Progetto LIFE18 NAT/IT/000972 - LIFE WolfAlps EU
"Coordinated Actions to Improve Wolf-Human Coexistence
at the Alpine Population Level"

Action C6 – Decrease Habitat fragmentation
and wolf traffic mortality through recovery
of identified sink areas

Technical report

Evaluation of previous studies and new data collected to identify corridors used by wolf in Susa Valley (Turin- Italy)

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Table of contents:

INTRODUCTION

The presence of wolves on the Western Alps is a consolidated reality for more than 20 years, and it's a result of the slow natural expansion of the Italian wolf population, still underway in the Central-Eastern Alps (Marucco et al. 2018).

In Italy, especially thanks to the legal protection granted to the species in 1971 (Boitani, 1982) and substantial changes in mountain areas ecology - such as the increasing of forest cover, the increasing of wild ungulates populations, the abandoning of rural areas, etc. - the wolf Italian population enhanced numerically, recolonizing the areas where the species was extirpated in the previous century, owing to its natural dispersal capacity (Boitani, 2003). Wolf is nowadays protected under various European laws in the field of wildlife conservation, such as CITES (Appendix II), Berna Convention (Attached II) and Habitat Directive 92/43 CE (Attached D).

Various studies confirmed that wolves of the Italian residual population naturally reached out the Western Alps though the Northern Apennines corridor in the '90 (Poulle et al., 1995; Marucco, 2009; Lucchini et al., 2002; Valiere et al., 2003). Fabbri et al. (2007) demonstrated genetically the Apennine origin of the western alpine wolf population.

During the last 20 years alpine wolf population had been the object of two main previous campaign of monitoring and research. The first Project "Wolf in Piedmont" was carried out under the European Initiative INTERREG II Italy – France (1994-1999) and continued until 2012 with regional funds. The LIFE WOLFALPS Project, co-financed by the European Union, under the LIFE + 2007-2013 "Nature and biodiversity" program, implemented the first alpine monitoring strategy, at the national level, involving 10 Italian partners, two Slovenian partners and many supporters, to manage the species via coordinated actions aimed to its long-term conservation in the Alps (https://www.lifewolfalps.eu/archivi/2013-2018/).

Nowadays, LIFE WolfAlps EU (2019-2024) was funded to improve wolf-human coexistence through a participatory approach, and to guarantee the long-term conservation of the cross-border wolf alpine population (https://www.lifewolfalps.eu/en/).

Under the LIFE Project the C6 Action is targeted to decrease habitat fragmentation and traffic caused wolf mortality through recovery of identified sink areas, in Upper Susa Valley (Province of Turin - Western Italian Alps) which represents the study area of this Action.

In North Western Italy, the main causes of wolves' mortality have an anthropogenic origin (direct or indirect persecution), and the most frequently documented one, from the winter 1998-1999 to the winter 2017-2018, is caused by collisions with vehicles (train or cars) (Marucco and Avanzinelli, 2018).

This phenomenon is particularly relevant in Upper Susa Valley (Western Italian Alps), where wolf presence is stable from 1997 when the Turin's Province first pack settled into the area (Bertotto and Luccarini, 1999). In this alpine territory (560 km2) high naturalistic value areas and many anthropogenic elements are present. In fact Susa Valley has a dense network of road infrastructures - which develops linearly along the valley (Frejus Highway A32, the Turin-Modane

Railway and the high-speed roads s.s 24 and 335) -, important ski areas (extended for about 1500 km^2) and urban settlements characterized by high touristic vocation, e.g., Bardonecchia, Oulx, Cesana, Sauze d'Oulx, Salbertrand (the detailed description in Cap. 1 "Territorial analysis of the study area"). All these features make Upper Susa Valley a particularly complex territory for wolf conservation, in fact, 53 episodes of accidental mortality due to wolf-vehicle collisions on the linear infrastructures were documented during the period 2001 and 2020.

The linear infrastructures network in Upper Susa Valley is especially along the valley bottom, where two main roads (SS 24 and SS 335), the Turin-Modane railway line and the Frejus Highway (A32) develop in parallel and side by side.

As mentioned above, this Alpine area has been stably occupying by wolves for 2 decades; in particular, the previous monitoring campaigns highlighted that 3 wolves packs gravitate in Upper Susa Valley (Marucco and Avanzinelli 2010; Marucco et al. 2012; Marucco et al. 2018), and each territory extend on both sides of the Valley, but they are fragmented by the linear infrastructure's development.

Wolves packs defend a large territory (99-241 km^2) (Okarma, 1998) through long movements by patrolling and odorous marking (Mech and Boitani, 2003), and they can easily cross roads and highways as documented by many studies (e.g. Boyd and Pletsher, 1999; Ciucci et al., 2009). In fact, a single road is not usually identified as a barrier for wolf dispersal. In Italy wolves are often killed by car accidents (Lovari et al., 2007), especially if they settle a territory in a region with a high road density, such as in Upper Susa Valley (Avanzinelli et al. 2007). In particular, in the study area, wolves show a neutral winter spatial behavior towards the linear infrastructures, which develop in parallel along the Valley bottom (Perrone, 2017). The landscape spatial configuration forces wolves to cross frequently roads and railway, where they are permeable, increasing the possibility that animals attempt to cross them sequentially, incurring the risk of being run over by vehicles (Fritts et. al., 2003). Upper Susa Valley, as far as highly fragmented by linear infrastructure, offers enough suitable habitat (Perrone, 2017) and wild ungulates high densities (Carnevali et al. 2009), allowing wolf' packs stay along the years. Marucco (2011) documented that not just the road density is a variable negatively related to wolf presence, but also human settlements, low forest cover and high rock elevation presence (Marucco, 2009).

Roads can even ease, territorial reconnaissance (Musiani et al., 1998; Whittington et al., 2005; Eriksen et al., 2009) optimizing hunting success, above all in winter, when the snow height affects wolves' spatial behavior (Whittington et al., 2011).

Although this western alpine sector is generally considered a "source area"[1] for the alpine wolf population, due to the wolf packs reproductive success and their stability, it can be considered in parallel a "sink area", because of the high and long-lasting number of road and railway line accidents involving the species (Marucco et al., 2018b).

The road and railway mortality issue in the C6 study area have not just involved wolf, but other teriofauna species too, above all cervids (roe deer and deer) (Avanzinelli et al., 2007); this issue is particularly alarming all over the Province of Turin as documented by recorded data of the Protection Wildlife and Flora Service - Province of Turin and by (2012) and all over the Piedmont

1 Source–sink dynamics is a theoretical model used by ecologists to describe how variation in habitat quality may affect the population growth or decline of a population (Gotelli 1998), such as, in this case, the wolf alpine population.

Region (Airaudo et al., 2008), above all as far as Oulx and Salbertrand Municipalities are concerned.
In addition to loss of biodiversity and wildlife conservation problem road accidents involving wildlife have economic and social costs, in effect damages to vehicle are generally consistent above all when big size species are involved (such as ungulates or great carnivores). In Piedmont, the Regional Wildlife Observatory estimated that damages can amount to 2900 € in case collision with wild boar, 2800 € with deer, and 1800 € when the involved species is a roe deer and, within the same Region, the recorded damages to persons and vehicles during the period 1993-2002 amounted to 2.909.639 € and 1.600.000 € during the period 2000-2004 (Picco, 2005).
Nowadays, the necessity of the implementation of mitigation measures for reducing the wildlife road accidents phenomenon in Upper Susa Valley is undoubted and supported by different technical reports and researches (e.g., Avanzinelli et al., 2007; Airaudo et al., 2008; Marucco and Avanzinelli, 2010; Perrone, 2017; Marucco et al. 2018).
Ciabò et al. (2015) within the LIFE11 BIO/IT/000072-LIFE STRADE – Project (E1 Action) provided a best practice manual concerning the road impacts on biodiversity, suggesting the processing of the available georeferenced wildlife mortality data, to obtain an overview about the more susceptible zones to the phenomenon of wildlife-vehicles collisions, along the linear infrastructures. This approach, applied in this technical report, allows to find the main risk zones in the study area, to program some mitigation plans according to site-specific features. In fact, as also recommended in the manual, the implementation of a strategic plan, which includes intensive monitoring together with the planning of specific mitigation measures are indispensable for the conservation of endangered species such as wolf (Clevenger e Waltho, 2004; Clevenger e Huijser, 2011), even for increasing road safety too.
The most performing strategy to mitigate roads and railway lines impact on wildlife is the installation of crossing structures, where possible, built according to ecological criteria for species conservation (van der Ree et al., 2015) (e.g. green bridges, landscape bridges, eco-ducts etc), but much more often wildlife crosses roads exploiting multifunction crossing structures (Forman et al., 2003) such as viaducts, multi-span bridges over large riparian areas, or drains built for water outflow, etc., which have a structural function. In these cases, the multifunction structures ecological performance can be limited, just because they are designed and maintained according to their primary structural function (Smith et al., 2015). Nevertheless, some multifunction underpasses can be a cheap but effective strategy to increase the opportunity for wildlife to cross roads in security.
However different studies show that when crossing structures are designed for wildlife conservation, they are able to reset or reduce considerably road wildlife mortality, increasing habitat connectivity in areas fragmented by anthropogenic barriers (Huijser and McGowen, 2010; Connolly-Newman et al., 2013). These mitigation strategies gave encouraging results even for different species of large carnivores (Clevenger and Waltho, 2005; Kusak et al., 2009; Clevenger and Huijser, 2011).

This report gathers the available technical studies and previous research, offering a cognitive framework about habitat fragmentation, wildlife road mortality (above all as far as wolf is concerned as umbrella species) and identifying effective ecological corridors within the C6 study area. In the following chapters the document highlights the territorial features of the investigated area and provides some wildlife mortality risk maps where the implementation of mitigation measures is a priority. The comparison with the ongoing Life Safe-Crossing project (https://life.safe-crossing.eu/) will surely suggest useful practical recommendations for implementing actions to reduce the impact of roads on wolf as priority species, also in this case of study.

The LIFE SAFE-CROSSING project aims to reduce the impact of roads on some priority species, from the conservation point of view, in 4 European countries: the species involved are brown bear (Ursus arctos marsicanus) and wolf (Canis lupus) in central Italy, the Iberian lynx (Lynx pardinus) in Spain, and the brown bear (Ursus arctos) in Greece and Romania. Action C6 of our LIFE project can be considered complementary to the LIFE SAFE_CROSSING Project as they operate on different regional areas, the continental one and the peninsular one, and in different protection contexts (in the case of this study the areas do not belong to the Natura 2000 network , while in the other project we intervene on Sic in the area).

Finally, LIFE WOLFALPS EU project is not intended to implement knowledge relating to reduce the loss of fauna due to interactions with the road network, but has the purpose, in a sink defined area, to concretely reduce accidents.

The main goal of this report is to identify traits of high risk for vehicular collisions along road and railways where mitigation measures will be planned and implemented to reduce wolf mortality and reconnect the two sides of the valley, attenuating the ecological fragmentation caused by linear infrastructures.

1. Territorial analysis of the study area

1.1 - The territory: Upper Susa Valley

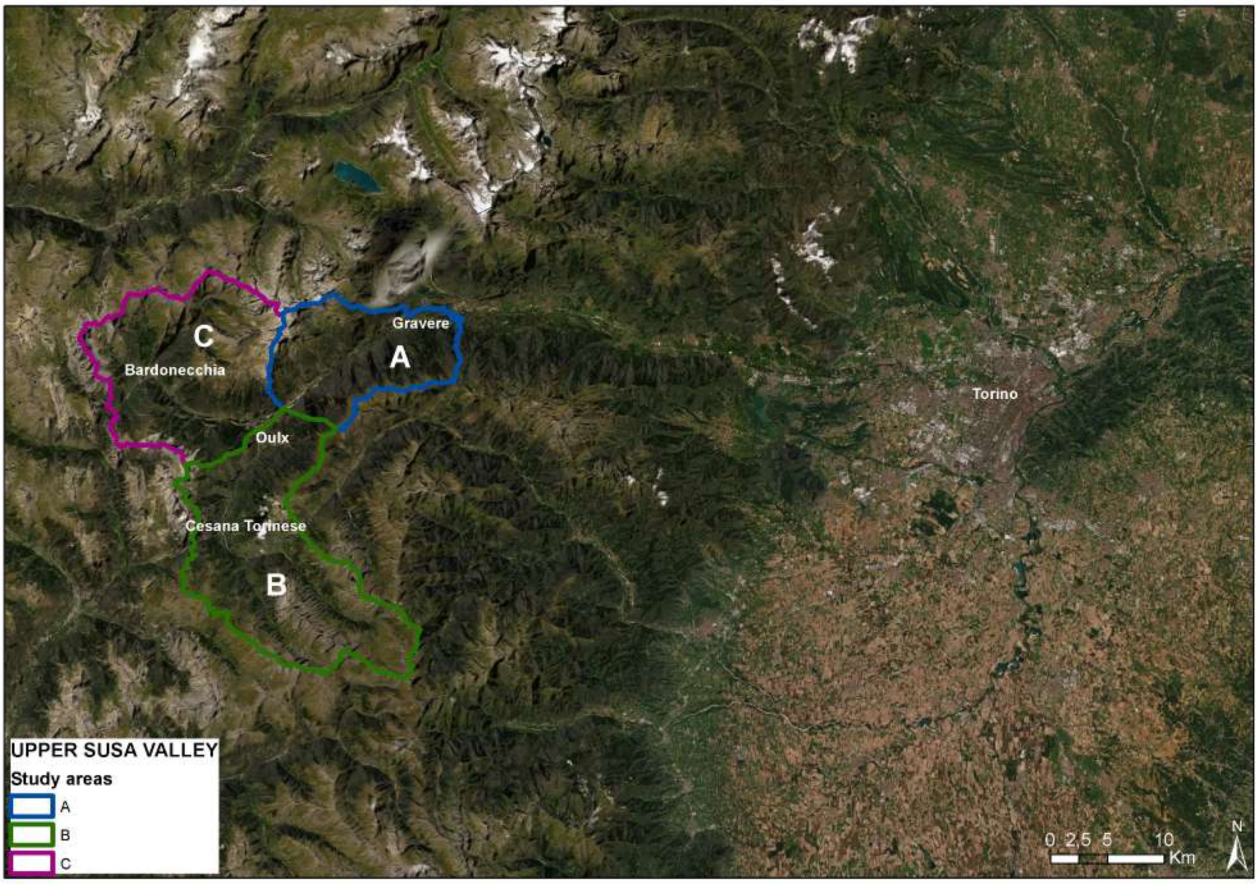
The study area is located in Upper Susa Valley, the main valley of the Cottian Alps, placed in the west side of the city of Turin (Piedmont, Italy); from an administrative point of view it falls within the territory of the Metropolitan City of Turin.

