Wildlife Vehicle Collisions

Road ecology, monitoring and mitigation, citizen science, pedagogical and socioeconomic aspects

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Content

GLOSSARY

Abiotic factor Non-living factor in an ecosystem. As part of the ecosystem, these factors do affect the living things in it, but they are not living themselves.

AVC – Animal vehicle collisions when wild or domestic animals are hit by moving vehicles.

Biodiversity The variety of life at any given spatial scale including all the levels contained within, including genes, species, communities and ecosystems and their complex interactions.

Biotic factor A living thing, as an animal or plant, that influences or affects an ecosystem.

Carcass A cadaver (a dead body) of an animal found along a road. Databases of carcass differ usually from those related to animal-vehicle crashes.

Citizen science Science done by ordinary people, often for or with the help of scientists.

Culverts A tunnel carrying a stream or open drain under a road or railway.

Degradation The process by which something is made worse, e.g. the quality of land.

Direct effects The effects of a project or action that are a direct and immediate consequence of the project or action, without any intervening steps (compare to indirect effects). Habitat loss due to clearing for road construction is a direct effect.

Ecosystem The community of living organisms (plants, animals, microbes) and nonliving components of their environment (e.g. air, water, soil) interacting as a system.

Environment The surroundings or conditions in which a person, animal, or plant lives or operates.

Ephemeral Lasting for a very short time.

Extinction The termination of an organism or of a group of organisms (taxon), usually a species.

Foraging Animals go from place to place searching for things that they can eat or use.

GPS abbreviation for global positioning system: a system that can show the exact position of a person or thing by using signals from satellites (= objects in space that send signals to earth).

Green infrastructure A system of bio-corridors which shall be used by wildlife. It often contains over- and under- passes.

Habitat The area or environment where an organism or community normally lives or occurs.

Habitat fragmentation Artificial division of originally spatially homogenous part of a land habituated by an animal species. Fragmentation causes physical separation of individuals of one species. Transportation infrastructure often causes fragmentation of habitats.

Herpetofauna The reptiles and amphibians of a particular region, habitat, or geological period.

Highway Major road, usually with more than two-lanes in each direction. Has many more access points than freeway/expressway/motorway/tollway/ autobahn.

Impact Have a strong effect on someone or something.

Interaction From an ecological perspective, the effects that organisms have on one another. Intraspecific interactions involve individuals of the same species; interspecific are individuals of different species.

Landscape A large area of countryside, especially in relation to its appearance.

Landscape fragmentation The physical process where habitats become separated, usually through clearing and dividing of habitat.

Migration Journey undertaken by some species in response to changing seasons or climatic events, such as rainfall.

Mitigation Methods used to eliminate or minimize the negative impacts of developments.

Monitoring A form of research where repeated measurements or observations are taken over time, usually to assess the change in a parameter over time or in response to a disturbance/intervention.

Overpass A road or wildlife crossing structure that facilitates movements over/above the road.

PDA - Personal digital assistant A term for a small, mobile, handheld device that provides computing and information storage and retrieval capabilities for personal or business use, often for keeping schedules, calendars and address book information handy.

Population All the inhabitants of a particular place.

Road ecology Science that seeks an understanding of the interactions between roads/railways/utility easements etc and the natural environment, including wildlife, natural resources, land use and climate change.

Roadkill An event on a road when a (usually motor) vehicle collides with and kills an animal. Carcass of an animal can then be found at that place.

Roadkill hotspot Road stretches with more WVCs than expected by chance, that is, aggregation of road- kills in some road stretches.

Roadkill rate Number of individuals killed by traffic along a unit of a road over unit of time. Roadkill rates should always be compared to the total number of individuals of the given species and population viability when comparing among species.

ROS – Roadkill Observation Systems This web system can be used by observers in the field to record observations of identifiable road-killed wildlife. This includes type of animal and/or species found, where the road-kill was located, when it was found, how long it might have been dead, pictures of the road-kill, and any additional details about road or traffic conditions. The system then displays a summary of this information for different animal groups across the state.

Traffic volume The number of vehicles which use the given road section over a unit of time.

Underpass A road or wildlife crossing structure that facilitates the movements of things under the road.

Ungulates Belonging or pertaining to the Ungulata, a former order of all hoofed mammals, now divided into the odd-toed perissodactyls and even-toed artiodactyls.

Wildlife Animals and plants that grow independently of people, usually in natural conditions.

Wildlife crossing structure Any structure designed and purpose built to facilitate the safe movement of wildlife across roads.

WVC Wildlife-vehicle collisions - when wildlife is hit by moving vehicles.

INTRODUCTION

EnVeROS (Environmental Education through Roadkill Observation Systems) is an Erasmus+ funded educational project, with the aim to raise public awareness and educate especially young adults about the Wildlife Vehicle Collision situation in Cyprus, Czech Republic and the Autonomous Province of Bolzano/Bozen (Northern Italy). The topic of the Wildlife Vehicle Collisions (WVC) is a global traffic safety and conservation issue. The Erasmus+ project EnVeROS (http://www.enveros.eu/) aims to:

1) review the current situation on WVCs,
2) assist the incorporation of relevant information on the education curricula,
3) enhance the involvement of citizens in the monitoring of WVC.

Accordingly, this report aims to:

1) give a brief overview over the WVC topic in Europe,
2) briefly present the current magnitude and trend for WVCs in Europe, summarizing all the available information in a way that can be used for educational purposes,
3) bringing an overview of the current online WVC initiatives and Roadkill Observation Systems (ROS) along with the existing mitigation practices in Europe and worldwide,
4) provide detailed information for Cyprus, Czech Republic and Italy, where the EnVeROS partners are located,
5) present mitigation measures that are implemented,
6) overview pedagogical aspects, successful practices and case studies regarding WVCs,
7) examine the citizens' awareness of WVCs impact on biodiversity, society and economy.

This report could be used as an educational tool, regarding the issue of WVCs. Accordingly, it could be used by citizens, teachers and public authorities in order to raise people's awareness on this issue. It could also be used to support, through scientific information and updated data, local authorities in managing WVCs and implementing the most efficient mitigation strategies.

AN OVERVIEW ON WILDLIFE-VEHICLES COLLISIONS (WVC) IN EUROPE AND WORLDWIDE

Roads and their impact on wildlife habitats

Transport infrastructures (e.g. road networks) have a variety of impacts on wildlife including traffic mortality, habitat loss, habitat fragmentation and degradation. In addition, roads impose movement barriers on many wildlife species, obstacles that can isolate animal populations and lead from long-term genetic impoverishment down to population decline. Habitat fragmentation, the splitting of habitats into smaller and isolated patches, is globally one of the biggest threats to the conservation of biodiversity. Habitat fragmentation is mainly the result of different forms of land use change. The construction and use of roads are major agents causing this change as well as creating barriers between habitat fragments (Iuell et al., 2003).

In more detail, the effects of transport infrastructure on nature are typically divided into two groups: primary (directly bound to the construction and further operation of a given piece of infrastructure) and secondary (effects that do not directly fall into the transport sector but are likely induced by it). The physical presence of roads and railroads in the landscape creates new habitat edges, alters hydrological dynamics, and disrupts natural processes and habitats. In addition, road maintenance and traffic contaminate the surrounding environment with a variety of chemical pollutants and noise. The various biotic and abiotic factors operate in a synergetic way across several scales and cause not only an overall loss and isolation of wildlife habitat, but also split up the landscape in a literal sense. Habitat loss, disturbance, barrier and mortality effects usually refer to single infrastructure links, yet their long-term impact on populations and ecosystem depends on the type of infrastructure, landscape, or species considered (Van der Zande et al., 1980; Bennett 1991; Forman 1995). Motorways affect wildlife in a different way than forest roads, railroads or canals. Disturbance effects spread more easily in open landscapes than in forested habitats. Also, individual roads and railroads always are part of an infrastructure network. Thus, synergetic effects with other infrastructure links or certain landscape features may aggravate or weaken the significance of the primary effects that derive from one single link. The overall fragmentation effect to the landscape caused by the combined infrastructure network may thus not be predictable from data on individual roads and railroads. Evaluating primary (ecological) effects of a planned road or railroad therefore requires studies at both local and landscape scale and must consider the single link as well as the wider infrastructure network (Seiler 2000).

Currently, 21.6 million km of roads worldwide in total (Meijer et al., 2018) occupy 20% of the land surface (Ibisch et al., 2016), although with a high spatial variability in their density. Northwest Europe and parts of South and East Asia have the highest road densities (>1km/km^2), whereas the northern parts of Canada and the Russian Federation, the Sahara Desert and most area of the Amazon forest are still road-free (Meijer et al., 2018). Around 50% of the Earth's land surfaces delimited by roads are smaller than one km^2, while only 7% are larger than 100 km^2 (Ibisch et al., 2016). Europe has a web of roads that totals almost 5 million km (Eurostat data for 28 countries) with an uneven distribution of densities between regions: higher densities occur in Northwest Europe while lower densities occur mainly in the Eastern part of the European territory with even lesser levels in the far North. Moreover, many countries in the EU and in the World have plans to expand the road network in the next decades (Laurance et al., 2014). At least 25 million km of new roads will be built mainly in developing countries, including many regions of exceptional biodiversity conservation interest at global scale (Laurance et al., 2014).

The above-mentioned extent of transportation infrastructure may lead to increasing and inevitable animal-human conflict. Roads and railways, if not mitigated in their impact on and integrated in the environment, represent almost unsurmountable barriers to the free movement of the animals. Animal-vehicle crashes would be then a logical outcome of this conflict.

Roadkill as a result of wildlife and traffic interaction and roadkill data

There are various factors that contribute to increasing the risk of WVCs. The numbers of collisions generally increase with traffic intensity, animal activity and road density. Temporal variations in roadkill indicate different biological periods that influence the species' activity, such as the daily rhythm of foraging and resting, seasons for mating and breeding, dispersal of the young-of-the-year, or seasonal migration between winter and summer habitats (Bruinderink and Hazebroek 1996). Also changes in temperature, rainfall or snow cover can influence the occurrence and timing of accidents (Gundersen and Andreassen 1998). Naturally, collisions with wildlife can only occur where a road or railroad dissects a species' habitat, but local factors can alter the relationship considerably. Roadkill seems to increase with traffic intensity, but very high traffic volumes, noise and vehicle movement seem to repel many animals and mortality rates may not further increase with traffic. Clearly, also the occurrence of mitigation measures such as fences or passages affects the local risk for accidents (Seiler 2000).

Collisions between vehicles and wildlife comprise a growing problem not only for species conservation, but also for traffic safety, private and public economy. In most countries, traffic safety is the driving force behind mitigation efforts against fauna casualties. Although human fatalities are relatively rare in wildlife-vehicle collisions, the number of injured people is high and the total economic costs, including damages to vehicles, can be substantial.

The Wildlife-Vehicle Collision (WVC) issue is a global problem that affects many species worldwide (McKenna et al., 2001; Erritzøe et al., 2003; Loss et al., 2014). From a conservation point of view, WVC can reduce the population size, promote isolation through the limitation of dispersal, and therefore increase the risk of extinction (Riley et al., 2003; Beaudry et al., 2008). WVC could be a contributor to this biodiversity loss and it is a concrete phenomenon that has not received appropriate attention at European and Global scale, regarding species conservation and well-being, and human safety. The losses due to WVCs are a serious issue that affects not only the wildlife but the society, yielding environmental and socioeconomic impacts.

Estimates of wild species that are killed due to vehicle-collisions are alarming. In Europe, it has been estimated that between 350,000 and 27 million birds are road killed per year (Erritzøe et al., 2003) while in USA and Canada the estimates are between 80 to 340 million and 4 million of birds, respectively (Bishop and Brogan 2013; Loss et al., 2014). To our knowledge, there are no global estimates for mammal roadkill, except in Brazil where predictions show that more than 2 million mammals may be hit by vehicles every year (Gonzalez-Suarez et al., 2018).

Several studies show numbers of annual road mortality for some species in many countries in Europe: 200,000 Roe deer (*Capreolus capreolus*) in Germany (Hothorn et al., 2012), 144,000 hares (*Lepus europaeus*) in the Czech Republic (Mrtka and Borkovcová 2013) and 50,000 badgers (*Meles meles*) in UK (Clarke et al., 1998). There are estimates of roadkill rates for many species. For example roadkill rates can reach up to nine individuals (ind.)/km/year Nathusius's pipistrelle (*Pipistrellus nathusii)* in the Czech Republic (Gaisler et al., 2009), 6.5 ind./km/year for European hamster (*Cricetus cricetus)* in Slovakia (Hell et al., 2005), 5.5 ind./km/year in Denmark for house sparrow (*Passer domesticus)* with (Møller et al., 2011), 2.4 ind./km/year for roe deer *(Capreolus capreolus)* in Sweden (Sjölund 2016), 1.17 ind/km/year for long-eared owl (*Asio otus)* in Slovenia (Hell et al., 2005).

However, the number of roadkill does not provide information on the real impact of crash mortality on the conservation status of wildlife populations, since it depends on the population density and on its recovery potential from the loss of individuals. Therefore, it is fundamental to quantify the proportion of the additional mortality of a certain wildlife population due to roadkill. For example, Clarke et al. (1998) estimated that around 4% of badger population are road killed in south East England while Huijser and Bergers (2000) found that mortality of hedgehogs can reach to 30% of the population in some areas in Netherlands. Moreover, in Vale Natural Reserve, Brazil, Cullen et al. (2016) found that 10% of jaguar (*Panthera onca)* population is road killed every year. While in Spain, 12% of the Iberian lynx (*Lynx pardinus)* population was road killed in 2006 (Simon 2012), both species classified by the IUCN as NEAR THREATENED and ENDANGERED, respectively (IUCN 2018).

Using the proportion of the population road killed combined with estimates of population growth, we can determine extinction risk due to roads and findings show evidences that same roadkill rates can impact populations differently. The challenge now is to promote more population viability studies to evaluate the impact of the observed roadkill on species and take action to reduce the additional mortality.

SOCIAL AND ECONOMIC IMPACTS OF WVC

WVCs can have a broad range of consequences for both motorists and animals, resulting in injuries and fatalities. More common socioeconomic impacts are: 1) vehicle damage, 2) secondary motor vehicle crashes, 3) emotional trauma, and less direct impacts such as 4) travel delays. WVCs can also require the assistance of law enforcement personnel, emergency services, and road maintenance crews for potential repairs and carcass removal.

WVC involving large mammal species, such as ungulates (UVC), can cause substantial vehicle damage and human injuries, and consequently are a key public safety, economic and social concern (Bruinderink and Hazebroek 1996). In the United States, large-body size species (such as bears and deer) are responsible of almost 2 million accidents each year that result in $8.4 billion in damages (Huijser et al., 2008). Annual deer-vehicle collisions in the USA increased by 69% from 1985 to 1991 and by 50% from 1991 to 2004 primarily due to increasing deer numbers (Huijser et al., 2008). Additionally, around 5% of WVCs result in human injuries (Bissonette et al., 2008). The white-tailed deer (*Odocoileus virginianus* Z.) in the USA cause 1.2 million vehicle collisions annually, incurring $1.66 billion in damages, 29,000 injuries, and over 200 deaths, making it one of the most dangerous large mammal in North America to humans (Gilbert et al., 2017).

In Europe UVC has also become a serious road-safety problem with a significant economic impact (e.g. Langbein et al., 2011; Mrtka and Borkovcova 2013). Most accidents with wildlife are caused by ungulates and can reach up to 500,000 accidents per year, with an average of 30,000 personal injuries and 300 fatalities with costs up to $1 billion (Bruinderink and Hazebroek 1996; Seiler and Helldin 2006). A more recent study in Great Britain, showed that there are in average 42,500 to 74,000 accidents/year, 550 human injuries and 12 human fatalities per year with cost around €25 million per year (Langbein et al., 2011).

In Spain, WVC account for almost 9% of all accidents, being the wild boar and roe deer responsible for 79% of the WVC, and carnivores for 5% of the WVC (Sáenz-de-Santa-María and Tellería 2015). Costs including car damages, human injuries and fatalities can reach to €105 million, being the wild boar and roe deer representing 43.6% and 31% of the economic costs, respectively (Sáenz-de-Santa-María and Tellería 2015). Accidents with wild boars represent 43%

of those people having injured and 47% of the ones with human fatalities (Sáenz-de-Santa-María and Tellería 2015). The number of accidents and associated costs are on the rise in the last years due to increase of the density and distribution of wild ungulates (Milner et al., 2006; Burbaitė and Csanyi 2009; Veličković et al., 2016), in parallel with the growth of traffic intensity and speed. Currently, for each Italian Province it has been estimated that 15,000 animals on average, considering both domestic and wildlife, are killed on the roads each year (Guccione 2008).

WVCs have financial implications for public agencies as well. Law enforcement agencies face direct costs of investigation and traffic control following a collision. Transportation agencies typically are responsible for carcass removal and disposal costs and infrastructure repair costs, if necessary. Public agencies may incur some financial losses based on the monetary value of the animal itself, value associated with its hunting or license fees or recreational attraction for wildlife viewing.

WVCs can have other impacts on travelers that are more difficult to quantify in fiscal terms. Accidents involving large animals can lead to travel delays or secondary accidents for subsequent motorists if the vehicle or animal lies in the right of way. Some drivers also experience emotional trauma because of the danger they experienced and the killing of a large animal.

EXISTING ONLINE PLATFORMS IN WVC AND ROS (Roadkill Observation Systems)

Not every European country has its own system of animal-crash evidence. In some countries, such as in the Czech Republic this is usually a part of the official police database. The police typically register only crashes with damages to vehicles or passenger injuries are recorded. Therefore, high number of AVC are remaining underreported. In addition, many records only contain limited additional information and only seldom species can be identified (Bíl et al., 2017). Other public authorities might also collect data on WVC. In Cyprus for example, the Public Works Department (PWD), which is responsible for the maintenance of the road network, keeps records on roadkill. However, it is typical in many countries that WVC are not systematically monitored.

