69	0	4	65	143	0	12	131	272	0	0	260
2019	75	0	0	75	112	0	0	112	579	0	0	578
2020	52	0	0	52	105	0	0	105	517	0	0	516

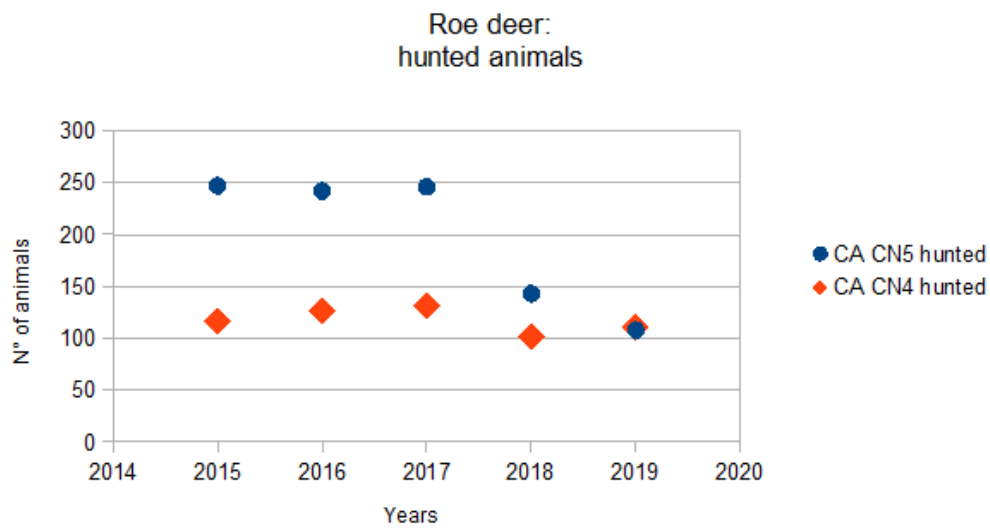


Figure II.9. Hunted roe deer in CACN5 from 2014 to 2019, and in the adjacent CACN4.

In terms of georeferenced data, it is important to underline that not all of them are correctly positioned and therefore, before any analysis, it is necessary to check their spatial validity and correct or discard erroneous data (Fig. II.10).

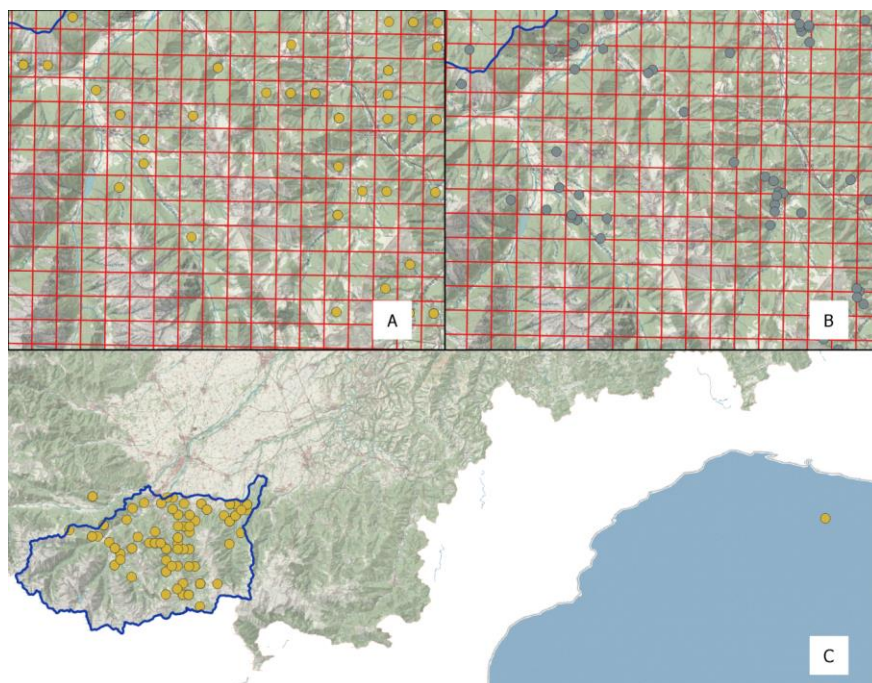


Fig. II.10. Examples and problems with georeferenced data: A) location with grid coordinates (roe deer, 2010). In red: 1-km regional grid. B) location with geographic coordinates (roe deer, 2020). In red: 1-km regional grid. C) An example of erroneous location data (roe deer, 2010 – yellow location in the sea, to the right).

Biometric data can be useful for analysing the relationship between animal dimensions and density or for pointing out changes in the abundance of age and sex classes that can be driven by hunting, predation or both. In conclusion, the data collected from hunted animals over more than a decade can represent an important starting point for understanding the complexity of the predator-prey-hunting relationships.

Land management and other human activities

The study area is in part inside Marguareis Natural Park, and part of the land is directly managed by the Park administration. The rest of the municipalities retain land use rights over the larger part of the study area, while a minor part consists of private properties. Forestry is an important economic activity in the area, inside and outside the protected areas, with different rules and regimes. Around 6000 people live in mountain areas of the study site, and summer and winter tourism are the most important sources of revenue. The presence of bikers and hikers is growing fast and the Regional Park is currently planning land use changes for mitigating human disturbance. Moreover, given its proximity to the urban areas of Cuneo and Mondovi, the site is a highly prized destination for other tourists, both in summer and winter, featuring also 3 alpine downhill ski resort areas and cross-country skiing.

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ANNEX 3 – Italian study site 2: Stelvio National Park

Authors: L. Pedrotti and L. Corlatti

Site location

Stelvio National Park (SNP), one of the Italian ‘historical’ parks, was founded in 1935 with the aim to conserve natural resources, favour socio-economic local development and promote touristic fruition. The SNP extends over some 1310 km², in the Lombardy region and in the Autonomous Provinces of Trento and Bolzano, in the central Italian Alps (Fig. III.1). The protected area encompasses the Ortles-Cevedale massif. A vast altitudinal range, ranging between 700 and 3900 m a.s.l., and a complex combination of sedimentary and metamorphic deposits have generated a high diversity of habitats, representative of the alpine biodiversity. The study area (“Valfurva”) is located in the north-western part of the park, within the province of Sondrio (10°25’N, 46°27’E). Year-round movements of individually marked red deer and landscape features such as ridges and valleys concur to define the boundaries of the study site. Valfurva has been chosen as an area devoid of wolves for Action C3 of the Life WolfAlps EU project.

