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Different approaches to solving wildlife mortality on roads and railways across Europe

Bachelor thesis

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Different approaches to solving wildlife mortality on roads and railways across Europe

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Objectives of thesis

The work aims to prepare a literature search on the topic, focusing on evaluating different approaches to the registration of animal mortality on roads and railways. Another goal is to evaluate how the decision to apply various measures in selected European countries is made which aim to reduce the number of accidents in specific areas (e.g. odour repellents, anti-animal reflectors, and acoustic deterrents), financial sources for these measures, and methods for evaluating the effectiveness of these measures.

Methodology

To obtain the necessary information, a responsible person will be selected in as many European countries as possible (from various organisations, with selection based on the responsibilities of this issue in each country). They will provide important information in the form of a questionnaire on: (I) the method of registering game mortality; (II) deciding on the location of mitigating measures; (III) sources of financing of these measures; (IV) monitoring of their effectiveness; and (V) the actual measures used.

The approach to this issue in individual countries will be evaluated based on the information obtained. The conclusion will be a recommendation for the Czech Republic, resulting from positive foreign experiences.

Work schedule (below are the partial goals; by the end of the given period, the student is obliged to submit the partial part to the supervisor):

May 2022 – August 2022: processing and submission of literature search

May 2022 – February 2023: obtaining necessary data and information

July 2022 – February 2023: data analysis

November 2022 – February 2023: compilation of work results and elaboration of a discussion

March 2023: collection of the final version of the work and its submission

The proposed extent of the thesis

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Keywords

Road ecology, European countries, evidence, game mortality, repellents, reflectors

Recommended information sources

Apollonio, M. et al. 2010. European ungulates and their management in the 21st century. – Cambridge Univ. Press.
Bíl, M. et al. 2020. Ungulate–vehicle collision risk and traic vol-ume on roads. – Eur. J. Wildl. Res. 66: 59.
Diaz-Varela, E. R. et al. 2011: Assessing methods of mitigating wildlife–vehicle collisions by accident characterization and spatial analysis. – Transport. Res. Part D Transport Environ. 16: 281–287.
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Rytwinski, T. et al. 2016. How efective is road mitigation at reduc-ing road-kill? A meta-analysis. – PLoS One 11: e0166941.

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Dean

Prague on 27. 03. 2023

Affidavit

I declare that I have developed my bachelor thesis „Different approaches to solving wildlife mortality on roads and railways across Europe“ separately under the guidance of the supervisor of the work and using peer-reviewed literature and other information sources that are quoted in the work and listed in the literature list at the end of the work. As the author of this Bachelor thesis, I further declare that I have not infringed the copyright of third parties in connection with creating the thesis.

In Prague the 5th of April ______________________________

Acknowledgement

I would like to thank this way to my supervisor doc. Ing. Tomáš Kušta, Ph. D. for guidance of my bachelor's thesis, to all respondents that answered my questionnaire and to my parents.

Rozdílné přístupy k řešení úmrtnosti volně žijících živočichů na silnicích a železnicích napříč Evropou

Souhrn

Mortalita volně žijících živočichů na silnicích a železnicích je velmi častým problémem. Aby se tyto problémy vyřešily a předcházelo se jim, existují různé typy zmírňujících opatření, která se liší v ceně i efektivitě.

Cílem této práce je zjistit, jak lze registrovat počet a riziko kolizí se zvěří a navrhnout doporučený plán pro Českou republiku na základě získaných znalostí.

K získání informací bylo použito dotazníkové šetření. Na dotazník odpovědělo celkem 23 organizací ze zemí napříč Evropou. Otázky byly zaměřeny na pět témat: I) metody registrace úmrtnosti zvěře; II) rozhodování o umístění zmírňujících opatření; III) zdroje financování těchto opatření; IV) sledování jejich účinnosti a V) skutečně použitá opatření. Údaje byly porovnány a zobrazeny v grafech.

Výsledky dotazníkového šetření ukázaly, že nejlepší metodou pro registraci úmrtnosti zvěře na silnicích a železnicích je elektronický systém, který by měl být současně přístupný veřejnosti a organizacím z jiných zemí a měl by fungovat na principu „občanské vědy”. Jako nejúčinnější zmírňující opatření se ve značném procentu případů ukázaly rychlostní limity, výstražné značky, přechody pro volně žijících živočichy a oplocení silnic. Při budování zmírňujících opatření bychom měli dávat pozor i na malé savce a obratlovce, kteří jsou součástí evropské fauny. Bylo také zjištěno, že v různých evropských zemích jsou odhadované počty úmrtnosti zvěře skutečně nepřesné.

Ideálním doporučením pro vývoj situace by bylo zlepšení systému srazenazver.cz v České republice nebo vytvoření nového systému, který bude sloužit veřejnosti prostřednictvím „občanské vědy” pro registraci úmrtnosti volně žijících živočichů na silnicích a železnicích. Tyto údaje mohou být použity k určení místa, kde dochází k nejvíce srážkám. Ta pak mohou být označena jako kritická a na nich lze na základě stanoviska vědeckých odborníků vystavět zmírňující opatření. Nejčastěji užívanými zmírňujícími opatřeními na základě jejich účinnosti by měly být zejména výstražné značky, omezení rychlosti, nadchody a podchody pro volně žijící živočichy a také oplocení.

Klíčová slova: Silniční ekologie, evropské země, evidence, mortalita zvěře, reflektory

Different approaches to solving wildlife mortality on roads and railways across Europe

Summary

Wildlife mortality on roads and railways is a very common problem. To solve and prevent these problems, there are several types of mitigating measures which differs in price and effectiveness.

The aim of this work is to find out how the risk of game collisions can be reduced and registered and to design an ideal plan for the Czech Republic from the gained knowledge.

A questionnaire investigation was used to obtain the data. A total of 23 European countries across Europe responded to this questionnaire. The questions were focused on five topics: (I) the method of registering game mortality; (II) deciding on the location of mitigating measures; (III) sources of financing of these measures; (IV) monitoring of their effectiveness; and (V) the actual measures used. The data were compared and shown in charts.

The results of the questionnaire survey showed that the best method for registering animal mortality on roads and railways is an electronic system that should at the same time be open to the public and organisations from other countries and operate on the principle of citizen science. Speed limits, warning signs, wildlife crossings and fencing proved to be the most effective mitigating measures in a considerable percentage of cases. When building mitigating measures, we should also look out for small mammals and vertebrates that are part of Europe's fauna. It was also found that in various European countries, estimated numbers of game mortality are indeed inaccurate.

An ideal recommendation for the development of the situation would be to improve the system of *srazenazver.cz* in the Czech Republic or to create new system that will serve the public through citizen science for registering wildlife mortality on roads and railways. These data can be used to determine where the most collisions occur. These can be then identified as collisions hot-spots and mitigating measures can be built on them based on opinion of scientific experts. The most used mitigating measures based on their effectivity should be in particular warning signs, speed limits, wildlife crossings and fencing.