This fact of underreporting and the lack of information on species involved gave rise to the emergence of systems and platforms based on citizen science involving volunteers in general. Many citizen science projects and mobile applications to report AVC currently exist across Europe (Table 1).

Data collection methods for WVCs

Accurate and standardized data related to WVCs are essential for the development of mitigation measures that protect species, public health and safety (Rytwinski et al., 2016). For example, exclusionary fencing (2m high) which is used to prevent wildlife from accessing roads is placed in high traffic road sections where WVCs are frequent. Wildlife crossings (e.g. bridges, green bridges, tunnels) are also placed in areas where WVCs occur (Rytwinski et al., 2016). Effective WVC mitigation is generally costly and high quality WVC data help ensure that limited mitigation resources are strategically targeted to areas that produce the greatest results for motorists and wildlife. Gathering data can be challenging because WVCs occur over broad areas, during all seasons of the year, and in large numbers. Collecting data of this magnitude requires an efficient data collection system.

The collection of data on roadkill started 100 years ago when the ecologists recorded WVCs data manually, using pen and paper. A century later, many if not most public agencies still use the pen/paper method to report animal carcasses that occur on roadways. However, this monitoring method is problematic as the data have low spatial accuracy, contain inaccuracies and a significant amount of time is required to digitize the data and insert them in a database and/or GIS system, in order to analyze and design mitigation measures.

The accuracy and efficiency of WVC data was a major problem for researchers and their improvement was a goal for many years. Global Positioning System (GPS) and Personal Digital Assistant (PDA) technology was first employed to generate accurate spatial locations. This method was a breakthrough in WVC data collection as it increased the location accuracy and eliminated the errors that typically occurred when uploading the records in a database. However, the introduction of smartphones replaced PDA reporting systems which were not adopted widely in WVCs data collection.

Hesse et al. (2010) developed a system using the Otto-driving Companion. The device was attached to the dashboard of the vehicle, and it allowed the driver to report animal carcasses with the push of a button while driving. The system generated spatially accurate locations using GPS but was limited by the number of species that could be reported. Again, WVC data had to be downloaded manually from each device to a database for the information to be useable. While this represented another step forward in WVC data collection, the Otto-Driving Companion has not been widely adopted.

Most recently, web applications have been developed for reporting WVCs (Bíl et al., 2017). These web-based systems allow users to report animal carcasses by accessing a website where they enter location and species information. Some of these systems are based on a citizen science approach and even allow the users to upload photos of animal carcasses. The development of web applications for reporting WVC data is a significant advancement. It standardizes data collection and eliminates transcription. However, this system requires users to have internet access. Nowadays, most web applications have built-in map viewers (e.g., Google Maps) that allow users to zoom to and select a location on the map, which makes defining the location relatively easy. However, locations errors associated with this technique are unknown and largely dependent on the user.

A good representative example is the work of CDV in the Czech Republic. To describe the system, the application allows users to insert data on WVCs which occurred on roads and railways. Three ways are there to enter the data into the application: 1) web-based form which is mainly used by people who gather data in the field first and then enter it from their offices. 2) Android mobile app directly from the position of the WVC. Users can collect data offline, including their GPS positions and photos and upload them via Wi-Fi later. 3) Via a standardized interface, e.g. in the case that a third-party information system is providing their data (e.g. Police).

The application automatically computes AVC hotspots every midnight and crash densities along road sections (Bíl et al., 2017). Approximately 1800 AVC hotspots, which cover 0.5% of the Czech road network, were detected and visualized on a map (Figure 1; 2).

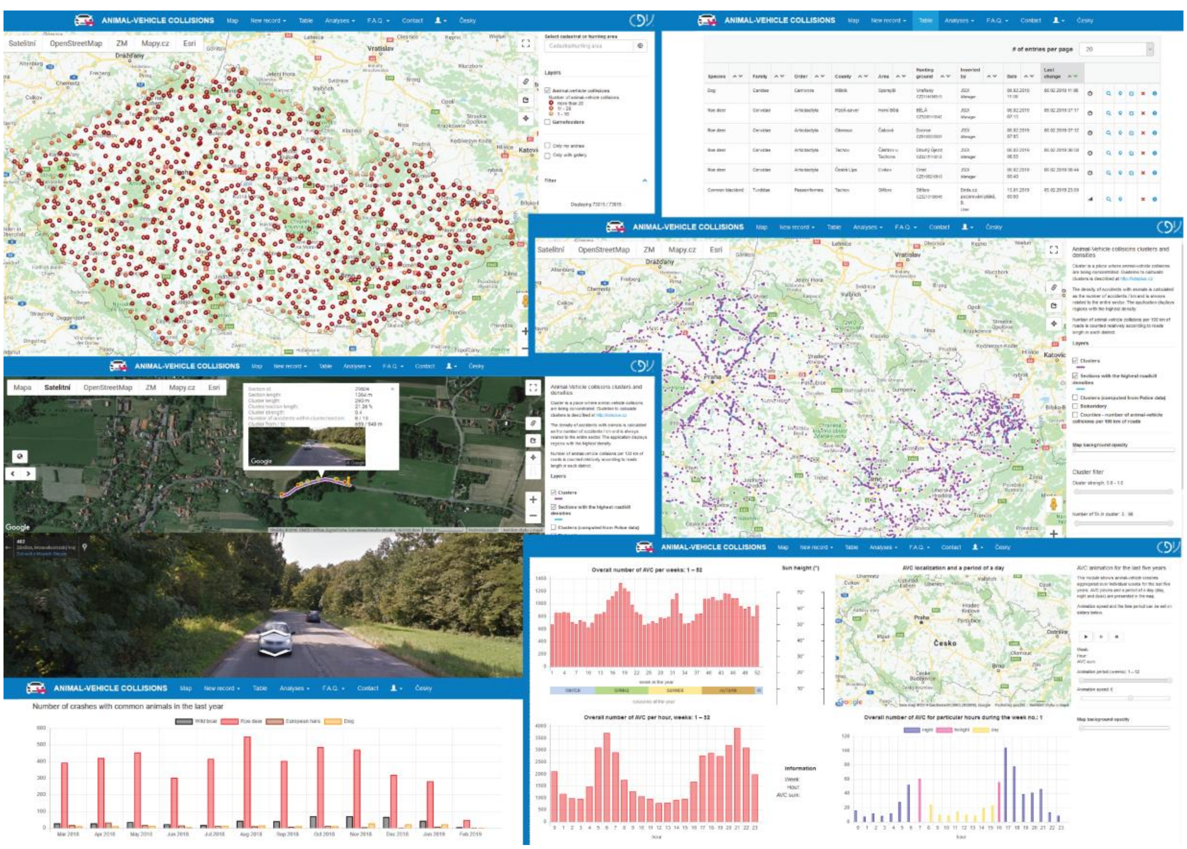


Figure 1. *Srazenazver.cz – an overview of the system.*

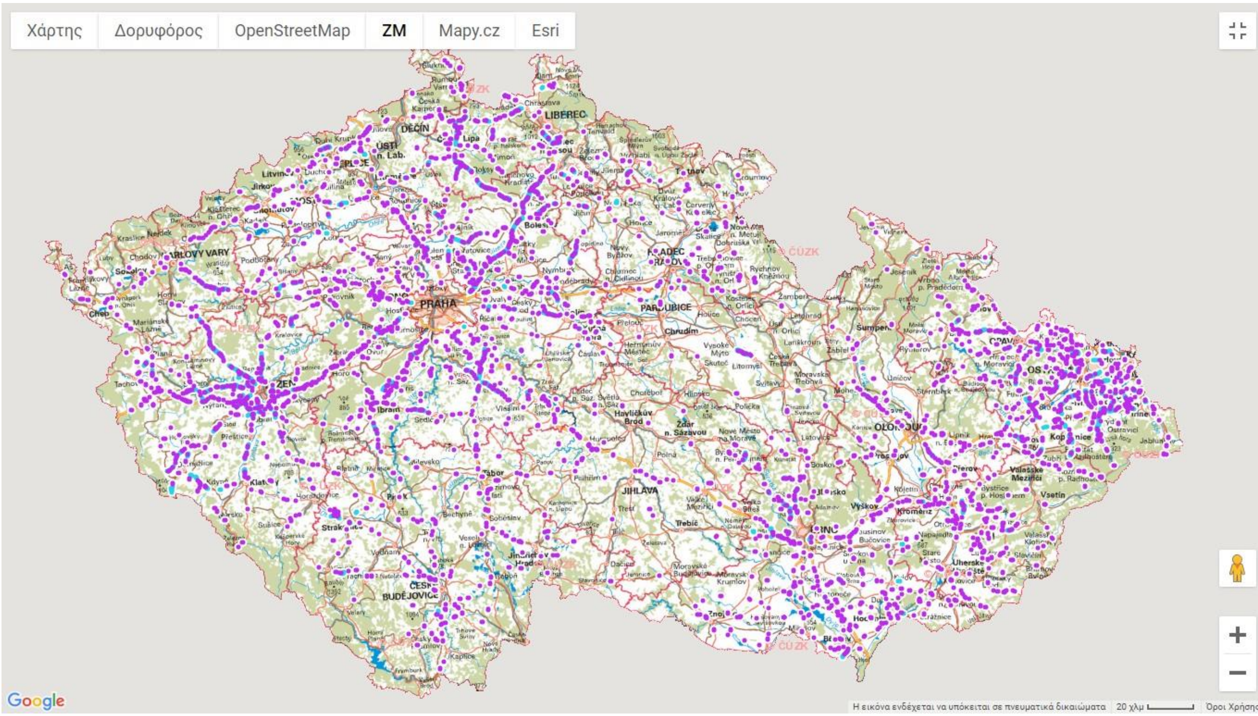


Figure 2. *WVCs clusters and densities in the Czech Republic.*
http://www.srazenazver.cz/en/cluster/

The Belgian ROS Waarnemingen.be offers to the users the potential to "adopt a road" and be responsible for reporting the WVCs in that road. It also accepts records from all Europe as well as the rest of the world, in its international version (https://observation.org/vs/start). Applications for observation are e.g. ObsMapp for Android, iObs for iOS and WinObs for Windows. Volunteers do the field observations. The data are included into a global digital system to create a tool for conservation, research, policy, experience and education.

Table 1: A list of citizen-science based AVC reporting applications that are running in Europe

Title	Organisation/ Country	URL	From	Focus / limit	Infrastructure	Input	Output	Type of reporter
Srazenazver.cz	CDV / Czech Republic	www.srazenazver.cz	2014	CZ/CZ	Roads, Railways	Mobile app., website	Hotspots	Registered users, Police
Dieren onder de wielen	Natuurpunkt / Belgium	www.dierenonderdewielen.be or www.observation.org/vs/start	2008	Flanders / no	Roads	Mobile app., website.	Roadkill locations in a map	Everyone (all types of background knowledge)
Project Roadkill	BOKU / Austria	http://roadkill.at/en/	2014	Austria / no	Roads	Apps for Android and iOS	Roadkill locations in a global map	Basically, everyone who uses roads
Project Splatter	Cardiff University / United Kingdom	https://projectsplatter.co.uk/	2013	UK / UK	Roads	Via website, direct email, Twitter, Facebook, iOS and Android apps, UK council data via freedom of information requests	Roadkill locations in a map	Members of the public (open to anyone)
Wildlife Incident Reporting Apps	Ireland	http://wildlife-incidents.com	2015	Ireland	Roads	Mobile apps	Incidents reporting in Ireland	Members of the public (open to anyone)
CyROS	Open University of Cyprus/ Cyprus	http://www.cyroadkills.org	2017	Cyprus	Roads	Mobile app/ website	Roadkill locations in a map	Members of the public (open to anyone)
Life strade	Region Umbria/ Italy	http://www.lifestrade.it	2016	Italy	Roads	Mobile app., website	Roadkill locations in a map	Members of the public (open to anyone)
S.P.I.A Cuneo	Province of Cuneo, University of Torino and University of the Piemonte Orientale/ Italy	https://www.facebook.com/spiacuneo/	2017	Italy	Roads	Mobile app	Preventing WVCs	Members of the public (open to anyone)
WUIDI-Wildwarner	WUIDI/ Germany	https://wuidi.com/	2016	Germany/ Austria/ Switzerland	Roads	Mobile app.	WVC warnings.	Members of the public (open to anyone)

MITIGATION MEASURES IN THE EU

A wide variety of mitigation approaches are used to reduce the mortality on wildlife populations for existing roads or for new road constructions (Glista et al., 2009). Drivers' safety has been the driving force behind the majority of WVC mitigation efforts. Nevertheless, the construction of roads in protected areas or in areas of endangered species occurrence has promoted the development of technical solutions aimed at maintaining viable populations.

Species respond differently to roads and mitigation measures according to their behavior patterns and traits (Gonzalez-Suarez et al., 2018). For example, fencing may prevent jumpers (e.g. deer) while small mesh size fencing with climbing guards prevents ground-dwelling species and climbers from accessing roads. Large animals often use overpasses or wide underpasses while small medium sized mammals (e.g. red fox, martens, badgers) use culverts (Grilo et al., 2008; Mata et al., 2008). Moreover, the same mitigation measure can be beneficial for some species and detrimental for others (Jakes et al., 2018). For example, fencing can reduce the mortality for mammals but can be harmful for birds that do not perceive fence and can be trapped in that structure.

The location of mitigation measures should consider the daily target species' movements as well the road sections having a higher incidence of mortality (Aresco 2005; Dussault et al., 2007). Track the individual movements can provide information on the specific road crossing locations (Beaudry et al., 2008). In parallel, through the combination of incidence rates of road mortality (e.g. Goncalves et al., 2018) and modelling it is possible to predict the riskiest road segments.

When the vulnerability to roads is ephemeral, the evaluation of the temporal activity patterns of species may help to identify risky periods when the mitigation must be more effective. For example, amphibians in temperate zones migrate to breed and disperse to new areas in specific periods of the year (Beaudry et al., 2008).

Mitigation measures encompass in general two categories:

- Measures aimed at changing the *behavior of the species* in the proximity of roads (e.g. fencing, vegetation clearance, dry ledges, overpasses and underpasses, olfactory repellents).

- Measures to change the *driver's behavior* (e.g. speed reduction, warning signs) including sophisticated devices as a part of automobiles.

Measures influencing wildlife behavior

Fencing

Several studies show that well-placed fencing (Figure 3) can reduce significantly the ungulates mortality of more than 80% (e.g. Clevenger et al., 2001, Bissonette and Rosa 2012). However, if species can find no alternative to reach the other side of the road, fencing can become an unsurmountable barrier and consequently isolate the populations, increasing the likelihood of extinction. Further research is needed to understand collateral effects of fencing on wildlife conservation (Jakes et al., 2018).

Figure 3. *Fencing along roads is capable to block movement of large mammals. Photo: Václav Šlauf, MAFRA, Czech Republic.*

Vegetation clearance

There is no consensus regarding the impact of vegetation clearance (Figure 4) in reducing the number of roadkill. Lindstrøm (2016) found no reduction in the number of ungulates collisions following vegetation clearing whereas Tanner and Leroux (2015) found that recently cut roadside areas may create a less attractive foraging habitat for moose and may reduce the likelihood of being road-killed. Vegetation clearance as an important and effective measures' is further supported by the recent analyses of WVC hotspots (e.g., Sjölund 2016; Seidel et al., 2018).

Figure 4. *Vegetation clearance close to a highway road in Germany.*

Dry ledges

Some underpasses and culverts (Figure 5) have water most of the year, which can prevent many mammal species to reach the other side of the road safely. One solution is to adapt the crossing structure to keep a part of its width dry. Several studies show that small and medium size mammals use these ledges (Meaney et al., 2007; Villalva et al., 2013) but it is not clear how much they reduce the mortality rates.

Figure 5. *Culvert crossing. Source:*
https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_018552.pdf

Overpasses and underpasses for wildlife

Along the roads and highways, we can observe overpasses (Figure 6), underpasses with the purpose to re-establish the linkage of landscape or maintain riparian galleries as well culverts to allow water to flow under the road. Although these existing crossing structures are built for other purposes, they can be used by many species and re-establish the habitat connectivity. However, not all species can use these structures and tend to respond better to passages with specific design characteristics. Herpetofauna use wide culverts with natural subtract (Woltz and Gibbs 2007). Vegetation at the structures entrance, the availability of suitable habitat, low level of human activity are significantly associated with the carnivores use (Ng et al., 2004; Grilo et al., 2008; Mata et al., 2008). New over- and underpasses are built if there are no existing ones which could be also modified to be used by wildlife. Overpasses are large and costly structures which have to be carefully placed to be used by the targeted species.

Figure 6. *An overpass, accompanied by fencing, across D2 motorway near Bratislava, Slovakia. Note the wooden barrier on the top of the overpass to block view of animals when crossing. Photo: M. Králík (HBH).*

Olfactory repellents

Repellents can be chemical, visual, acoustic or a combination of these (Mason 1989). Taste repellents were used as useful tools in preventing damage to plants and odor repellents in reducing WVC (Hedlund et al., 2004). Most studies have been focused on taste repellents inducing a gastrointestinal malaise, whereas chemical repellents are tested only occasionally (e.g., Nolte and Wagner, 2000; Kinley et al., 2003). Recently olfactory repellents (Figure 7) were tested in a four-year long study in the Czech Republic. It has been found that they are capable to decrease the number of ungulate-vehicle crashes (roe deer and wild boar) between 26 – 43% (Bíl et al., 2018).