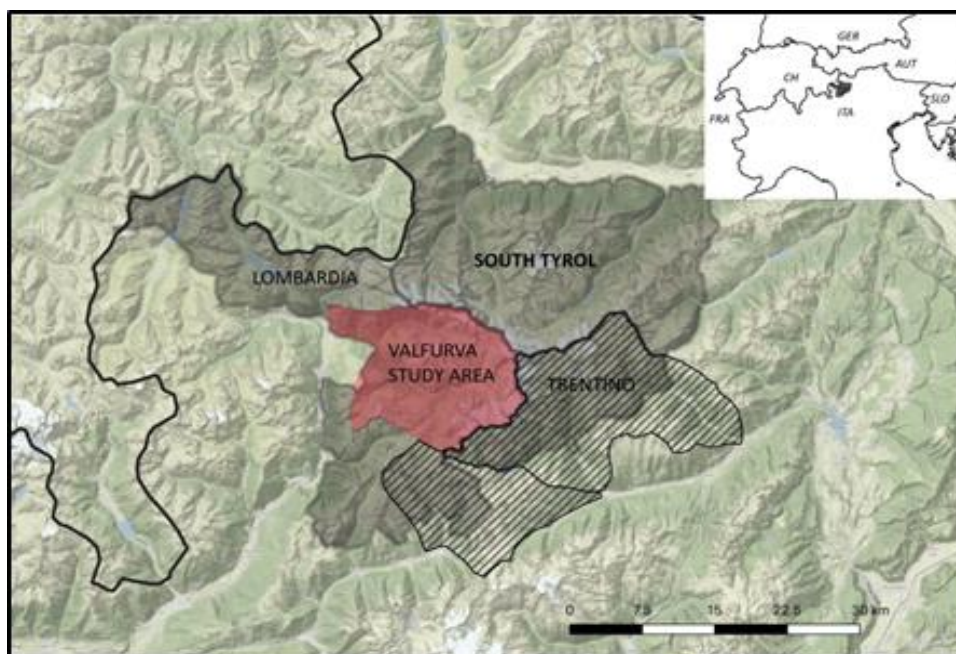


Figure III.1. Location of the Stelvio National Park. The three sectors (Lombardia, Trentino, South Tyrol) are shown as shaded areas. In red, the study site “Valfurva”, that will be used as a blank area (i.e., without stable wolf presence), for the Action C3 of Life Project. The dashed area is a site where the presence of a wolf pack has been recently ascertained. Although this area is not included in the Life Wolfalps EU project, a monitoring scheme similar to that implemented in Valfurva is being currently planned, with the aim to investigate the spatial ecology of the predator.

Habitat configuration

The study site encompasses the whole municipality of Valfurva, as well as the Zebrù and Forni valley. It extends over about 22 000 ha and ranges between 1200 and 3850 m a.s.l.. The climate is alpine continental, with mean temperatures between 15.7°C in July and –2.8°C in January, and yearly precipitation of about 765 mm. Forests are dominated by spruce *Picea abies*, larch *Larix decidua* and stone pine *Pinus cembra* interrupted by mesic meadows of *Trisetum flavescens* and other xeric associations. Above the treeline, alpine grasslands of *Carex curvula*, *Festuca halleri*, *Carex sempervirens* and *Carex firma* are the prevalent vegetation. Forests cover about 30% of the surface, while vegetated open areas represent another 30%.

Wolf presence and diet

Wolves are currently not permanently present in Valfurva. In the past three years, only three observations have been recorded, possibly of dispersing individuals, and no predation on wild ungulates has been confirmed. At present, no data are available on wolf use of prey, as no predation has been recorded so far in Valfurva (only a few uncertain cases have been reported on red deer, before 2019). However, a wolf pack settled in 2019 in the southern portion of the park (Fig. III.2), and another pack has been present in the eastern part of the park since 2018, between Bolzano and Trento.

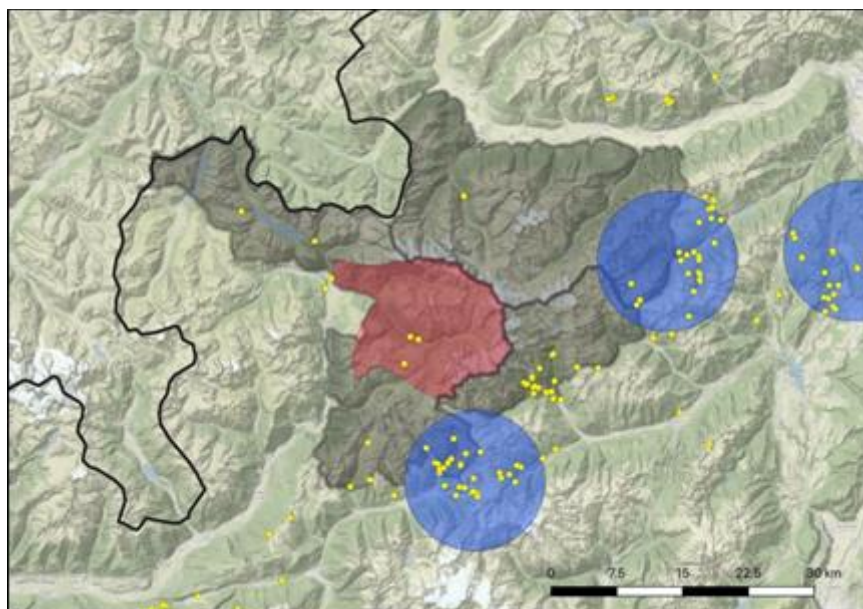


Figure III.2. Data of wolf presence in the Stelvio National Park and neighbouring areas. The study area “Valfurva” is shown in red; yellow dots represent presence data from 2018 to 2020; blue circles indicate the approximate location of wolf packs.

Wild ungulate presence

Five species of ungulates are present in Valfurva (red deer, chamois, ibex, roe deer and wild boar). At present, wild boar is limited to some dispersing individuals during summer as a result of illegal releases outside the park. Roe deer density is very low all over the park, especially in Trentino and Lombardia, likely because of strong interspecific competition with red deer. Average density of roe deer in Valfurva ranges between 1 to 4 individuals/km², based on a pellet-count distance sampling conducted in 2007. Regular yearly abundance estimates are not available for roe deer. Red deer density in Valfurva is high and stable, with fluctuations between 13 and 18 deer/km² (average values) over the last few years. The spatial distribution of red deer in Valfurva is widest in summer, while in winter and early-spring animals move to lower elevations, when local density can reach values of up to 30 individuals/km² (Fig. III.3). From 2015, density of red deer started to decrease slightly in the part of Valfurva, following the start of a culling program in 2011 (Fig. III.4). The red deer population is monitored regularly, on a yearly basis, by means of spring spotlight counts (for numerical trend) and summer block counts (for population structure).

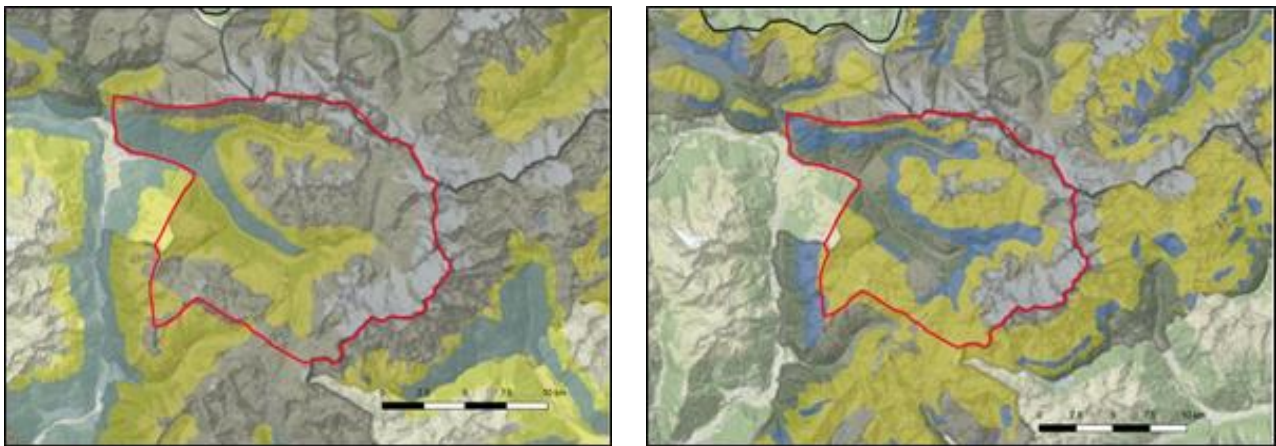


Figure III.3. Roe deer and red deer distribution (left, in yellow) and chamois distribution (right in yellow) in Valfurva Study Site (red); winter distribution in blue.