Figure1 – The location of the Metropolitan City of Turin in the Alps.

This study focuses on the upper part of the Susa valley, crossed by the many infrastructures subject to intervention, namely in the municipalities of: Bardonecchia, Oulx, Salbertrand, Exilles, Chiomonte, Gravere, Cesana and Claviere.

From a morphological point of view, the Y-shaped Susa Valley can be mainly divided into 3 different traits: from the lowland to the city gates of Turin, it widens with a flat valley floor until it reaches Susa (in over 40 kilometres approximately 100 meters of difference in altitude) then the Valley divides into 2 different sections, the Cenischia Valley and the Upper Susa Valley, which is clearly separated from the lower part for a remarkable difference in altitude (on a 1 air-line kilometer almost 300 meters of difference in altitude).

Figure 2 – Satellite images of Cottian Alps where it can be observed the development of the Susa Valley west of Turin. The study area is highlighted by colored lines.



The above-mentioned municipalities extend for 487 km² (Table n.1) and are characterized by a mainly forest cover with wide green areas dedicated to pastures and permanent grassland to testify the strong livestock vocation of the area.

Despite of slight variations occurring within the municipalities, the overall population has stabilized from 2011 to 2019; due to the amplitude of the territory, there is a concentration of only 20,66 inhabitants per Km² and the resident population, concentrated in Bardonecchia and Oulx, mainly occupies the settlement located on the valley floor.

During wintertime however, there is a considerable increase in tourism, due to the ski resort of Via Lattea (Sestriere-Cesana-Claviere-Sauze d'Oulx) and Bardonecchia ski: vehicular traffic increases along the main roads and at the same time highest number of fauna collisions is registered.

In 2018, the regional Tourist Observatory has registered in ATL (it includes Susa Valley and Pinerolese) more than 245.000 arrivals, which can reach 1.000.000 if we add daily tourist influx data. This daily tourism do not take advantage of the accommodation facilities and comes mainly from the nearby chief town of Turin, using infrastructural axis with a significant increase of vehicular traffic in the area. In conclusion, various elements may improve vehicular traffic in the area in this period, just when the greatest accidents are recorded.

Table n.1- List of the municipalities crossed by SS 24, SS 335, A32 and railway line Turin-Modane. (Source: ISTAT)

Municipality	**Area (km^2)**	**Inhabitants (2011)**	**Population Density (2011)**	**Inhabitants (2019)**	**Population Density (2019)**
Bardonecchia	132,2	3212	24,30	3129	23,67
Oulx	99,79	3160	31,67	3343	33,50
Salbertrand	38,32	579	15,11	631	16,47
Exilles	46,55	266	5,71	251	5,39
Chiomonte	26,76	932	34,83	887	33,15
Gravere	18,99	715	37,65	676	35,60
Cesana	121,7	1007	8,27	943	7,75
Clavière	2,69	192	71,37	204	75,83
Total	**487**	**10.063**	**20,66**	**10.064**	**20,66**

1.2 - The current linear infrastructures

Over the years, the conformation and the geographical position of the study area has led to a progressive reinforcement of the infrastructures related to the carriage of goods and people.
The whole communication lines – major and secondary – separate the two slopes of the Susa Valley, mainly crossing the valley floor, which is the natural habitat of this territory wildlife.
There are 4 main heavy-traffic lines, along with the rest of secondary lines: A32 Frejus highway, SS 24, SS 335 and the railway line Turin-Bardonecchia.
The study area can be divided in three main sections:

- ***Section A from Gravere to Salbertrand/Oulx***: in this section, the Valley is crossed by SS 24, A32 and the railway line. In particular, most of trajectory of A32 and the railway line goes through viaducts and tunnels. The first trait of the valley is very steep and thus the SS24 is characterized by a sequence of hairpin bends and the railway mainly runs throughout the tunnel; reaching the settlement of Gravere, the territory becomes flatter and the valley widens and maintains these characteristics until Chiomonte, the road runs more rectilinear and the railway is at the ground country level.
Upstream of Chiomonte, where the valley becomes narrower and the slope increases until it reaches the village of Salbertrand in Serre la Voute locality, the SS24 extends along the slope with

high retaining walls on the side and the railway runs mostly through tunnels except nearby the disused Exilles railway station.

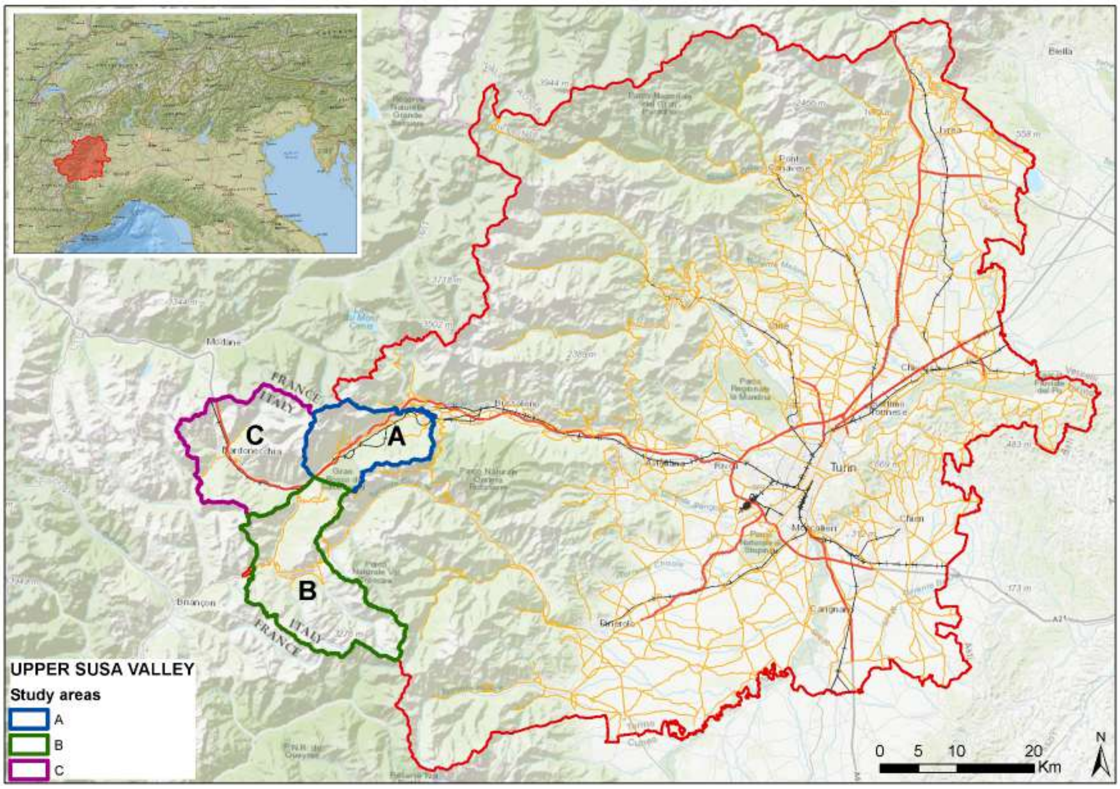
Starting from Serre la Voute (in an extremely strict point of the valley) the valley widens and becomes nearly flat until the boundary of the municipality of Oulx where it separates into Bardonecchia's Dora Valley (zone C) and Dora Riparia Valley (zone B); here the road runs rectilinear and the rails of the railway are at the level of the land surface. The highway develops along tunnels or in high viaducts until it reaches Serre la Voute, where, after the settlement, it proceeds at the ground level.

- ***Section B from Oulx to Claviere:*** This section is crossed only by SS 24, which represents the only way to reach France and Briancon. In particular, the trajectory between Cesana and Claviere mostly goes through tunnels, under the Chaberton Mountain. The first section between Oulx and Cesana is quite rectilinear and fast to travel, then, from the half, the trajectory starts to develop and in some points are present retaining walls; the higher stretch towards Claviere is more tortuous instead.

- Section C from Oulx to Bardonecchia: in this section, the Valley is crossed by the railway line, the SS 335 and the A32 highway, whose trajectory mainly goes through viaducts. The railway station mostly runs at the ground level and, when it reaches the Beaulard's settlement, it comes up beside to the SS335 until Bardonecchia.

Figure 3– A picture of the Upper Susa Valley between Beaulard and Oulx (a spatial section of the high- speed road A32. View from Sauze d'Oulx (picture by S.Perrone).

Figure 4- Linear infrastructure network in Province of Turin and the subdivision of the study area into the 3 reference areas.



1.2.1 - The A32 highway

The Frejus Highway is entirely extended in the territory of the Metropolitan City of Turin with a total length of 72,4 Km, connecting Turin with France. In total, it runs through 19 Km of viaducts and 18 Km of a four-lane tunnel. Half of the sink area related to this study is interested by this highway (32 km), between Gravere and Bardonecchia.

SITAF Spa oversees the management of the highway and of the Frejus tunnel and it also provides usage and access data of the infrastructure.

Between 2014 and 2019, there has been a sensitive increase of the number of vehicles passing though the A32 Salbertrand highway barrier, equal to +12,3% compared to previous years (www.sitaf.it)

Table 2 – Annual data on Salbertrand barrier passages. (source: www.sitaf.it).

Year	Salbertrand barrier passages
2019	3.791.989
2018	3.821.374
2017	3.742.644
2016	3.555.633
2015	3.488.266
2014	3.376.806

1.2.2 - Railway line

The railway line connects Turin to Modane, always through the Frejus tunnel, and its trajectory can be divided in metropolitan areas (between Bivio Pronda to Avigliana), lower valley area (between Avigliana to Bussoleno) and finally the upper valley area from Bussoleno to Modane.

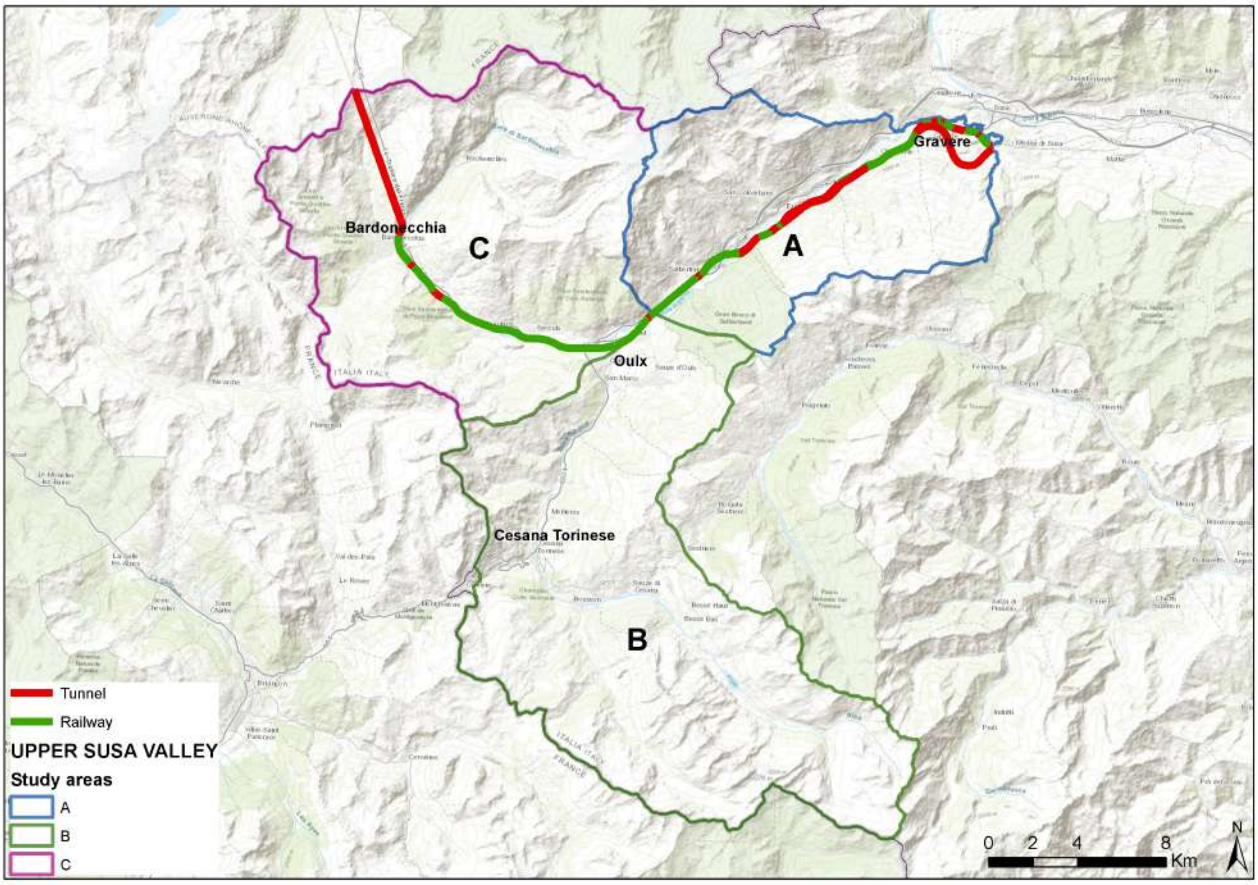
Their respective lengths are 17,6 km, 21,4 km and 59,4 km for a total of 98,4 km. In the last stretch Bussoleno-Modane, the difference in altitude between Torino and Modane is reduced. Right after Bussoleno's station, the railway line crosses the valley and starts climbing the steep mountainside. Between Bussoleno and Salbertrand, there are many tunnels to overcome the slope.

In 2018 RFI measured the transport capacity of the upper valley railway and of the tunnel; results shows that the traffic is 94 trains per day, however nowadays the Frejus traffic has not reached its highest capacity in relation to the estimates issued before the modernization process of 2011.

The railway line mostly develops through tunnels, mainly downstream (zone A), in the stretch between Gravere and Chiomonte and as well as from Chiomonte to Salbertrand.

Heading uphill, starting from Salbertrand up to Bardonecchia's settlement, rails run quite always at the land level, and subsequently, the railway line converges in the long Frejus' tunnel, which connects Italy to Modane (as it shown in the map below).

Figure 5 – Torino – Modane's Railway line, stretch between Gravere and Bardonecchia. Tunnel traits are highlighted in red while those at the ground level are in green.