Figure 7. *Olfactory repellents are installed along many roads in central Europe. This particular kind of installation is, however, not recommended. Source: https://www.kr-zlinsky.cz/pachove-ohradniky-u-silnic-branici-stretu-se-zveri-se-osvedcily-aktuality-12324.html*

Measures influencing drivers' behavior

Speed reduction

Car speed ranks among the most important factors related to the risk of WVC. It was recommended therefore that lowering car speed in certain places with poor visibility should decrease the number of WVC. Seiler (2005) observed that the reduction of speed from 90 to 50 km/h on roads with 8,000 vehicles/day/year traffic intensity can reduce the risk of accidents with moose of 50%. Road bumps can be an approach to reduce the speed of vehicles. However, they can only be applied in protected areas or secondary roads and under specific conditions as it also affects traffic safety in general.

Active and passive drivers' wildlife warning signs

Drivers' wildlife warning signs (Figure 8) are one among the most commonly applied and widespread forms of mitigation measures aimed at reducing the number of roadkill. Unlike fencing and wildlife passages, these systems do not attempt to keep animals off the road; rather, they attempt to modify driver behavior by detecting animals near the road and warning drivers with flashing signs Grace et al., 2017). There is evidence that the passive, i.e. animal road signs are not effective (e.g., Knapp et al., 2004; Meyer 2006). Certain success in lowering the number of WVC was achieved when the passive warning signs were installed during critical times. Some studies show that drivers are more likely to respond positively to animal-activated and vehicle speed-activated warning signs (Bond and Jones 2013; Grace et al., 2017).

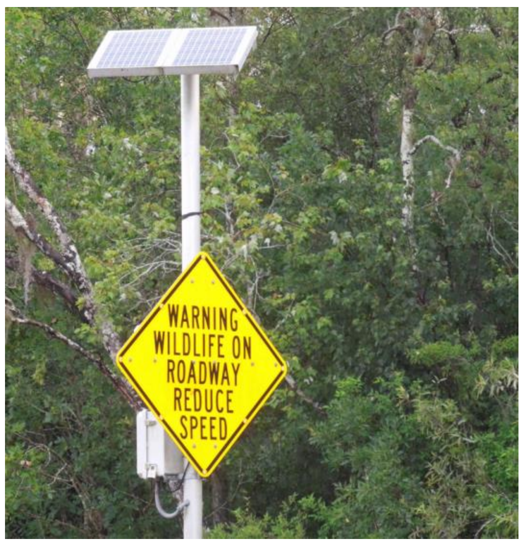


Figure 8. *A text-based RADS warning sign in Big Cypress National Preserve, Florida, USA. When an animal is detected near the road, the lights begin to flash. Credit: Molly Grace*

Warning systems for both drivers and animals

An innovative system was established and tested in Italy during the project LIFE-STRADE. The roadkill prevention system was composed of:

1) a central control unit,
2) four radar doppler sensors (two to register the speed of vehicles on both the sides of the road and two to record the presence of animals approaching the road),

3) two road signs that alert the car drivers,
4) an acoustic and optical scaring system.

The system works in the following way (see also Figures 9 and 10): the radar Doppler sensor (1) registers the presence of an approaching animal and sends the information to the electronic control unit (2). The control unit activates an alert signal for drivers (3), inviting them to slow down to an acceptable speed. Another sensor (4) measures whether the car slows down to the desired speed. If it does, the system stops to act. Otherwise the radar sends a signal back to the control unit (2), which activates the optical and/or acoustic scaring system (5), which shall drive the animal to escape. The system consists of sensors linked to a software platform that allows a full remote control and monitoring. In this way the drivers travelling that specific road segment are adequately alerted and should be more careful to the danger signs.

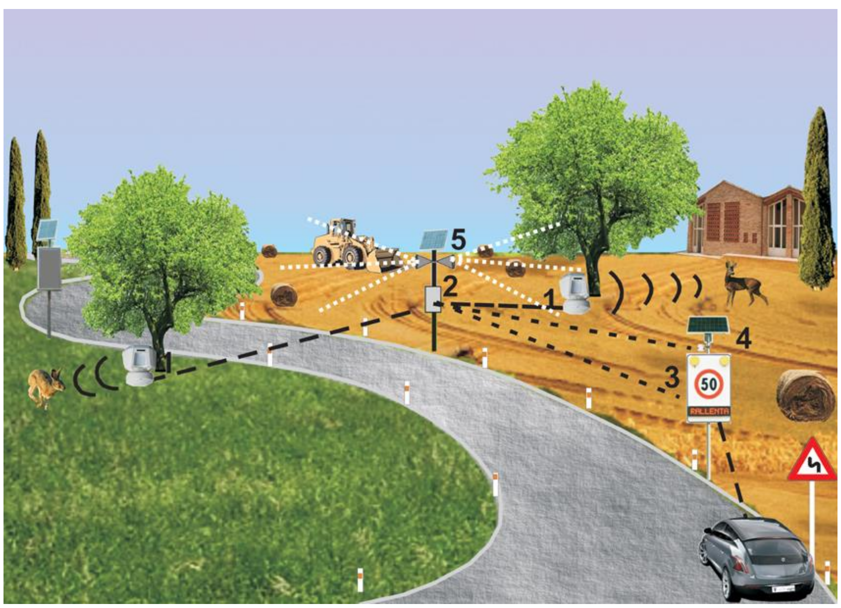


***Figure 9**. The system developed for the need of the project LIFE STRADE*
(http://www.lifestrade.it/index.php/it/)

Figure 10*. A detail of the system, based on acoustic warning of ungulates, developed during the LIFE-STRADE project. See the loudspeakers from which voice of humans and dogs barging is emitted. Photo: M. Bíl (CDV).*

Car technology, identification of animals by onboard sensors

New car technology including night vision assistant (Figure 11) has already been used. These systems are not, however, still available for most drivers.

Figure 11. *Thermal cameras can detect not only pedestrian but also wildlife on or close to roads. Source:* http://www.technected.com/wp-content/uploads/2013/11/Night-Vision.jpg

DESCRIPTION OF THE WVC ISSUE IN THE PARTNERS REGIONS

The EnVeROS project areas are presented in Figure 12. In the following paragraphs of the report, the situation regarding the issue of WVCs in the project areas is presented.

Figure 12. *EnVeROS partner regions on the map of Europe.*

Italy and the Autonomous Province of Bolzano/Bozen

Species involved in WVC and roadkill

In Italy, the phenomenon of WVC is mostly considered under the aspect of a serious road safety issue: 3% of the total number of national claims are related to WVCs, injuring and killing people all among the territory. The described phenomenon is related to collisions with animals of large size (Figure 13), especially with Cervidae (red deer, roe deer, fallow deer), Bovidae (chamois, ibex, mouflon and wild goats), Suidae (wild boar), Ursidae (brown bear (Figure 13), Marsican brown bear) and Canidae (wolf, fox, golden jackal, domestic dog). Collisions with smaller size animals, with often high conservation value, are, if at all, documented on regional or provincial level but rarely reported in national statistics (Cerofolini, 2006; LIFE Strade, 2015). The phenomenon of Wildlife Vehicle Collision is not yet monitored systematically on national level in Italy. Only an estimation by Guccione (2008) indicates a number of 15,000 animals killed per year in the 107 Italian Provinces, on a total public accessible road network of 181,619 km.

Figure 13. *Brown bear "M14", killed on local highway A22. 21.04.2012. ©dpa 2012.*

Countermeasures

To warn the driver along the national roads from collisions with animals, the Italian legislator uses two types of warning signs (Figure 14; Decreto del Presidente della Repubblica 16 dicembre 1992):

Figure 14. *Traffic signs used in Italy do warn drivers before domestic (left) and wild (right) animals.*

According to the national hunting law (Legge 11 febbraio 1992, n. 157, 1992) wildlife in Italy is a state property. On a local level, this management is assigned to the responsible administrative authorities in the region or province. Due to limited resources and legal uncertainties, the local administration does not have adequate strategies to encounter this WVC phenomenon. Related to this, the approaches to manage and monitor the problem vary from region to region and, within regions, from province to province (LIFE Strade, 2015). Roadkill can have a crucial impact on biodiversity, economy and society. This impact has been documented and evidenced in a variety of projects and initiatives in Italy.

Bellow, current and past initiatives and projects on the Italian territory to mitigate the roadkill phenomenon could be found:

- **Gufi e Strade**: Monitoring of owls hit by vehicles through a citizens' cooperation (https://www.ebnitalia.it/QB/QB006/penne2.htm)
- **Life STRADE:** WVC monitoring in 3 Italian regions http://www.lifestrade.it/index.php/it/)
- **Italian Road Mortality:** Records of voluntary reports on roadkill on an online platform called **iNaturalist** (https://www.inaturalist.org/)
- **Delta Road Kill project:** Monitoring of vertebrate roadkill near the Po river delta (http://storianaturale.comune.fe.it/826/delta-road-kill-animali-investiti-sulle-strade-del-delta-del-po)
- **ROADKILL.IT:** Initiative to inform and reduce roadkill in the Province of Varese (https://www.roadkill.it/).
- **LIFE Safe-Crossing**: Demonstration of Best Practices targeting priority species in South-East Europe (https://www.facebook.com/lifesafecrossing/)

WVC in the Autonomous Province of Bolzano/Bozen

The Autonomous Province of Bolzano/Bozen is in the northeastern part of Italy, in the heart of the Alps. On a total area of 7,400 km2, the local public accessible road network covers 5,076 km (ASTAT, 2017) (Figure 15).

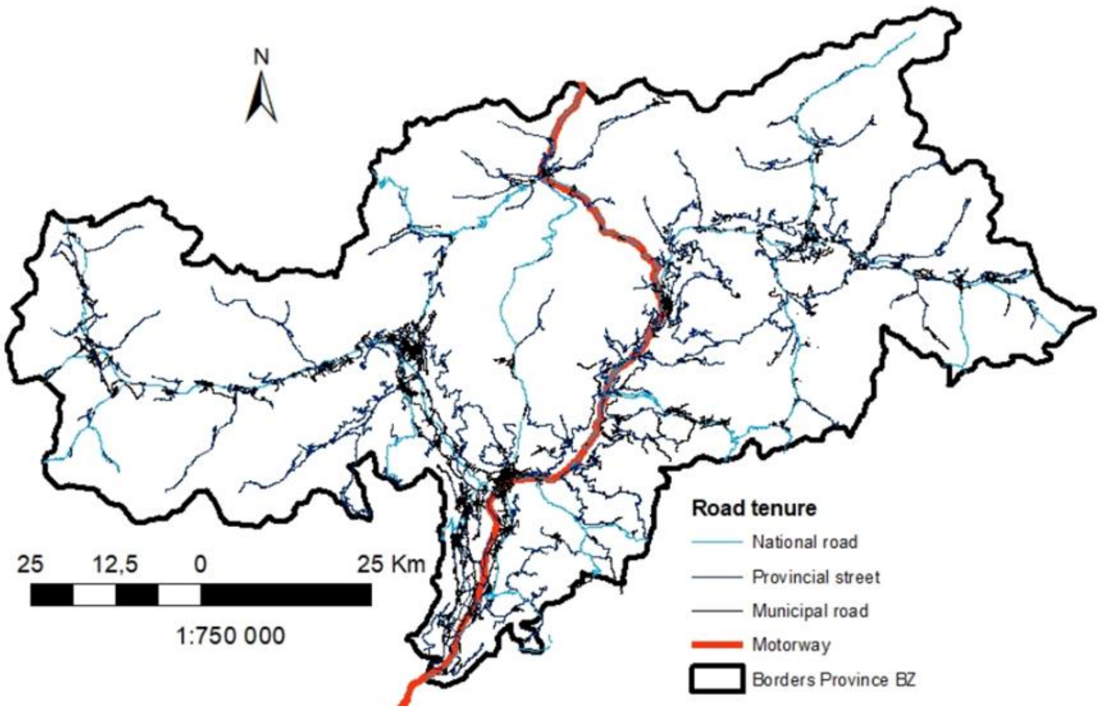


Figure 15. *A detail maps of the Bozen region showing road network. ©Eurac 2019.*

Starting from 2012, the local hunting association (Südtiroler Jagdverband) collects data about WVC on the territory of the province (Figure 16). This dataset includes mainly game species like red deer, roe deer, chamois, fox and badger but, to a certain extent, considers also the most dangerous species regarding road safety. The number of reported WVC in the Autonomous Province of Bolzano-Bozen is in average 855.28 ± 100.17 collisions per year.

The Autonomous Province of Bolzano/Bozen has the primary competences for the wildlife legislation, traffic and also road management since 2001 (Südtiroler Landesverwaltung 2019). A clear and concise strategy to manage the roadkill phenomenon is still missing.

To reduce WVC with amphibian, the following actions have been conducted:

- Project **"Amphibienschutz" (=amphibian protection**): Information and conservation of autochthon amphibian species (Figure 17) (http://www.herpeton.it/de/AmphibienschutzKaltern.html)

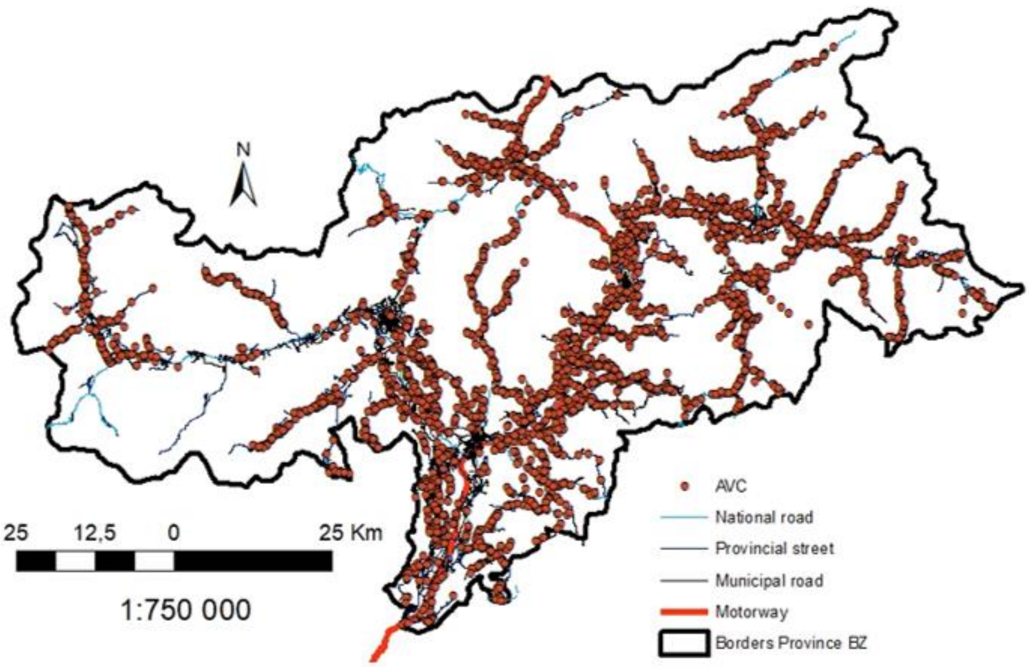


Figure 16. *Total 5,987 registered WVC on the provincial road network. ©Eurac 2019.*

Figure 17. *Action of Project "Amphibienschutz". ©Herpeton*

Other initiatives:

- Project "Corridori ecologici" (ecological corridors) (Tornambé and Halilaj 2015) This study points at finding examples of ecological corridors in South Tyrol and give it a critical analysis considering also the problems with fragmentation due to the presence of linear infrastructure in narrow valleys, which constitute significant barrier effects for various wildlife species.

- Gufler (2000) elaborated a map to visualize the potential corridors for big-ranging wildlife species in South Tyrol, also considering its importance for genetic exchange. The study could show that ungulates adapt their crossing areas accordingly with the landscape due to anthropic and/or natural barriers.
- Eisenstecken (2013), referring to the work done by Gufler (2000), identified and prioritized seven corridors in a large-scale ecological network, in order to quantify the permeability of the South Tyrolean landscape to red deer and roe deer.
- Favilli et al. (2018) considered temporal (visual analysis) and spatial (KDE+ software) patterns to locate possible hotspots in South Tyrol for AVC with red and roe deer. This is the first time; this approach is used for the province of Bolzano.

Czech Republic

General overview

Animal-vehicle conflict on the Czech roads is both traffic safety and nature conservation issue. The Czech Republic has a dense road network which fragments natural habitats of wildlife into small isolated patches (Figure 18). Only recently, several large overpasses were built, and suitable culverts and bridges were modified to be used by large mammals as underpasses. Research is currently focused on assessment of permeability of roads to wildlife and identification of dangerous road locations due to WVC.