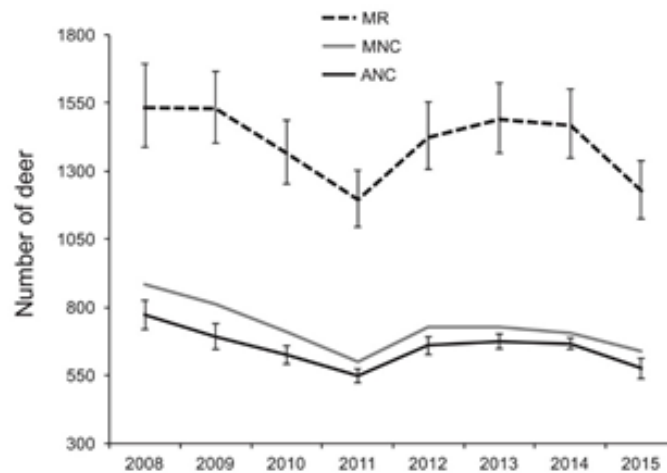


Figure III.4. Red deer population trend in Valfurva between 2008 and 2015 (from Corlatti et al. 2016).

Chamois is widespread in Valfurva, with a stable population of about 400-500 individuals in the last 10 years (Fig. III.3). Ibex is present in the southern part of Valfurva with some dispersing individuals only, while the population in the northern part counts some 250-300 individuals. Chamois and Ibex are regularly monitored on a yearly basis by extensive block counts, conducted in September and June respectively.

Livestock presence and preventions systems in use

On average, about 600 cows and 2300 sheep and goats are present in summer on the alpine pastures of Valfurva. Cattle is regularly managed and protected, while sheep are managed by professional shepherds only if they occur in large flocks, which typically move to the Alps in early summer. No predation on livestock has been recorded yet in Valfurva (though wolf predation occurs quite regularly where packs have settled). As a consequence, no preventive system against wolf depredation has been introduced and no LGDs are present in the area.

Hunting regime

Hunting in the Stelvio National Park is not allowed. However, a red deer culling program started in 2011, partly including the study site Valfurva, with the aim to reduce deer impact on forest regeneration. Around 100 local hunters are involved in culling actions conducted on a yearly basis. The culling period starts towards the end of October and ends in December or January, depending on meteorological conditions. Culling is organised and supervised by the staff of the national park; shooting occurs in 10 culling sections encompassing about 20 km² of red deer wintering sites. Normally,

about 15-20 culling days are necessary to shoot 130-170 deer, depending on the year. On average, 20-30 hunters cull each day.

Land management and other human activities

Valfurva is almost completely inside Stelvio National Park, though no public land is present or directly managed by the park administration. Municipalities retain land use rights over the large part of the study area, while a minor part consist of private properties. Around 2500 people live in Valfurva; summer and winter tourism are the most important source of revenue. The presence of bikers and hikers is growing fast and the national park is currently planning land use changes for mitigating human disturbance.

Reference

Corlatti, L., A. Gugiatti and L. Pedrotti. 2016. Spring spotlight counts provide reliable indices to track changes in population size of mountain-dwelling red deer *Cervus elaphus*. *Wildlife Biology* 22:268-276.
<https://doi.org/10.2981/wlb.00244>

Annex 4 – French study site: The Bauges National Hunting and Wildlife Reserve

Author : R.N. Simon

Site location

The Bauges National Hunting and Wildlife Reserve (hereafter called simply Bauges Reserve or Reserve) is located in the eastern part of the Bauges massif in the Savoie (74% of the Reserve's area) and Haute-Savoie (26%) departments in the northern French Alps (Fig. IV.1). The Reserve is located within the Bauges Massif Natural Regional Park and covers 5214 hectares over the territory of 14 municipalities.

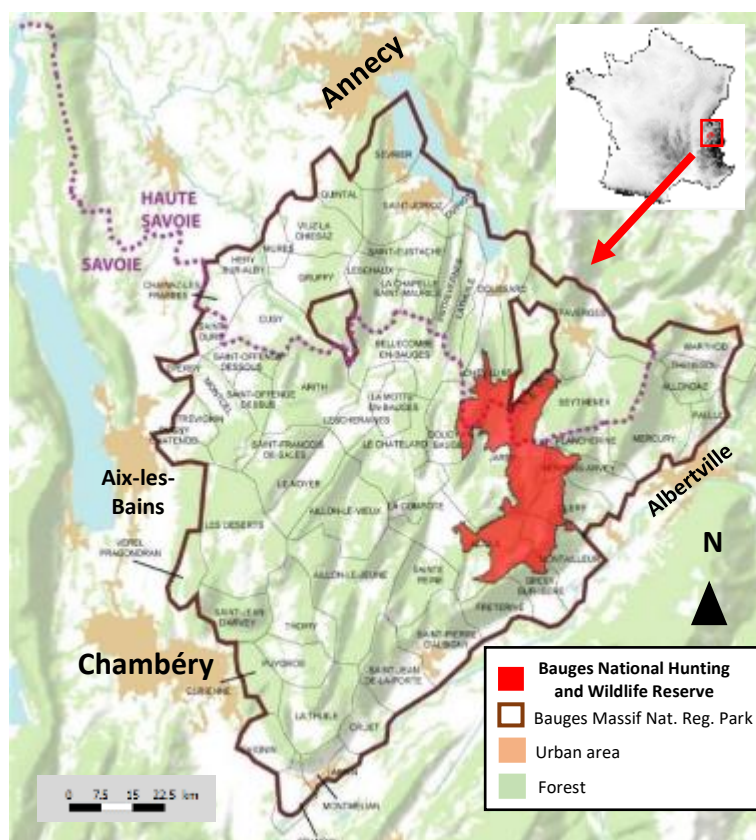


Figure IV.1. Location of the Bauges National Hunting and Wildlife Reserve within the Bauges Natural Regional Park in the northern French Alps. Modified from “Plan de Gestion de la Réserve Nationale de Chasse et de Faune Sauvage des Bauges” (2014).

Habitat configuration

The climate in the Reserve is humid and cool, characteristic of the pre-Alpine massifs which form one of the first barriers standing in the way of oceanic disturbances, resulting in heavy rainfall, generally distributed evenly throughout the year. Indeed, precipitation is among the highest in France, around 1400 mm per year, with a high proportion of snow for 3 to 5 months. The average annual rainfall is between 1100 and 1900 mm. The average annual temperature is below 10°C,

influenced by a cold winter. The annual thermal amplitude can reach more than 50°C, between a minimum winter average of -20°C and a maximum summer average above 30°C. Snowfall can occur from October to May and represents a significant part of the annual precipitation (up to 50%).

