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Temporal patterns of ungulate-vehicle collisions in a subalpine Italian region.

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Abstract

Over the last few decades, in Italy as in the rest of EU, both the number of wild ungulates and the volume of traffic have increased significantly. Consequently, ungulate-vehicle collisions have increased with significant costs in human death and injury, animal welfare and material damage. In this study we provide information about temporal patterns of collisions in a subalpine Italian region. We analyzed 1110 reports of accidents that occurred in Cuneo district from January 2008 to December 2011. Most of them were caused by roe deer and wild boar, while red deer, fallow deer and chamois were occasionally involved. Monthly distribution of accidents showed two peaks, with a higher risk of collision during spring mainly related to roe deer and a secondary peaking autumn caused by wild boar. No evident daily variations were noticed. In the case of roe deer, we reported the existence of a primary hourly peak at dusk and another secondary peak at dawn. Wild boar were most frequently involved in collisions during dusk and night. We hypothesized that these temporal distributions are the result of a complex interaction of phenological, behavioral and human-related reasons. Information provided in this study allows us to better understand the dynamics and patterns of wildlife-car collisions and represents an indispensable element for the implementation of any mitigation strategy.

Introduction

"*The roe deer survives in some alpine reserves, but is now virtually extinct in the rest of the Italian territory", and "the wild boar still exists in some areas of Tuscany, Sardinia and in a few Alpine valleys*": this Italian situation, described by Ghigi and co-workers (Touring Club Italiano 1959, pp. 122-123) has radically changed in the last few decades, when the abundance and distribution of wild ungulates have increased exponentially (Raganella Pelliccioni et al. 2013). This growth should be seen as part of a wider and general phenomenon, because ungulates have also been increasing in Western Europe in the last 100 years (Putman et al. 2011). Fuller and Gill (2001) individuated six main reasons for this trend: increase of woodland or forested areas, changes in agricultural practices (mainly the proliferation of winter cereals), reduction of livestock husbandry, changes in hunting and management (including reintroduction) practices, presence of a warming climate trend and disappearance of large predators.

In Italy in particular, not only the abundance but also the distribution range is rapidly increasing, especially for roe deer (Capreolus capreolus L., 1758) and wild boar (Sus scrofa L., 1758), long diffused in wooded or mountainous regions and at present widespread in cultivated areas (Carnevali et al. 2009).

In a densely populated territory with well-developed railroad networks and elevated traffic volumes, like many European and North American regions, this has led to an intensification of ungulate-vehicle collisions (Hubbard et al. 2000; Madsen et al. 2002; Cserkész et al. 2013). Collisions with ungulates are likely to cause serious damage to humans and vehicles, due to the size of these animals, representing an important menace for human health and a source of socio-economic complications (Williams & Wells 2005; Morelle et al. 2013). Moreover, collisions have important conservation implications, because they represent a direct cause of death for large numbers of animals every year (Trombulak & Frissell 2000). In the United States, Forman and Alexander (1998) hypothesized that road-kills probably overtook hunting as the principal human cause of terrestrial vertebrate mortality.

This problem represents an increasing threat, because conflicts at the road interface will likely increase with the future growth of traffic volume and ungulate populations (Ramp et al. 2005; Langbein 2011). Many studies have underlined that this phenomenon responds to non-random patterns in both temporal and spatial aspects, highlighting the importance of behavioural and environmental elements in determining the timing and location of collisions (Madsen et al. 2002; Gunson et al. 2011; Rodriguez-Morales et al. 2013). Recently, Steiner et al. (2014) reviewed 47 papers about this topic, with the majority originating from North America (n = 37), some from Europe (n = 10) and only one from Italy (Dal Compare et al. 2007). Increasing our knowledge about the main factors driving this events is essential to elaborate effective mitigation strategies. The aim of this study is to describe, for me first time in Northwestern Italy, temporal patterns of ungulate-vehicle collisions in a subalpine region.