1.2.3 - SS24 and SS335

SS24 and SS335 represent the most impacting state routes for wildlife in the study area.
Originally, state route SS24 was meant to connect Turin to the Italian French boundary and was totally managed by ANAS: starting from the chief town of the district, after intersecting the freeway, its trajectory was reaching Caselette, where the uphill way towards Susa Valley started, mainly flanked by the A32 highway.
Starting from 2001, after the issuance of the Legislative Decree No. 112/1998, the management of the state route had been modified: its first part between Turin and Susa was handled by the Province of Turin, whereas the rest (Susa-Claviere) remained under ANAS's responsibility.
The amendments established by the Decree also affected the route classification: between Turin and Susa, the SS24 was considered a provincial road (55,2 km), whereas the part between Susa and Claviere was classified as state route (40,9 km).
Starting from Susa, SS24 touches the municipalities of Gravere, Chiomonte, Exilles, Salbertrand, Oulx, where it intersects with the SS335 of Bardonecchia, and Cesana Torinese,). Overall, 41.5 km of SS24 and 12.4 km of SS 335 will be analyzed in this study
As far as vehicular traffic data, the SS24 registers an average of 5.530 passages per year of light vehicles and 313 of heavy vehicles (source: Anas, 2019).

1.2.4 - Turin – Lyon high speed railroad line

The project of the TAV (High speed train) was approved in 2001 and leads the construction of a railway line of 84 Km length (35,3 implemented in the Italian territory). Despite the many project revisions and the fact that it is still under initial development, it is expected to have the new line in substitution of the historical one who dates 1871.
Up to now there has been no additional railway traffic, but the expansion of the Chiomonte and Salbertrand sites will cause an additional movement of people and heavy vehicles are to be considered relevant for the purposes of this study.
In the current state of the environmental impact assessment analysis of the TAV construction site, it is expected to implement a processing area for the spoil coming from the excavation of the tunnel stored in the Salbertrand plain. The new construction site will be extended among the SS24, the railway station, the torrent Dora Riparia and the narrow passage of Serre La Voute. In this part of the valley, it has been documented the presence of wolves and ungulates: indeed, many accidents involving these species have occurred both on the SS24 and the railway line. For this reason, TELT, the enterprise in charge of the tunnel construction, has subscribed the supporting declaration of the LIFE Wolfalps Eu project and become available for a meaningful dialogue to improve the valley floor infrastructures permeability.

TELT commissioned a study to the Department of Life Sciences and Systems Biology of the University of Turin, in the vast area of Salbertrand to realize a protocol of monitoring species that could be affected negatively by future building site with a significant impact on their conservation status (Avanzinelli et al., 2020). Results of this winter wolf surveillance campaign (2018-2020) are mentioned in 2.3.

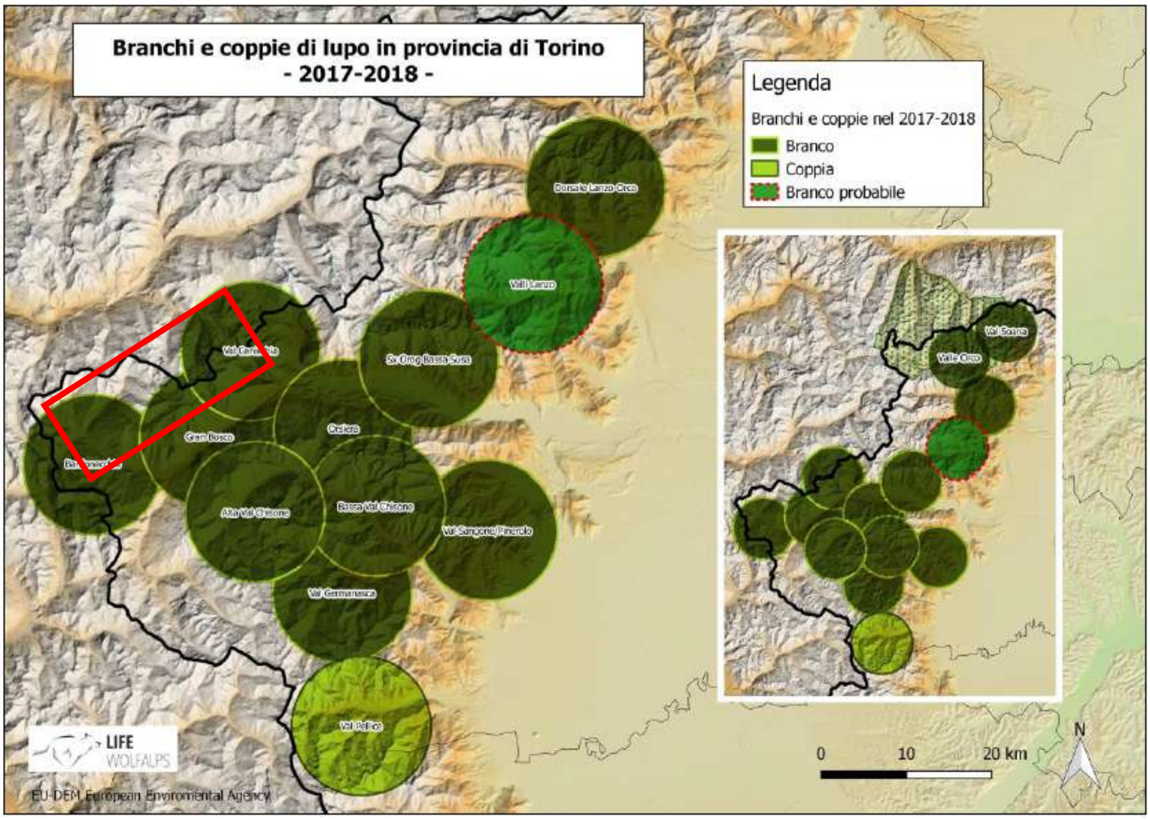
1.3 - The presence of the wolf and its preys

1.3.1 - Wolf Status and distribution

Wolf has been documented in the Susa Valley from 1997 when the first pack settled (Bertotto and Lucarini, 1999). Several Project has been conducted to monitor wolf presence and distribution in the study area: the first was financed by the then "Province of Turin", the second by "The Wolf in Piedmont" Project and the last by the European Community by LIFE NATURE project "WolfAlps". The first pack stabilized in Salbertrand area (Gran Bosco Natural Park and neighboring areas) between 1996 to 1997, the second one in the Bardonecchia area during the two-year period 2000/2001, and lastly the Orsiera pack during 2005/2006 in the lower part of the valley (Marucco et al., 2010).

As a result of the last monitoring season, occurred during 2017/2018, it has been documented 4 wolf packs in this part of Susa Valley: 2 of them - Orsiera and Val Cenischia - occupied a marginal part of the study area (Marucco e Avanzinelli, 2018).

Figure 6 – Packs and couple of Wolves monitored during 2017/18 in the Province of Turin (source: Marucco e Avanzinelli, 2018). Red line countered polygon identifies C6 Action Study Area.



A rich wild ungulates population and vast forest cover have permitted favourable conditions for stable wolf settlement over 20 year in Upper Susa Valley (Marucco et al., 2018).

Despite Susa Valley is highly attractive for wolf, immediately alarming data on the road and railway wolf mortality appeared. Indeed, as mentioned before, the valley is crossed by many linear high-

speed infrastructures which have caused a significant wolf mortality over the years: the first wolf anthropic cause of death in the Piedmont Region is due for traffic collisions (Marucco et al., 2018).
All data collected over 20 years confirm the presence of one "sink area", located in the upper part of the valley, which has progressively extended, reaching the lower part as well. A more elevated wolf mortality was documented, especially for young wolves of the settled packs and for dispersals coming from other packs. Susa Valley is an ecological trap for the packs that have their home-ranges in this sink area (Marucco and Avanzinelli, 2017). Wolf pack territories are fragmented by line infrastructures, that wolves are forced to cross to move from one side to the other of the valley (Marucco and Avanzinelli, 2018).
The enormous sampling effort and data collected in the Life WolfAlps project permitted to evaluate packs territory and composition present in the study area during 2014-2018 (Marucco and Avanzinelli, 2018); moreover, thanks to genetic analysis, in many cases it had been possible to trace the belonging pack of wolves found dead.
A coordinating action between Territorial Public Institutions of Piedmont and the University of Turin has been important to collected data on wolf mortality. This collaboration was formalized in the 2006 with the subscription of the " Recovery protocol of dead or injured wolves" signed various Institutions, such as Metropolitan City of Turin, Local Health Board-ASL, Cottian Alps Park-APAC, Forest Consortium Upper Susa Valley-CFVAS, Forestry Police-CUFA, Large Carnivore Center-CGC, The Department of Veterinary Sciences of the University of Turin, the Zooprophylaxis Institute-IZS, Maritime Alpls Park - APMA, Forestal Police (CUFA), with the aim of mutual collaboration and sharing data on wolf mortality and injuring.

1.3.2 - Wild Ungulates

Other species relevant for the aim of this paper are ungulates for their dangerousness in case of collisions and because they are wolves main prey.
The five-year plans "Organisation and management of ruminant ungulates" (OGUR), written by the Alpine District Turin 2 (CATO2) (Bennati and Musso, 2020) gave informations about the presence of chamois, red deer and roe deer in the study area. CATO2 territory overlaps the study area, and for this reason, available data of CATO2 are perfectly adapted to this report.

Red Deer Status and distribution

Red deer was introduced by the Provincial Administration in the "Gran Bosco di Salbertrand" Natural park during the Sixties. Red deer population had grown constantly until it reached considerable dimensions that have contributed to damage the forest recover in the Nineties.
Red deer is an herbivore and feeds on 10-15 Kg of plant material per day, mainly grass but also barks trees and shrubs (for example stone pine, larch, beech, ash).
Despite this species has been hunted, over the years, census data are constantly growing. Wolf's predation activity seems to regulate red deer population and it may prevent more significant pressures caused by the deer on the forest heritage.

Table n.3- – Number of red deer registered in CATO2 from 2014 to 2019.

RED DEER	2014	2015	2016	2017	2018	2019
	1363	1379	1481	1656	1588	1519

Roe Deer Status and distribution

Roe deer has been introduced in Piedmont starting from Sixties, with 42 animals released in the territory of "Gran Bosco di Salbertrand" Natural Park.

Since then, roe deer population registered a consistent positive trend reaching a total of 911 specimens in total in 2013. Although, in recent years there has been a sensitive decrease due to concurrent factors as wintertimes with abundant snowfalls, wolf depredation and changing environmental conditions of the area (increase of forest cover rather than clearings, best habitat for the specie). Roe deer is the most involved in road collisions and is usually predated by wolves.

Table 4 – Number of roe deer registered in CATO2 from 2014 to 2019.

ROE DEER	2014	2015	2016	2017	2018	2019
	618	550	517	590	395	487

Wild Boar Status and distribution.

The wild boar had disappeared in the area since the first decade of the last century but now has spontaneously re-colonized the Susa Valley.

As a main difference with other ungulates still living in the high part of the valley, the boar is not subject to annual census by CATO2 or other Institutions, due to the extreme complexity and effort that a census of this animal might request.

However, it is possible to estimate the population’s dynamic by indirectly analyzing data referring to the agricultural crop damages.

The table below shows data referring to damaged events caused by boar to the agricultural crops in the study area and the extend of these damages.

Since the damage extent mainly depends on the value per hectare of the damaged crops, it results that data remain approximately constant over the years, not considering precise events fluctuations.

In fact, settling on an average of ten events per year, the result shows a modest value if compared to the damage entities reported on the residual metropolitan area.

The above-mentioned considerations suggest considering that boar presence in the Upper Susa Valley is constant and quite abundant.

Table 5- Damages caused by boar to agricultural crops in the study area from 2014 to 2019 (Source Metropolitan City of Turin)

WILD BOAR DAMAGES	2014	2015	2016	2017	2018	2019
N. damaged events	13	6	4	15	7	10
€ estimated	4.803€	2.758€	4.515€	10.448€	4.888€	4.022€

Chamois Status and distribution

Chamois is the only species not reintroduced as wild board. It counts on a considerable population, throughout the Piedmont territory, representing a significant part of the Italian population.

Chamois is a typical ungulate of mountain area as Susa Valley, widespread between 1000 m o.s.l and 2800 m o.s.l, mainly characterized by broad-leaved and coniferous forest and alpine pasturages.

During summertime, chamois prefers to live in more elevated quote areas while during wintertime it prefers those with more forest cover. Its road-collisions involvement is mostly absent.

Table 6 - Number of chamois registered in CATO2 from 2014 to 2019.

CHAMOIS	2014	2015	2016	2017	2018	2019
	1907	2058	2183	2065	1641	1763

2. Effects of infrastructures on wildlife

The following elaborations are based mainly on two dataset:

1. dataset on wolf mortality, as mentioned before, is achieved with the collaboration of several Territorial Institutions (the Metropolitan City of Turin, Local Health Board-ASL, Managing Protected Areas Agency of Cottian Alps-APAC, Forest Consortium Upper Susa Valley-CFVAS, Forestry Police-CUFA), Large Carnivore Center- CGC, the Department of Veterinary Sciences of the University of Turin, the Zooprophylactic Institute (IZS). All wolves found dead or injured between 2001 and 2020 in the Province of Turin, were recorded in the dataset with discovery coordinates and biometric information for each specimen that has been autopsied.
2. dataset regards all the known collisions with wild ungulates, from 2002 to 2020 (until the 31 of October); a report on this topic has been drafted by the "Flora and Fauna" service of the Metropolitan City of Turin.

   Dataset on wild ungulate collision have different sources:

   - police forces minutes attached to the compensation of the Solidarity Fund (L.R 9/2000, art. 4) enabled from 2002 to 2011 requested by car drivers that had accidents with a wild ungulate. The compensation request always had to be accompanied with the police forces minutes as evidence of the accident;
   - occasional police forces minutes of claims' reports with wildlife by even in the absence of the Solidarity Fund reimbursement;
   - claims directly done to the specialized function of Flora and Fauna of Metropolitan City of Turin and complaints of damage presented by law firms;
   - cases taken over by the CANC (Non-Conventional Animal Center) of the Department of Veterinary Sciences of the University of Study of Turin, based on an agreement with the Metropolitan City Of Turin;
   - data collected by RFI, ANAS, SITAF and APAC.

   The regional fund, which had to reimburse all involved in road accidents, was no longer funded since 2012, so the incentive to report wildlife accident has failed. For this reason, all data referring after 2011 are less representative in representing the trend rather than those of 10 previous years, and do not permit significant elaborations. In general, actually, the trend of all incentives' requests is decreasing from 2012 to 2020.

   Public awareness of the fact that the solidarity fund has no longer been financed has not yet spread among drivers, so that in 2020 requests for reimbursement were sent to the Metropolitan City; however negative responses are leading fewer and fewer drivers applying each year.

Table n. 7 - Number of accidents known by the Metropolitan City of Turin from 2012 to 2019.