Geologically, the entire Bauges massif is composed of limestone and is largely covered by karstic surfaces, resulting in a very rapid flow of surface water and a well-developed underground circulation of water. As a consequence, the surface hydrographic network is of relatively low density. Only three rivers drain the Reserve. The local geological context, dominated by limestone or marl-limestone substrates, as well as human uses and variations in altitude are the main factors determining the distribution of habitats. The Reserve hosts some of the highest peaks in the massif, including the Arcalod that culminates at 2217 m above sea level (Fig. IV.2A).

The habitat (Fig. IV.2B) is dominated by beech woods (*Fagus* spp.), which cover about 25 km² and thus roughly half the total area of the Reserve (52 km²). Other habitat types that are well represented are alpine and subalpine limestone grasslands (about 12 km²), mountain hay meadows (3 km²), vegetation of continental limestone cliffs (2 km²), alpine limestone scree (2 km²), alpine and subalpine megaphorbia (1.5 km²), and subalpine thickets and tall grass communities (1.4 km²). 92% of the habitat of the Reserve is considered of conservation interest under the EU Habitat, Fauna and Flora Directive of 1992.

Wolf presence and diet

Sporadic signs of wolf presence (tracks and scat) in the Bauges massif in general and in the Reserve in particular have been observed intermittently since the early 2000s, with a peak occurring during 2008 and 2009 followed by a relative decrease during the 2010s. In 2020, however, clear signs of wolf presence were again observed frequently, and reproduction was eventually confirmed by provoked howling in the summer of 2021, providing evidence for the establishment of a pack. Since then, signs of wolf presence continue to be regularly collected in the Reserve and surrounding areas (Fig. IV.3A), particularly by camera traps in the Bellevaux valley in the south-west part of the protected area (Fig. IV.3B). This tool has allowed local stakeholders to most notably monitor the number of wolves in the pack, with a peak of eight individuals being recorded in November 2021.

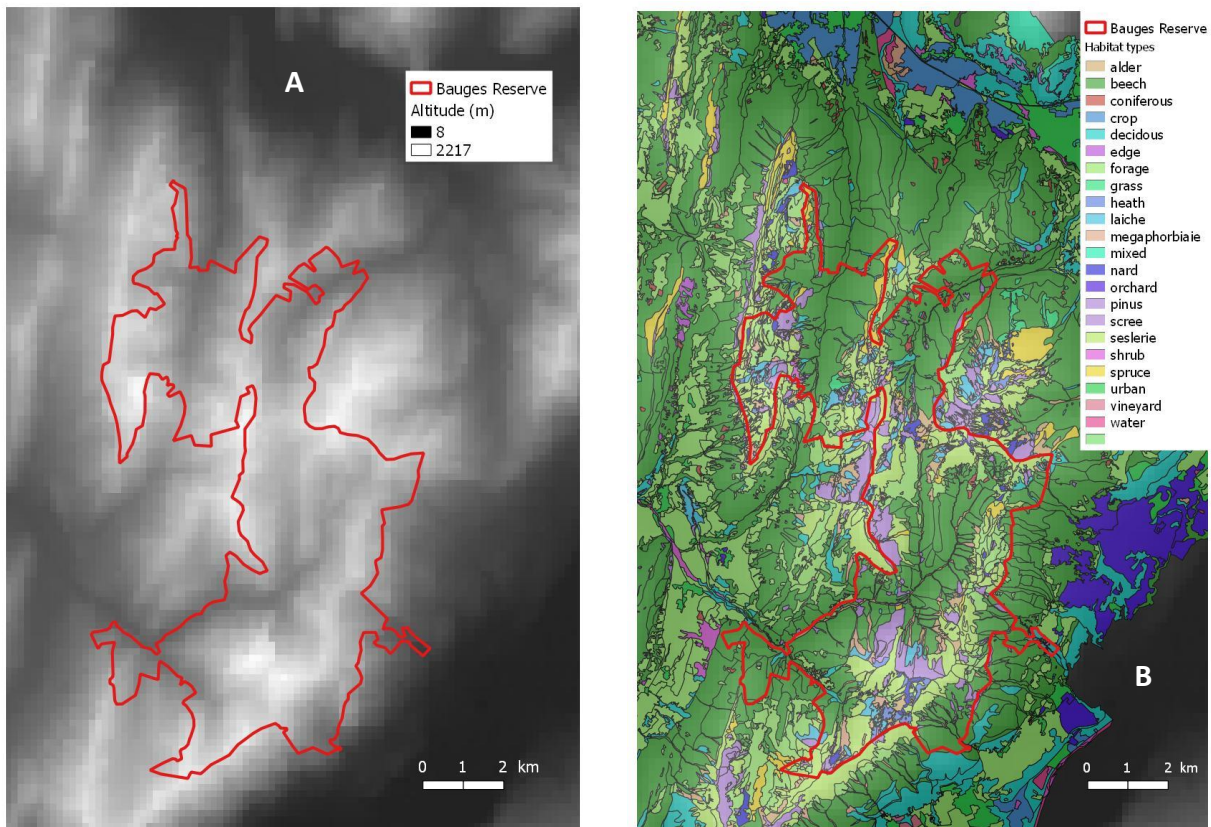


Figure IV.2. Habitat configuration of the Bauges Reserve : A) Altitude above sea level, and B) habitat (vegetation) types.