Keywords: Road ecology, European countries, evidence, game mortality, repellents, reflectors

Content

List of figures:

List of graphs:

List of tables:

1 Introduction

Wildlife mortality on roads and railways is a big problem across the world nowadays. In Europe, we have very dense road and railway infrastructure. It affects a large number of both large and highly visible mammals, as well as small ones (Bíl et Bartonička, 2022). In the 20th century, it was reported that the number of wildlife animal road collisions mortality was higher than the number of the animals being shot during one decade in the United States of America (Forman et Alexander, 1998). Road transport accounts for the largest share of direct game mortality and also has other negative impacts on the environment such as noise, chemical pollution, landscape fragmentation etc. (Bíl et Bartonička, 2022).

Animal collisions on the railway represent another European problem. Trains cannot stop in short distances and cannot change the route to avoid them. Even so, humans are still trying to make trains quieter and faster. The collisions with trains are mainly large ungulates occurring around tracks in herds. Such cases can only be avoided by acoustic signals, to which the game usually responds too late. The other dangers of railways are that animals can die because of electricity or even by getting stuck and then dehydrated, stressed or eaten by predators (Bíl et Bartonička, 2022; Seiler et Olsson, 2017).

To tackle this problem, several approaches have been suggested and put into practice worldwide. One solution is constructing eco-bridges or wildlife crossings over or under roads and railways to provide a safe passage for animals, reducing the number of collisions and fatalities (Clevenger et al., 2002; Rytwinski et al., 2016). Fencing along roads and railways is another measure to guide animals to crossings and prevent them from accessing dangerous areas (Forman et al., 2003). Additionally, wildlife detection systems such as animal-activated warning signs and infrared sensors have been developed to alert drivers and train operators of the presence of animals and prevent collisions (Clevenger et al., 2002; Rytwinski et al., 2016).

Further research is necessary to assess the effectiveness and cost-effectiveness of these measures and devise customized ones for specific wildlife species and local contexts. The aim of this bachelor's thesis is to present a comprehensive overview of the various methods used to solve wildlife mortality on roads and railways, highlighting their strengths, weaknesses, and suitability in diverse settings. Through systematic literature review and case studies, this thesis will provide recommendations for policymakers, wildlife managers, and other stakeholders on how to mitigate the impacts of roads and railways on wildlife and promote sustainable transportation infrastructure development in the Czech Republic.

2 Objectives of thesis

The work aims to prepare a literature search on the topic, focusing on evaluating different approaches to the registration of animal mortality on roads and railways. Another goal is to evaluate how the decision to apply various measures in selected European countries is made which aim to reduce the number of accidents in specific areas (e.g. odour repellents, anti-animal reflectors, and acoustic deterrents), financial sources for these measures, and methods for evaluating the effectiveness of these measures.

3 Literature research

3.1 European transport infrastructure

The number of roads has increased since cars were invented with their growing numbers. There are 5,5 million registered passenger cars in the Czech Republic, which means that one car „belongs“ to two people in the population. In 2010, there were one million fewer cars in the Czech Republic. The ever-growing numbers are creating increasing conflict between human population and the environment (Bíl et Bartonička, 2022).

Data from 2020 counting cars in the European Union says, we have an average of 560 passenger vehicles per 1,000 inhabitants. This represents a big increase from 2016, when there were only 524 cars per thousand people. The highest numbers belong to Luxembourg (696 cars per 1000 inhabitants), followed by Italy (666 cars per 1000 inhabitants) and Poland (662 cars per 1000 inhabitants). The Czech Republic is slightly above the European Union average of 573 cars per 1000 inhabitants. The lowest figure belongs to Lithuania with only 353 cars per 1000 inhabitants (Acea, 2023).

Road infrastructure causes fragmentation of the landscape, which disrupts game migration routes. It is also found in places where game regularly migrates. In such cases, there are more frequent game collisions in certain locations than in other places, or the possibility of migration is completely impossible (Bíl et Bartonička, 2022).

The earth's surface is divided into about 600 000 fragments, and more than half of those areas are less than one square kilometre. Historically, Europe has a very developed transportation network and very small landscape fragments. Areas that are relatively undisturbed by traffic include only remote or inaccessible areas, national parks, and military areas (Ibisch et al., 2016; Bíl et Bartonička, 2022).

3.1.1 Traffic intensity and factors affecting accidents frequency

Studies have shown that communications with a moderate intensity of around 2500 to 10000 cars per day are the most dangerous for game (Seiler, 2001). It has also been shown that collisions with game are more likely to occur on lower-class roads than on highways (Clevenger et al., 2003).

Inside the game's home range, there are roads that the game regularly crosses. It often passes for food, shelter, water or mating. (Putman, 1997). Crossing highways is often avoided because they are fenced and animals cannot cross them (Langbein et al., 2011). Large game movements, especially among adult males, occur during the rutting season depending on the species. This corresponds with the fact that between September and November the number of collisions with game has been shown to increase in the rutting season (Pokorny, 2006; Bíl et al., 2020b). The harvest season also has a significant impact (Langbein et al., 2011).

Most accidents happen during the night when it is dark. The largest amount of game collisions occurs at dusk and dawn. (Pokorny, 2006). However, this could also be due to rush hour traffic, driver distraction, and poor visibility during autumn (Langbein et al., 2011). The start of hunting season in most European countries may also cause more deer migration (Etter et al., 2002).

The risk of collision with game also increases in areas where the road meets the forest or other types of vegetation, especially where it forms a long border (Madsen et al., 2002). Accidents happen less often where the game does not have its natural habitat (Langbein et al., 2011). The number of collisions may also be related to the number of road lanes or the relief of the terrain (Seiler, 2004). Overpopulation of game can be one of the causes of frequent collisions (Langbein et al., 2011).

3.2 Registration of game mortality

On the roads there are collisions with both small and clawed game. The most commonly hit clawed game is roe deer *(Capreolus carpreolus)*, wild boar *(Sus scrofa)*, moose/elk *(Alces alces)*, red deer *(Cervus elaphus)*, fallow deer *(Dama dama)*, european mouflon *(Ovis musimon)*, etc. Other frequently killed game species include the field hare *(Lepus europaeus)* red fox *(Vulpes vulpes)*, racoon dog *(Nyctereutes procyonoides)* and hedgehog *(Erinaceus concolor)* (Langbein et al., 2011; Balčiaskuas et al., 2020).

There is not much information on game mortality statistics because there is no central system of registration in Europe. Research has been made in Sweden which has shown that only about 50 % of the collisions are actually recorded (Seiler, 2004). Cases are often recorded only for damage to personal property. Consequently, when the damage is negligible, road kills are often not recorded at all (Bíl et Bartonička, 2022).

3.2.1 Systems for registration of animal mortality

Most European states collect data using the national authority of the police. Hospital data is used in some states (e.g., Slovenia, Sweden, Denmark). Sweden has its own database "STRADA", which collects information from both the police and hospitals and compiles them together (Bíl et Bartonička, 2022; Carlsson et Lundävl, 2019).

Also, some international databases are available, however, their data is not very accurate. There is a CARE (Community database on road accidents) database in Europe that contains basic data on every car accident in the European Union (Bíl et Bartonička, 2022; Bauer et al., 2016).