Material and methods

Study area

The study area corresponds to the "Provincia di Cuneo", an administrative district of Piemonte (NW Italy). The territory presents a surface of 6903 km² and is typically subalpine, with 50.8% occupied by mountains, 26.6% by hills and 22.6% by lowlands. The Cottian, Maritime and Ligurian Alps form a large U-shaped border, which comprises a high alluvial plain crossed by the Po (the longest Italian lotic system) and Tanaro rivers. The human population density is approximately 85 inhabitants per square kilometre. The road density is 1070 km/1000 km² (Provincia di Cuneo, Settore Viabilità).

Ungulate-vehicle collision data

We analyzed collision reports collected by Settore Politiche Agricole, Parchi e Foreste of the "Provincia di Cuneo" from January 2008 to December 2011. In Italy, it is not mandatory to give information to local or national authorities about accidents involving wildlife, so usually data are scarce and fragmentary. However, in this period, a plan to refund damages caused by wildlife collisions was implemented in Cuneo district, allowing us to produce a homogeneous database of considerable interest. The accident-related information contained in the database included: accident ID, year, month, day, hour, route, kilometre (from control section), day of week and ungulate species. Since we have not verified year effects on monthly (analysis of variance, ANOVA F 3,44 = 0.99, P = ns), daily (ANOVA F 3,24 = 0.13 P = ns (not significant)) and hourly (ANOVA F 3,88 = 0.69, P = ns) distributions, yearly data were pooled. In our study, we performed analysis on the influence of month, day and hour (GMT (Greenwich Mean Time) + 1). Moreover, we also considered the influence of time of day (dawn, day, dusk, night). According to Lagos et al. (2012), the year was divided into four seasons for roe deer phenology and hunting periods: breeding season (15 April-15 June), mating season (July-August), hunting season (September to January) and the rest of the year. For the analysis involving wild boar, we only differentiated drive-hunting season (September to December) from the rest of the year. A contingency table was used, and χ^2 square test and odd ratio (OR) values were calculated far each risk factor. The OR is a measure of association between an exposure and an outcome. The OR represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure.

Results

We analyzed 1110 reports of ungulate vehicle collisions (UVC) in Cuneo. Most of them (92.7%) were caused by roe deer (64.7%) and wild boar (29.5%). Collisions with red deer (Cervus elaphus L., 1758) represented approximately 5%, while fallow deer (Dama dama L., 1758) and chamois (Rupicapra rupicapra L, 1758) were involved occasionally (Figure 1). Figure 2 illustrates monthly, daily and hourly distributions of UVC in the study period. Monthly occurrence of collisions was not uniformly distributed (X^2 = 150.4, df (degree of freedom) = 11, $P < 0.001$), with two distinct peaks (spring and autumn). The number of road casualties varied throughout the week (x^2 = 18.4787, df = 6, $P < 0.005$), with a maximum on weekends and a minimum on Tuesdays. Regarding hourly occurrence, we noticed a non-random distribution (X^2 = 940.4, df = 23, $P < 0.001$), with a first peak after dusk and a second, minor peak at dawn.

Considering all data together, a higher collision risk was found in March, April and October (odd ratio > 1.0), while in January and February the risk was significantly lower (odd ratio < 1.0; Table I). Regarding the time of the day, the most dangerous periods were night and dusk, while the safest was daytime (Table II).

Figure 3 illustrates temporal distributions of UVC for the two most involved species, roe deer and wild boar. Monthly collisions showed non-random distributions (roe deer: X^2 = 231.5, df = 11, $P < 0.001$; wild boar: X^2 = 140.7, df = 11, $P < 0.001$) and distinct seasonal patterns. Most collisions involving roe deer occurred in springtime (April-May) but also in summertime, while a maximum frequency of wild boar-related accidents was noticed in autumn (September-December; Table I).