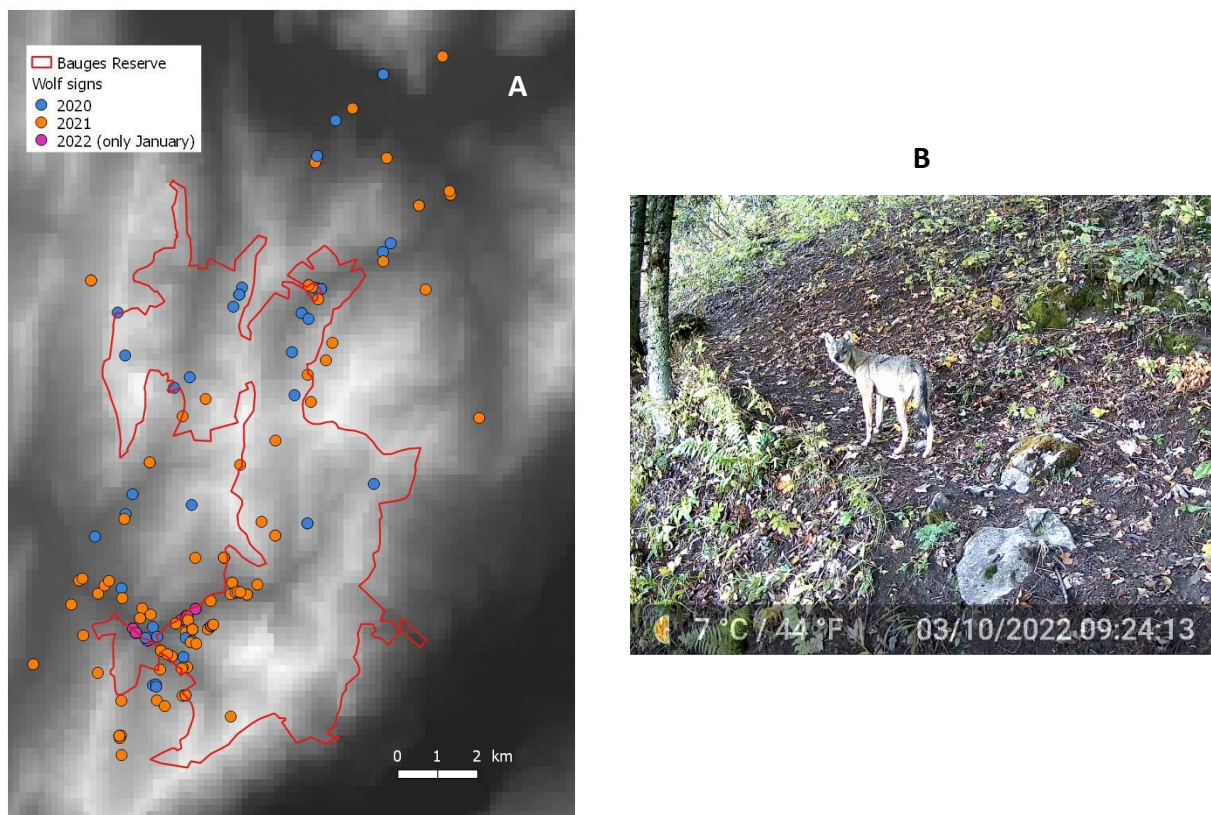


Figure IV.3. Signs of wolf presence in the Bauges Reserve: A) distribution of wolf signs observed in the Reserve and surrounding area from 2020 to January 2022, and B) a local wolf captured by a camera trap in October 2022 (image courtesy of the Bauges Massif Natural Regional Park).

Due to the fairly recent establishment of the pack in the Reserve, little to no information is available on their diet, although some anecdotal and correlative evidence (see the next section) suggest that the local mouflon population is currently an important source of prey. One objective of action C3 will be to characterize the diet of the local pack. However, it is important to note that although the pack's territory is clearly not limited to the Reserve (Fig. IV.3), local constraints mean that most if not all activities of action C3 will need to take place only within the confines of the protected area.

Wild ungulate presence

The Bauges Reserve is an exceptional site for the study of wild ungulates because of the diversity of species present in the area and because scientific research has been conducted there on this group of animals since 1985.

Chamois

Chamois are found throughout the Reserve, and mostly in the alpine and subalpine habitat. The abundance of this species in the Reserve is currently stable, despite some spatial and temporal variability observed in validated count indexes (Fig. IV.4A). This situation is typical of a population under density-dependent conditions (i.e., the number of individuals in the population is close to the maximum allowed by resources). Accordingly, the weight of individuals (an index of individual performance) and their index of reproduction both currently exhibit a downward trend (Fig. IV.4B and 4C). For the purposes of scientific research, the population is managed so as to maintain it in a state of density-dependence. With this objective in mind, every year about 100 chamois are harvested and between 30 to 60 are captured and fit with GPS collars.

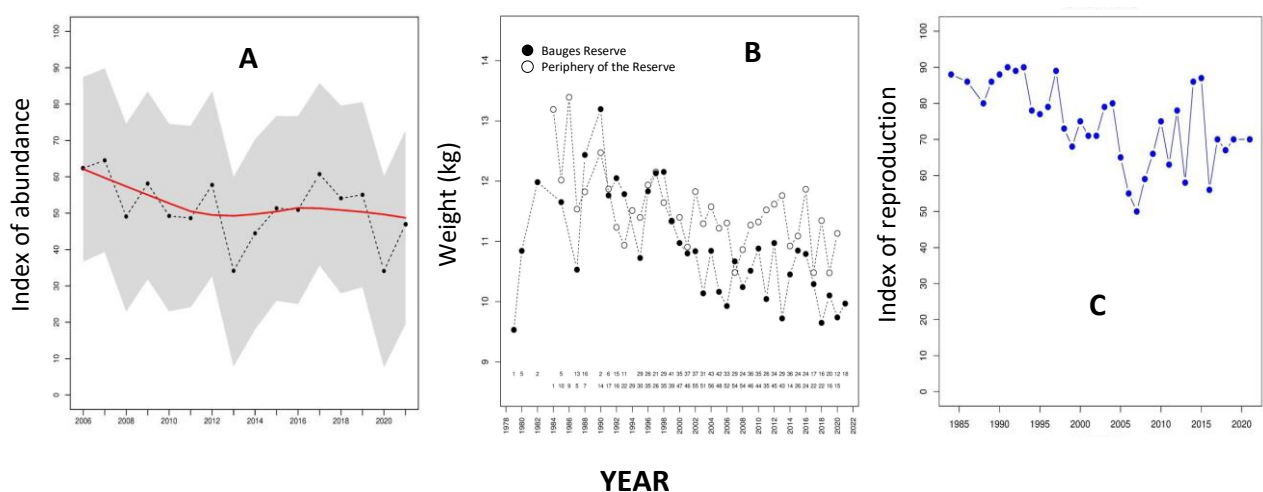


Figure IV.4. Temporal trends in demographic data for chamois in the Bauges Reserve: A) Index of abundance, B) index of performance (weight) and C) index of reproduction. Trends in these figures indicate a population under density-dependent conditions.

Mouflon

This non-native ungulate was introduced in the Bauges massif by hunters in the mid-1950s. Today it occurs throughout the Reserve, but with a marked expansion of their area of distribution during winter as compared to summer (Fig. IV.5). Although analysed through the use of a currently non-validated index, abundance of the adult component of the population appeared stable over 2006-2021 (Fig. IV.6A). A downward trend is nevertheless observed from 2020 to 2021 which might be related to wolf predation and/or harsh meteorological conditions. Forestry agents have indeed found a significant number of wolf-consumed carcasses of mouflon during the last two winters (personal communication). An alternative index of abundance, validated for the species but used only since 2018, suggests a significant decrease in the number of mouflon (in this case, both adults and young) in 2021 (Fig. IV.6B). Accordingly, the value for the index of mouflon reproduction observed in 2021 was among the lowest since the 1980, although this parameter is highly variable across years (Fig. IV.6C). Given this situation, it has been decided to reduce the number of mouflon hunted in the Reserve by 25 to 30% (40 to 50 individuals). A handful of individuals are captured and collared every year.