The IRTAD database (International Traffic Safety Data and Analysis Group) includes data from 32 countries around the world, but it is not accessible to the public, and we can only get the summary of the data for a given territory and year. We can also read from these statistics the number of kilometres driven in the given countries (Bíl et Bartonička, 2022; Bauer et al., 2016).

Other databases from which we can obtain data from multiple states are databases Eurostat, UNECE (United Nations Economic Commission for Europe) and WHO (World Health Organisation) (Bíl et Bartonička, 2022; Bauer et al., 2016).

3.2.2 Volunteer databases and citizen science

Citizen science has experienced a significant increase in the last decade (Bautista-Puig et al., 2019). More and more environmental conservation organisations are using this method of collecting data. This way of data collection is relatively widespread these days. Smartphones nowadays have a built-in GPS system, camera, maps and constant network access. They allow us to focus on large-scale data collection from large territories (Bíl et al., 2020a).

Many universities and research institutes lack of the financial means to process the data (Hothorn et al., 2012). From the data, we can also determine the viability of the population and avoid danger to drivers. We can find successful databases for example in California (USA) or Taiwan with the participation of volunteers (Bíl et al., 2020a).

Comprehensive information on animal collisions can be found on the site *globalroadkill.net* (Bíl et Bartonička, 2022). There are many databases in Europe in which we can enter the road mortality of game. In some countries, we can even "adopt" the road we take every day (Bíl et Bartonička, 2022).

In the Czech Republic we can find several of those databases (Bíl et al., 2020a). An example of this is *srazenazver.cz* which was developed by the Czech Transport Centre (CDV). It is a web-map based database whose first purpose was to ensure traffic safety, but soon its application was extended as a tool for gathering data on game collisions (Bíl et al., 2020a). Thanks to this database, we can also record the effectiveness of preventive measures against game collisions. This data is then used for research (Bíl et al., 2018). This app automatically creates animations (like charts, maps, etc.) on the data obtained. The data enters the official database of police records. Thanks to the map, we can even look at the information about where the most collisions occur. We can enter information either through a mobile app or an internet web browser (Bíl et al., 2017). Another existing database for volunteers in the Czech Republic is the *birds.cz* project. It was created by the Czech Ornithological Society. It is used to collect data on birds in the Czech environment, including their collisions with cars. This data is then transferred to the database *srazenazver.cz.*, which shows the possibility of connecting two databases (Bíl et al., 2020a).

In Austria, database called *Project Roadkill* was established in 2013 to collect data on game mortality on roads in Austria (Heigl et al., 2016). This app is mainly used for collecting death data of wildlife animals on roads except the game. For collecting data on game collisions in Austria exists the Spotteron mobile. Thanks to this database, several academic works have been created on this topic (Heigl et Zaller, 2014).

Animals under wheels *(„Dieren onder de wielen“)* is a volunteer database used in Belgium. It is the longest running project involving volunteers to monitor wildlife-vehicle accidents. Data can be entered through a web browser or mobile app. The data is linked to a database of fungi, insects, plants, etc. An option to monitor specific transects was added to the app in 2014 and can regularly monitor them. While driving, the mobile app can be turned on and monitor anywhere the dead animals on the roads (Bíl et al., 2020a). Since 2015, the app has been allowed to enter a collision with game in one click, as well as voice input, as it is possible in Belgium to use handsfree while driving a car (Bíl et al., 2020a).

There is a Splatter (Social Media PLAtform for Estimating Roadkill) project in the UK. The project was launched by Cardiff University and since 2013 volunteers have been able to enter data into the database (Bíl et al., 2020a). Data on wildlife road accidents can be entered into the app using forms. The project monitors and identifies outbreaks of collisions. Most of the data is entered using a mobile app and is evaluated at the end of the week (Schwartz et al., 2020).

3.3 Game mortality on roads statistics in Europe

Formal data is only recorded in a few countries and even these records are not completely accurate (Langbein et al. 2011). The number of collisions keeps rising (Apollonio et al., 2010). European statistics show that most game collisions occur in central Europe, specifically in Germany, Austria and the Czech Republic due to very dense road infrastructure. (Grilo, 2020).

In 1982, there were 10,000 road accidents involving ungulated game in Sweden. That number increased to 55,000 by 1993 and turned out to be general statistics for most European countries. In 2005, that had already exceeded to 61,000. The statistics are influenced by the fact that not all collisions are officially recorded. In the reality the numbers are estimated to be double.

There are not many records for other countries because they do not have data. In any case, however, the numbers increase with the number of cars as in Sweden (Apollonio et al., 2010).

3.4 Measures to reduce game mortality on roads

The aim of reducing the number of collisions with game is not to completely prevent game crossing the road, but to make it safer. The total avoidance of game crossing the road proves ineffective and so often game remains trapped on the road and the risk of collision is even higher (Langbein et al., 2011; Diaz-Varela, 2011). Total road obstruction also leads to disruption of migratory routes and complete fragmentation of the landscape (Forman et Alexander, 1998). The most effective measures should be those that allow game to cross the road, but at the right time and in the right place with sufficient driver vigilance or hive off the road (overpasses, underpasses,…). Most devices for reducing mortality become more effective in combination with another solution (Langbein et al., 2011).

In general, these measures belong into three groups:

a) to prevent or control crossing;
b) to provide safer crossing places;
c) to increase driver awareness
(Putman et al., 2004, Langbein et al., 2011).

3.4.1 Measures to prevent or control crossing

3.4.1.1 Roadside fencing

Roadside fencing is particularly used where there are large highways and for avoidance of collisions in high risk areas (Putman et al., 2004). Its purpose should not be to fully prevent game from migrating, but to direct it to safer places.

Specifications on the visual and technical aspects of the are already laid down by the European Union through the European Commission (Langbein et al., 2011). High-quality fencing should have a sufficient height, a suitable mesh size to prevent animals from crawling through it, good anchorage, fixed ending, intact structure, location on both sides of the road, possibility of escape for strays (ramps), etc. (Anděl et al., 2011).

If there is any evidence of fencing deficiencies, it's in locations where the fencing isn't long enough, or where the intersections are. It is advisable to use deer jumps or jump ramps in such locations (Mastro et al., 2008).

Electric fencing is also used at times in practice, which has shown positive results and reduced game access to the road (Leblond et al., 2007).

However, full fencing proves to be very ineffective in the long term, as in the absence of an alternative route animals are forced to cross the route and there is an unnecessary risk of the game getting stuck inside. This isolates previously contiguous populations of deer and other ungulates (Iuell et al., 2003).

Fences should be made of stainless steel materials and be mounted well on places. The height should be at least 2,2 m for larger species and at least 1,5 m for smaller species, but we need to be careful in locations with a large snow pack. If damaged, the fence must be repaired in time (Anděl et al., 2011; Hlaváč et al., 2019).

3.4.1.2 Roadside wildlife warning reflectors

Warning reflectors (Fig. no. 1) are not used to stop game from crossing roads, but to alert game about road traffic until the road is empty. The headlight of the car reflects off the reflectors and warns the game of an approaching vehicle. This will either prevent the game from fully entering the road or delay it (Langbein et al., 2011).