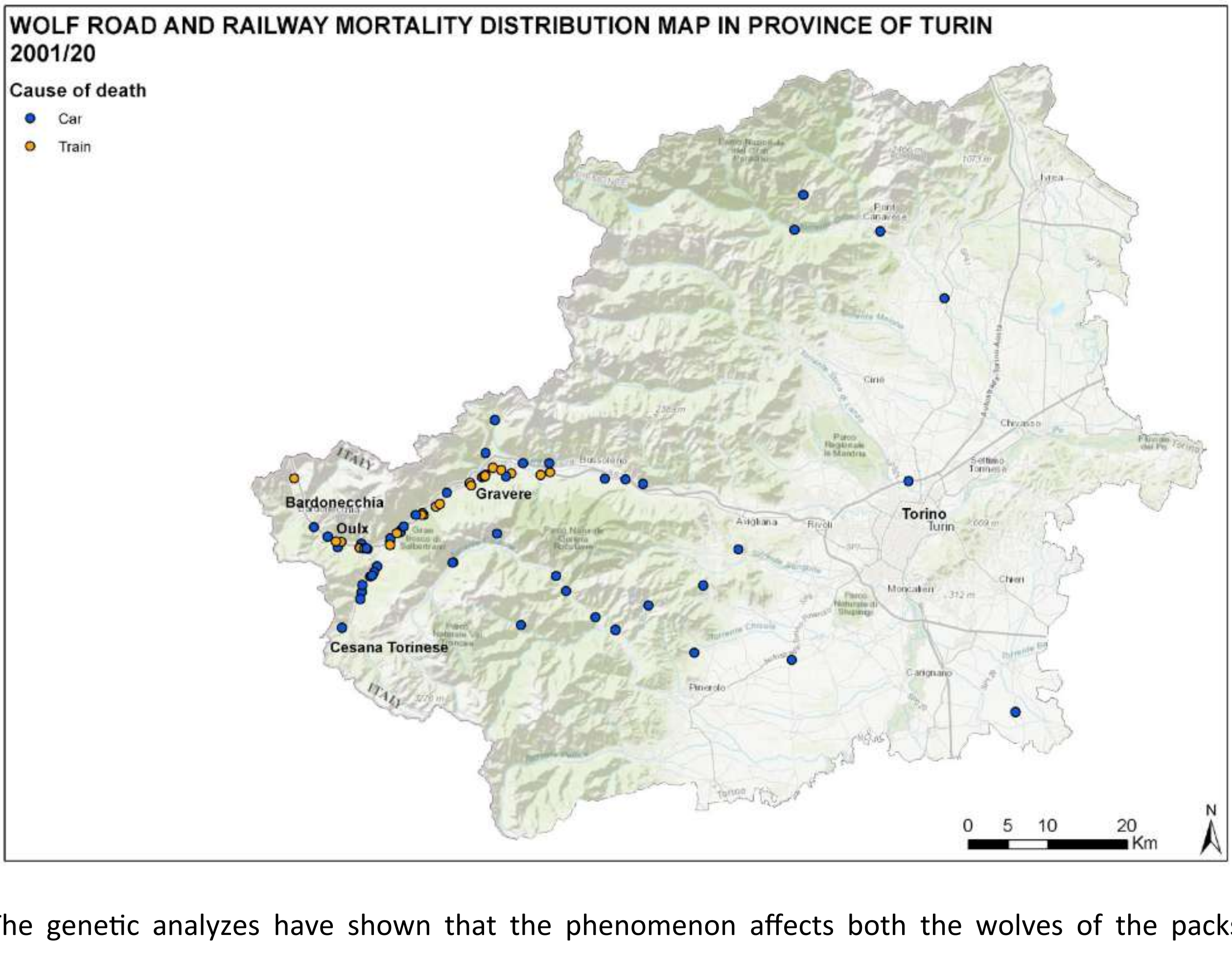
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
N. of accidents	191	118	79	81	77	62	66	54

Considering dataset by RFI and constant number of complaints received by Metropolitan City of Turin, allow to consider that in general, trend of wildlife accidents does not register a significant real reduction.

2.1 - Road and railway collisions with wolves in Upper Susa Valley

In the Metropolitan City of Turin, the main causes of wolves' mortality from 2001 to 2020, have an anthropogenic origin (direct or indirect persecution), and collision with vehicles (train or cars) is the most frequently documented. Data on wolf mortality in Upper Susa Valley present an alarming situation compared with the mortality at provincial scale. Between 2001 and 2020, in the Turin metropolitan Area, there have been registered 110 dead wolves, 53 of which found in the upper part of the Susa Valley (48% of cases). As can be seen from the graph below, the impact with car or train (generically classified as collision/accident) is the main cause of wolf mortality, especially in Upper Susa Valley.

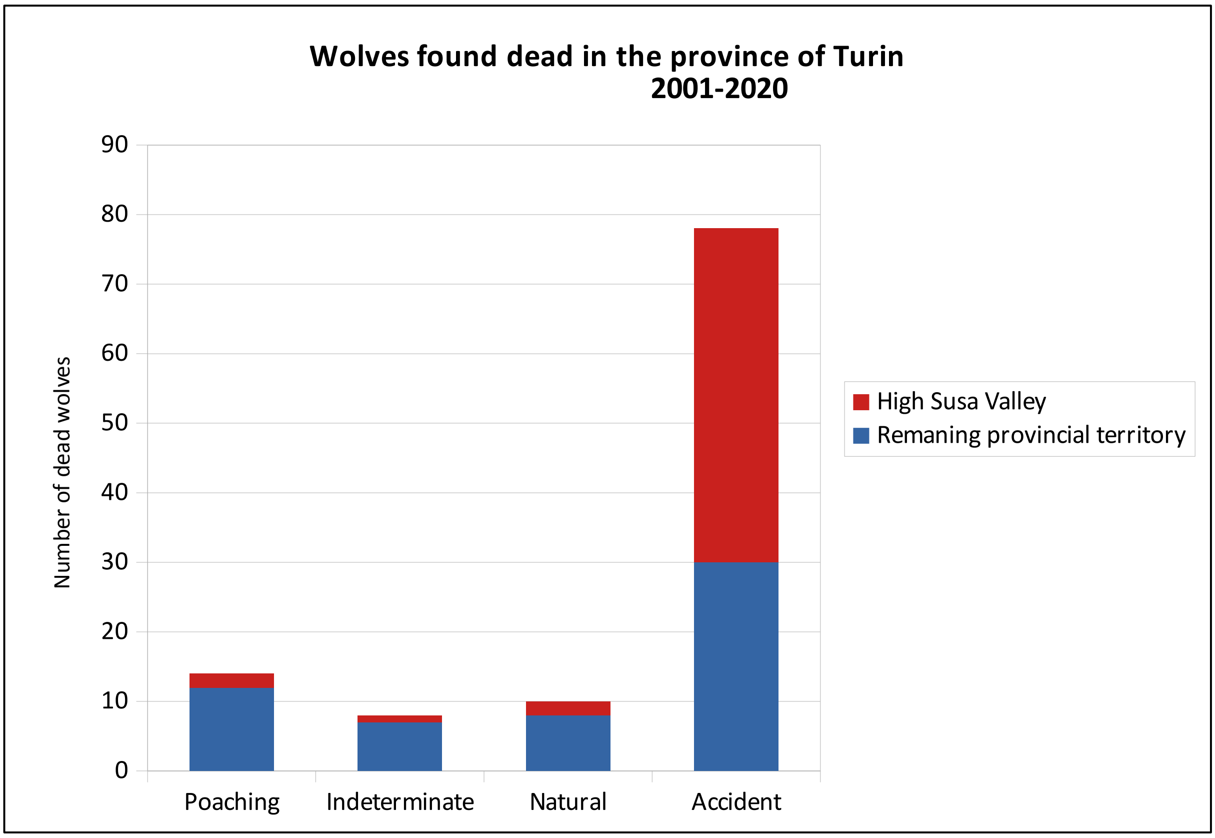
Figure 7– Wolf road and Railway mortality distribution map in Province of Turin.



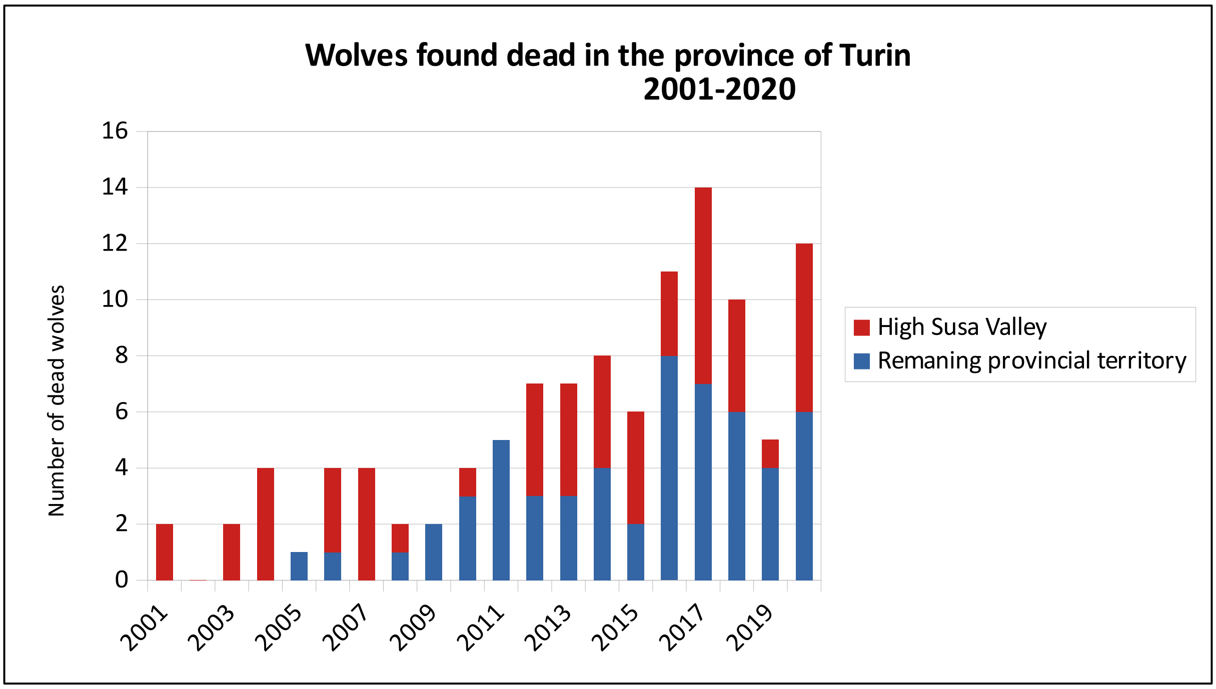
The genetic analyzes have shown that the phenomenon affects both the wolves of the packs settled and the scattered ones.

Wolves collisions with the vehicles has increased over years in all territory of Turin Province due to the expansion of the wolf population in the Alpine area (Marucco et al, 2018).

Graph 1 – Wolves found dead in the Province of Turin from 2001 to 2010, divided by cause of mortality.

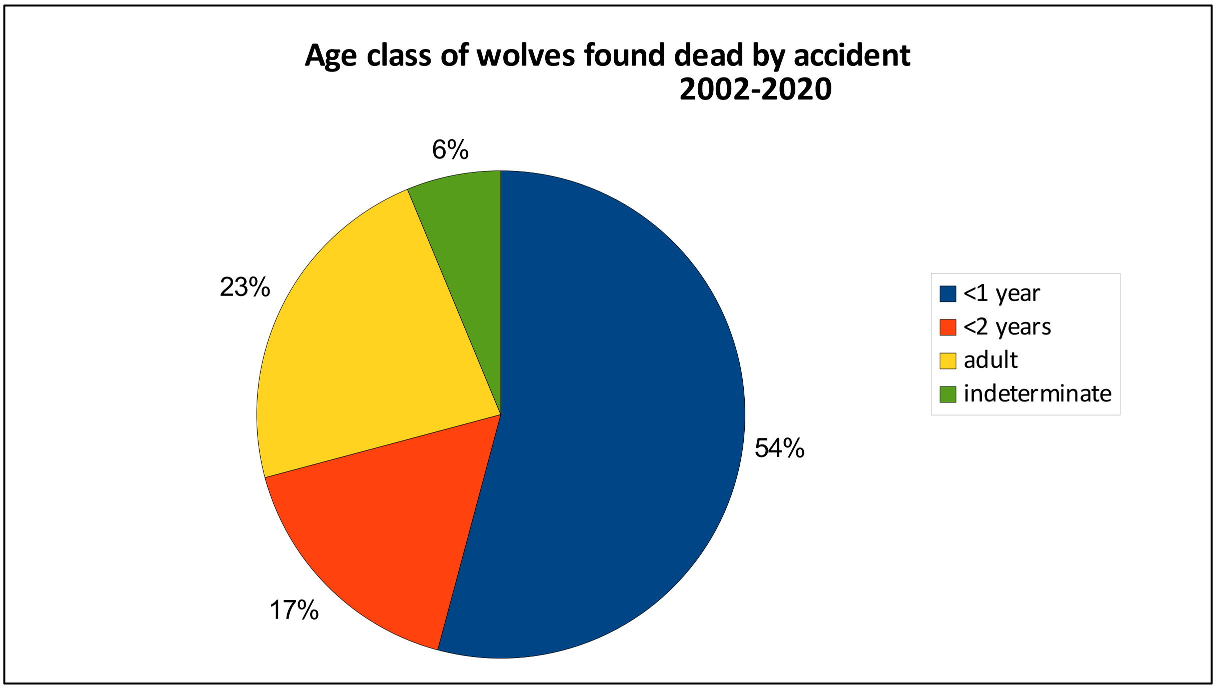


Graph 2 – Wolves found dead in the Province of Turin from 2001 to 2020 divided by year. In red the wolves found in Upper Susa Valley, in blue the rest of the territory.



During 2001-2020, impacts have been provoked mainly by trains (n=26) rather than by cars (n=22). However, if we consider also the low part of the Susa Valley as well, from 2010 onward, road collisions with cars have increased , carrying the number of accidents to a substantial parity.
The collision incidence seems to be related to the age class of wolf; it can be noticed in fact a large predominance of young wolves (with less age of 12 months) (n=26), followed by those of one year old (n=8) and adults (n=11). Among the 53 wolf road mortality events (collisions by car or train) 29 occurred along the Turin-Modane railway; 18 along the main roads SS24 and SS335; 3 along the Frejus Highway and 1 along the secondary roads,

Graph 3 - Wolves involved in road or rail accidents from 2001 to 2020 in the Upper Susa Valley. The non-specified cases are referred to those situations in which carcass has not been found but there were present unequivocal traces in the place of accident (for example blood samples)



All wolf road mortality data have been processed applying Kernel Density method (Bailey and Gatrell, 1995), obtaining a distribution map (see Fig. 8) of wolf road mortality spatial aggregation sites which indicate the risk level of collision.
This spatial density map clearly shows that, all over the Province territory, the main and extensive mortality risk zone corresponds to Upper Susa Valley.
Focusing the Kernel density analysis to the only cases recorded in Upper Susa Valley (see Fig. 9), it can be found 2 macro-areas of high mortality risk: a first macro-area between the village of Savoulx and Oulx and a second between Salbertrand and Gravere.
Kernel method has been applied separately on wolf collision occurred along the railway lines or on the road network to find out all the critic and priority sections where to intervene with mitigation measures respect to the infrastructures.
As it is shown in the charts (see Fig. 10 and 11) below analyses figure out different areas with a higher collision density along on the railway lines as well as along roads.