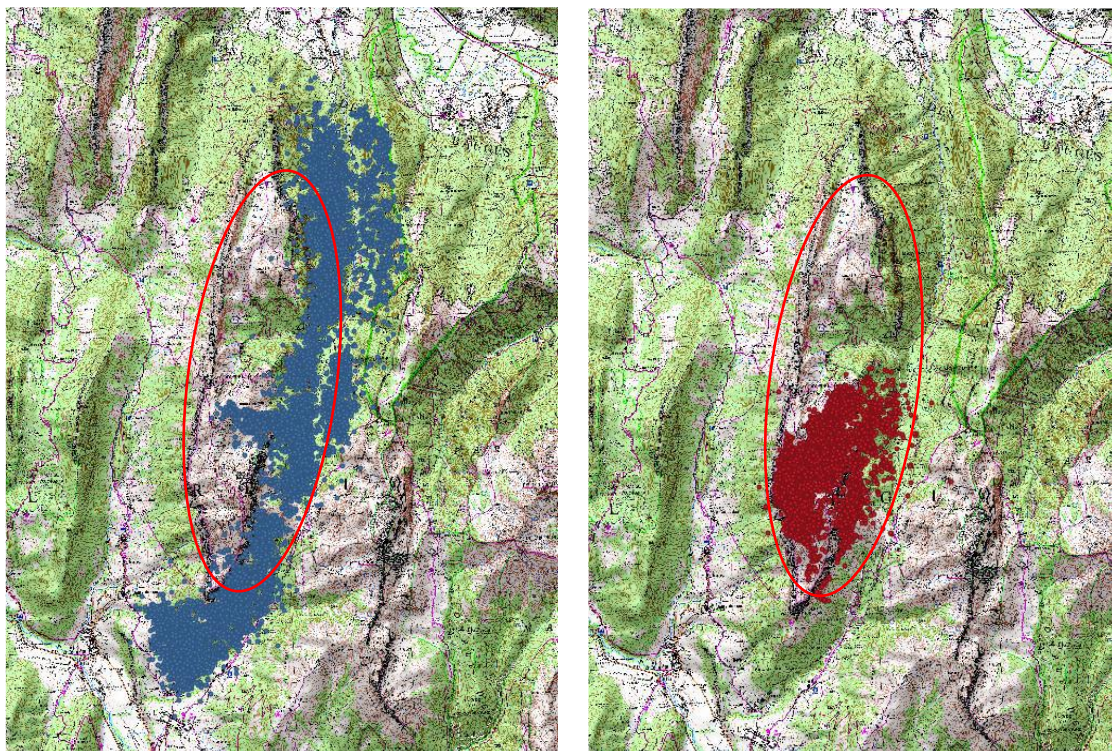


Figure IV.5. Mouflon distribution in and around the Bauges Reserve in winter (December to March, in blue) and in summer (July and August, in red), showing how the population expands its home range during winter. The red ellipse roughly indicates the boundaries of the Reserve. Points are locations of animals equipped with GPS collars.

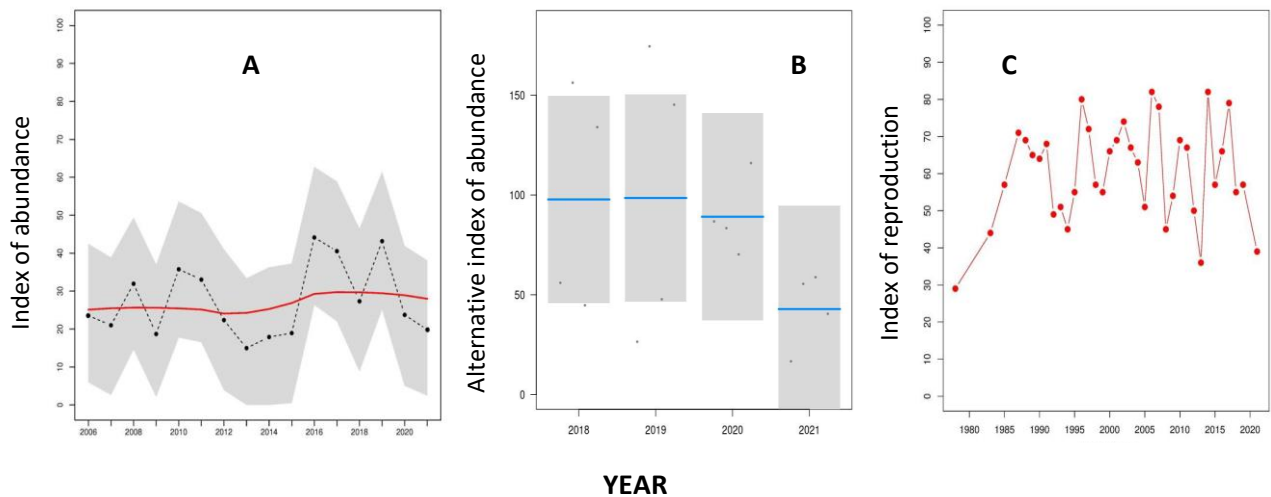


Figure IV.6. Temporal trends in demographic data for mouflon in the Bauges Reserve: A) index of abundance (non-validated) for the adult component of the population, B) an alternative, validated index of abundance for both the adult and young components of the population, and C) index of reproduction.

Roe deer

There are little to no data on the distribution of roe deer in the Reserve and in the Bauges massif in general. Nevertheless, abundance of the species is considered to be relatively low but possibly on the rise at both scales (Fig. IV.7A and 7B). Because the Bauges Reserve is the reference site to study roe deer in a mountainous environment (as opposed to animals living in low lying, relatively flat areas), hunting of the species in the Reserve is kept at a minimum (only 3 to 5 individuals a year). A handful of individuals are captured and fit with GPS collars every year, but since the establishment of the wolf pack, several (3 out of 5) have been predated by wolves (Fig. IV.8). One objective of Action C3 is to increase the number of roe deer captured and collared in the Reserve.

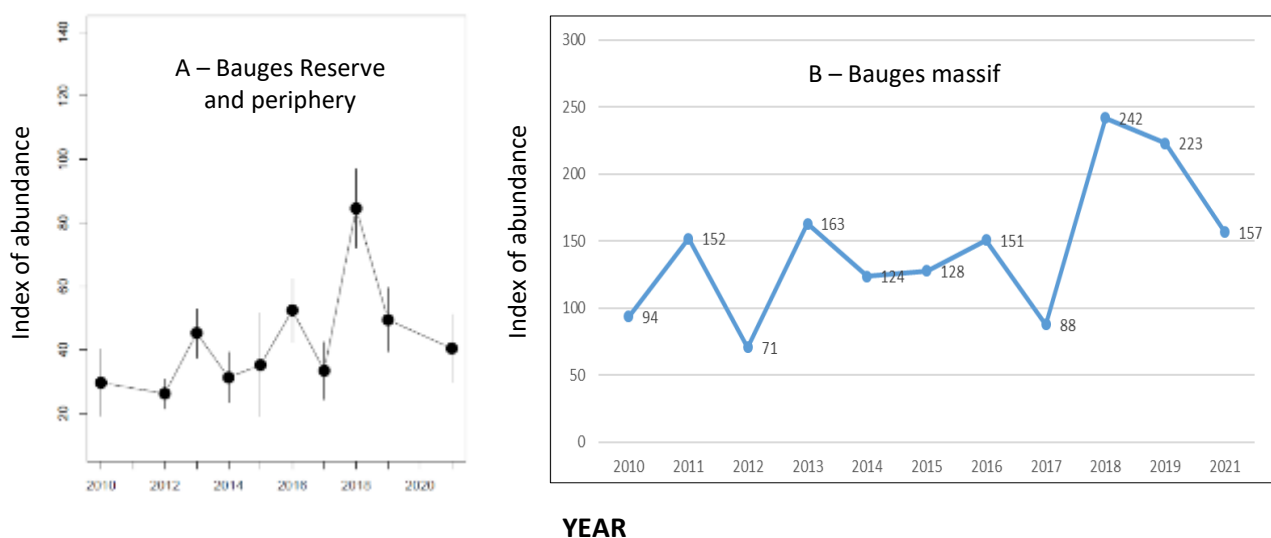


Figure IV.7. Temporal trends in the indexes of abundance for roe deer in the Bauges Reserve and periphery (A), and in the wider Bauges massif (B). Both indexes were obtained through line transect counts.



Figure IV.8. A roe deer captured and GPS-collared in the Bauges Reserve in early 2021 and that was predated by wolves only a few days later.

Red deer

As for roe deer, little information is available about the distribution of red deer in the Bauges massif. Local abundance in and around the Reserve appears to be decreasing, although this trend is not observable at the scale of the massif (Fig. IV.9A and 9B). This downward trend in and around the Reserve could be partially explained by the management objective of keeping the species at a low density in the protected area. Hunting bags have therefore been kept relatively high (12 attributed animals/year) since 2015.