However, we must take into account that such means of reducing animal mortality only work at night, because you cannot see the reflecting light during the day (Langbein et al., 2011). Given that most traffic accidents occur at dawn and dusk, these methods are relatively ineffective (Pokorny, 2006). Even if the warning-reflectors are only useful at night, they can only be used on roads where traffic is low to allow safe crossing (Putman et al., 2004). On busy roadways, the game is getting used to the reflectors. Even if these reflectors are put on highly travelled roads and the game still does not get used to it, it will still try to cross the road despite the risk of collision with a car.

There have been many cases of inappropriate location of reflectors in Europe, e.g. on a highway in the United Kingdom. (Langbein et al., 2011). There are still extensive scientific debates about the effectiveness of these reflectors (Voss, 2007). Research suggests that when applied correctly, they can have a quality efficiency that weakens over time (as a result of getting used to it, growing vegetation, etc.) (Benten et al., 2018).

However, it is very difficult to estimate and predict when and how a collision will happen (Putman et al., 2004; Voss, 2007). Relatively few studies have been conducted on this topic. In some cases, the use of reflector has also proved to be counterproductive. It has been shown that in some cases, reflectors by infrared light may even increase the likelihood of game jumping into the road (D'Angelo et al., 2006).

Reflectors can have different colors. Most commonly used in Europe were red ones because, as with humans, red is thought to cause fear, and European directives dictate it because of the glare of an oncoming car (Langbein et al., 2011). This is a problem because ungulates are thought to have a relatively limited spectrum of colour vision. This statement has been supported by a number of scientific studies. Red reflectors are therefore seen by the ungulates probably as grey or black and there is no big contrast from the dark during the night (Langbein et al., 2011). Deers have best vision in the blue-green part of the spectrum and therefore red reflectors have been replaced by these colours, but according to research this has not led to improved efficiency (Langbein et al., 2011).

These means of reducing collisions between cars and game are often used thanks to low acquisition costs and easy installation in the environment, even if they were not proved to be working (Iuell et al., 2003).

Fig no. 1: Blue reflector in Germany (www.waldwissen.net)

3.4.1.3 Acoustic roadside deterrents

Acoustic deterrents are often a complement to reflectors, reducing the chance of getting used to them. They can emit signals ranging from infrasound to ultrasound. Acoustic deterrents operate on the principle of sensing batteries in daylight and are triggered when it gets dark, or when the light of passing cars falls on them. These devices show good effects in the hunting literature during the first two years. However, no research has yet been carried out to confirm the long-term functionality of the acoustic scarecrows (Langbein et al., 2011).

Research has been carried out in Slovenia to confirm the positive effects of anti-collision devices. The number of collisions decreased by up to 83 % in the first six months. The number of collisions fell by about 47 % in 2007 and by about 62 % by mid-2008 (Langbein et al., 2011).

However, a longer-term study conducted in Germany from data from insurance companies saw no reduction in the accident rate of any of the methods, and the data before and after application of the device were comparable. An interesting feature of this study was that transects of road were checked regularly by the police over a period of three years before and after the application of means for reducing collisions with game on the roads (Voss, 2007; Langbein et al., 2011).

3.4.1.4 Chemical deterrents

These are fences imitating the smell of large beasts (lynx, bear, wolf, ...) or human. They are conducted of encapsulated chemicals in foam or granules. The purpose is to deter animals from crossing the road, slowing down or accelerating their movements. The reaction of the game is that it either avoids the place or surpasses it at maximum speed (Liškutín, 2013). Fences operate on the basis that the game senses a predator and increases its antipredation behavior (Barrio et al., 2010).

Research from Germany indicates up to 60 % success rate of chemical fences and says that game is returning into untreated areas. The numbers further demonstrate that 20 % of the game passed very quickly and the other 20 % was unaffected (Langbein et al., 2011). Further research has shown that accidents at the edges of chemical fences, on the other hand, have increased and are not as effective. The positive effects of odour fences have not been confirmed (Voss, 2007). In the Czech Republic, the positive effects of fencing and a reduction of 37 % in the number of game collisions has already been proved in two years of use (Kušta et al., 2015).

3.4.1.5 Car-mounted warning whistles

These are devices that can be directly attached to the means of transport and give off high frequencies that should repel the game (Langbein et al., 2011). However, research has not indicated any success of these devices or a reduction in the number of collisions. Deer in normal automobile traffic just like humans can't hear that sound (Romin et Dalton, 1992).

The whistles are usually activated when the car is travelling at more than 30 kilometres per hour. Their functionality depends on the game's ability to hear. The whistle emits sounds between 16 - 20 kHZ, while the hearing range of the deer is 1 - 8 kHZ. Scientists later discovered that the range of whistle starts from 3,3 to 10 kHZ, depending on the manufacturer. But this is the same frequency as passing cars (Mastro et al., 2008).

The sound of electric whistles was later found to be audible to the game, but the effect on the game from the passing vehicle is unknown (Mastro et al., 2008).

3.4.1.6 Local reductions in game populations density

A number of studies claim that clawed game's numbers are overgrown. The amount of game may or may not be linearly related to the number of collisions (Rondeau et Conrad, 2003). But in reducing populations, it is important to watch out for migration from surrounding habitats. Demonstrably, places with more hunting record have less game collisions (Langbein et al., 2011).

However, animal-vehicle collision numbers also fluctuate even on test surfaces each year, making it difficult to determine the accuracy of such studies (Rondeau et Conrad, 2003). The number of accidents is influenced by a number of other factors, such as population density of ungulates, climate change, road traffic density, agriculture, the state of the forests or the passage of people. There are also cases where a reduction in the number of game has not affected the number of collisions with vehicles (Voss, 2007).

3.4.2 Safer crossing

3.4.2.1 Overpasses and underpasses

Green bridges are often a means of migrating game in Europe. They reduce fragmentation of the landscape and make roads safe. They can be made of concrete, iron or even wood (Langbein et al., 2011; Anděl et al., 2011).

Underpasses (Fig. no. 3) are objects used for migration, where movement takes place at the bottom. These are either underpasses or green bridges on roads. The underpasses are mainly used for water flow, but also for the migration of small vertebrates. The underpasses should have swatches of land on either side of the water bed and off the water bed. They must be designed in such a way to avoid permanent flooding of the site (Anděl et al., 2011).

Bridges are constructed on roads to overcome off-road obstacles under the relief of the road. This is a secondary way of using bridges, as building special bridges for game is expensive and rather exceptional. We can have both bridges small from a few meters to a few hundred meters. The carriageway can be located both directly above the bridge and there can be a layer of earth that reduces the road noise (Anděl et al., 2011).

The overpasses (Fig. no. 2) are divided into bridges over communications and tunnels. Bridges are relatively rare and are intended to connect to an existing forest or dirt road and take it over the road. This solution is used for transport communications of different classes. Most of the time, these bridges have multiple purposes. There are constant width bridges and hyperbolic bridges. The width optima is similar to roads. The hyperbolic shape of the bridge is preferred because of animal guidance. Tunnels are created to overcome the relief of the terrain of the road. They are suitable for all game species due to their large size (Anděl et al., 2011; Iuell et al., 2003).