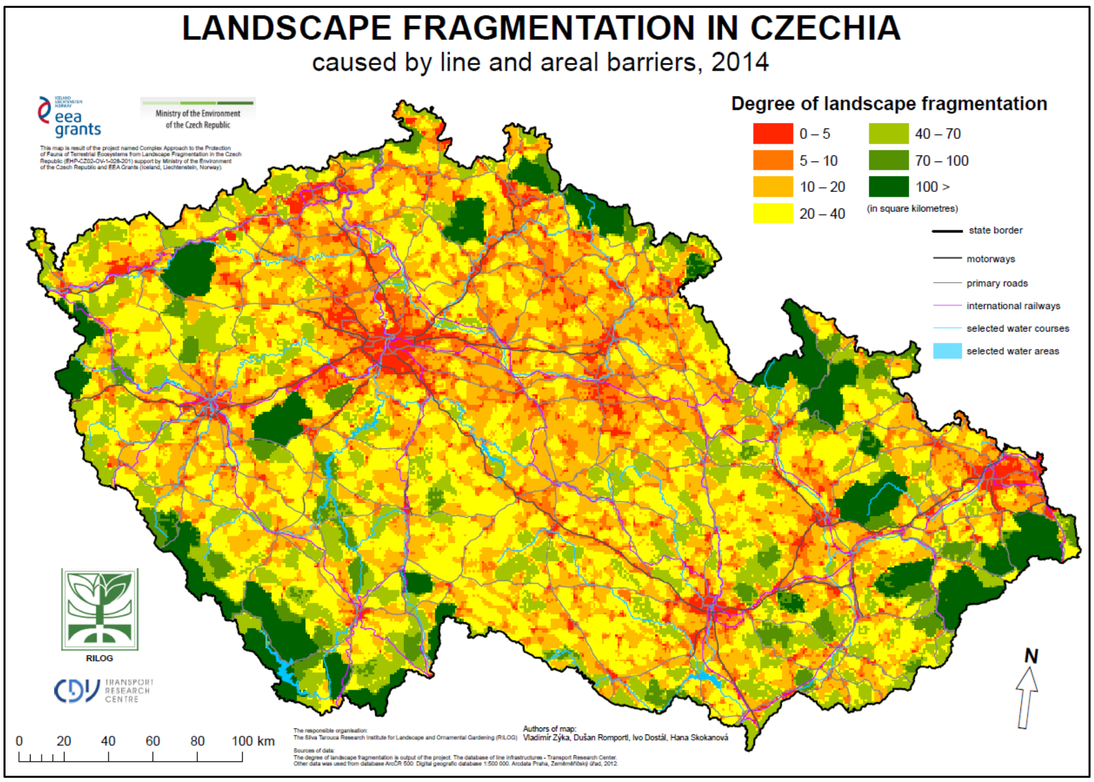


Figure 18. *An example of landscape fragmentation due to transportation infrastructure in the Czech Republic. Legend shows areas according to their size. Orange and red colors represent polygons with low extent.*

Recent projects related to WVC and roadkill

Several projects related to WVC issue have recently been completed in the Czech Republic. A project (EHP-CZ02-OV-1-028-2015) was carried out by the Nature Conservation Agency of the Czech Republic (other involved partners were CDV, Evernia and the Silva Tarouca Research

Institute for Landscape and Ornamental Gardening). It focused on the complex assessment of the landscape connectivity. A database of barriers to free movement of wildlife, due to transportation, a database of suitable bridges to be utilized for wildlife movement across primary roads, conflict point identification were among the outputs of this project. Landscape fragmentation was considered separately for forest and non-forested ecosystems, amphibians, reptiles and birds. An education movie about landscape fragmentation was filmed (https://www.youtube.com/watch?v=H9oT6vuyO60&feature=youtu.be).

Another important project, TransGreen (Integrated Transport and Green Infrastructure Planning in the Danube-Carpathian Region for the Benefit of People and Nature), has recently been completed by a consortium led by WWF International Danube-Carpathian Programme (Austria). It primarily focused on the Carpathians which are located on the eastern part of the Czech Republic. The assessment of landscape permeability for large mammals was also completed in the frame of a project (VaV SP/2d4/36/08). A map defining corridors for long-range migration within the Czech Republic was completed (Figure 19).

Figure 19. *A map, the result of the project VaV SP/2d4/36/08, demonstrating identified the long-range migration corridors in the Czech Republic with respect to protected large mammals.*

Another project No. TD03000306 (Blackspots: Places at crossings at Green and Grey Infrastructures) analyzed WVCs blackspots and the system of existing long-range migration corridors (Figure 20).

Figure 20. *The map locating places with the highest WVCs clustering rate on the Czech roads.*

WVC crash database

AVC is a traffic safety issue in the Czech Republic. The overall number of registered AVC is on the rise recently (Figure 21) reaching up to 12% of all registered traffic crashes in 2018.

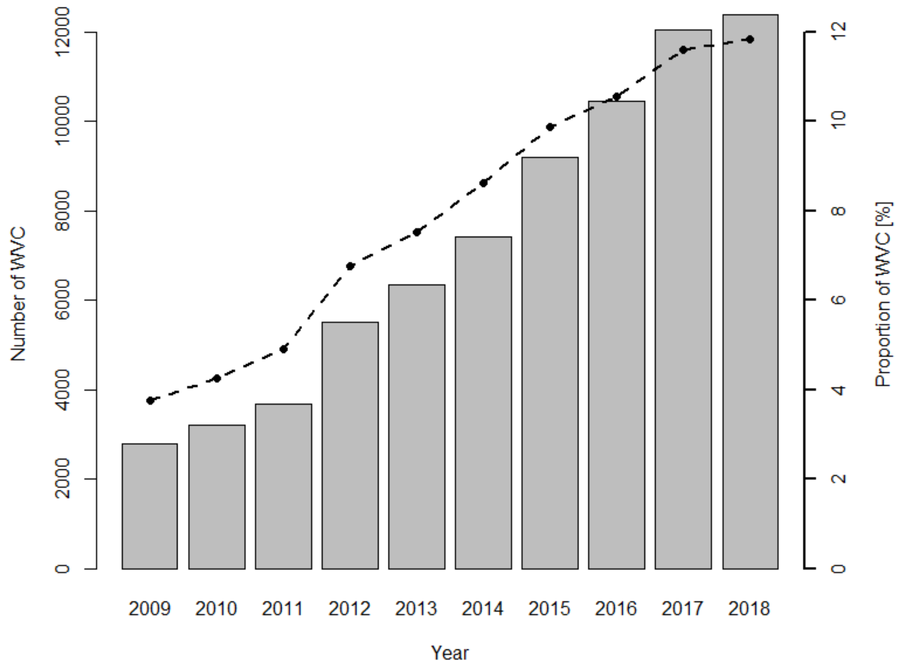


Figure 21. *An increase of both absolute number of WVC records and their proportion to all registered traffic crashes can be observed. Data from the Czech Police crash database and www.srazenazver.cz.*

The srazenzver.cz, a web map application for reporting AVC, was developed by CDV to collect as much information as possible on species involved in AVC at one place. WVC, but also crashes with domestic animals and carcass findings, are included in the database. This system is the most complex database of this kind in the Czech Republic as it contains data from many sources (see Figures 22a, b).

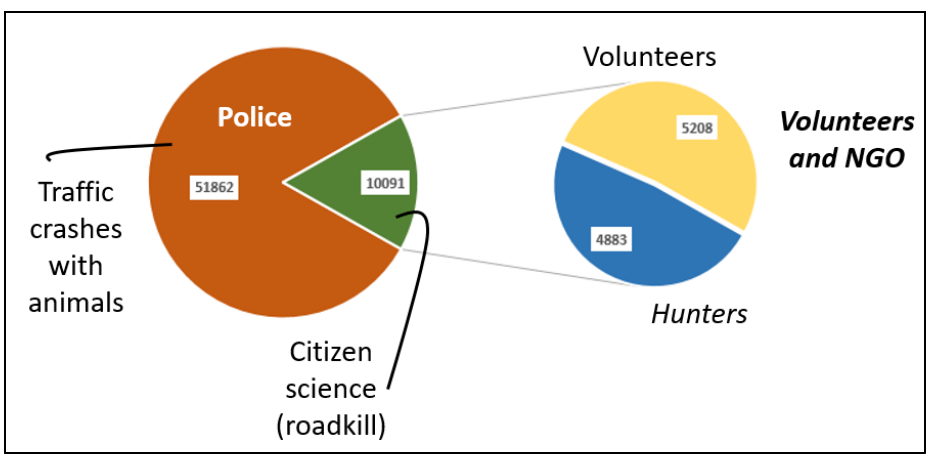


Figure 22a. *A structure of database records according to the type (traffic crash reports or carcasses) and the authors' employment status.*

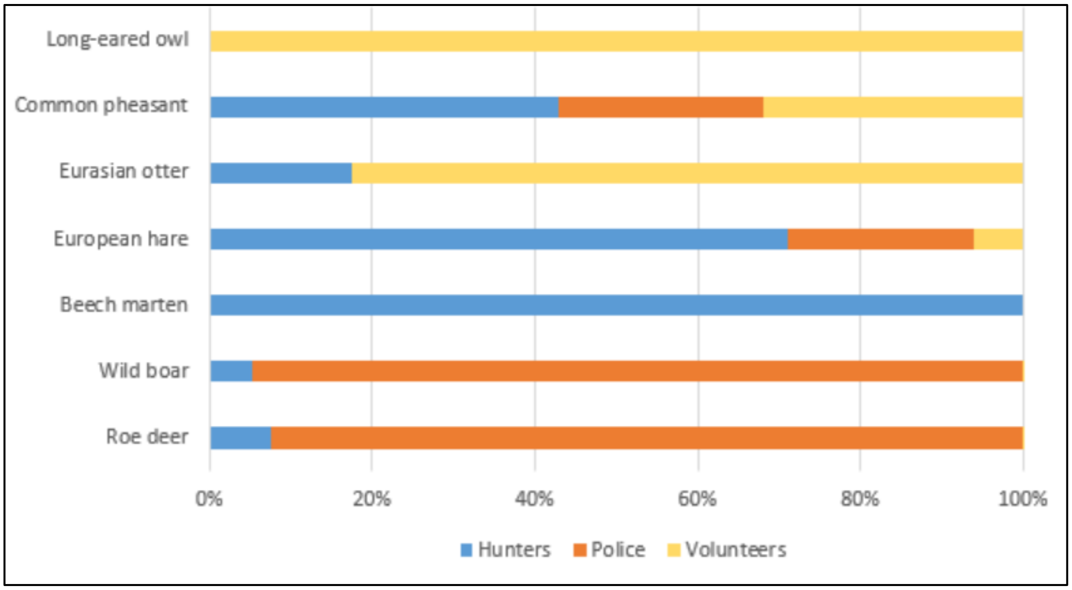


Figure 22b. *Some examples of a various portion of records provided according to employment status.*

There were 73,043 records until February 2019. 55% of data included information on species, the remaining 45% were traffic crashes reported by the Police, but without species determined. Most records where species was determined were related to Roe deer (*Capriolus capriolus*) (Figure 23) reaching 58%, followed by Wild boar (*Sus scrofa*) (10%). Most of the records are mammal species (Figure 24). Accidents with large animals have safety and economic impacts (Figure 25).

Figure 23*. Roe deer (Capreolus capreolus) killed during AVC, Czech Republic. Photo Jiří Kasina.*

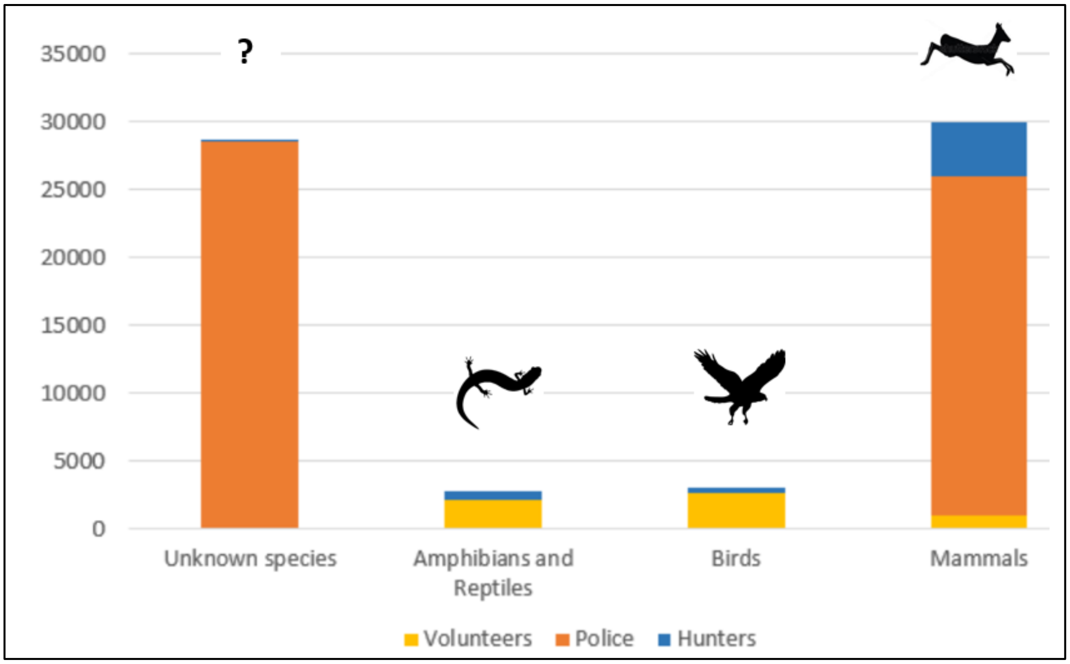


Figure 24. *Most species are mammals. Data from Srazenazver.cz.*

Figure 25. *A car damaged as a result of a crash with a wild boar, Czech Republic. Photo: Generali.*

Roadkill of endangered species

Srazenazver.cz contains most data related to traffic crashes which are caused by large animals. Therefore, the most endangered species are not present among the most frequent records. This is particularly true for Amphibians. Most records are those with *Bufo bufo*, followed by *Rana* *temporaria*. and *S. salamandra,* which is not so common, can be endangered locally, as its populations are not so large when compared to both above-mentioned species (Krása 2018).

Birds are also killed by motor vehicles frequently. Owls, due to their low flight and hunting behavior, are particularly vulnerable to collisions with vehicles. Most records are related to Long-eared owl (*Asio otus*), as this is quite common owl currently replacing Barn owl (*Tyto alba*) at many habitats (Zbyněk Janoška, *Pers. Com*). Barn owl and Little owl (*Athene noctua*) are considered as endangered due to roadkill. The most serious situation, among mammals, in the Czech Republic is in all probability with weasels (Poledník et al., 2005; Větrovcová et al., 2010). Also, many hedgehogs are killed in towns and cities, as well as bats which are particularly vulnerable species.

Temporal and spatial distribution of roadkill

Highways are in their majority still not fenced in the Czech Republic and therefore many ungulate-vehicle crashes are recorded every day. The risk of these crashes is the highest during sunrise and sunset and is related to behavior of roe deer and wild boar (Figure 26). Spatial distribution of roadkill was studied using KDE+ method (Bíl et al., 2016). Cluster of WVC, based on crashes with large mammals, are visualized at www.kdebourame.cz ("Where do we crash?" in English) which is administered by CDV and used in their work by the National Road Administrator (Figure 27).

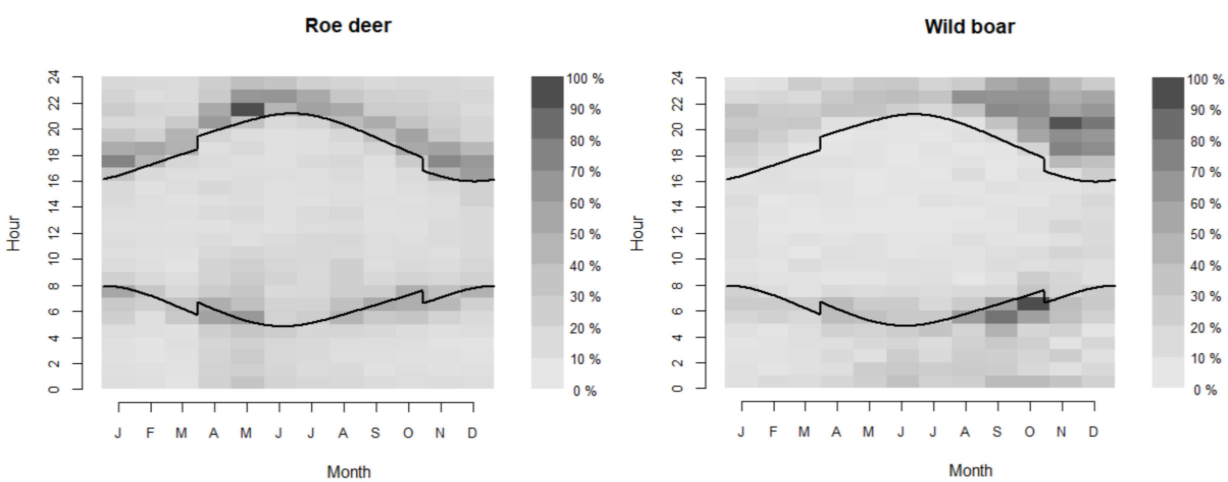


Figure 26. *A relation between the number of recorded crashes with Roe deer (left), Wild boar (right) and the time do a day and month.*

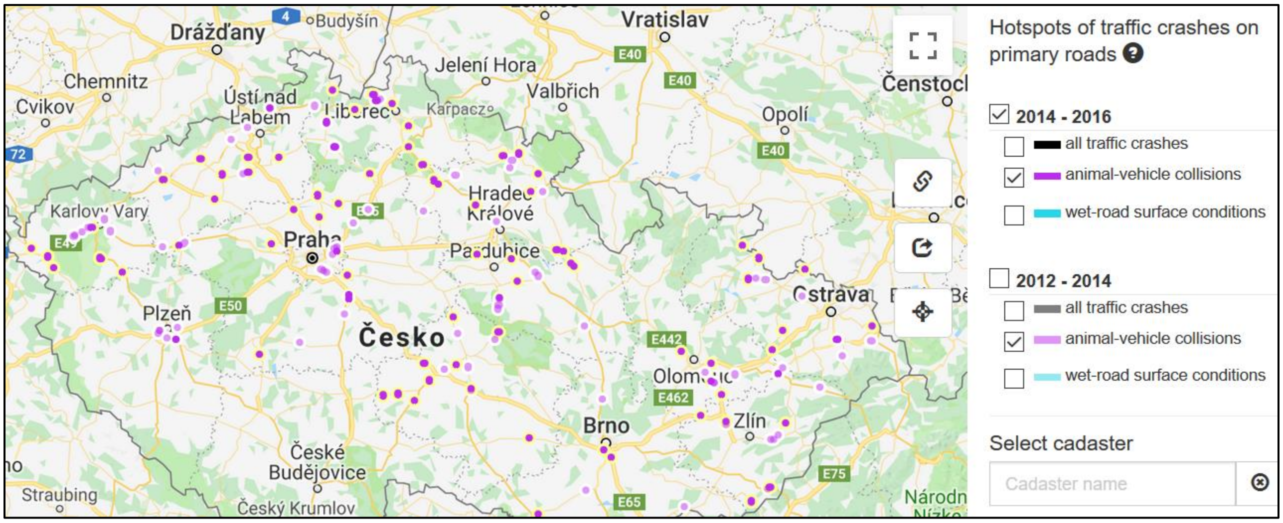


Figure 27. *Kdebourame.cz website where KDE+ clusters of traffic crashes with large mammals are visualized.*

Existing mitigation measures in the Czech Republic

Only certain highways and primary class roads which were built recently are fully fenced and accompanied with the overpasses (Figure 28). The remaining road network is, however, free of fences allowing thus the animals crossing the roads. On certain primary and many secondary roads two elementary types of countermeasures, odor repellents and reflectors, are being installed.