Figure 8 - Wolf road and railway mortality risk distribution map in Province of Turin.

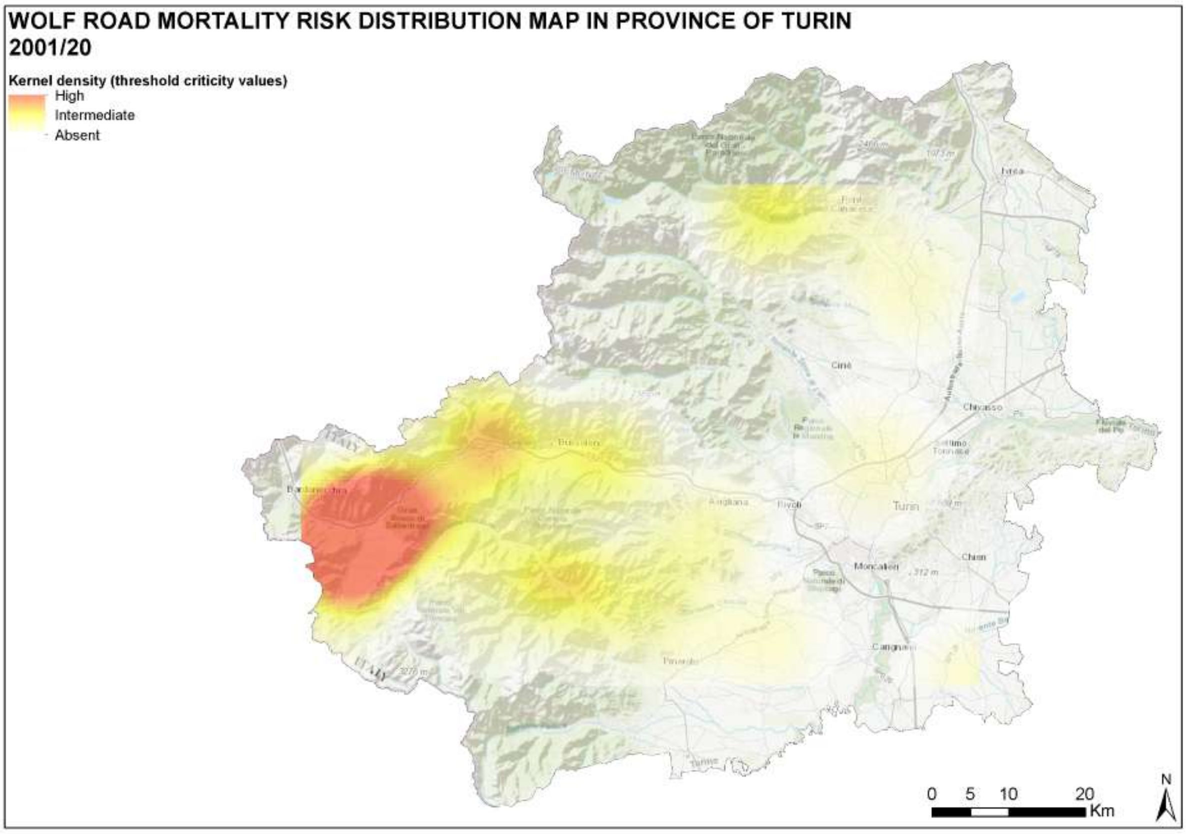


Figure 9 - Wolf road and railway mortality risk distribution map in Upper Susa Valley.

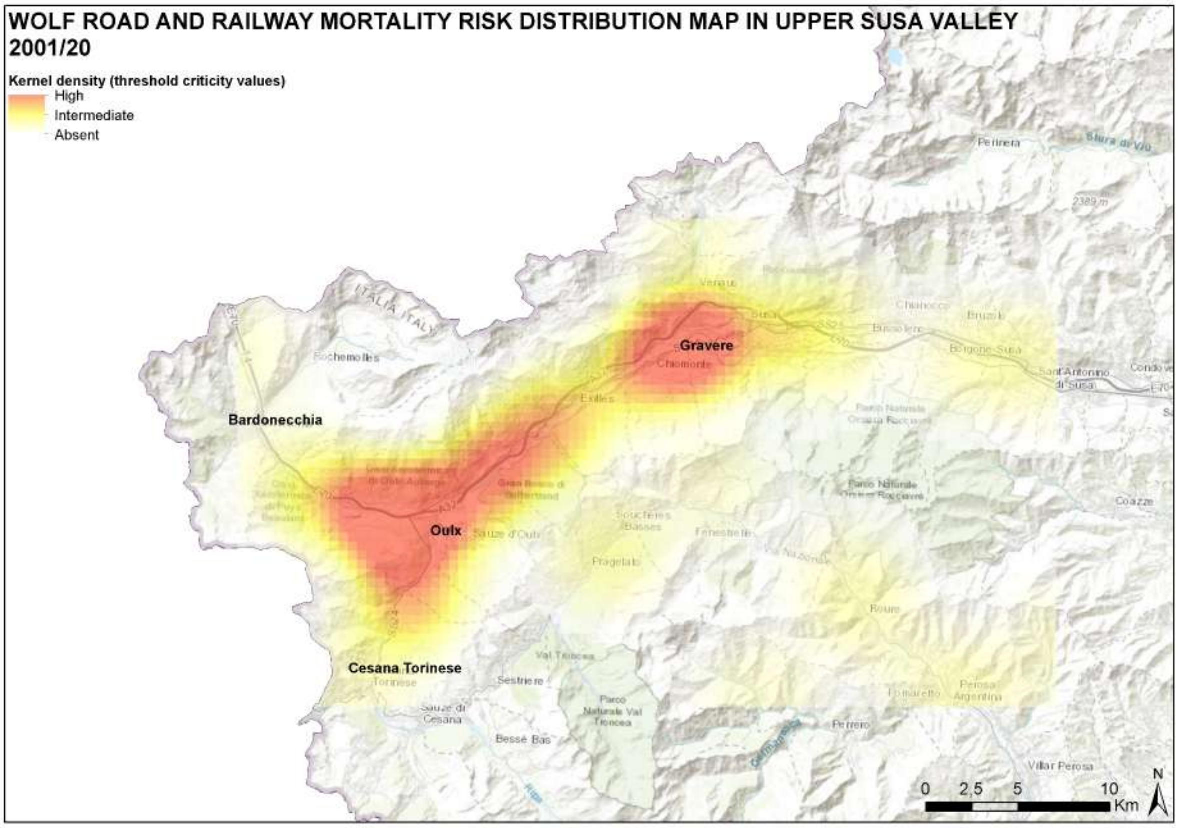


Figure 10 - Wolf railway mortality risk distribution map in Upper Susa Valley

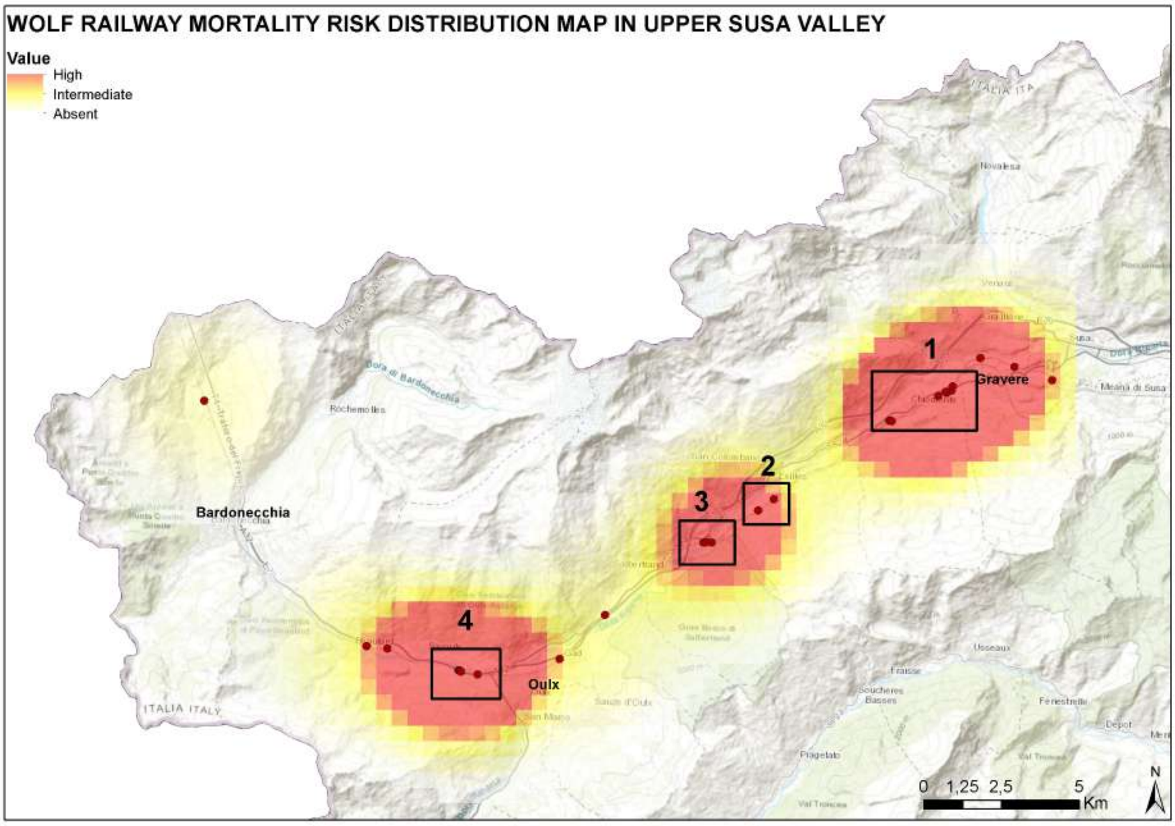
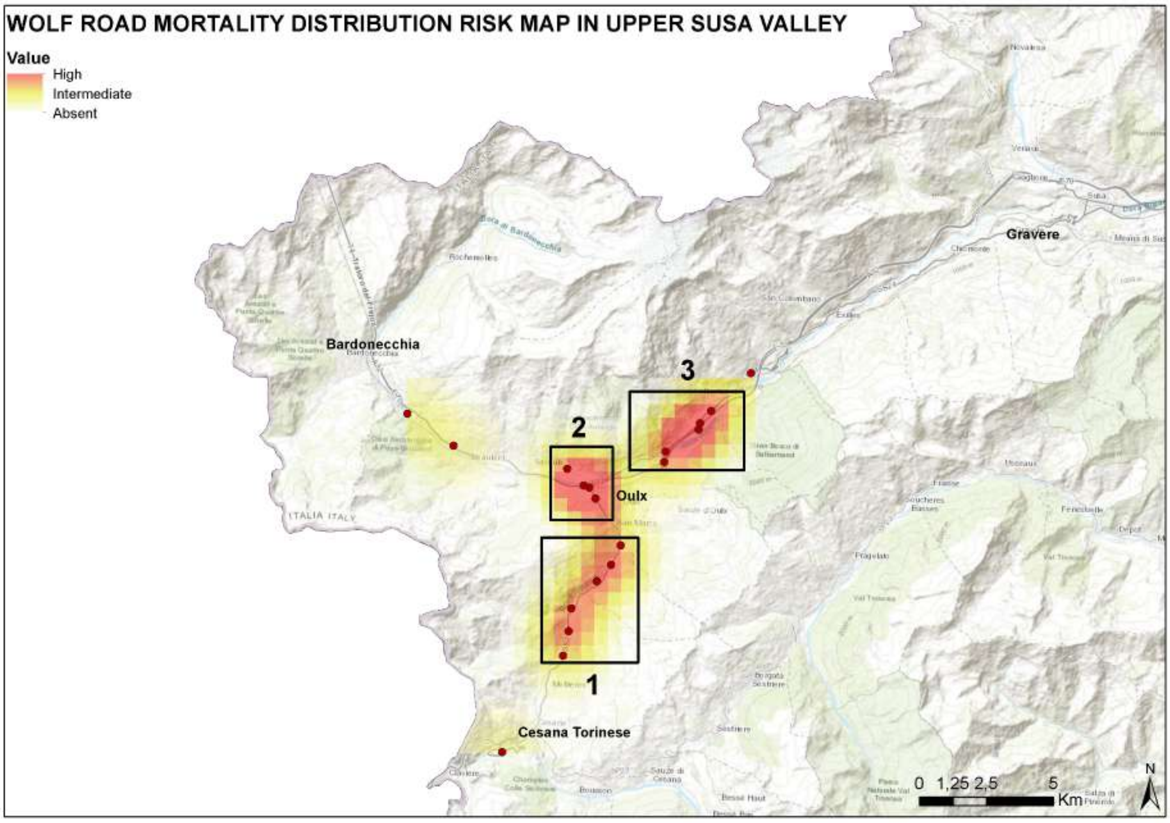