The bridge must have specific size ratios in order for the game to pass under it - e.g. for a red deer at an optimal width of 40 m, a height of 10 m. The index that makes up the value of 10 m for the deer is also important (Anděl et al., 2011).

Quality research on this topic was made by Iuell et al., 2003. The research found that underpasses were used from 44,7 % while overpasses from only 22,4 % of road crossings. For red deer, the level of exploitation was lower. There has also been evidence of use by vertebrates from other surveys using track counts and from infrared video surveillance. Video footage has shown that animals are most likely to use green bridges and overpasses, while fewer underpasses with streams. Often the degree of utilization of the overpasses increases along with their width. In locations where overpasses are combined with facilities for guiding animals to the overpasses, their width can be reduced (Olsson et al., 2008). But the main goal is to reconnect the fragmented landscape. It can therefore be demonstrably said that underpasses and overpasses, especially at the time of the rutting or departure of young individuals of the natal home range, can significantly reduce the mortality of game on the roads, even if they are not effective for the whole population. Small overpasses and underpasses are still of great importance (Langbein et al., 2011).

Fig. no. 2: Overpass on the D1 motorway, Czech Republic (www.skanska.cz)

Fig. no. 3: Underpass in Denmak (www.handbookwildlifetraffic.info)

3.4.3 Increasing driver's awareness and reducing speed

3.4.3.1 Wildlife warning signs

These are elements for raising driver awareness, which are most commonly used for reducing the number of accidents involving ungulates. These are warning signs which warn drivers of an increase in the presence of game in a given locality in places with an increased number of game-vehicle collisions (Langbein et al., 2011). Their effectiveness is not verified because they are easily adapted to and later ignored by drivers unless they actually come into contact with the game (Putman, 1997).

The large number of road signs around roads has led to the situation that they become more often overlooked. However, they are also placed on communications due to the judicial aspects of road maintenancers (Langbein et al., 2011).

3.4.3.2 Enhanced or dynamic signs

Special improved types of signs have been developed to increase drivers' attention on the roads, with warning signs that are activated by game movements (Mastro et al., 2008). Their use serves in particular to warn the driver of the presence of game and not to prevent the crossing of game across the road. They are particularly used in areas where accidents occur very frequently (Iuell et al., 2003). But research shows that there was no difference between the speed of vehicles in sections with or without special signs. Nor has the number of traffic collisions involving game been reduced. In some cases, the speed of passing vehicles has only decreased during autumn and spring (Sullivan et al., 2003).

Devices have also been developed that, by means of vibrations, laser beams, heat detection, etc., have been able to warn drivers that there are animals close to or approaching the road (Langbein et al., 2011). These systems can be combined with a system to detect the speed of a passing car and alert it to a reduction in speed (Hardy et al., 2006). These systems are mainly used in Europe and North America, and their effectiveness in slowing down a passing car has been shown in up to 80 % of cases (Hammond et Wade, 2004).

These signs have been shown to affect drivers in particular in cases where their permanence is only temporary. It really reduces the speed of drivers (Hardy et al., 2006).

Even though special road signs have high efficiency in reducing drivers' speeds on the roads and protecting wildlife, it is not directly clear whether it is financially effective (Hardy et al., 2006).

3.4.3.3 In-vehicle deer detection system

Systems have also been developed to track and improve game detection on the roads, especially at night. They operate on the basis of infrared sensors that detect game on or next to the road in advance and display images on the car dashboard (Langbein et al., 2001).

Studies have shown that this can be a very efficient and rapid method for detecting animals (Israel, 2012). Another method on offer for drivers is map applications showing the number of accidents in passing locations and driver warnings when passing through locations with a higher risk of collision with game (Langbein et al., 2011).

3.4.3.4 Management of roadside vegetation

This is particularly the maintenance of roadsides from tall grass, trees or shrubs. This can result in increased visibility for both drivers and the game (Waring et al., 1991). Research has been carried out to confirm a reduction in game collisions of up to 20 % in locations where vegetation on both sides of the road was cut of at a distance of 20 metres (Lavsund et Sandegren, 1991). The removal of vegetation around train lines at a distance of 20-30 metres proved to be very effective and in the high-risk locations the collision rate for game was reduced by up to 56 % (Jaren et al., 1991). However, Voss (2007) has not confirmed this theory in his research in Germany. Since the removal of vegetation around all roads and railways is not always possible, research suggests at least doing this in at-risk areas with large numbers of game collisions.

However, scientists warn that this could lead to an early increase for the game of fresh and attractive vegetation, which will serve for a taste. This could, on the other hand, increase the number of collisions even further and it would therefore be advisable to plant grasses in such locations which do not have high nutritional values and which will therefore have no incentive to graze them (Rea, 2003).

3.5 Measures to reduce game mortality on railways

Railway collisions are not dealt with as much as road collisions, but more and more attention has been paid to this topic lately (Dorsey et al., 2015). The main difference is that trains cannot avoid their route, so more emphasis must be placed on preventing animals from entering the railways (Borda-de-Aqua et al., 2017). Mitigating measures used on roads and railways are very similar only some cannot be used for railways.

There are crossing structures that can be built either from pre-existing railways or newly built railways (Borda-de-Aqua et al., 2017). It mainly uses water-flow bridges (Jackson et Griffin, 2000), tunnels that depend on the size for which the species serves (Dorsey et al., 2015) underpasses, which serve for undercoming of the railway (Glista et al., 2009) and overpasses, which are also otherwise called ecoducts and are used for crossing of animals over the train line (Jackson et Griffin, 2000).

Another type of mitigating measures are devices for preventing game from entering the railways (Borda-de-Aqua et al., 2017). These devices include fencing, which seems to be the most effective, but is only effective for those species that cannot crawl through or climb over (Jackson et Griffin, 2000). They also include sound signals and barriers, which do not so much prevent the free movement of animals, but warn them against a passing a train (Babińska-Werka et al. 2015). The physical barrier, for example, are the trees and shrubs around the railway, which serve as a physical barrier to entry the railway especially for birds (Kociolek et al., 2015). Lighting and reflectors are also used, especially for nocturnal species of animals, which are often combined with acoustic deterrents and emit lightning before the train passes (Borda-de-Aqua et al., 2017).

Other widely used methods include population management of wildlife animals, roadside management and reducing train speed in critical locations. Slower trains cause significantly fewer accidents in the long term than fast ones (Belant, 1995).

3.6 Analyses of cost-effectiveness of using mitigation measures

Only general conclusions can be drawn from the observed data, as the measured efficiency values of the game-car collision reduction devices are not absolute. In all scientific research, it is simply a matter of researching specific areas before and after installation of equipment, so the resulting claims cannot be taken into account for all sites (Langbein et al., 2011).

Every year there is a large variation in animal related accidents both before and after installation of the mitigating measures. There is a relatively small number of animal collisions on most of the studied roads, which makes it hard to examine the differences before and after application of the device. Years of high mortality potentially reduce the risk of collision in years to come (Voss, 2007).