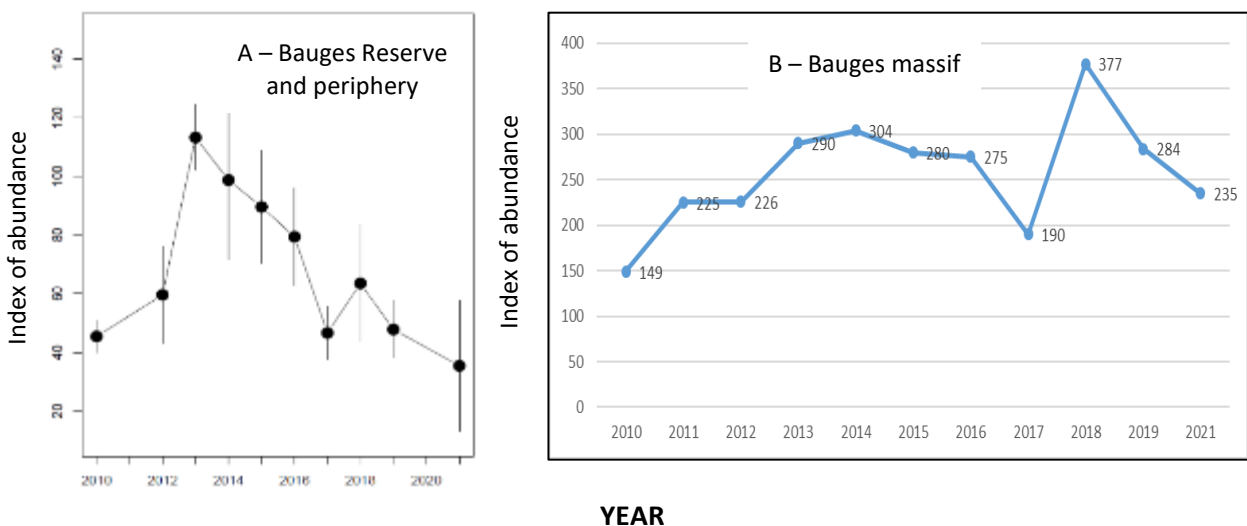


Figure IV.9. Temporal trends in the indexes of abundance for red deer in the Bauges Reserve and periphery (A), and in the wider Bauges massif (B). Both indexes were obtained through line transect counts.

Wild boar and ibex

No data is available on wild boar distribution and abundance in the Reserve or the massif. However, anecdotal observations suggest their presence in the Reserve might be increasing (personal

communication). Ibex are currently not present in the Bauges massif after a reintroduction programme was put indefinitely on hold.

Livestock presence and prevention systems in use

Contrary to most other areas of wolf presence in France, livestock bred outdoors in the Bauges Reserve and massif are mostly cattle instead of sheep and goats (although these domestic animals are not entirely absent). The mountain pastures of the Reserve are divided into twelve pastoral units comprising 713 ha (14% of the surface area of the Reserve) (Fig. IV.10). Two are currently not exploited, mainly due to lack of infrastructure. All the pastures of the Reserve are grazed extensively by cattle (heifers, dairy cows or dry cows) during the summer, except for one pasture which also hosts goats and sheep.

For breeders, one of the main economic advantages of the pastoral activity is the transformation of milk into cheese (“AOC Tome des Bauges”). The mountain pastures of the reserve are vital to the farms that use them, as the local transhumance of the herds of heifers onto these areas during the summer make it possible to free up other fodder surfaces for the feeding of dairy cows or for the constitution of fodder stocks for winter. Local breeders are small operators who often have difficulty finding accessible mountain pastures, demand being greater than supply in the sector.

No information is available on the use of preventive systems against wolf depredation in the Reserve. However, preventive measures are unlikely to be currently in use given the recent establishment of the wolf pack and the fact that most livestock grazing in the Reserve are cows, for which no public funds are available to finance protection against depredation. Field observations by LWA EU staff tend to confirm that preventive measures are not used: all cow herds observed in the Reserve during captures of chamois and roe deer were free-ranging and unattended by people. Wolf depredation has been reported on cows in the massif, although there is controversy over to what extent. It is currently unknown if the few sheep and goat herds in the area benefit from preventive measures.

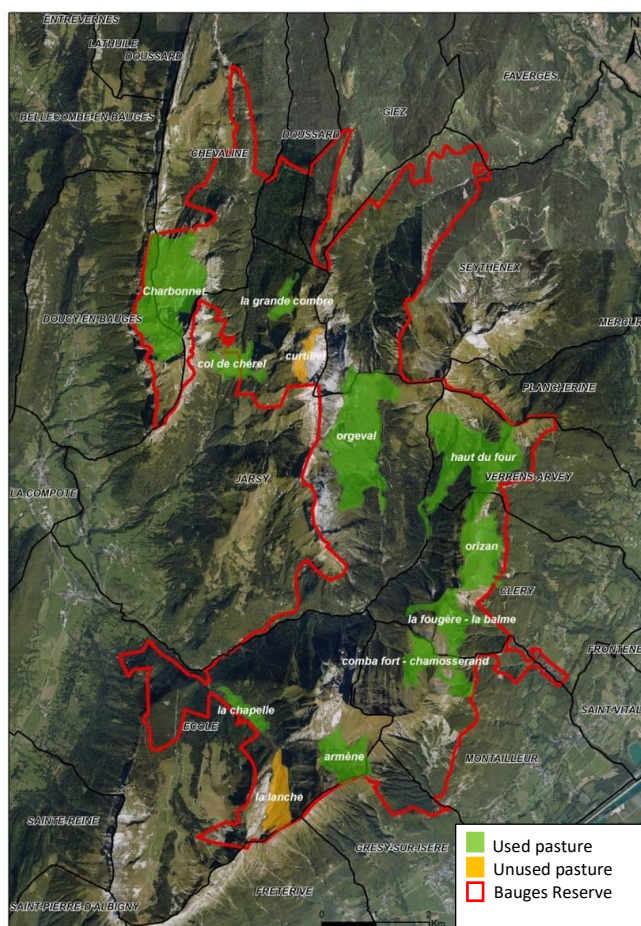


Figure IV.10. Location of the summer pastures in the Bauges Reserve. Modified from “Plan de Gestion de la Réserve Nationale de Chasse et de Faune Sauvage des Bauges” (2014).

Hunting regime

The very existence of the Bauges Reserve is closely linked to the conservation of game species and hunting activity, and, as such, chamois has been and still is the emblematic species of the area. Yet even though the establishment of the reserve initially responded to requirements for the conservation of chamois, current hunting objectives and practices have evolved significantly, in particular through the direct contribution of hunting to scientific research conducted on mountain ungulates and through the development of hunter training programs. Hunting in the Reserve today meets multiple objectives: 1) contribution to scientific research on wild ungulates, 2) maintenance of an equilibrium between hunting, agriculture and forestry, and 3) implementation of a hunting management model based on the involvement of local hunting societies, in a coherent approach at the scale of the massif.

The OFB and the French Forestry Agency (ONF) hold the hunting rights in the Reserve, the ONF for public forests, the OFB in other areas where it leases hunting rights to private landowners. The ONF is responsible for hunting management in the Reserve. An assessment of the hunting exercise of the

previous season is carried out annually during the Reserve's steering committee. A harvesting proposal is then made for the following season, based on various indicators of the population dynamics of the species of interest. Once validated, the proposed plan is forwarded to the hunting plan sub-committee (a structure operating at scale of the massif), and finally to the Departmental Commission for Hunting and Wildlife.