Figure 11 - Wolf road mortality risk distribution map in Upper Susa Valley

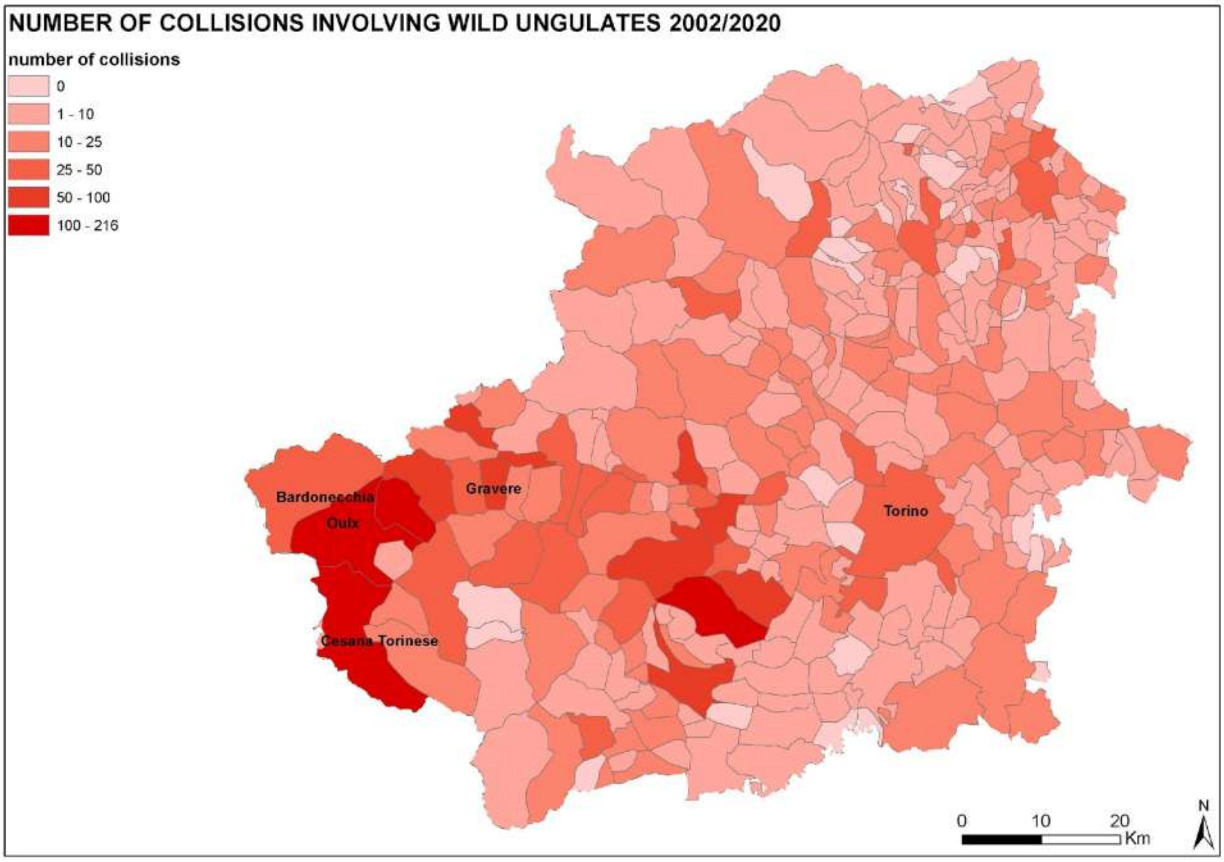


2.2 - Road and railway collisions with wild ungulates in Upper Susa Valley

Road collision

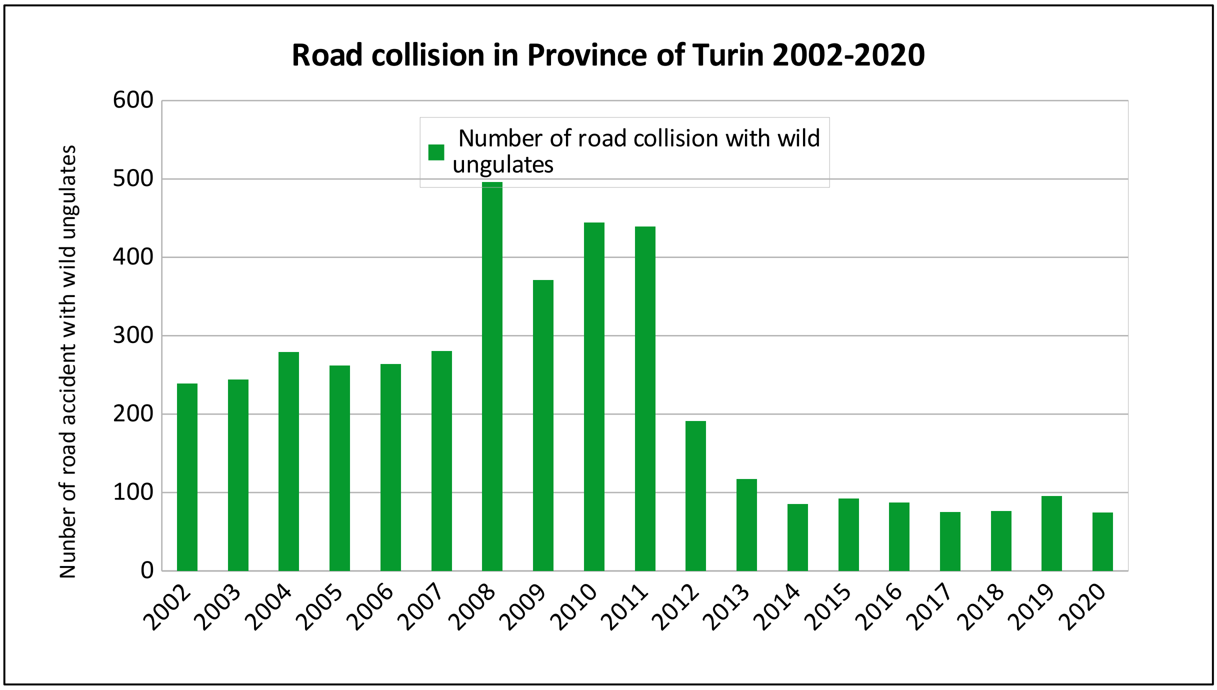
The dataset on Wild Ungulates Collisions covers the past two decades, as the one of wolves, and registered cases far exceed the 4000 road accidents in the entire Province (of which more than 500 in the study area).

Figure 12 – Wild ungulates collision distribution map in the Province of Turin municipality

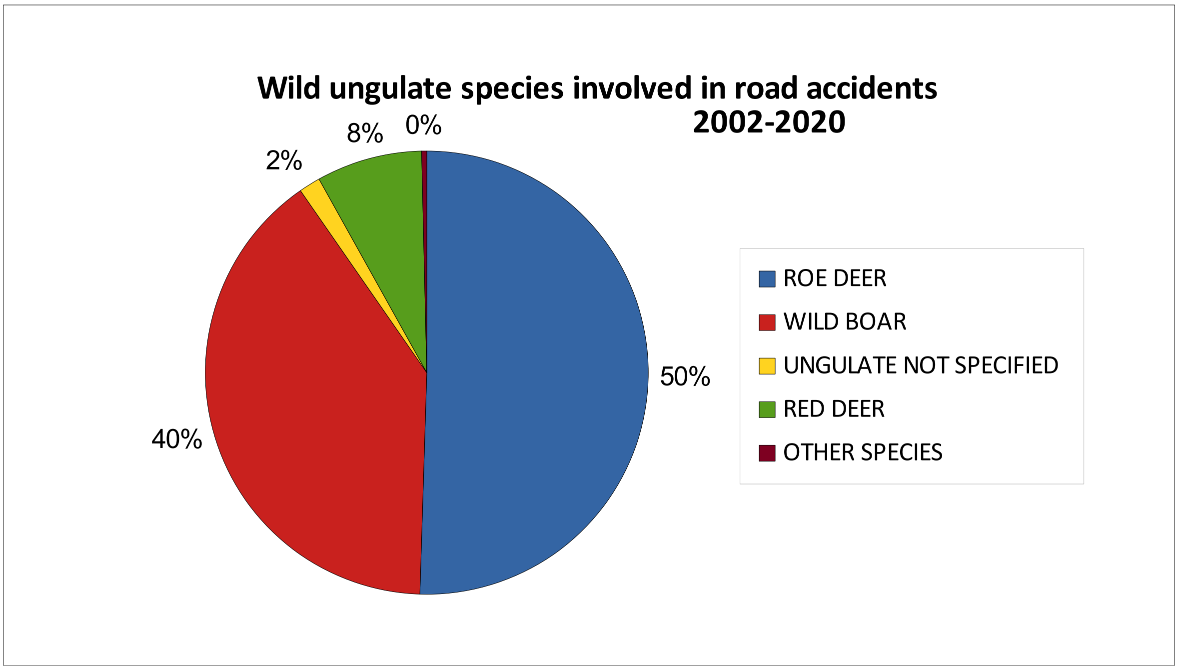


Considering the whole area of Turin Province roe-deer is the main specie involved in vehicular collision (n=2128), followed by the boar (n=1679) and by the deer (n=325). Less significant are the percentages referred to fallow deer and chamois (n=16) and ungulates whose species could not be traced (n=66).

Graph 4 - Accidents with wild ungulates occurred in Turin province collected from 2002 to 2020 divided by years. It is easy to see the decrease in reports following the non-financing of the Solidarity Fund from 2012 onwards.



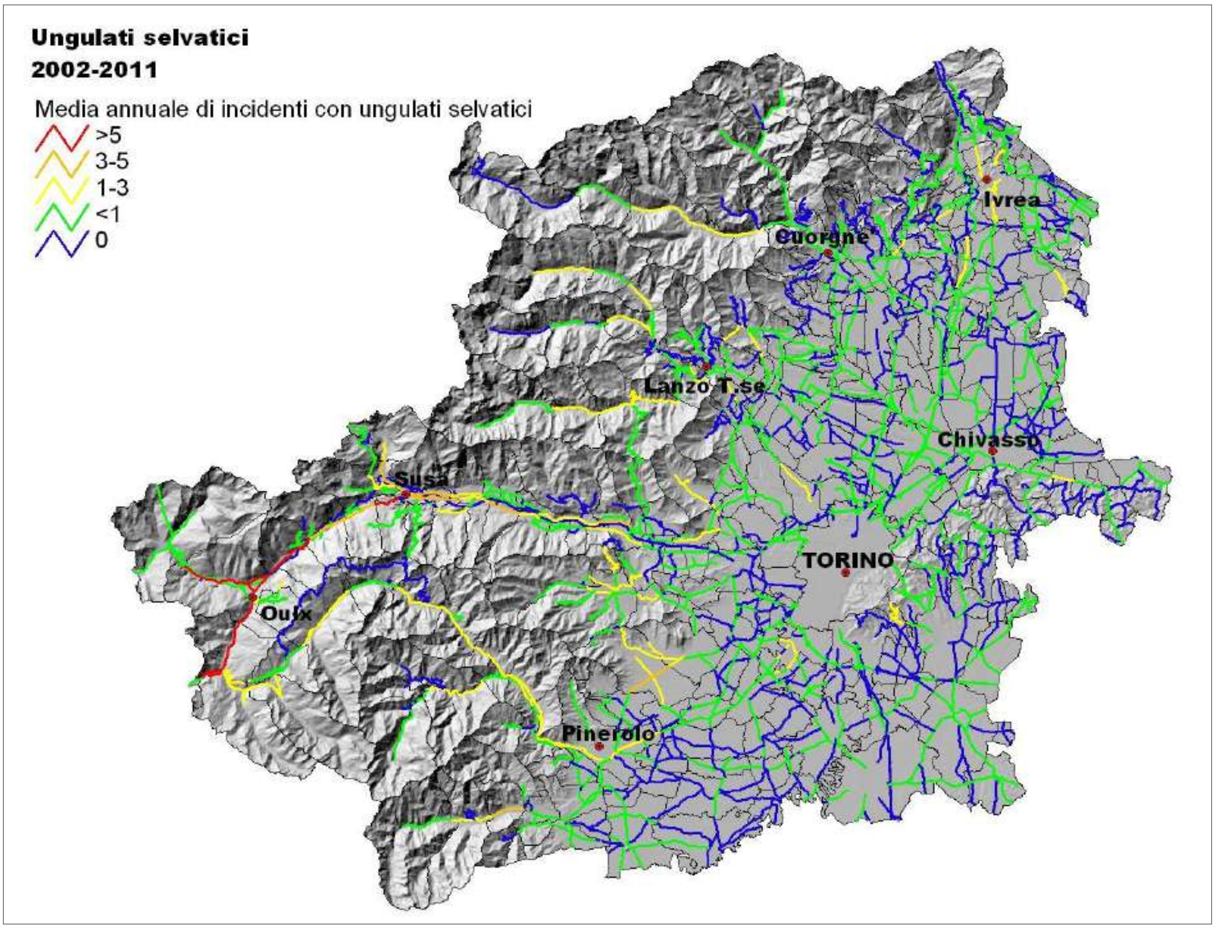
Graph 5 -Road accidents in the province of Turin collected from 2002 to 2020 divided by species involved.



A lot of collisions has been occurred along the mid-high speed state and provincial roads (n=3516), while on municipal roads, where the average of speed is lower, the rate of accident density is lower. Fewer cases occurred along on the fenced infrastructures as high-speed or ring roads (n=82).

This relation had been already underlined by another analysis realized at the municipality scale in 2012; it had been underlined that faster roads show a higher value of accident density (Province of Turin technical report, 2012).

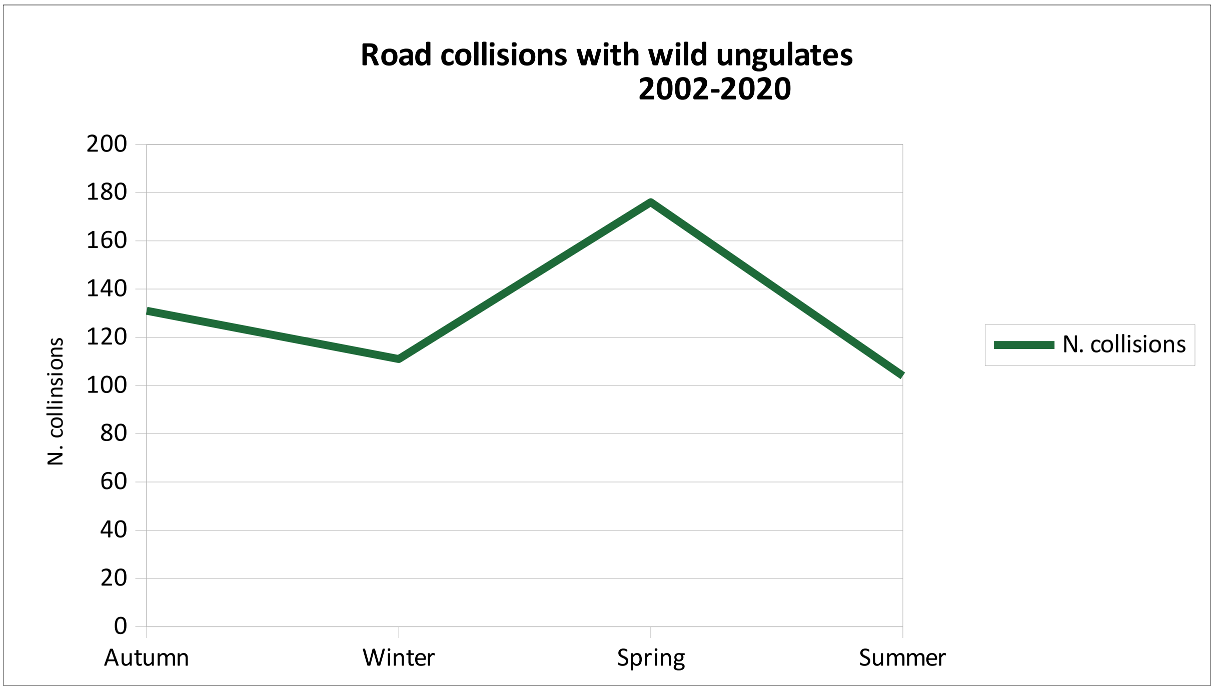
Figure 13 - Road network and vehicular collisions with wild ungulates. The road sections with the highest number of accidents are in red while roads with no collisions registered are in blue. Numbers in the legend are referred on annual average with a time horizon of 10 years of studies.