Breeding season highly increased the collision risk for roe deer, and hunting season for wild boar (Table III). At a daily scale, the collision distributions were uniformly distributed for both species. Both species showed a peak of collisions in the evenings, between 19:00 and 23:00, but roe deer collisions have a secondary peak at dawn (Figure 3).

Considering the localized distribution (for red deer: approximately 7.00% of our study area) and the small sample size (for chamois and fallow deer), no significant influences of temporal patterns were found for these species.

Discussion

The assessment of the main temporal patterns related to ungulate-vehicle collisions is an essential factor to increase road safety and enhance wildlife conservation strategies. Road collisions involving ungulates represent an increasing problem in many developed countries (Conover 2002; Malo et al. 2004; Steiner et al. 2014) and, with a few exceptions (Ponzetta et al. 2006; Dal Compare et al. 2007; Primi et al. 2010), scarce data are available for Italy. This paper covers this blank for a subalpine Italian region where high volumes of traffic overlap with growing populations of ungulates. The rate of ungulate-vehicle collision (UVC/year/1 000 km^2) for Cuneo district (40), even if higher than that observed in another subalpine Italian area (Belluno: 18-24; Nardo et al. 2001; Dal Compare et al. 2007), is lower than those reported in other European countries, such as Slovenia (153; Pokorny 2006), Austria (483; Putman et al. 2011) and Germany (635; Kerzel 2005). Comparing to CentraI

and Southern European data, the UVC rate is reduced in North America (4.5; Huijser et al. 2009) and in Scandinavia (7.2; Haikonen & Summala 2001), likely because of mitigation efforts, but even perhaps because of significantly lower urbanization and road density (Olsson et al. 2008). Several authors underlined the development of road networks among the main factors affecting UVC increase (Mysterud 2004; Seiler 2004; Langbein 2011).
Our data confirm the findings of studies carried out in similar ecological and environmental conditions, reporting that Cervidae and wild boars represent the main component of UVC (Dal Compare et al. 2007; Diaz-Varela et al. 2011). In our study, an evident non-random temporal distribution was found considering all datasets, and further interesting considerations can be made with a species-pattern approach. The two most frequently involved ungulates, roe deer and wild boar, are the most common species in the area (also in the whole Italian peninsula; Apollonio et al. 1988; Lorenzini et al. 2002), whereas red deer, chamois and fallow deer have localized distributions and relatively low densities. Monthly UVC showed two peaks, corresponding to spring (April-May) and autumn (October-November). The coincidence of rush hour traffic peaks with twilight in spring and autumn may be important in exacerbating the seasonal peaks in traffic accidents, as suggested by Langbein (1985).
The higher risk of collision during spring months was due to roe deer, according to other studies (i.e. Diaz-Varela et al. 2011). This peak was situated in the period of dispersal of young males and territorial males movements as reported in several studies (Nardo et al. 2001; Pokorny 2006; Lagos et al. 2012). The dispersion of yearlings from natal ranges to new territories leads to an increased probability to cross main roads, resulting in a greater vulnerability to collision (Langbein & Putman 2006; Langbein 2007). Moreover, in this period, large wintering groups collapse (Vincent et al. 1995), males initiate a territorial behaviour (Wahlstréim 2013) and many females start important migratory movements (Ramanzin et al. 2007). Another factor is that in this subalpine area, April and May correspond to vegetation