The practice of hunting brings together very diverse actors who may have significantly different perceptions of the Reserve and its objectives. Four types of hunting actors can be found hunting in the Reserve:

1. Hunting trainees. The ONF is the structure in charge of organizing hunting training programs in the Reserve (technical/discovery, bow, and young hunter programs). ONF and OFB field agents are in charge of supporting and mentoring the trainees. These training programs are important activities in the Reserve, since through the various courses offered, they account for a substantial percentage of the animals harvested every year. For example, nearly 63% of the chamois hunted during 2010-2011 and 2011-2012 were harvested during these events. **Courses all include a time of theoretical and practical training, and since the autumn of 2022, LWA EU staff have participated by providing information and debating wolf ecology with trainees.**
2. Guests from the ONF and the OFB. As holders of hunting rights, these structures can grant guests the right to hunt in the Reserve.
3. Local hunters from the Bauges Hunting Interest Group (GIC). Founded in 1982, this group is composed of 23 hunting societies (local associations and private hunts) operating in and around the Reserve. An agreement between the co-managers of the Reserve (see next section) and the GIC allows the members of the latter, under certain conditions, to hunt in the Reserve, in exchange for their active participation in the monitoring and scientific research carried out on wild ungulates outside the Reserve.
4. Private hunters. Owners of private land in the Reserve rent their hunting rights from the OFB in the form of chamois, mouflon or deer allocations.

It should be noted that the Savoie and Haute-Savoie Hunter Federations have no particular role in the management of the reserve. They benefit from a preserved territory with low hunting pressure, from knowledge obtained through scientific research carried out in the Reserve, and from participating in the training program for young hunters. The Bauges Massif Natural Regional Park, as co-manager of the Reserve, intervenes little in hunting aspects.

Only the hunting of wild ungulates is authorized in the Reserve. Chamois is the most widespread species, and therefore the most hunted, followed by mouflon, wild boar and roe deer. The only type of hunting authorized is stalking, which must be practiced with an accompanying hunter or guide (members of the GIC are also subject to this rule). This mode of hunting guarantees the selective removal of individuals, and is the only type of hunting that can be practiced in the steep terrain that characterizes most of the Reserve.

Land management and other human activities

Land in the Reserve is composed of public forests managed by the ONF or the Savoie department, as well as private land and land owned by the OFB (Fig. IV.11). The Reserve is co-managed by the ONF, the Bauges Massif Natural Regional Park and the OFB. The legal framework is rather complex as several texts from the municipal to the national level apply. Nevertheless, the current management plan is based on:

1. Conserving and managing the biodiversity of the Reserve through hunting and other activities to ensure an adequate balance between wildlife and humans, notably through the training of hunters;
2. Pursuing scientific research to better understand the population dynamics of wild ungulates (chamois, mouflon, roe and red deer) and their impacts on the vegetation and ecosystem functioning, as well as on the monitoring of galliformes and the management of their habitat; and
3. Raising public awareness and promoting respect and information about wildlife and its habitat.

Reference document: Amand, B., Duprez, C., Michel, G. and Lutz, M. *Plan de Gestion de la Réserve Nationale de Chasse et de Faune Sauvage des Bauges*. Juin 2014. 168 pages.

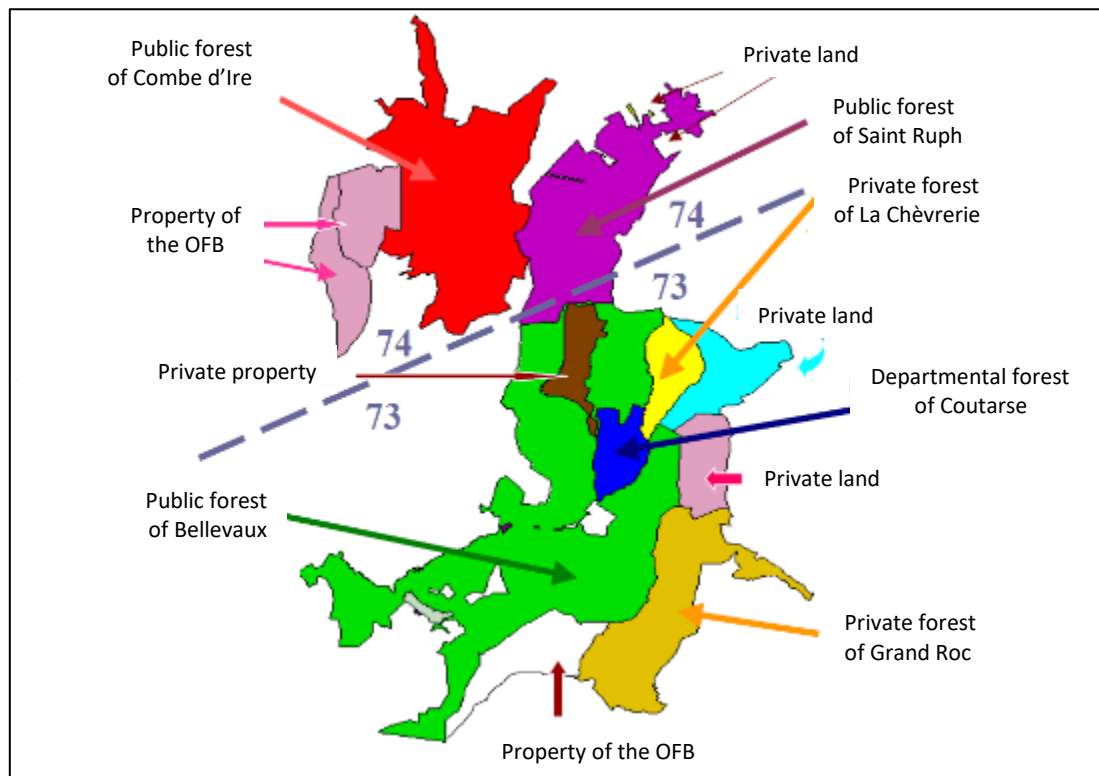


Figure IV.11. Land ownership in the Bauges Reserve. 73: Savoie, 74: Haute-Savoie. Modified from “Plan de Gestion de la Réserve Nationale de Chasse et de Faune Sauvage des Bauges” (2014).

Forestry is a major economic activity and about half of the forested area in the Reserve is exploited, mostly by the ONF since the majority of the forest is of public ownership. Five public forests occur in the Reserve (Fig. IV.11). They are managed to meet ecological criteria (varied habitat types favourable to floristic and faunal biodiversity, maintenance of forest cover), landscape and tourism expectations (a "natural" aspect) and economic factors (timber quality and diameter). In 2011, only 1% of the forest surface of the Reserve was exploited, with sales of wood representing a volume of 2266 m³ and generating 122 763 € in revenue, or an average of 54 €/m³.

Tourism in the Reserve is also an important activity given the presence of a rich fauna and an unspoiled and dramatic landscape which is a strong point of attraction for visitors and local people alike. The main tourist activities in the Reserve are hiking, mountain biking, horse riding, skiing, rock climbing, free flying (delta and paragliding) and fishing. The number of visitors to the Reserve has increased in recent years, particularly following the COVID-19 episode. One of the objectives of research recently and currently undertaken in the Reserve is to better understand the impact of tourist activities on the behaviour of wild ungulates.