In the locations studied, the data on the roads is often recovered, so at that time the research was not focused on it and therefore the numbers may be lower. In the absence of positive results from the site, there is often a termination of research and therefore many negatively examined areas may be excluded from the research (Langbein et al., 2011).

Many factors, including those mentioned above, hamper cost-effectiveness findings. Therefore, only the relative costs determined by the suppliers of mitigating measures can be ascertained (Putman et al., 2004).

3.6.1 Fencing

The cost of road fencing varies depending on the mesh size of the fence, which must be small enough not to be crawled through by the smallest species against which the fencing is used, as well as the height, which is determined on the basis of the specific deer species that cannot jump over it. In Birmingham in 2003, fencing was taken along a 9 kilometres of highways. This fence was 1,9 m high to prevent red deer and muntjac deer jumping over and cost 455000 € to create. That's 50 € for a metre. These costs might have been lower if fencing had not been used to prevent deer jumping (Langbein, 2003). If otters and badgers were excluded, this fencing would cost just 35 € (Putman et al., 2004).

Other estimates in 1999 for a metre of fence in Essex against deer were around 35 € per metre, while for standard fencing it would have been only 13 € (Putman et al., 2004).

On roads that are not as busy with traffic, the owner of the neighbouring property is often responsible for the fencing, who has to be careful that the livestock do not flee the property. However, such fences often do not comply with the standards set for game, and if we want to avoid game collisions, the transport authority or the owner of the communication must be responsible (Putman et al., 2004).

3.6.2 Reflectors

Danielson et Hubbard (1998) reports that the cost of reflectors per mile is about 7400-9200 € without repairs and maintenance, but after three years of research, only 61 % operates in good condition (Reeve et Anderson, 1993). For Swareflex in the UK, price for a single red reflector was around 6 € in 2004 and there was a quantity discount when buying more (Putman et al., 2004).

In 1999, the cost per reflector, including its installation, was around 12 € and the maintenance of 70 cents (Putman et al., 2004). In other locations these costs were much bigger, namely concrete 680 installed reflectors for 38700 €, which is almost 57 € per reflector (Putman et al., 2004).

3.6.3 Signage

Standard road signs for slowing drivers' speeds on the roads due to game do not have a set price on the market, as they are mostly handled by maintenance workers and road managers. In 2004, the price per one road sign in the UK was around 170 € (Putman et al., 2004).

LED road signs responding to the driver's speed and forcing him to slow down are installed rather exceptionally. Exact prices are not known, as they are also handled by the transport communications manager and can therefore only be debated on sections where prices are around 17000-23000 €. Radarlux manufactures portable units that can be placed in locations with increased numbers of collisions with game and the price of a smaller one is around 2850 € and a larger one is around 4000 € (Putman et al., 2004).

The cost of dynamic warning signs to detect game using infrared or radar detection appears to be very high even though the range of their functionality is only 100 metres. There have been many systems on the market and some have proven to be effective and others have not and they have subsequently been taken out of the market (Huijser et McGowen, 2003). For functional systems, the cost of the device ranged from 10540 to 41250 €, and the cost of the installation ranged from 18300 to 32000 € (Putman et al., 2004).

3.6.4 Dedicated overpasses/underpasses

In some European countries, and in particular the Netherlands, Germany and Spain, green bridges have been built and many more are planned not only in those countries. The cost of such structures is very high and is in the millions of euros, around 2 - 10 million euros in 2004 (Iuell et al., 2003).

A green bridge was planned to be built in Britain in 2004. If this bridge was only 20 metres wide, which is the minimum width for a red deer, the price of this bridge would be around 3 million euro. For a wider 52-metre bridge, the cost of the bridge would already be around 7,4 millions euro (Putman et al., 2004).

The cost of underpasses of already existing roads is significantly lower. Prices in the U.S. for a two-lane road are about 84000 € and for a four-lane road about 158000 € (Lehnert et

Bissonette, 1997). In the UK, the cost of a 12 m x 32 m underpass is around 3,5 million euro. Of this, 2,8 million euro would be spent to ensure that the underpass meets the requirements of game (Putman et al., 2004). An underpass that does not meet the minimum requirements required by COST341 (Iuell et al., 2003) can be much cheaper. For example, an underpass in the UK measuring 4.5 x 4.5 m is priced at around 220000 €.

New builds may not always be involved in overpasses and subways and prices may therefore be lower. They can be built using an old structure or its modification and may not meet the exact requirements set out in COST341 (Iuell et al., 2003; Putman et al., 2004).

The cost of building mitigating measures of game collisions is expensive, but it has to be taken into account that collision rates are large and the financial cost is high (Putman et al., 2004). The cost per game collision, for example, was around 57000 € in the UK around 2004. Attempts to calculate the financial efficiency of the measure are very theoretical, as avoidance of collisions will never be 100 %, fatal accidents and accidents where only material damage has been caused can be distinguished. Quality studies where the prices of cost are aligned are written by Schwabe et al., (2002) and Rondeau et Conrad, (2003), but apply to America.

Schwabe et al., (2002) examined precipitation rates in the USA-Ohio with white-tailed deer. He focused on the numbers of cars, farmland, deer density and the numbers caught in previous years, etc. We have to take into account the price of a piece of game, the destruction of game vegetation, the cost of consumption and also the cost of its habitat. In 2001, in the U.S., Ohio, the price of white-tailed deer was roughly 140-180 € (Schwabe et al., 2001). Schwabe et al., (2001) claims, the cost of human life in America is around 2,2 million, 156000 € is the price of serious injury, 30000 € for minor injury and 15500 € for non-injury game-vehicle collision. In the U.S., the only thing that could be reported at the time was the collision, which was over 140 euros. It was calculated that the cost of the average deduction was 2178 €. But these accidents only involve collisions with white-tailed deer and not larger species. In collisions with larger species, the cost would be significantly higher.

In conclusion from these studies, reducing game numbers seems to be the cheapest and the most efficient solution. The loss of human life is considered very significant (Iuell et al., 2003).

3.7 Sources of funding for mitigating measures

Measures to reduce game-vehicle collisions are funded by many different sources in Europe, and often a combination of these. They can be financed either by government or private organisations. These include, in particular, government agencies, non-profit organisations and private companies that contribute to the conservation of wildlife (van der Grift et al., 2012).

In the paragraphs above, we were able to read what mitigating measures exist (3.4) and what their efficiency and financial effectiveness are (3.5). It should be added that in Europe, hundreds millions of animals are killed annually on roads and railways, so it is important for organisations to fund facilities to reduce the number of collisions with animals on roads and railways (van der Grift et al., 2012).

Generally speaking, the funding of these funds is mostly linked to several organisations. Joint funding means that all parties involved are accountable and want to play a part in reducing the negative impact of roads and railways on game. This division is very important in practice because responsibility is then shared by all parties (Riley et al., 2014).

4 Methodology

The aim of the practical part of the work was to observe the numbers of game collisions on roads and railways in countries across Europe, the methods for registration game mortality on roads and railways, the methods for deciding the location of game mitigation measures, the sources of their funding, the monitoring of efficiency and the methods actually used in practice. For this investigation, the method of the questionnaire was chosen, which was then sent to the appropriate organisations and persons across Europe in particular from the fields of hunting, forestry, zoology, transport, etc. The conclusion of the questionnaire investigation in the form of positive test results in European countries will be a recommendation for the Czech Republic.