renewal, with the availability of new feeding areas (Nilsen et al. 2008). All these factors increase the probability of roe deer crossing roads. Our results, reporting a significantly lower risk of collision with roe deer in December-February, agree with previous studies, which have reported a typical pattern with a main peak in spring, declining numbers during summer and low values during autumn and winter (Krop-Benesch et al. 2013; Steiner et al. 2014). The severe climatic conditions, snow cover and reduced food availability probably inhibit or reduce movements, so that roe deer spend most of their time in localized and advantageous wintering areas.
Wild boar is the main species involved in the autumn peak (September-November), when the risk of collision was about 2 times higher. Autumn and winter peaks were previously reported for wild boar, and rutting period, longer nights and hunting are frequently used to explain this pattern (Groot Bruinderink & Hazebroek 1996; Primi et al. 2010; Lagos et al. 2012). Life cycle and seasonal changes in home range size were other factors that should be considered (Diaz- V arela et al. 2011), and even the effect of autumnal outbreak of family groups. Another factor could be represented by winter road conditions, also if the role played by harsh weather is controversial (Hartwig 1993; Garrett & Conway 1999). Moreover, we could hypothesize that the presence of autumn feeding areas (i.e. related to local chesU1Ut abundance) plays an important role in increasing displacement and, consequently, accidents.
Our findings suggest that hunting could have influenced seasonal patterns for wild boar. Indeed, during this period, there was a risk of collision 3.29 times higher than during the rest of the year. Lagos et al. (2012) demonstrated the combined effect of hunting and longer nights on differences in numbers of accidents with wild boar in the autumn-winter months, even if Primi et al. (20 10) reported no correlation between UVC occurrence and drive hunting days. The reduction of wild boar collisions observed in our study after the hunting season could be related to the fact that almost 6000 hogs are harvested every year in Cuneo district, with an important lowering of density (Bonetto D. personal communication, 2014).
The available literature about UVC per day of the week is very scarce. In Spain, two studies (Diaz Varela et al. 2011; Lagos et al. 2012) reported evident weekly patterns with Sunday peaks, probably related to hunting influence. In our study, daily patterns evidenced a non-uniform distribution with a greater rate of accidents during weekends. This distribution was more pronounced for wild boar.
Hourly patterns showed a different distribution between the two main species involved. We observed a primary peak at dusk for roe deer: between 19:00 and 22:00, the risk of collision was 3.54 times higher than in other daily periods. Another secondary peak was found at dawn, between 05:00 and 07:00. These findings were comparable to those reported in the Netherlands (Groot Bruinderink & Hazebroek 1996) and in Finland (Haikonen & Summala 2001). A partially analogous pattern was described for roe deer in Spain (Diaz-Varela et al. 2011; Lagos et al. 2012) and in Siovenia (Pokorny 2006). This could be related to the activity patterns of deer that increase during sunrise and sunset (Romin & Bissonette 1996). Wild boar was most frequently involved in collisions during dusk and night, while dawn and day were periods with a lower risk of accident according to previous studies (Primi et al. 2010; Diaz-Varela et al. 2011; Lagos et al. 2012). We could hypothesize that the reason for this distribution is mainly behavioural, because the activity of this species is mainly concentrated during sunset and nocturnal periods (Boitani et al. 1994).