Figure 28. *An overpass built near Žehuň (Central Bohemia region, Czech Republic) to allow wildlife crossing D1 motorway. Photo: I. Dostál (CDV).*

WVC Awareness, legislation, etc.

WVC issue can be seen from various perspectives in the Czech Republic. Many hunters are currently involved in www.srazenazver.cz reporting. They are primarily focused on the game animals and therefore they report these species only. They report not only Roe deer carcasses, but also small game animals, such as European hare. Hares are reported frequently by hunters in certain hunting grounds. Hares are only seldom causing traffic crashes and are therefore underrepresented in the Police crash database. This reporting brings thus an important overview of the roadkill of hares. Hunters are also frequently involved in application of roadkill counter measures, particularly the low cost, such as olfactory repellents.

The WVC issue is frequently discussed among car drivers as the major insurance companies only recently included WVC into the basis insurance. Many of them are still not aware the fact that the killed game animals is owned by a respective hunting group. Drivers, when collided with a wildlife, must call the Police first. Then a local hunter area administrator is called to remove the carcass. Environmentalists and members of nature-conservation focused NGOs are aware of the WVC and roadkill issue well. They are often involved in campaigns during which, particularly small animals such as amphibians, are gathered and moved when trying to cross roads.

Cyprus

As in other places in the EU and the world, the problem in Cyprus has several dimensions; environmental, governance, policy/legislation, awareness and socio-economic are considered as the most important.

Environmental issues related to WVCs

Considering the environmental dimension, even though road network is a key factor for economic development (e.g. tourism, transportation) it also causes irreversible changes to habitats and species. According to data from the Statistical Service (2012) the road network has increased over 88% in the past 20 years in Cyprus and intersects many protected areas, especially Natura2000 (Figures 29, 30).

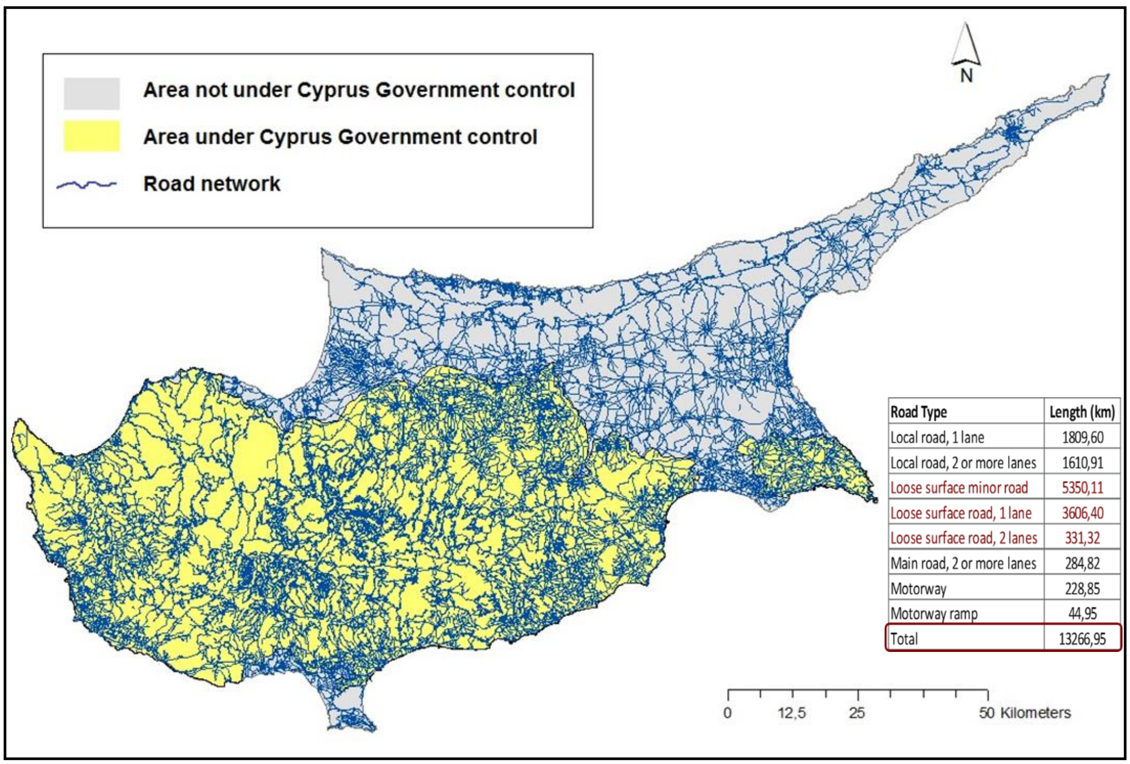


Figure 29*. Road network in Cyprus. The legend refers to the areas under control by the Republic of Cyprus.*

The road length situated within Natura 2000 network is now 25% and 4.5% of the island area is not covered by the road network; that is patches of less than 1 km^2. Regarding the protected areas, two very small terrestrial SCIs are not intersected by roads (Periochi Agiatis CY4000011 &

Periochi Drymou CY4000014), which highlights the potency of WVCs to act as a threat to maintaining a good conservation status for wildlife species protected there in (Zomeni and Vogiatzakis 2014).

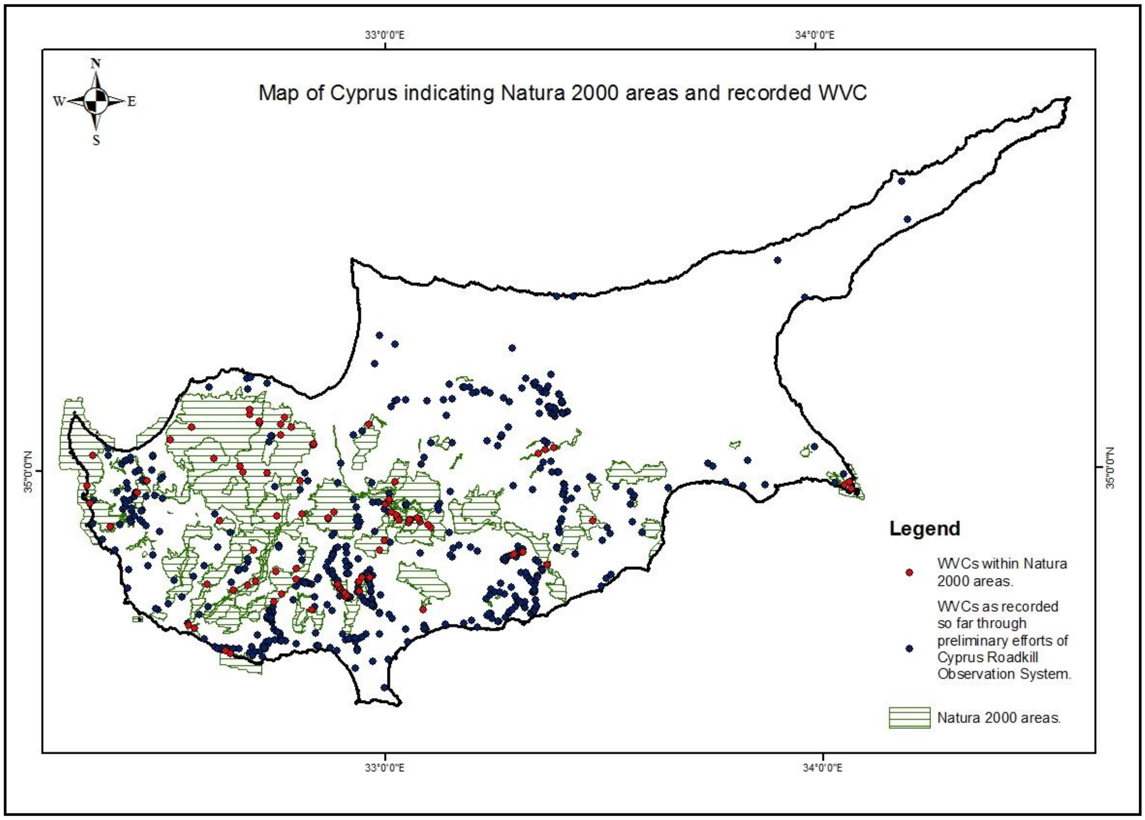


Figure 30*. WVCs recorded in the platform CyROS. With red color are the WVCs into the Natura2000 areas (data until 2018).*

Species involved in WVCs

WVCs in Cyprus involve species of EU concern, protected under Annex II of the Habitat Directive (e.g. *Coluber cypriensis, Ovis orientalis*), Annex I of the Birds Directive (e.g. *Caprimulgus europeus, Otus scops cyprius*). The island lacks large mammals, except the strictly protected Cyprus muflon (*Ovis orientalis*; Figure 31).

Figure 31. *Young Cyprus mouflon (Ovis orientalis ophion) found dead on Road from vehicle collision at Paphos forest (copy right - K. Nicolaou, GFS). Cyprus mouflon is an endemic subspecies included in the Annex II of Directive 92/43/EEC.*

From the species perspective, WVCs affect many different species (Figures 32 and 33) and vary according to the landscape, road types and habitats. Reptile, amphibian, mammal and bird species might be severely affected. Moreover, Game and Fauna Service (GFS) data suggest that 13% of the mortality for the protected Cyprus mouflon is due to WVCs. The preliminary data suggest that the most accidents take place in spring, early summer (Figure 34).

Figure 32. *Hierophic cypriensis (Annex II of 92/43 and endemic species) in the side of the road.*

Figure 33. *Common chameleon roadkill in a rural road in Cyprus*

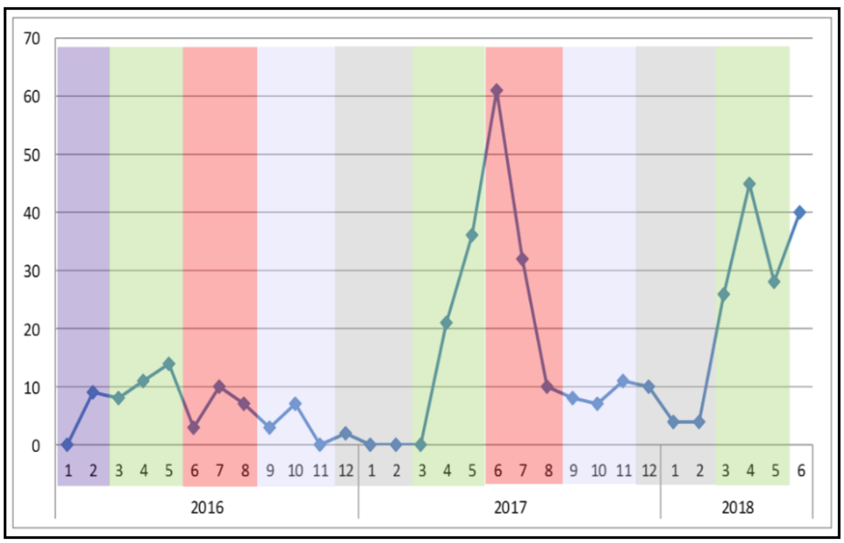


Figure 34. *Number of WVCs (dead animals) during 2016-2018.*

The situation is clearly different than in other areas of Europe, where efficient monitoring/ mitigation is applied. The data from the CDV, Czech Republic that are representative for the condition in central Europe suggest that the largest portion of the WVCs involve ungulates; >90% (e.g. boar, deer) while the remaining involves mainly birds. Regarding the current monitoring of the WVCs in Cyprus, the PWD (Public Works Department) owns the only long-term effort for recording WVCs, focusing on road network users' safety. The PWD has 1,454 records, since 2013, which mainly involve foxes, hedgehogs and snakes. They also reported 1,245 WVCs with pet animals (e.g. cats, dogs). However, PWD covers only highways and the recording is conducted in an inconsistent manner, in terms of registration and species identification and outdated protocols were used. In addition to the PWD, the Game & Fauna Service (GFS), the Department of Forests (DoF) and the Department of Environment (DoE) hold sporadic counts of roadkill, collected in an ad hoc manner.

In addition to these efforts, a parallel activity which started a year ago by the Open University of Cyprus has recorded more than 600 incidents all over Cyprus (Figure 35; CyROS – www.cyroadkills.org). While government departments rely exclusively on their own resources for data collection CyROS uses an expanding network of volunteers (138 so far) using a Citizen Science approach (collecting environmental data and sharing it with the public). The non-coordinated and fragmented nature of this important environmental information, results in underreporting of WVCs and inconsistent assessment (and planning) regarding its contribution to biodiversity loss.

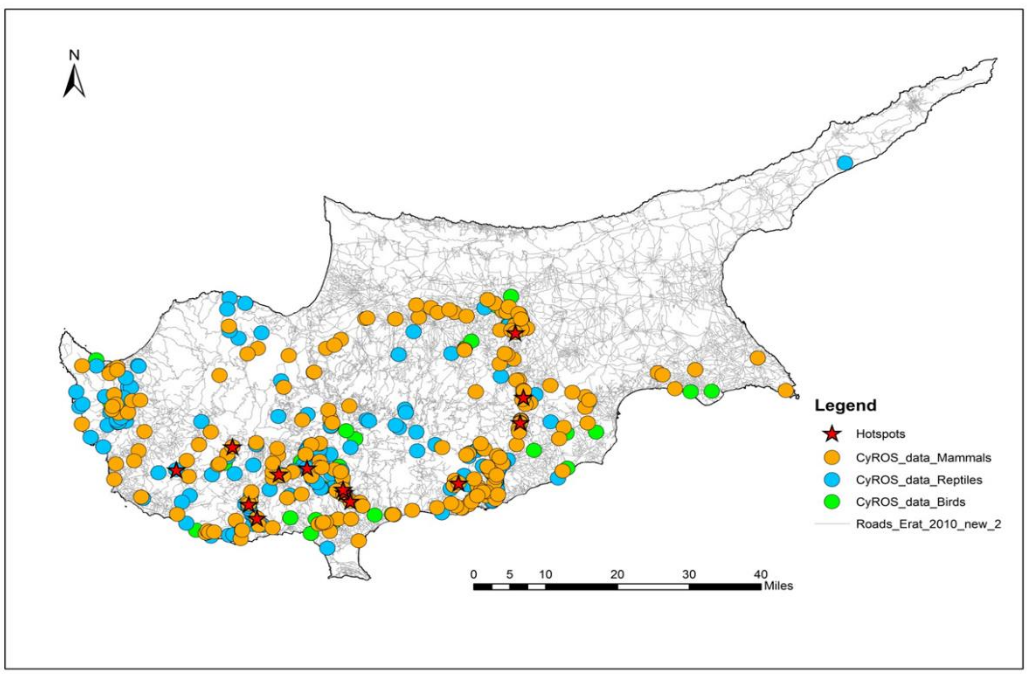


Figure 35. *WVCs data for mammals, reptiles and birds and hotspots in Cyprus.*

Governance

Considering governance related to WVCs in Cyprus, despite the importance of this matter for biodiversity protection, it is not a priority for the authorities. There is insufficient monitoring and handling of WVCs (lack of know-how) which results in underreported incidents. Additionally, there is poor communication and inter-sectoral collaboration between public authorities (e.g. PWD, DoF, DoE, GFS) resulting in the absence of a holistic strategic planning on WVC management. The rapid growth of the road network substantially decreased the ability of authorities to monitor effectively the WVCs and there is serious lack of government (and public) awareness on the contribution of WVC to biodiversity loss and ways to prevent them. The result of the current governance issues, as presented, is the absence of policies/ legislation in Cyprus for the monitoring of roadkill and the implementation of mitigation measures. Despite the potential severity of the problem, the socio-economic impact of the WVCs is largely unknown in Cyprus.

CITIZEN SCIENCE AND PEDAGOGICAL PRACTICES

Currently, there is a lack of adequate information on pedagogical practices on WVCs and this fact was the limiting factor for not using more sources at this stage. For this review, 23 projects and 10 published papers/ reports (Annex 1, 2) were identified and selected, in line to the objectives of EnVeROS.

Review on projects employing the Citizen Science approach

Most of the projects that have been implemented in the area of WVCs have focused on the collection of roadkill data on a platform- app that was created for the needs of each project, mainly by activating a citizens' science network and therefore collecting a large amount of data, which would help identify the roadkill hotspots (massDOT report, 2018). Many were looking at the impacts of roads on animals and the development of informational strategies for the WVC problem. The focus of many projects was:

1) the better use of data for mitigation measures implementation
2) the reduction of roadkill
3) the identification of the most vulnerable species to VCs
4) the improvement of public safety.