4.1 Questionnaire survey

„Questionnaire surveys are a technique for gathering statistical information about the attributes, attitudes, or actions of a population by a structured set of questions. Administered by mail, in person, through the Internet, and over the telephone, questionnaire surveys provide broad coverage of populations enabling us to explore spatial and social variations in people's attributes, attitudes, and actions. The aim is to obtain information suitable for statistical analysis, so attention is paid to how respondents are selected, the extent to which questions relate to underlying concepts, and completion rates.“ (Preston, 2009)

This questionnaire focused on five thematic question headings: (I) the method of registering game mortality; (II) deciding on the location of mitigating measures; (III) sources of financing of these measures; (IV) monitoring of their effectiveness; and (V) the actual measures used. First, it was necessary to identify the respondent's country of origin and whether they were from the state or private sector, in order to determine their ability to access information.

The first set of questions concerned methods for wildlife animal mortality registration on roads and railways. Questions were asked about who was in charge of mortality registration, which species accounted for the highest number of collisions, whether these accidents happened more frequently on roads or railways, whether there was a system for registering animal mortality on roads in their country, in what form (electronic/paper), if it was open to the public, accessible to other countries, and how they registered dead animals. If this system does not exist, we asked if there is a plan to create it and why the respondents think that this system does not yet exist.

Another type of question was devoted to the topic of localization mitigating measures. Here we asked about who decides on their location and on what basis.

The third set of questions was about resources of funding mitigating measures. Here we asked who funds them and what their price is.

The fourth type of question is the effectiveness of mitigation measures. Here we questioned who was monitoring the efficiency, who decides whether they were effective, whether they were regularly checked, if there was a reduction in the number of collisions involving animals and, if not, what might be the cause.

In the last questions we were interested in the actual used mitigating measures, if they are applied at all in different countries, what type they use and what kind of game they were most often for.

Finally, we wanted to know in how many animals are killed separately on roads and railways each year in a given country.

This questionnaire was created using the Google Forms platform and then sent to respondents from 56 European countries. In particular, the questionnaire was sent to hunting organisations that are members of the FACE (European Federation for Hunting and Conservation) and to forestry and transport representatives of individual countries. It was sent via email to 84 representatives from different countries.

The questionnaire was subsequently evaluated, charts showing the data were created, and verbal comments were added. The data was processed in Microsoft Excel app.

The positive results found in European countries will subsequently serve as a recommendation for the Czech Republic.

4.1.1 Questions used in questionnaire

1. What country are you from? (dropdown)
2. Do you belong to the state or private sector? (multiple choices)
3. Who registers wildlife animal mortality on roads in your country? (checkbox)
4. What kind of game is the highest number of road collisions recorded? (checkbox)
5. Are animal collisions more common on roads or railways? (multiple choices)
6. Is there a system in your country in which game collisions are entered? (multiple choices)
7. Is this system in electronic or paper form? (checkbox)
8. Is this system open to public? (multiple choices)
9. If there is a registration system, is the data from it accessible to organisations from other countries? (multiple choices)
10. If this system does not exist in your country, is it at least planned to be created? (multiple choices)
11. If this system does not exist yet, what do you think is the reason for it not existing? (long answer text)
12. What are the methods for registering game collisions in your country? (checkbox)
13. Which of these methods do you use the most often? (checkbox)
14. Are you taking any precautions to avoid collisions with game on the roads? (multiple choices)
15. If you are taking precautionary measures, which ones? (checkbox)
16. What type of game are these measures most often for? (checkbox)
17. Who decides about the location of these measures? (checkbox)
18. Based on what do you decide about the location of these measures? (checkbox)
19. Who finances these measures? (checkbox)
20. How do you monitor the effectiveness of game collision measures? (checkbox)
21. Who decides whether these measures are effective? (checkbox)
22. Is the functionality and safety of these game facilities regularly checked? (multiple choices)
23. What approximately is the annual cost of these measures in Euros? (including construction, maintenance and reconstruction) (long answer text)

24. Has there been any reduction in game mortality in localities with mitigating measures? (multiple choices)
25. If not, what could be the reason? (Write your opinion.) (long answer text)
26. Do you have an estimate of how many ungulates get killed on the roads each year in your country? (short answer text)
27. Do you have an estimate of how many ungulates get killed on the railways each year? (short answer question)

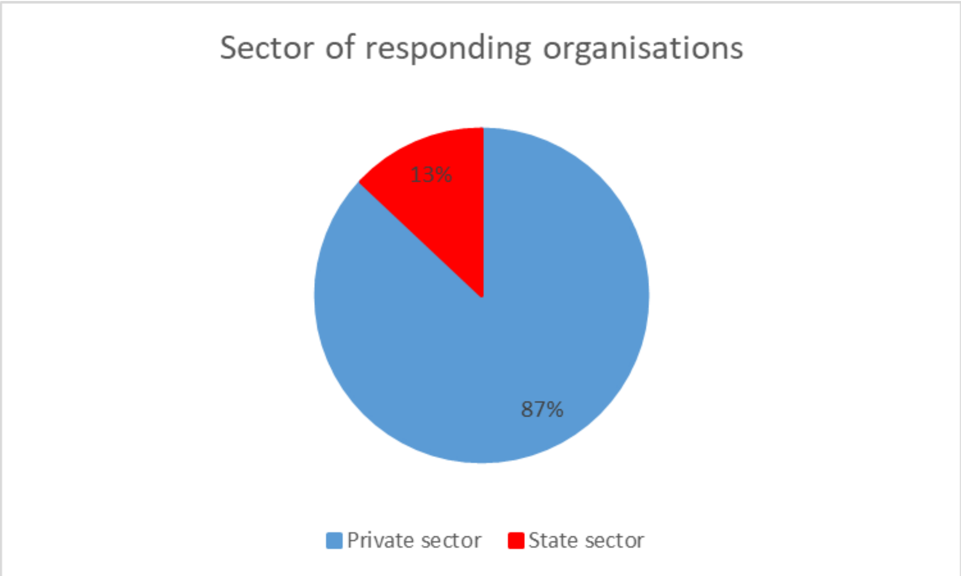
5 Results

5.1 Respondents

This questionnaire was sent to 86 representatives from 50 European countries and 6 partially recognised states. A total of 24 representatives from 23 different countries responded (see list below).

<u>List of countries that responded:</u>
Andorra, Austria, Belarus, Belgium, Bulgaria, Croatia, Estonia, France, Germany, Greece, Iceland, Italy, Lithuania, Malta, Netherlands, Poland, Russia, San Marino, Serbia, Slovenia, Spain, Sweden, the United Kingdom

The organisations that replied to this questionnaire were from the state or private sector, which may be significant for this research in terms of their access to information. Twenty respondents (87 %) were from the private sector, while only three respondents (13 %) from the state sector, which was specifically the Netherlands, Belarus and Poland.