522 accidents have been documented from 2002 in Upper Susa Valley along the main roads (highway, SS24 and SS335) covering a total length of 96,7 Km: 376 collisions involved roe deer, 136 red deer and 9 wild boars (there has been registered just one case with non-specified ungulate). In the High part of the Susa Valley, it has been registered an average of 5,4 collisions per Km, while at the provincial scale this datum decreases at 0,8 collisions/km. Torino Metropolitan City road network comprises 4132 km in Highways (AA), State roads (SS) and Provincial roads (SP).

These data demonstrate that the high-speed linear infrastructures present in Upper Susa Valley are an ecological trap for wild fauna; even for other taxa as well, for example birds, reptiles, and other mammals.
Seasonal trend of accidents shows a maximum in the springtime, when the forest restart in the floor valley attracts wild ungulates searching for food, followed by a less significant maximum in the autumn.

Graph 6 - Seasonal breakdown of claims with wild ungulates in the Upper Susa Valley along the A32, SS 24 and SS335, from 2002 to 2020.

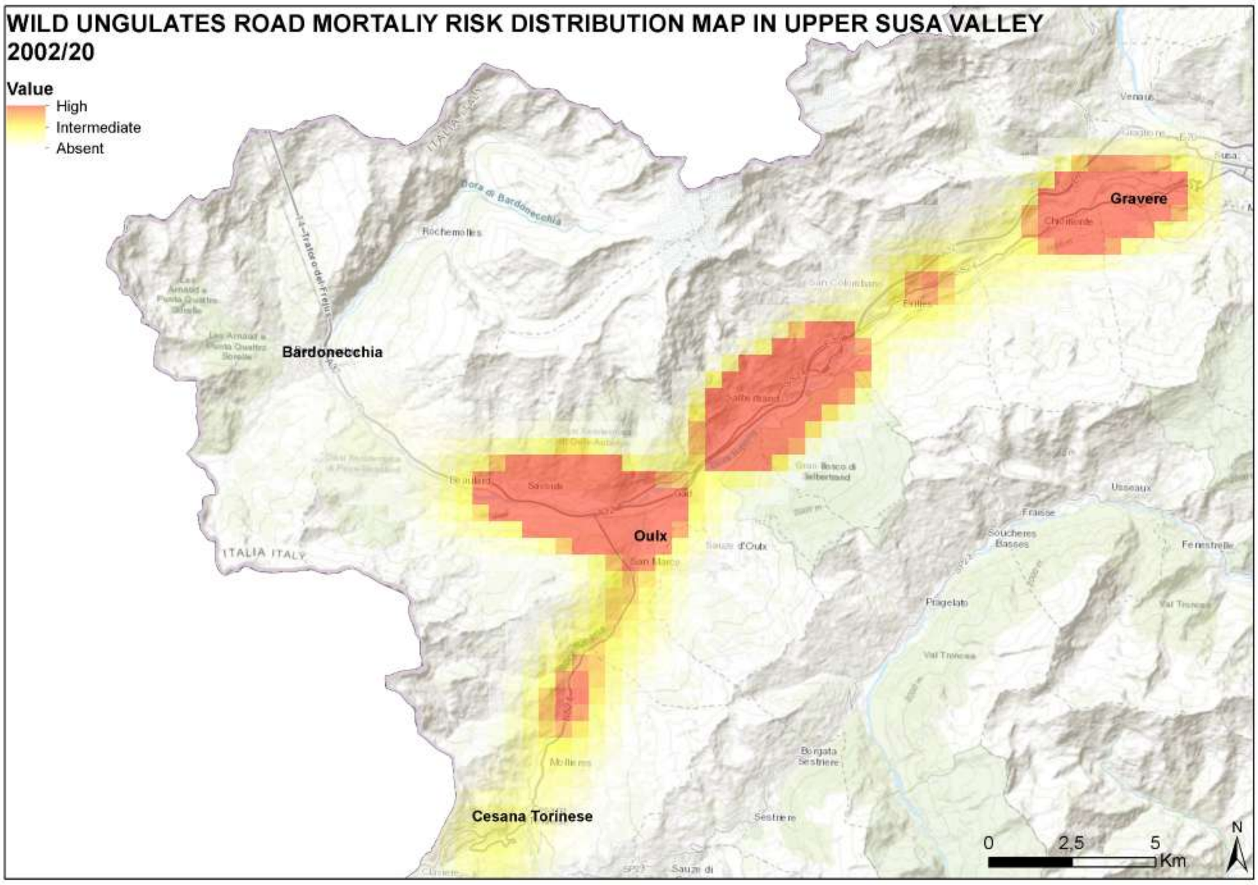


Excluding those few cases occurred on the A32 (n=4), road section A (Susa – Salbertrand) shows a higher collision density rather than the rest of the valley.

Table 8 – Number of collisions with wild ungulates for road section between 2002 and 2020 along the A32, the SS24 and the SS335

Road Section	**N. collisions**	**Total Km**	**Collisions/Km**
A (Susa -Salbertrand)	260	21,5 (SS24)	12,1
B (Oulx-Claviere)	139	20 (SS24)	6,9
C (Oulx-Bardonecchia)	119	12,4 (SS335)	9

Finally, Kernel method has been applied to vehicular collisions to identify the most critical road sections for wild ungulates.
Figure 14 – Wild Ungulates road mortality risk distribution map in Upper Susa Valley.



Railway accidents with wild ungulates in Upper Susa Valley

Train collisions along the railway line have never been collected in a systematic way, and the majority of data descend from sporadic reports written by RFI train drivers and APAC park rangers. We are talking about approximately 25 reports, the majority of which do not outline the species involved but just generic information concerning the animal size, recovering date and collision position. The most involved specie is the red deer, as specifically stated in 7 reports, whereas other 7 mention large animals.

2.3 - Ecological fragmentation and potential connectivity elements in Upper Susa Valley

The ecological fragmentation effects on wolf due to linear infrastructures in Upper Susa Valley, were faced in a first technical report (Avanzinelli et al. 2007). The main goal of this study was to locate crossing zones used by wolf along the railway and road network and the use of underpasses. Road underpasses can assume an ecological function when opportunistically exploited by wildlife as crossing structure although built for structural function (Forman et al. 2003). Yet, as designed and maintained according to their primary structural function, their ecological performance can be limited and must be checked (Smith et al., 2015).

Therefore, this prior investigation, which led to the detection of 50 underpasses and culverts, was followed by a second research (Perrone, 2017), carried out by the Turin University, under the Piedmont Wolf Project (1999-2010) (Marucco and Avanzinelli, 2010). Perrone (2017) monitored 25 selected structures more potentially suitable as road crossing structures for wolf such as underpasses, viaducts span above riparian areas, functional to the flow of water bridges, walk/vehicular passages, roads drainage facilities etc (some of these in Figure 1). The underpasses distribution map in Upper Susa Valley of Fig. 16 shows that, as the highway and the railway mostly develop in parallel along the main branch of the Valley, some underpasses are contiguous (n=12).
In Perrone (2017) the underpasses had been intensively monitoring for 2 winter seasons (2007-2009), with the aim to detect their use as crossing structures by wolf[2], via two methods:

1. snow-tracking survey the day after each snowfall to detect wolf prints on the snow at the underpass entrance and exit (n=16 underpasses);
2. setting 3 m wide and 2–4 cm deep sand strips (as tracks detection substrate) at both ends of the structure, and transversely placed with respect to the underpass transit direction, repeating the underpasses inspection every other 3-6 days (n=9 underpasses) (Fig. 16).

In Table 9 the list of surveyed underpasses, their relative size and the sampling effort during the monitoring campaign (2007-2009) are shown.

Figure15 - Road and railway line underpasses in Upper Susa Valley (Photo: Elisa Avanzinelli).

2 At each underpasses' inspection wild ungulates (*Cervus elaphus*, *Capreolus capreolus*, *Suus scrofa*) and human passages were even noted.

Figure 16 - Road and railway line monitored underpasses distribution map in Upper Susa Valley

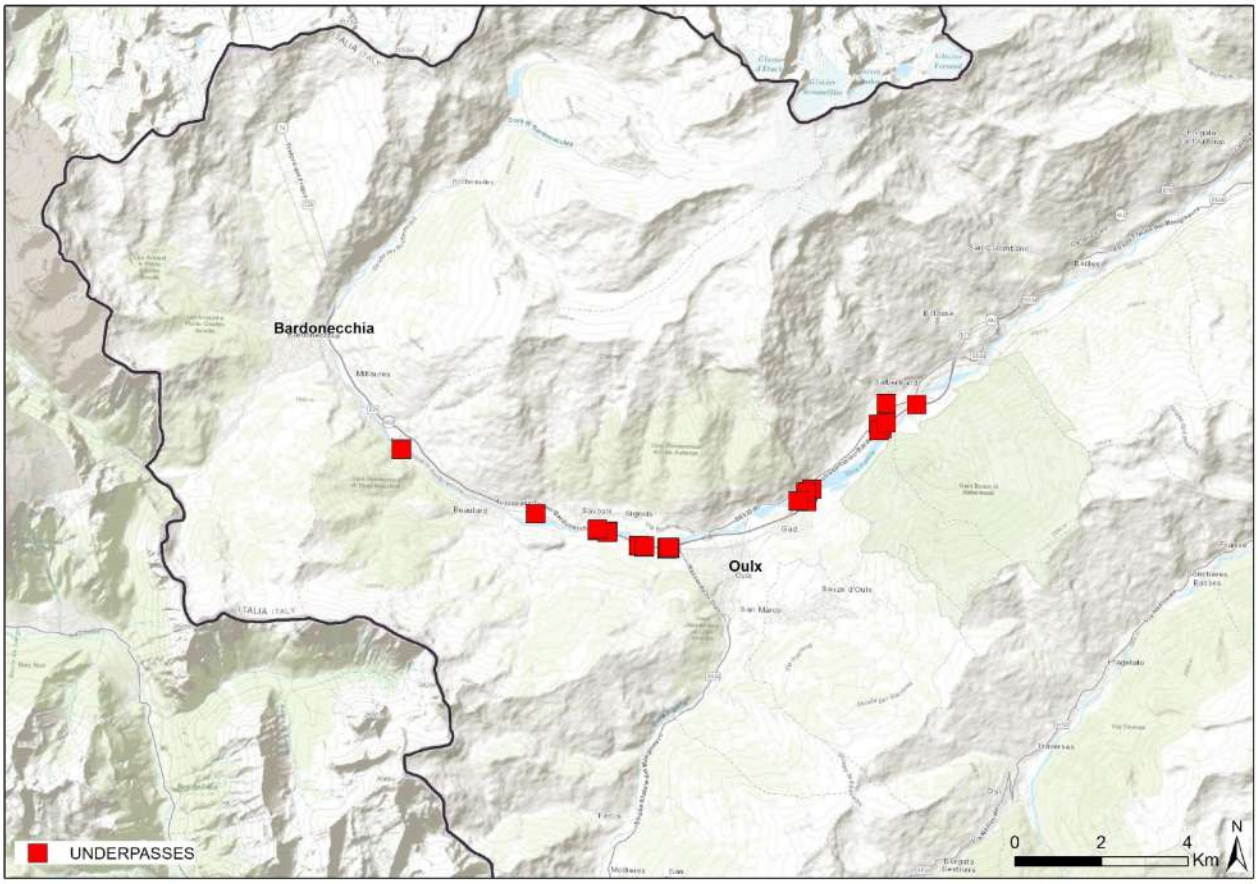


Table 9 – Intensively monitored underpasses, with size and sampling effort during the two winter seasons 2007-2008 and 2008-2009 (Perrone, 2017).

Underpass Code	Underpass size (m)			Linear infrastucture	Monitoring technique	Number of inspections (November – April 2007-2009)
	Hight	Width	Length			
63S	4.15	15	9.5	State road	Snow-tracking	16
58A	4.6	6.05	21.7	High-speed road	Sand strips	46
57F	3.55	2.5	9.5	Railway line	Sand strips	46
56F	4.15	10	8.6	Railway line	Snow-tracking	16
55A	6.5	25	20	Frejus Highway	Snow-tracking	20

59S	1.9	3	8.5	Main road	Snow-tracking	12
43S	8.8	50	8.5	Main road	Snow-tracking	16
42F	4.5	55	12.6	Railway line	Snow-tracking	16
44A	8.8	115	40	Frejus Highway	Snow-tracking	16
40A	1.5	1.5	40	Frejus Highway	Sand strips	45
36F	1.9	1	15.5	Railway line	Sand strips	21
30A	2	2	50	Frejus Highway	Sand strips	47
31F	0.8	1	9	Frejus Highway	Sand strips	47
26A	2.3	2.7	25	Frejus Highway	Sand strips	46
27F	2.4	4	9	Railway line	Sand strips	46
25F	1.7	2	9	Railway line	Sand strips	46
5S	3.5	15.2	9.1	Main road	Snow-tracking	27
22A	7.8	30	21.5	Frejus Highway	Snow-tracking	25
20F	5.7	20	8	Railway line	Snow-tracking	25
8F	1.8	1.7	9.4	Railway line	Snow-tracking	25
17A	4.5	6.1	26	Frejus Highway	Snow-tracking	25
18F	4.0	4.0	9.4	Railway line	Snow-tracking	25
28A	0.7	6.1	30	Frejus Highway	Snow-tracking	27
29F	1	6	8.3	Railway line	Snow-tracking	26
64A	4.1	60	20.8	Frejus Highway	Snow-tracking	18

Figure.17- Sand strip placed as wildlife tracks detection substrate within the underpasses (Photo: Serena Perrone).

Calculating the ratio between the number of wolf passages through each underpass, and the number of underpass inspections, "Frequency of Passage" (FP_{wolf}) index was achieved. This index explains the frequency which the underpasses was used as crossing structure by wolf considering monitoring effort.

Perrone (2017) found that wolves used, at least once, 9 structures during the two winter monitoring seasons, (twice detected by sand strips and all the other times via snow-tracking activity) and that their FP_{wolf} mean value corresponds to 0.20±0.18 S.D.