Conclusions

Information provided by this and similar studies is essential to understand the dynamics and patterns of UVC. The effectiveness of any mitigation strategy strongly depends on the level of our knowledge of this phenomenon. Regarding the presence of distinct temporal peaks, some studies suggested the use of seasonal warning signs (e.g. Dussault et al. 2006) or to realize a campaign of public awareness with local data and examples, to increase drivers attention in particular periods of the year or day. Thinking to eliminate the prob1em of wildlife-car collisions is absolutely unrealistic. Let us consider that already in his pioneering work, Dickerson (1939, p. 115) wrote that the

"solution of the problem of destruction of wildlife on highways by automobiles is not a search for means of eliminating such destruction entirely but rather of finding means to reduce to a minimum the death toll in each kind of highway environment. It is a subject of investigation that should enlist the cooperation of the wildlife manager, the landscape engineer, the horticulturist, and the highway engineer."

With the exponential growth of vehicle traffic and road extension, this problem is still growing enormously. At present, since it is almost impossible to modify ungulates behaviour, the mitigation of this problem should be focused on the modification of human behaviour, changing drivers attitudes and road engineering.

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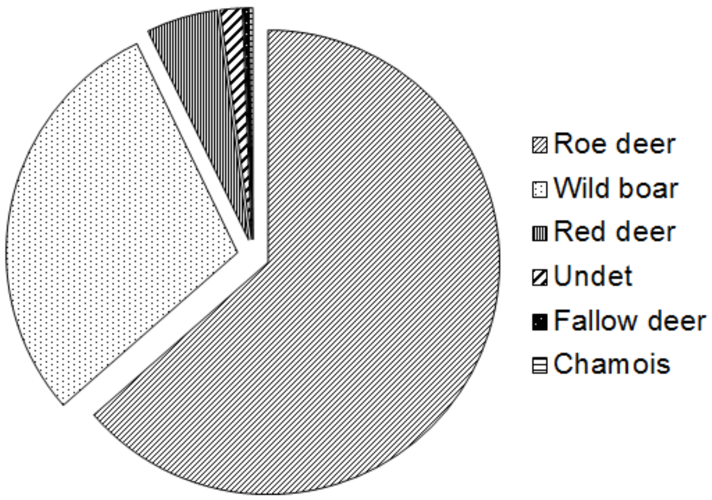

Fig. 1: Relative importance of ungulates species in the collisions

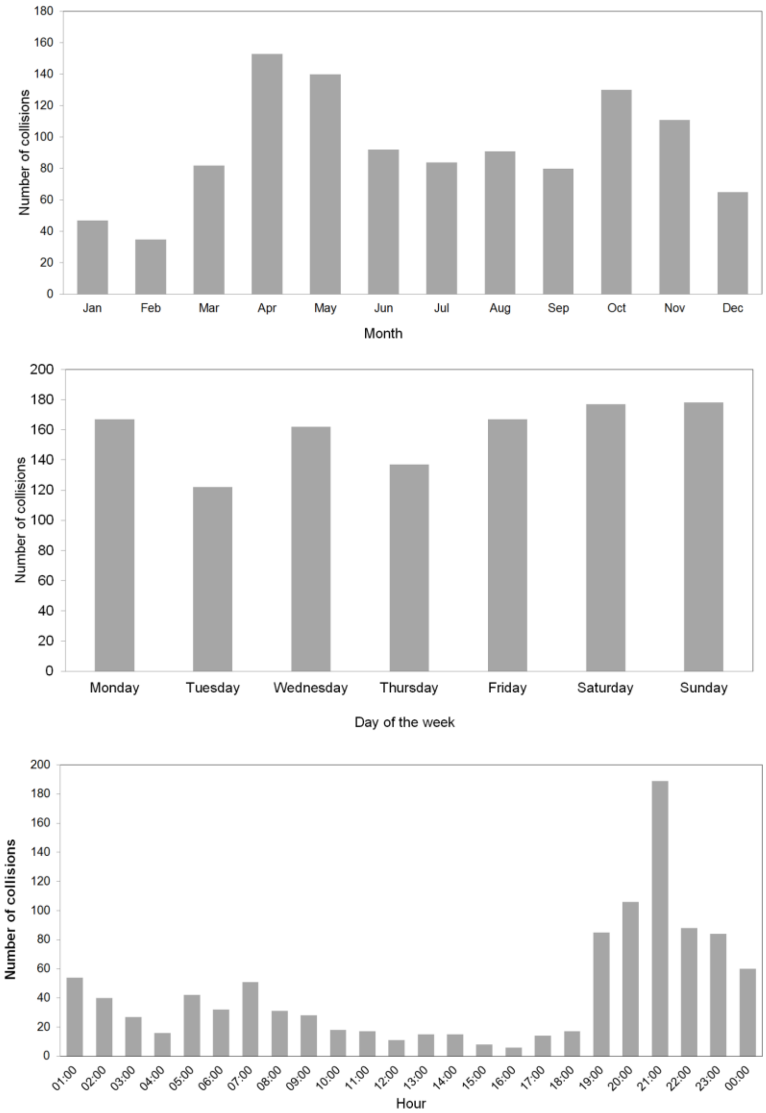

Fig. 2: Monthly, daily and hourly occurrence of ungulate-vehicle collisions in Cuneo district.