Their ambition usually was to provide all the needed data for policy makers to raise awareness among drivers and general public for the importance of safe driving for animals and for people. A very limited number of projects were targeting education and using pedagogical approaches to introduce the concept of WVC to children and young adults.

According to the outcomes of the projects where citizen science was a cornerstone (Table 2):

1) having citizens involved from the beginning of the project
2) asking for their feedback on how to develop the project in order to motivate them and get them involved until the end
3) keeping them informed throughout the project about the progress and results was necessary.

This allowed citizens to feel part of the project team and increased the chances of their commitment (Citizen Science Best Practice Guide 2012).

It also requires training and provide citizens with all the necessary information and material that will make it easier for them to get involved in the process of data collection (https://www.ceh.ac.uk).

***Table 2**. Projects following the Citizen science approach for WVC monitoring and mitigation*

Project's name	Description	Main goals
Splatter (https://projectsplatter.co.uk/the-project/)	A citizen science project which allows everyone to report observations and collect data all year round and upload it to a central web platform with the use of an app.	1. Collate data on roadkill reported by the public in the UK. 2. Identify hotspots for wildlife roadkill on UK roads. 3. Determine which species are most observed as roadkill. 4. Raise awareness of this conservation issue. 5. Ultimately reduce the impact of roads on UK wildlife.
Linking Landscapes for Massachusetts Wildlife (LLMW) - (https://www.linkinglandscapes.info/)	A long-term and multifaceted volunteer based monitoring program which is utilizing expertise from various state departments along with collaboration with the public. Citizens are becoming volunteers for the project and upload data to the project's platform.	1. Minimize the impact of the existing road network on rare and nongame wildlife. 2. Improve highway safety, through cost-effective research, planning. 3. Implementation of partnerships with citizens and communities of the Commonwealth of Massachusetts. 4. Enhance, protect, and restore habitats impacted by roads.
Spotteron Roadkill - https://roadkill.at/	Citizens participate in a scientific project by providing data on roadkill.The projects website is also providing simple information on how to avoid roadkill.	1. Identify roadkill hotspots. 2. Mitigation of hotspots in cooperation with local authorities. 3. with a greater aim to reduce roadkill.
StopJež - http://stopjez.lutra.si/	With the collected data the project is trying to determine the most critical sections for roadkill.The data is being uploaded on the project's website. Its main target audience is the young drivers and driving schools.	1. Suggest proper solutions to improve safety of all participants in the traffic.

Educational practices

Parallel to the WVC projects overview, we compiled pedagogical approaches that are applied or developed for different age target groups but for other scopes. The aim was to find successful educational approaches targeting other problems (biodiversity, ecology, science) that could be used as the basis for developing new approaches for WVC.

For WVC learning to have any lasting effect, its concepts and approaches need to take a central position in schools. Hutchison (1998) has described three general approaches to conducting environmental learning:

1) a supplemental approach in that educators are provided with curricular materials they may use in addition to regular teaching
2) an infusionist approach in which environmental themes are integrated into curricular topics (usually in Science)
3) an intensive experience approach in which students participate in short, outdoor immersive trips and experiences.

Accordingly, the following educational practices (age dependent) were used and are believed to be good practices for introducing children and young adults to the concept of WVC.

Primary and secondary education level

The level of primary education needs to focus mainly on providing the base information about the animals and the ecosystems. The definition of WVC needs to come as a result from the thematic of habitats destruction. So, in these ages we need to focus on sensitizing the students to understand the need of protecting species and habitats.

The most commonly used teaching methods are hands-on instruction, experiential learning, and teacher presentation. The least used ones are games, roleplay, debates, study trips, and visits.

Interactive games

Roleplay, games, study trips and visits are rarely used as teaching methods and mainly used at the primary and secondary levels. According to some studies, they have multiple benefits for all educational levels. Roleplay in science teaching and learning-as with ‘active’, ‘experiential’ or ‘child-centered’ learning-encourages students to be physically and intellectually involved in their lessons, allowing them to both express themselves in a scientific context and to develop an understanding of difficult concepts (Taylor 1987) such as WVCs.

Games are efficient learning activities when engaging students in active participation and interaction (Green and Bavelier 2012). Such approaches can be adapted to the theme of WVCs and provide an effective way of delivering the information of this thematic to younger ages. For example: Students will be representing different characters (deer, turtle, owl, car etc.) on a hypothetic scenario of different animals trying to cross the road while a car is approaching with high speed. Students will then be asked to think of the animal’s reactions, the driver’s reaction and the result of that incident. This will allow them to come up with solutions and understand the problem of WVCs.

For these, an activities guide was developed by the Defenders of Wildlife organization (https://defenders.org/sites/default/files/publications/watch_out_for_wildlife_fun_book_teachers_guide.pdf)

The focus of the specific activity book goes to alerting the children about the behavior and ecology of the animals, to remind them how to behave while being in a car so not to cause distractions to the driver, and how they could help by alerting the driver in case they see an animal getting close to the road.

Short lectures

The most commonly chosen teaching methods to promote learning for biodiversity issues at all educational levels are hands-on instruction and teacher presentation (Yli-Panula et al., 2018).

For this reason, there is a major need on creating detailed educational activities for the WVCs (which currently does not exist) for the different educational levels, so that the teachers can have the base line for their teaching, starting from the in-class process.

A special attention could be given to fitting in the thematic of WVC to other existing thematic in the school syllabus (e.g. food chain, habitats, biodiversity). Educational material about WVC will be created which will aim to help the other subjects meet their goals. This will allow the WVC subject to become part of the tools that educators can use to address their lessons and therefore raise the awareness about the problem of WVCs.

Poems and songs

The use of poem and song writing as a way of learning through expressing, is a method that is being followed in some subjects, but it can mainly be used as an after learning process and in younger ages. Children need to know in advance some of the main information so to be used in their poems or songs. We do not consider it as the most effective way to approach the WVC theme at this early stage since the subject of WVCs is not well known and approached until now and also because the teachers that do use the method need to have worked on how to write poems and songs beforehand.

Drawing activities

Drawing competitions were held in schools asking the students to draw solutions for safer wildlife passages on roadways. Drawing sums up the information gained through other activities-lessons, and helps students express their feelings about a problem. It is recommended as a successful way to get students involved especially in smaller primary school ages. In secondary education it is considered childish by teenagers, so they would not choose to be involved, unless it transforms in a 3D model creation, which proves more skills.

Tertiary educational level

Research shows that the change to more engaged scientific teaching techniques which involve active-learning strategies (Chamany et al., 2008) to engage students in the process of science, and use teaching methods demonstrated to reach different students, is a widely accepted reform, but adoption is slow (Handelsman et al., 2004).

In several cases universities have included in their curricula WVC related topics either within Landscape Ecology or Road Ecology courses. For example:

The Road Ecology Center at the University of California, integrates ecological sciences, engineering, and social sciences to study the interactions between roads and the surrounding natural and human environment, and to develop sustainable transportation solutions that are environmentally and socially friendly. The purpose of the UC Davis Road Ecology Center is to foster and develop a science of road ecology; to support university-based training and education in road ecology; develop scientifically-sound assessment tools, frameworks, and practices to be used in planning and management of sustainable transportation systems; and to share research findings and information in partnership with environmental scientists, professional organizations, governmental agencies, and public interest groups. https://escholarship.org/uc/jmie_roadeco

At Litzsinger Road Ecology Center (LREC), teachers learn how to engage their students in place-based education: using local ecology as a framework for studying a variety of subjects while interacting with the local community. Class visits help students become familiar with, and learn how to investigate, local natural habitats. https://litzsinger.org/education/

At Portland State University, their lessons approach the WVC with lessons that will familiarize the students with the use of animal tracking techniques, geographic information systems (GIS), road-kill surveys, and land surveillance devices in order to better understand the impact of roads on living organisms and transportation routes. Furthermore, they also study the impacts of roads on waterways, vegetation, landscapes, and living communities.
https://www.pdx.edu/roadecology/road-ecology-at-psu

At the University of Montana, road ecology is being included in Wildlife Habitat Conservation & Management syllabus. The lesson is being delivered by lectures based on Power Point and additional materials, including class discussions, films, discussion on current events and questions. http://files.cfc.umt.edu/syllabi/spring/WILD370.pdf

Methods/ tools that could be useful in tertiary education to teach WVCs are: 1) lectures, 2) case studies, 3) games/ software, 4) interactive learning tools.

1) Lectures

Typical common learning activities are lectures and related activities by the students (e.g. paper writing, group work, labs, and student or group presentations).

E-learning is being widely used and has replaced the presence of the lecturer and the need of a classroom. A very interesting example is the climate literacy project (https://climate-literacy.eu/) and the UNDP Learning for Nature 2018, Ecosystem services valuation: a step by step guide (https://learningfornature.org/). Both can easily be adapted for the needs of WVCs. For the need of this age group, a detailed informational package needs to be created in order to support their existing knowledge end expand it to the scope of WVCs and road ecology. At the end of each chapter, a self-assessment exam would also be ideal for the student to evaluate the knowledge gained by the lesson. The interactive demonstration method described below will also be a part of the e-learning package of EnVeROS.

2) Case studies

It is more important to have students actively engaged with activities that deepen conceptual understanding, no matter where they do it (in or out of class) for higher learning gains (Jensen et al., 2015). The presentation of case studies is a good tool to engage students in WVC related learning. A simple case study must consist a scenario (the context), a statement of the issues (the focus of the case), a task (the open problem) and any resources needed for the task. Additional supporting materials such as documents or videos may also be provided. Learners need to be given clear instructions about what they are required to do with the case material. This might be a question such as ‘what would you do next in this situation?’ or it might require learners to develop a solution.

Case studies have the benefits:

- They give a real-world context, which illustrates how the material taught applies to the real world.
- They increase motivation of learners, as they can see how the material directly relates to the real world and their future careers.

- The complexity of the real-world is reflected, demonstrating how data is often not clearly defined.
- They give the opportunity for learners to explore multiple perspectives and see how a decision may impact people differently.
- They use critical analysis, to analyse data so to reach a conclusion

3) Games

A very good example for the use of games in education, to promote knowledge on road ecology and WVCs is the game developed by the project Albionet (https://www.jecami.eu/). The "GAME (ecology without borders)" (https://www.jecami.eu/explore/) targets to educate students on issues related to road ecology, ecological connectivity and roadkill. A lot of interesting applications have been recently developed, addressing issues related to ecology and environmental protection and they could be used in WVCs teaching. Access to these applications could be reached through Common Sense Education.

(https://www.commonsense.org/education/top-picks/excellent-ecology-and-environmental-science-apps-games-and-websites)

4) Interactive learning tools

Other potentially useful activities to engage students are minute papers (students write response to a question in 1–2 min) and may also be used as an assessment. This will be used with the e-learning modules so to maintain the involvement of the trainee during the learning process. Animations can also add a more interactive element to the e-modules and are also fun. In some circumstances they can get a message across that words or audio cannot. Keeping in mind that the thematic of WVC can be cruel in real pictures or videos, the animation becomes a valuable approaching tool, less stressful for the audience. Such a tool can easily be used in all ages.

Finally, the work implemented in several road ecology and WVCs related projects (see Tables 1, 2) could be used to extract teaching material and be used in new drivers' education. The initiative Wuidi for example (https://wuidi.com/) aims at reducing AVC by targeting three groups: hunters, drivers and driving schools. Through an APP local hunters can signalize dangerous sections for AVC in their district. The driver gets informed by the APP when entering a risky road section. If an accident happens, the APP tells the driver what to do and marks the accident site in the map. On the one hand, the hunters get information about problematic sections in their district and can install mitigation measures. On the other hand the driver can be warned and drive more carefully in certain areas. The third target groups are driving schools. They can request material for their teaching activities to create awareness and inform their students about AVC.

The citizen science approach in higher education could be also employed and was found suitable for:

a. courses with weak lecturer-to-student ratios
b. addressing important elements of motivation for learners
c. familiarizing students with scientific research (Heigl and Zaller 2014)

The use of an app was the main base of the project, were students had to collect the roadkill data along with other environmental parameters and upload them to a central web database. (BOKU roadkill project)

The students have the chance to learn scientific working in an applied way from defining a hypothesis to gathering data, analyzing data, making graphs and interpreting the findings. The project increased their roadkill awareness when gathering data and thinking about the findings. In addition, participants found that over the course of participating in this project, they became more sensitized to wildlife and conservation issues and will more likely share this awareness with others. In this way, students acted as knowledge multipliers increasing the topic of the project and citizen science in general.

The topic of animal roadkill has been used to explain ecological processes and animal behavior (e.g., migration of animals for mating and foraging and territorial behavior) while raising student awareness of human road traffic behavior.

There has also been reported the use of roadkill carcasses of the animals killed in the roads, for the practical classes of paleontology students and for different research in other universities.

The roadkill can provide clues to where species are and where they were going. Analyses of their tissues can point to where pollutants that humans release into the environment have been ending up. (Auricchio et al., 2014)

Skins and skeletons can be processed as taxonomic material and stomach contents provide information about feeding habits and ecology. In addition, regional scientific collections can be improved and these animals can be used for practical classes in different areas, including environmental conservation.

WVC AWARENESS AMONG PUBLIC AND EXPERTS

To study awareness among experts and public, we have designed two questionnaires:

1) for experts (https://opinio.eurac.edu/s?s=5800),
2) for citizens (https://opinio.eurac.edu/s?s=5799).

Both kinds of questionnaires were translated in five languages (English, German, Italian, Czech and Greek) and opened between 20. 1. 2019 and 24. 2. 2019. Then the data were retrieved, coded and processed. The following paragraphs present the major findings of the related research.

Results of questionnaire survey

Questionnaires about the awareness of both experts (https://opinio.eurac.edu/s?s=5800) and public (https://opinio.eurac.edu/s?s=5799) about animal-vehicle crashes in the respective countries were prepared. The both kinds of questionnaires were prepared in five languages (English, German, Italian, Czech and Greek) and opened between 20. 1. 2019 and 24. 2. 2019. Then data were processed.

1) Public

We received the respective numbers of questionnaires from public (Figure 36) in the three regions:

- 218 Cyprus
- 167 Czech Republic
- 123 Bolzano region

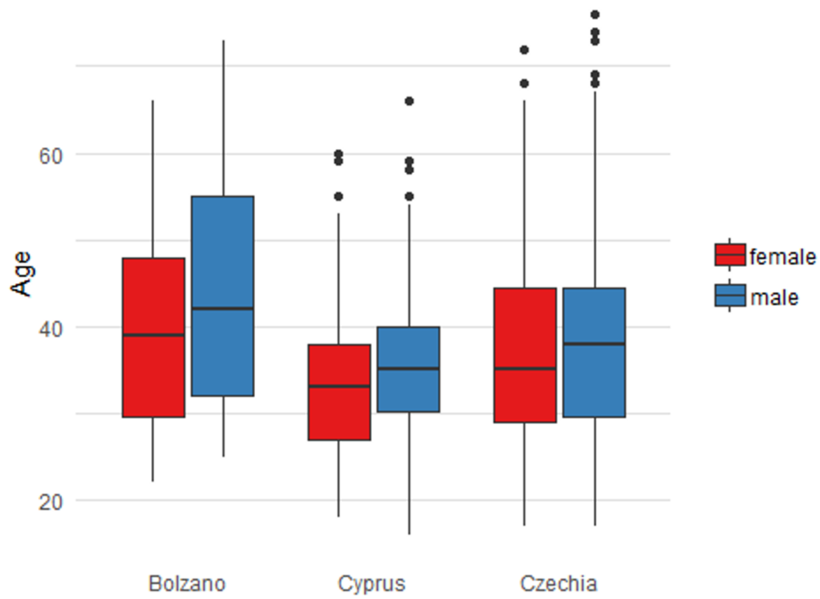


Figure 36. *Age and gender related to questionnaires received from public.*

People were asked if they knew any of the terms related to the issue of WVC and citizen science (Figure 37).

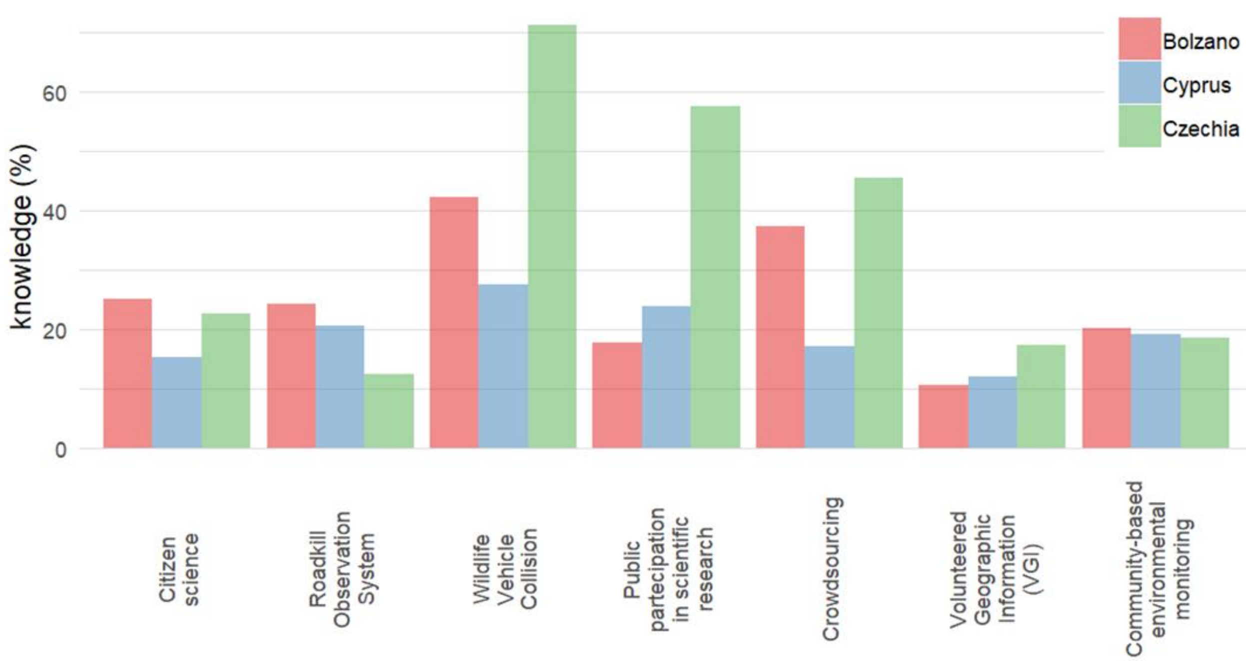


Figure 37. *Answers to question "Do you know any of the following terms?"*

Other questions were related to an experience with WVC (Figure 38). First, people answered a question “*Do you know someone who collided with an animal?*”, then a question “*have you ever had an accident with a wild animal“?* At all three regions more people know someone who collided with an animals (the highest portion recorder among the Czechs, 80%). Similarly, more than 30% of respondents from the Czech Republic answered that they collided with an animal.