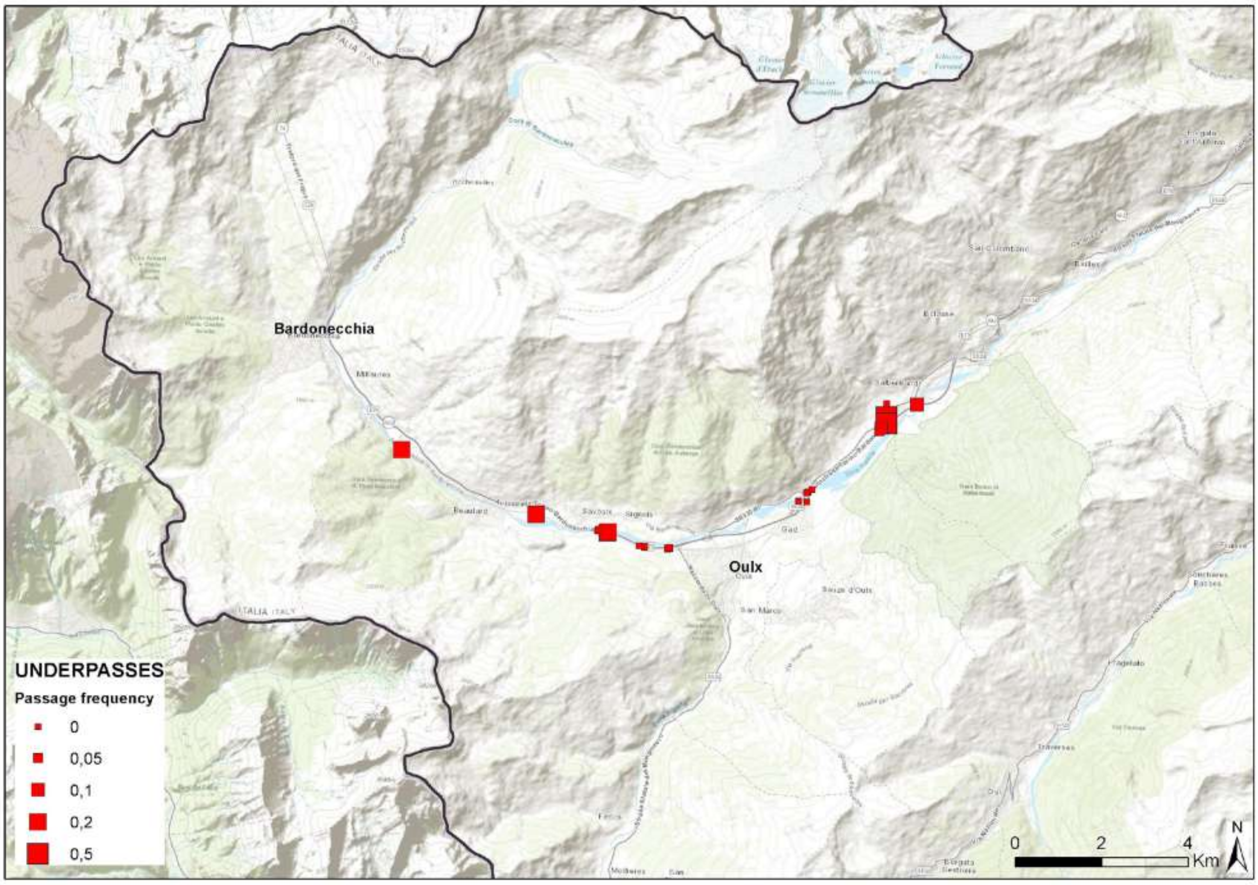
The monitoring results highlighted mainly that in Upper Susa Valley, the underpasses used by wolf:

- are poorly effective as crossing structures, sice the Frequency of Passage mean values are overall modest, as shown in the map of Fig. 18;
- are on average 4.63±1.79 m high, 18.93± 18.28 m wide and less than 14.29±6.40 m long, and that the species used even a 2 m wide and 1.8 m high underpass, but wolves never used more than 21 m long structures;
- are characterized either by suitable and unsuitable habitat; they are all located within 50 m from forests, and, in some cases, an extreme closeness to settlements and the use of the same structures by people was documented;
- are not ecologically adequate for wildlife, probably because these underpasses do not have fences denying to access on the road/railway line, or due to the absence of other

structures encouraging the underpasses use (Clevenger et al., 2001; Dodd et al., 2007; Grilo et al. 2015).

Wolf is an umbrella species, in fact planning mitigation measures to reduce wolf road mortality can provide an ecological benefit for other mammals' species present in the study area. The background knowledge of wolf collision risk is a beginning point to set up an effective mitigation planning, even including an upgrading of the underpass's ecological performance.

Figure 18 – Distribution map of the underpasses used by wolf during the intensive winter monitoring 2007-2009, thematized according to the index Frequencies of Use (Perrone, 2017).

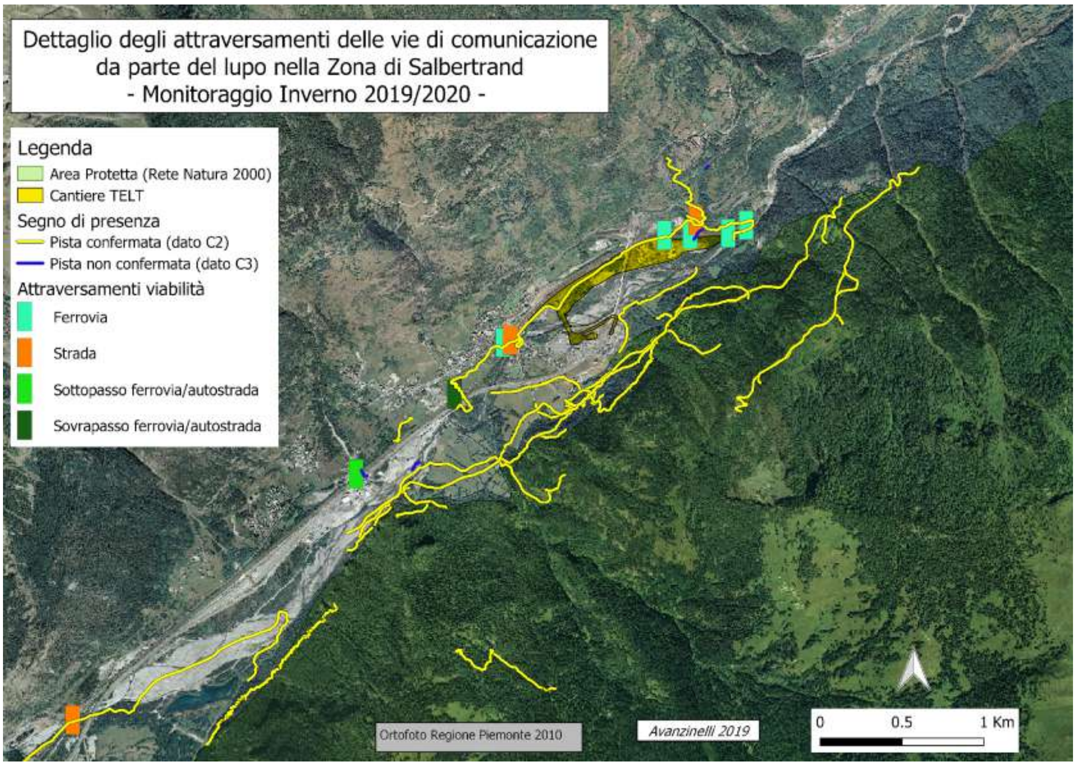


Perrone (2017) showed that, in Upper Susa Valley during the winter season (November-April) the higher habitat suitability zone corresponds to the valley bottom, despite human and road presence, since altitude and snow depth can seasonally influence both wolves' distribution and prey species too.
It was demonstrated that, in the study area, wolves can tolerate a dramatic high road density (8-12 km/km2), underlining a rare result in comparison with other study cases (Mech, 1989; Mladenoff et al., 1995). Roads and railway line are an integral part of the landscape in Upper Susa Valley, and although anthropogenic elements, they are perceived by wolves as neutral elements of the ecological landscape.

The wolf's neutral behavior towards the linear infrastructures in Upper Susa Valley likely explains the wolf's high road mortality rate. On the other hand, a reach ungulates community could have compensated this threat counterbalancing the risk-benefit assessment in favor of the benefit. In fact, wolf tolerance towards human dominated landscapes is determined by food availability and by mortality risks (Basille et al., 2009).
The Frejus Highway seems to make a different pressure on wolf survival, in fact it is fenced and part of it is built on viaducts or gallery. The 3 wolf-vehicle collisions occurred in the A32 Highway are due to accidental holes and gaps along the motorway fences.

A recent study was conducted in Salbertrand area - where future TAV building planned by TELT will be located - in order to steel a monitoring protocol for building site impact assesement on wolf conservation; wolf presence monitoring was also conducted and linear infrastructure crossings by wolf and wild ungulates surveilled including overpasses and underpasses monitoring (Avanzinelli et al. 2020). This field work has confirmed that the future TAV building site area is a corridor used by wolf to reach the opposite sides of the valley. Wolves used to cross the high-speed linear infrastructures where A32 higway runs entirely on overpass; this area will be totally fenced in the future TAV building site.
Avanzinelli et al. (2020) found that wolves directly crossed the linear infrastructures mainly near Salbertrand between the village and Loc. Serre La Voute; 3 passages of the railway have been documented within the future TELT building site area (figure 19). The future TAV building site with fences and service roads, in addition to the strong continuous lighting and the presence of the workers, will greatly reduce the permeability of this area to the fauna and consequently increase the environmental fragmentation of the valley. This will lead to a variation in the spatial dynamics of the species that inhabit the area, especially wolves and cervids, with possible negative effects related to habitat loss, greater isolation between the two sides and greater risks of vehicular collision (Avanzinelli et al. 2020).
Avanzinelli et al. (2020) found that wolves used only the underpass located in Illes Neuves, the same site was documented also by Perrone (2017) (57F, 58A). This underpass allows the A32 highway crossing and railway but not the SS24. Avanzinelli et al. (2020) suggested several specific mitigation measures to ensure connectivity between slopes of the valley and reduce mortality from impact with vehicles in particular: maintenance interventions on existing underpasses and overpasses used by wolves; structures to direct the passage of animals towards these corridors; sensors indicating to drivers the passage of animals and / or speed reducers of road traffic along SS24 road where the mortality risk is greater. Periodic maintenance of fences along the A32 motorway was also suggested as important interventions to prevent wildlife entrance on highway (Perrone, 2017; Avanzinelli et al., 2019).

Figure 19. Wolves crossing on railway (in light blue), SS24 road (in orange) and using the underpass (in dark green). Data documented during winter 2019/2020 in Salbertrand area where planned TAV building site by TELT (from Avanzinelli et al. 2020).



3. Conclusions

Upper Susa Valley is in general a potential road mortality risk zone because of the linear infrastructures, developing linearly and in parallel along the valley bottom; high speed linear infrastructures are barriers for wolves daily movements inside pack territory (especially for the two packs settled in the area).
The main roads (SS335 and SS24) and the railway line are almost permeable, and sometimes the access to galleries by wolf has been documented (e.g., into the Chiomonte and Salbertrand and Frejus rail tunnels).
The Frejus Highway is almost fenced, and it develops on viaducts or gallery, therefore, if the lateral gates are closed, this infrastructure is almost impermeable to wildlife and it rather represents a barrier to wolves' movements.
High habitat suitability forest complexes bordering on the railway line are highly dangerous zones for wolf survival, e.g., between Savoulx and Oulx villages and between Salbertrand and Gravere. This criticity is exacerbated where railway line develops side by side to the A32 motorway (mostly impermeable for wildlife). This spatial configuration likely increases the railway line danger, because wolves cannot find a gap to go beyond the highway barrier.
In the area described, which is already highly critical, soon the building site for the location of the waste muck oh the TAV high-speed railway, will be placed. This building site will entail the subtraction of a crossing area currently used and quite permeable, increasing the use of other corridors. So, in the absence of interventions, is likely that the incidents with wildlife will increase.
Actgually, high speed road segments are those where the danger of collision with cars is greater (Seiler 2005). The main risk zones, where the roads develop straight-line, allowing vehicles travelling high-speed correspond to the following segments:
1) The SS 24 stretch connecting Oulx and Fenils villages
2) The SS 24 stretch between Pont Ventoux and Serre La Voute sites
3) The SS 335 stretch between Royeres and Oulx villages.

In conclusion the whole valley presents a critical overall situation for wolf conservation, but to effectively plan adeguate interventions it is necessary to analyze the railway line separately from the road network.
Results obtained with the Kernel method highlighted that the cases of registered dead wolves are concentrated in some traits (see Figure 10) as followed:
1. **Chiomonte**: between the Chiomonte railway station and Gravere and as well in the section just upstream of the station there have been 8 accidents (respectively 5 and 3). If the downstream section of the station is characterized by gentlest slopes, woods and clearings, the upstream section is shorter because the train, after leaving the station, immediately enters the tunnel (just over 1000 meters);
2. **Exilles**: the railway line between Chiomonte and Salbertrand passes throughout the tunnel, except for 1200 meters, in correspondence of the old Exilles Railway Station (no longer used nowadays), where there have been found 2 wolves dead.

3. **Serre la Voute**: between Exilles and the Salbertrand plain there is the narrower point of the valley; just upstream of it, where the railway line leaves the tunnel 3 wolves have been run over;
4. **Savoulx**: just downstream of Oulx, at Signol, in just over 100 meters 4 wolves have been run over.

The other railway accidents are less concentrated (see Figure 11). The four mentioned critical areas will be the railway sections where future interventions will be planned in collaboration with RFI.

As far as the road network, collisions are distributed homogeneously in the upstream of the Serre la Voute area, whereas in the downstream trait no accidents have been documented. In the downstream trait of Serre la Voute the road passes in the slope and it is bordered by high support walls and there are some short sections of the tunnel.

There are some traits in which the concentration of collisions are greater, as already outlined by the Kernel method application:

1. **Along SS24**:
- between Fenils and Oulx, 7 wolves have been run over;
- between Gad and Serre la Voute, 6 wolves have been run over and the a very high mortality of ungulates documented;

2. **Along SS335**: between Oulx and Signols, 3 wolves have been run over; this trait is characterized by higher mortality of wild ungulates as well.

Unlike the railway line, roads collision are closely related to the speed of vehicles, so this aspect has to be considered in planning adequate mitigation measures along these critical traits of road network.

In the past a lot of car impacts with wild ungulates happened in a place near Oulx (Gad) along the SS 24; after the construction of a roundabout led to a reduction in the speed of vehicles, a decrease in wildlife collisions have been registered in the area.

As part the cited report (Avanzinelli et al.2020) need to proceed together with TELT in planning the best solutions to be adopted in the area before the final closure of the TAV building site is a priority. As a first step the company signed the declaration of support for the project and a technical working group will be set up.

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