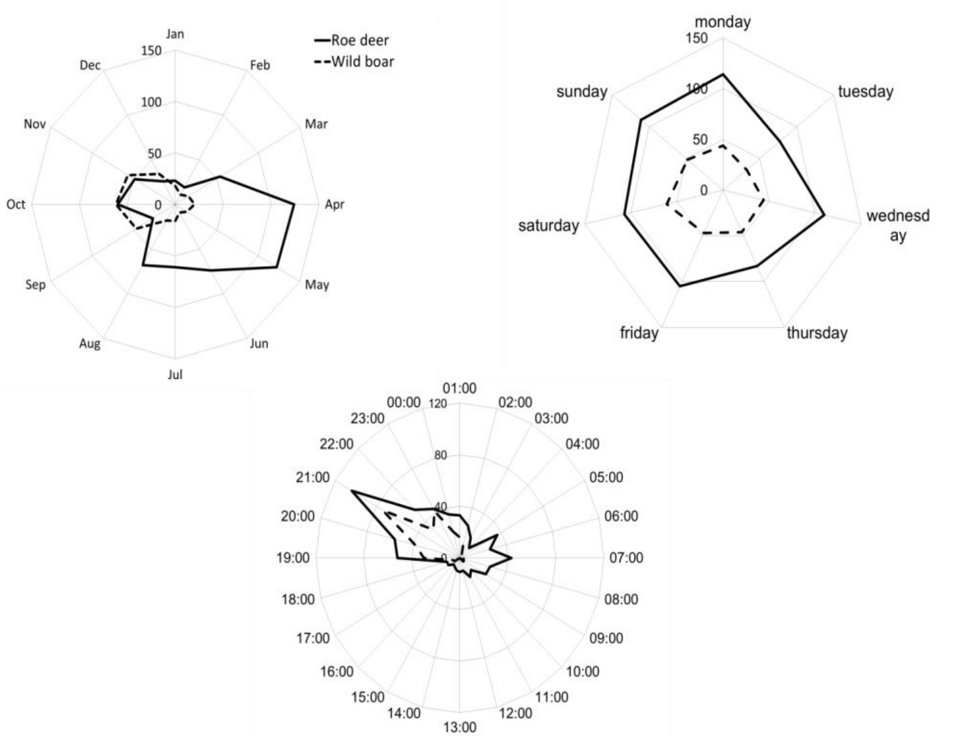

Fig. 3: Monthly, daily and hourly distribution of collisions for roe deer and wild boar

	All ungulates		Roe deer		Wild boar	
Jan	0.49	***	0.38	***	0.65	
Feb	0.36	***	0.31	***	0.39	**
Mar	0.86		0.91		0.57	
Apr	1.74	***	2.36	***	0.72	
May	1.56	***	2.27	***	0.5	*
Jun	0.99		1.29		0.31	***
Jul	0.90		1.06		0.57	
Aug	0.99		1.19		0.65	
Sep	0.85		0.43	***	1.87	**
Oct	1.47	**	1.04		2.6	***
Nov	1.23		0.83		2.35	***
Dec	0.69		0.43	***	1.29	

Tab. 1: Monthly values of Odd ratio for all ungulates, roe deer and wild boar.

	All ungulates		Roe deer		Wild boar	
Dawn	0.89		1.21		0.25	***
Day	0.3	***	0.4	***	0.13	***
Dusk	3.45	***	3.54	***	2.83	***
Night	1.45	***	1.02		1.54	***

Tab. 2: Daily values of Odd ratio for all ungulates, roe deer and wild boar.

	Roe deer		Wild boar	
Breeding season (May-June)	1,91	***		
Mating season (July-August)	1,11			
Hunting season (September-January)	0,49	***	3,29	***
Rest of the year (February-April)	1,16			

Tab. 3: Seasonal values of Odd ratio for roe deer and wild boar.