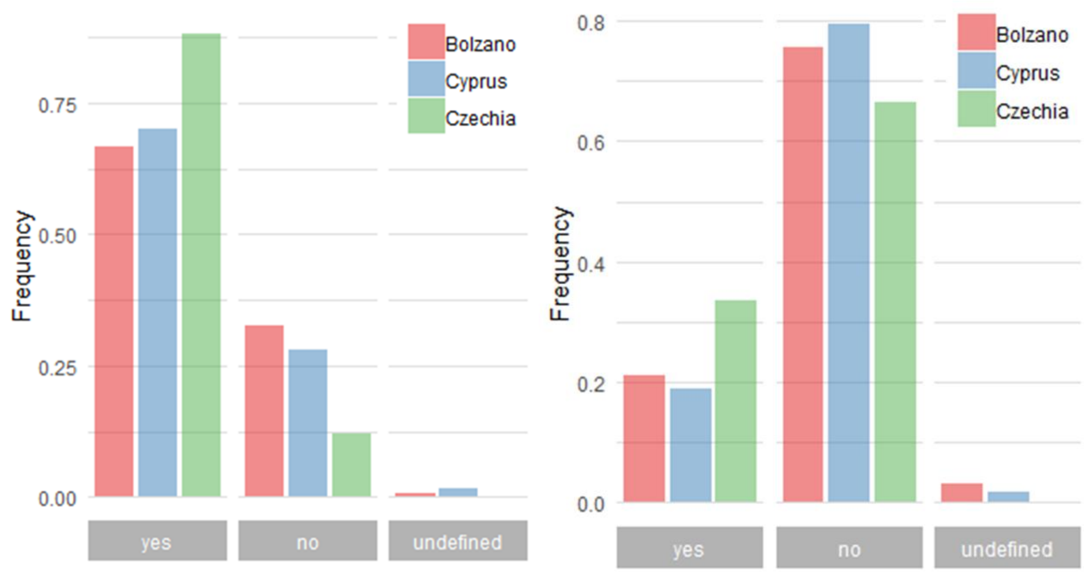


Figure 38. *Do you know someone who collided with an animal? (left), have you ever had an accident with a wild animal? (right)*

Animals are frequently seen dead on roads (Figure 39). More than 80% of respondents from all three regions declared that they have seen a dead animals on a road.

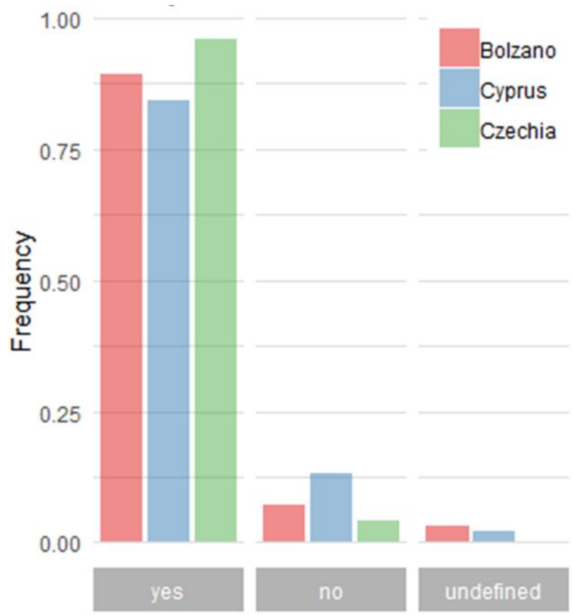


Figure 39. *Have you ever seen an animal, victim of a WVC, on or close to a road?*

We further asked public which are the 3 species most frequently involved in WVC in their regions (Figure 40). Small mammals were most frequently identified as these species in all regions. In Bolzano, public also declared that ungulates are frequently involved in the collisions, whereas reptiles were identified on Cyprus. This is logical as ungulates are not occurring on Cypriot roads. Carnivores and ungulates were further identified as the species involved in WVC on Czech roads.

The other question was targeting on 3 most endangered species due to roadkill. It is interesting to mention that in Bolzano the pattern of responses is almost the same as for the previous question. Czech respondents identified amphibians as the second most endangered group of species.

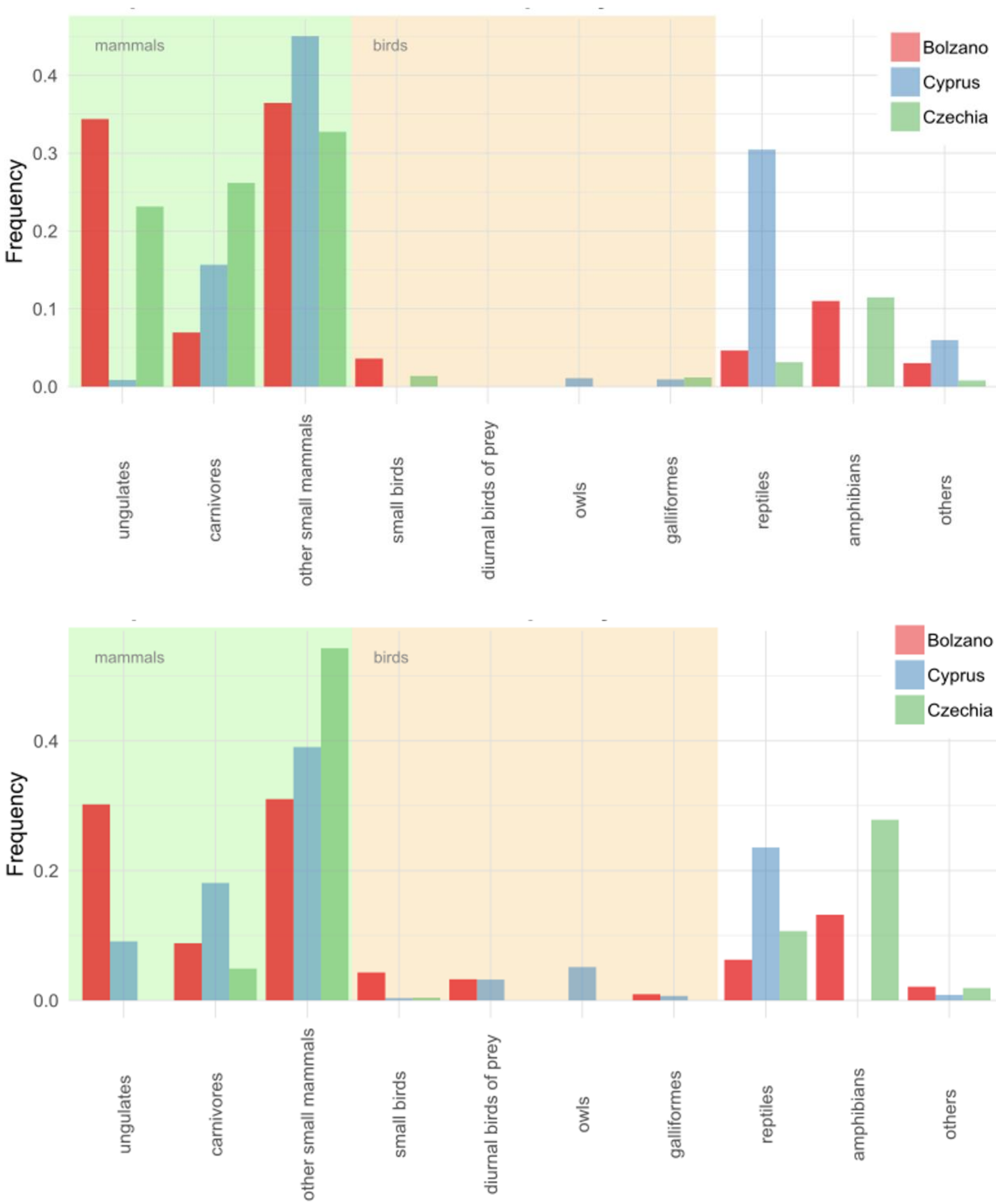


Figure 40. *In your opinion, which are the 3 species most* _frequently involved_ *in WVC in your country/region? (top) and which are the 3 species* _mostly endangered_ *by WVC in your country/region from a conservation point of view? (bottom)*

A question related to a theoretical situation what people would do after a WVC followed. Interesting differences among the regions can be seen in Figure 41. The only correct answer in the Czech Republic is to “Contact the police” for large mammals, but many people often also contact, as can also be seen from the graph, their insurance agencies. This can also be correct, if the animals do not belong to game species, however. In the Province of Bolzano, most people would contact the local gamekeeper or the police, which both correspond to an appropriate handling of the situation.

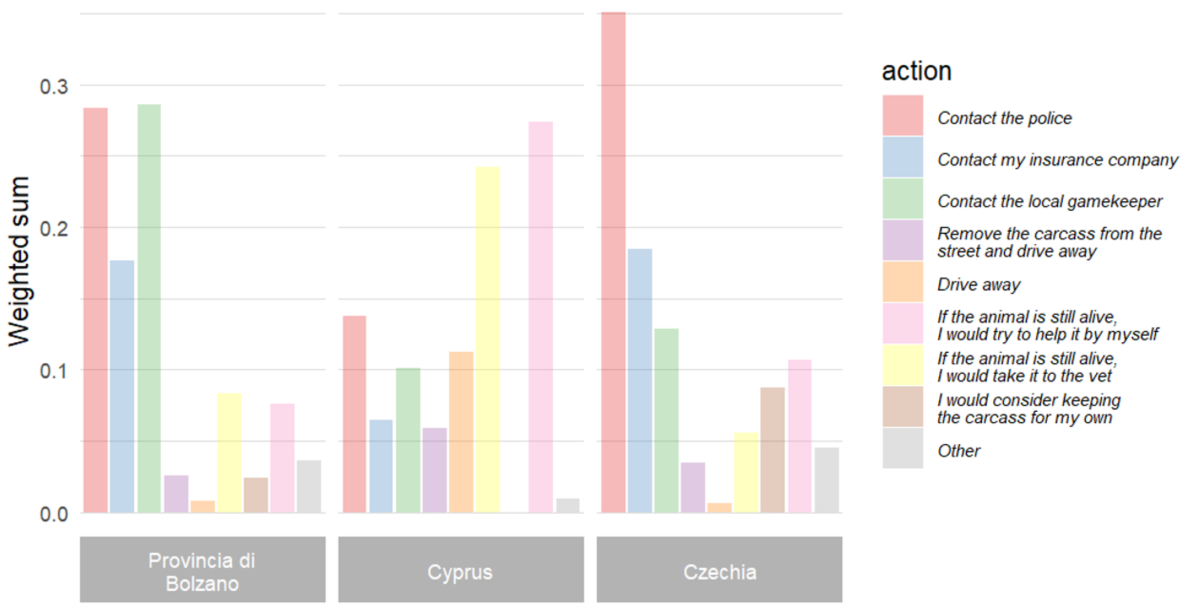


Figure 41. *Imagine that you have just collided with an animal. What would you do after a WVC as a driver?*

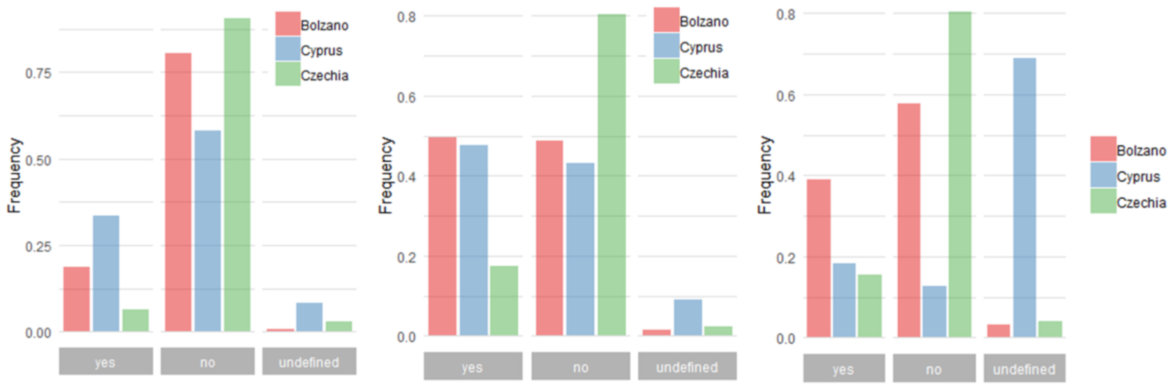


Figure 42. *Have you ever collected (left), Would you be interested in participating in a WVC reporting programme (centre) and Would you be interested in participating actively as volunteer in WVC mitigation measurements? (right)*

Citizen science could have a potential in WVC research. We asked public if they ever collected data on WVC. Most of the responses were negative. The following question investigated the willingness to participate in WVC recording (Figure 42). Here almost half of the respondents from Bolzano and Cyprus were willing to participate, in contrast to only less than one fifth of Czech respondents. The last question investigated the interest to participate as volunteers at a mitigation measures installation.

2) Results for experts

We received most answers, from people who declared themselves as experts, from the Czech Republic (57), followed by Province Bolzano (14) and Cyprus (5). Only 27 answers have been received from states across Europe. We therefore compared data for four regions: Czech Republic, Bolzano, Cyprus and the Europe keeping in mind the fact of rather low statistical significance of the results for Cyprus and Europe.

More than a half of the experts are members of both environmental or a hunting organizations (Figure 43) in all regions. Knowledge of terms related to citizen science varied among the four regions considerably (Figure 44). Whereas most experts from Cyprus and Europe knew the term “citizen science”, only one quarter of Czech experts were aware of this term. For the province of Bolzano, most experts are not aware of the terms and the graphs clearly show, that there is room to improve the knowledge about it.

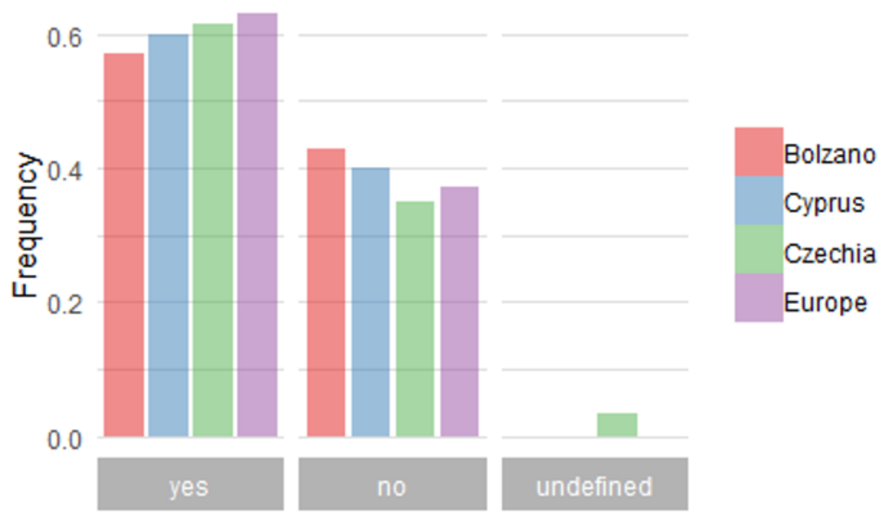


Figure 43. *Are you member of an Environmental or hunting organization?*

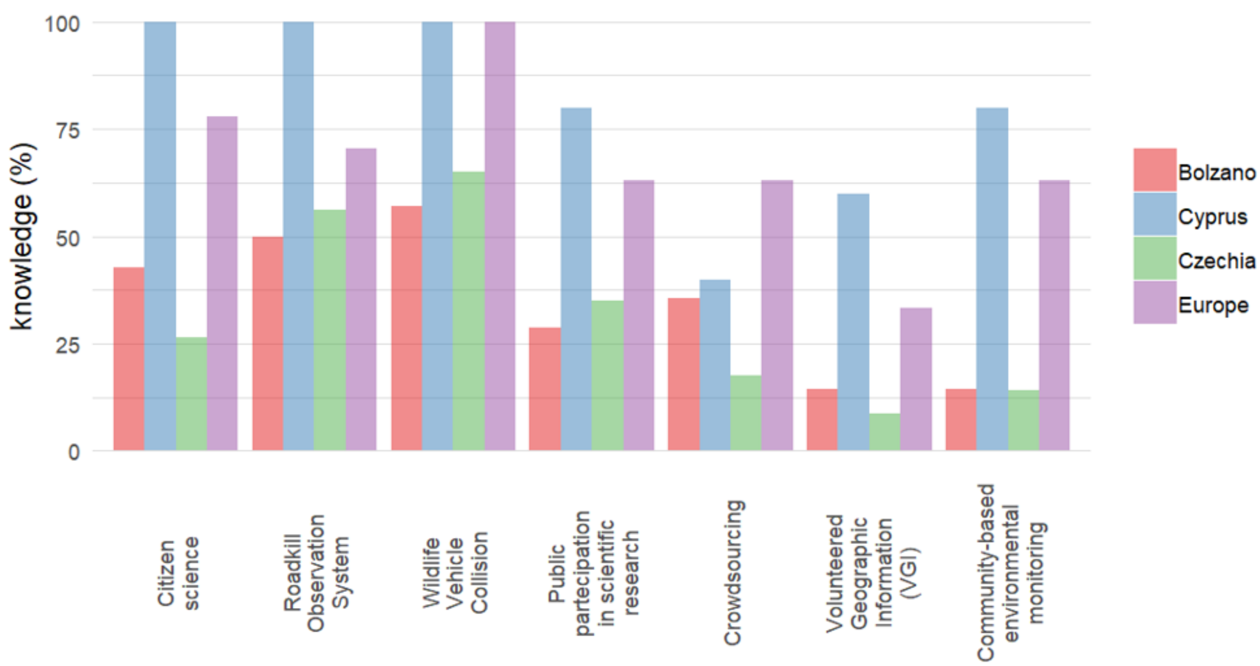
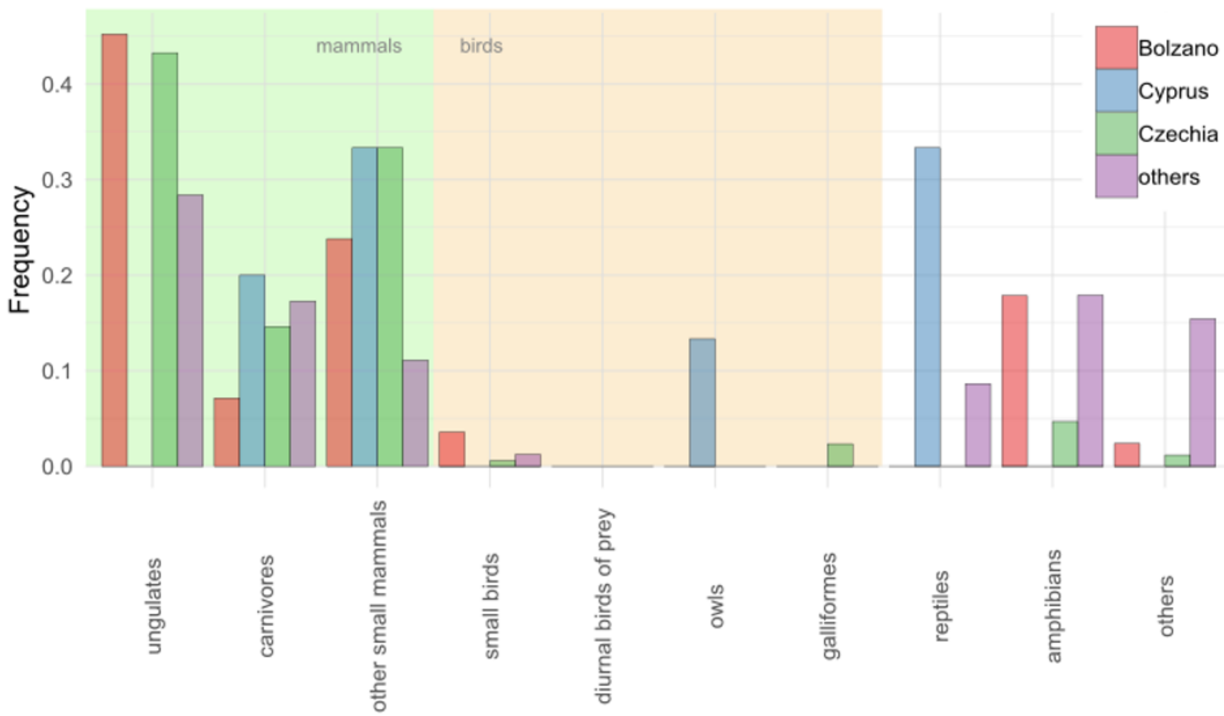


Figure 44. *Do you know any of the following terms?*

We further asked the experts on their opinions related to the species most frequently involved or endangered due to WVC (Figure 45).



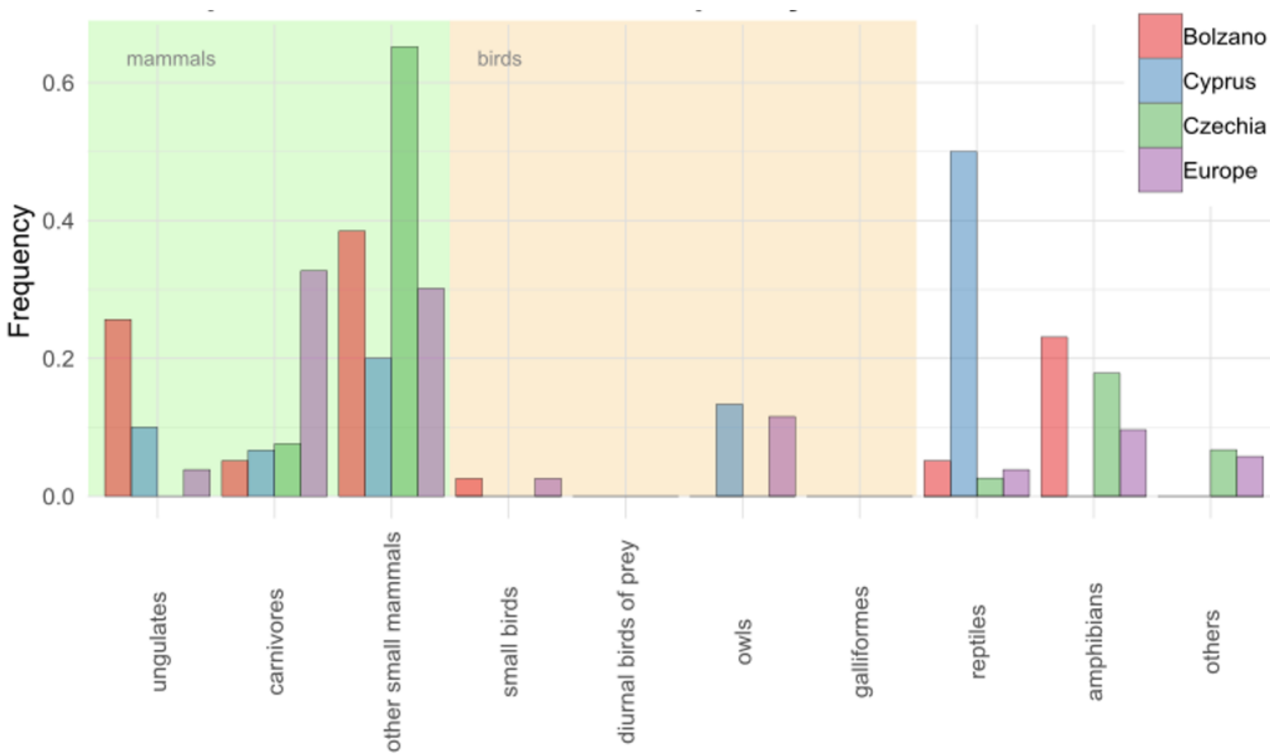


Figure 45. *Species the most frequently involved in WVC (top) and the most endangered due to roadkill (bottom)*

Experts sometimes apply mitigations measures, particularly when they are both working with a road administration or are hunters, etc. Half of Czech experts applied olfactory repellents, which were not used by experts from the other regions. Odor repellent are thus a typical Central-European mitigation measures (Figure 46). Wildlife warning reflectors were often used by expert in Bolzano region. This is probably caused by the fact that crashes with ungulates are the major concern there. They also use measures for drivers, probably also related to the fact, that they find speeding the main cause of WVC in their region (see Figure 47). The lack of time and especially money is probably also a reason that more expensive measures as fences are not really in use in Bolzano. Finally, in Figure 48, the experts view for the major obstacles to obtain an adequate implementation of mitigation measures for WVC in your country.

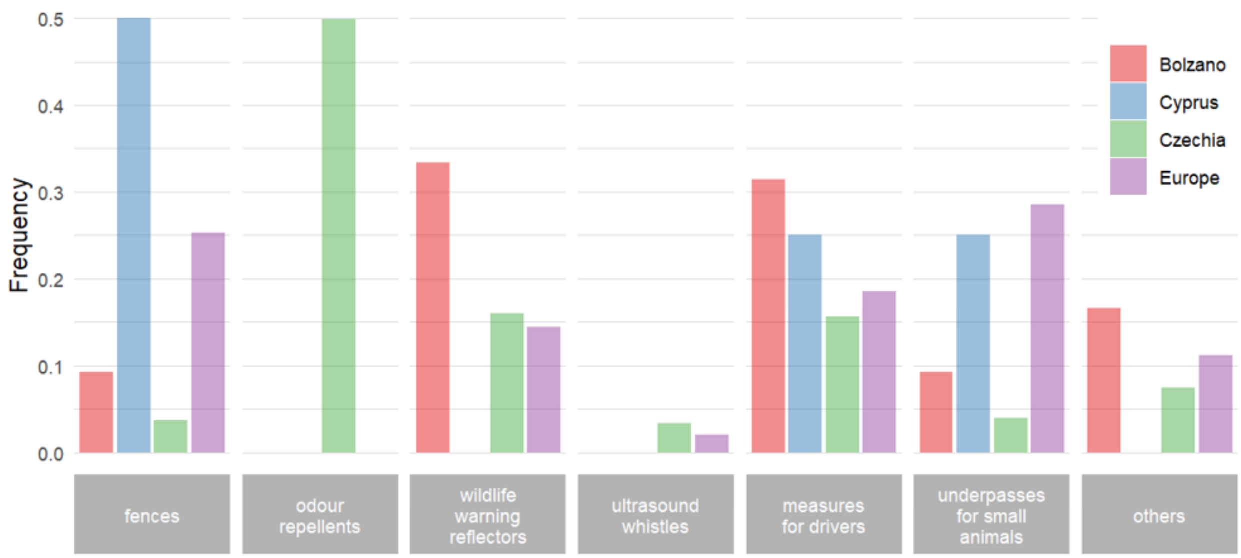


Figure 46. *Which measures are you using / a list of measures?*

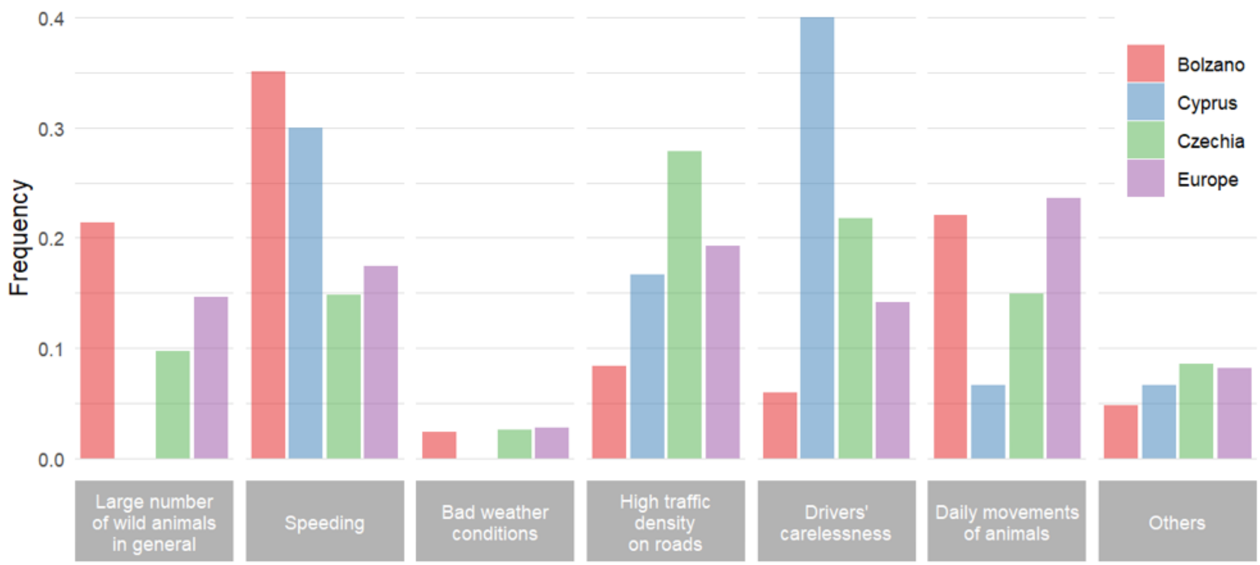


Figure 47. *What do you consider to be the main causes for WVC, in your region?*

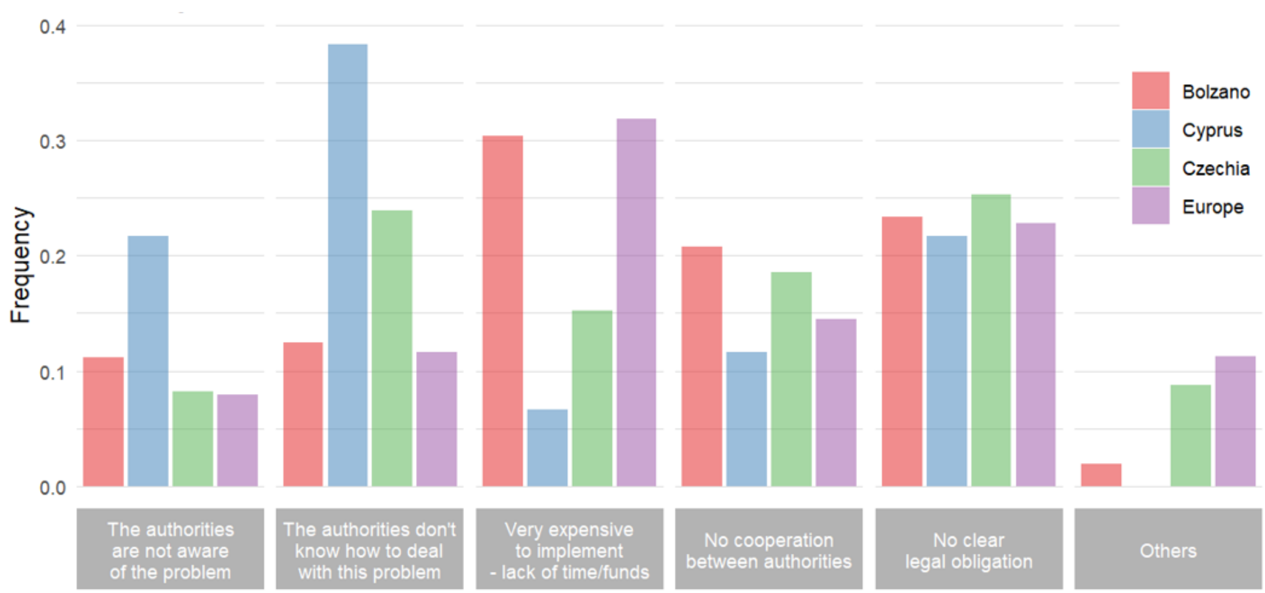


Figure 48. *What are the major obstacles to obtain an adequate implementation of mitigation measures for WVC in your country?*

CONCLUSIONS

The topic of the Wildlife Vehicle Collisions (WVC) is a global traffic safety and conservation issue. Accordingly, this report aimed to give a brief overview over the wildlife-vehicle collisions (WVC) topic in Europe.

From a conservation point of view, WVC can reduce the population size, promote isolation through the limitation of dispersal, and therefore increase the risk of extinction. One of the most serious threats for ecosystems globally is the loss of biodiversity. Transport infrastructures have a variety of impacts on wildlife including traffic mortality, habitat loss, habitat fragmentation and degradation, environment pollution, changes of the microclimate and hydrological conditions around the infrastructures and increasing human activities in adjacent areas.

There are various factors that contribute to increasing the risk of wildlife-vehicle collisions. The numbers of collisions generally increase with traffic intensity, animal activity and density. Temporal variations in roadkill indicate different biological periods that influence the species' activity, such as the daily rhythm of foraging and resting, seasons for mating and breeding, dispersal of the young-of-the-year, or seasonal migration between winter and summer habitats.

WVCs can have a broad range of consequences for both motorists and animals, resulting in injuries and fatalities. More common socioeconomic impacts are:

1) vehicle damage,
2) secondary motor vehicle crashes,
3) emotional trauma, and less direct impacts such as
4) travel delays.

WVCs can also require the assistance of law enforcement personnel, emergency services, and road maintenance crews for potential repairs and carcass removal. Effective WVC mitigation is generally costly and high quality WVC data help ensure that limited mitigation resources are strategically targeted to areas that produce the greatest results for motorists and wildlife. Gathering data can be challenging because wildlife-vehicle collisions occur over broad areas, during all seasons of the year, and in large numbers. Collecting data of this magnitude requires an efficient data collection system. Today, there are various successful examples of roadkill observation systems and the challenge is to engage citizens and public authorities to participate in the collection of WVC data.

Currently, there is a lack of courses related to WVCs in the primary, secondary and tertiary education. In the primary education, the challenge is how to present roadkill to youngsters. For the secondary and tertiary education, educational material could be found in related projects and road ecology lessons in the universities.

The questionnaire survey in the EnVeROS project regions (Cyprus, Czech Rep. and Bolzano, Italy) revealed that citizens are not fully aware on the issue of roadkill while experts need further education and training in order to apply mitigation measures.

This report could be a tool for citizens, teachers, drivers and public authorities in order to raise people's awareness. It could also be used sustain, through scientific information and updated data, local authorities in implementing the most efficient mitigation strategies in the most risky road sections.

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