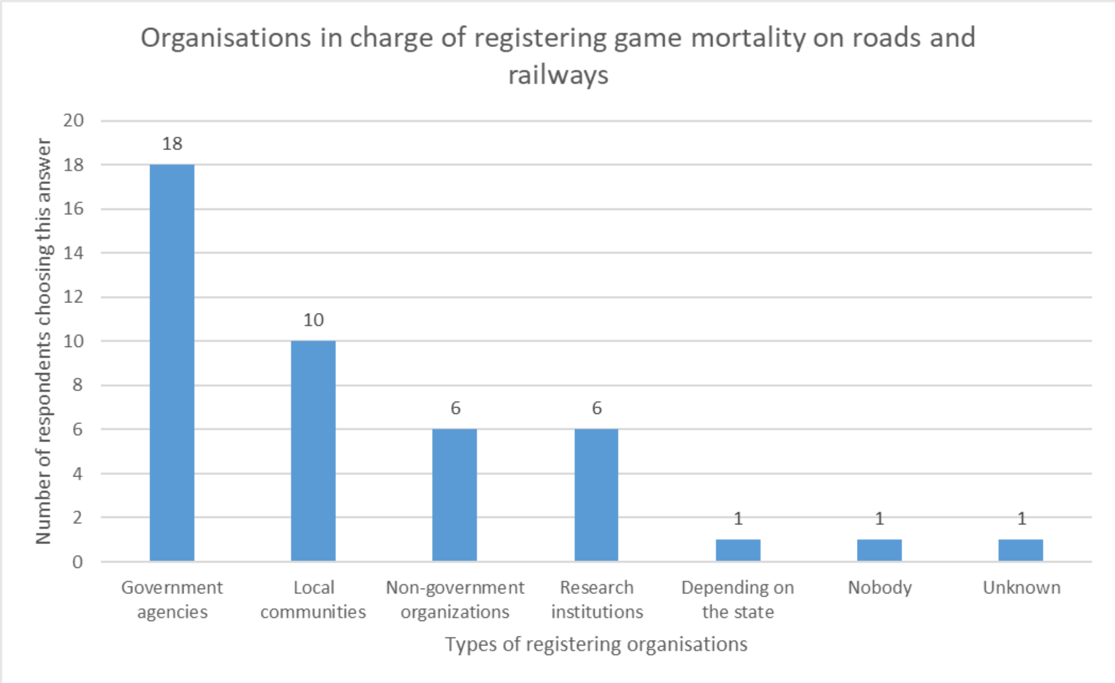


Graph no. 1: Sector of responding organisations

5.2 Methods of registering game mortality

In European countries, various organisations are in charge of registering animal mortality on the roads. Among the most common are government organizations, which is for example state police. Other types of organisations are non-governmental organisations (wildlife rescue centres, conservation organisations), research institutions (universities, scientific organisations), local communities (citizens, hunters) or registration authorities may even differ on a national basis (for example in Germany).

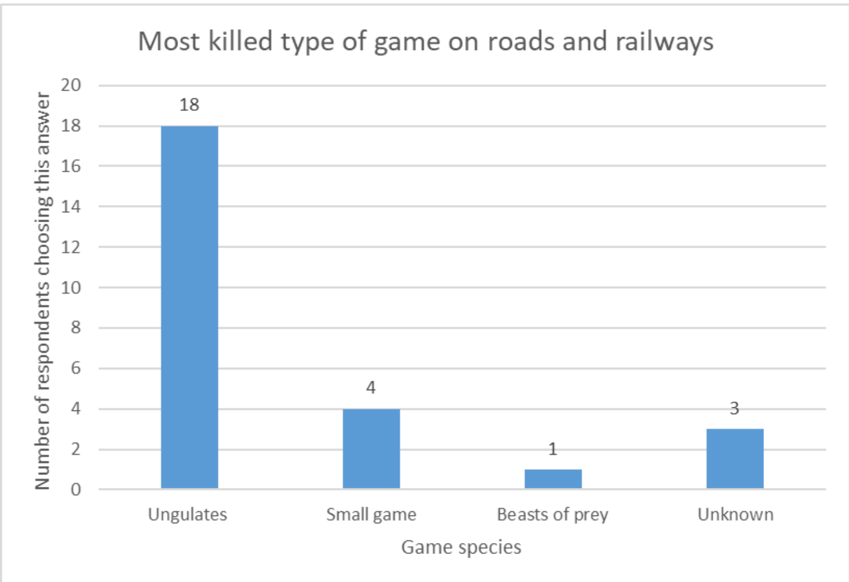
Different countries used either one or more responses, only in San Marino they did not know if someone was registering game mortality and in Iceland, they replied that nobody.



Graph no. 2: Different organisations registering game mortality

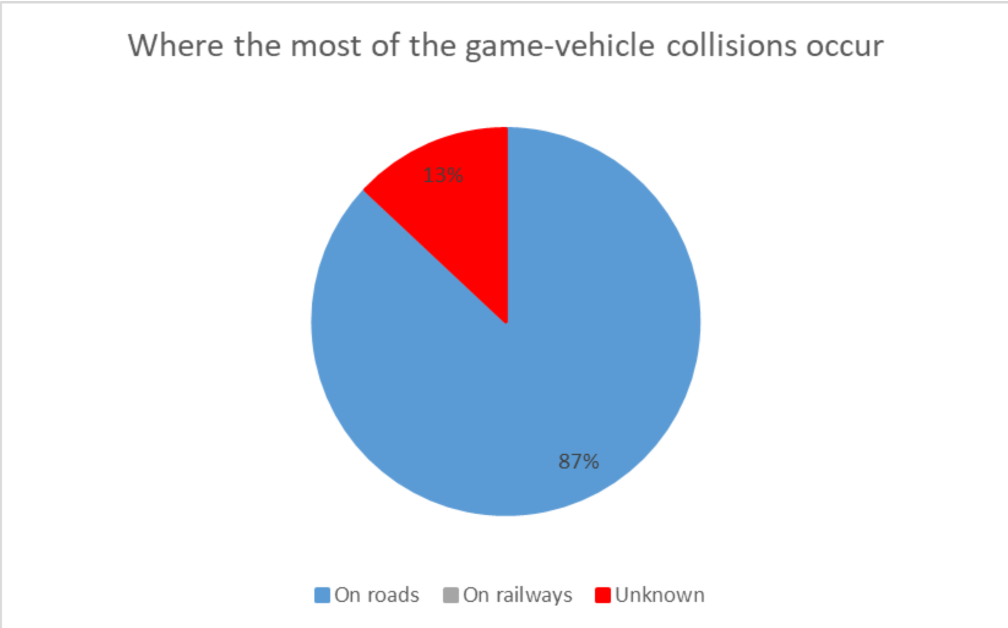
In different countries, different types of wildlife are most likely to cause collisions. The results of the research suggest that the most common type of game are ungulates (wild boar, roe deer, red deer, ...), followed by small game (field hare, squirrels, ...) and beasts of prey (red fox, wood badger, wolf, ...).

In three countries, they did not know the answer to this question (Iceland, Croatia and San Marino). In four countries, the most common species is the small game (Malta, Greece, Belarus, Andorra) and only in one country beasts of prey (Austria).



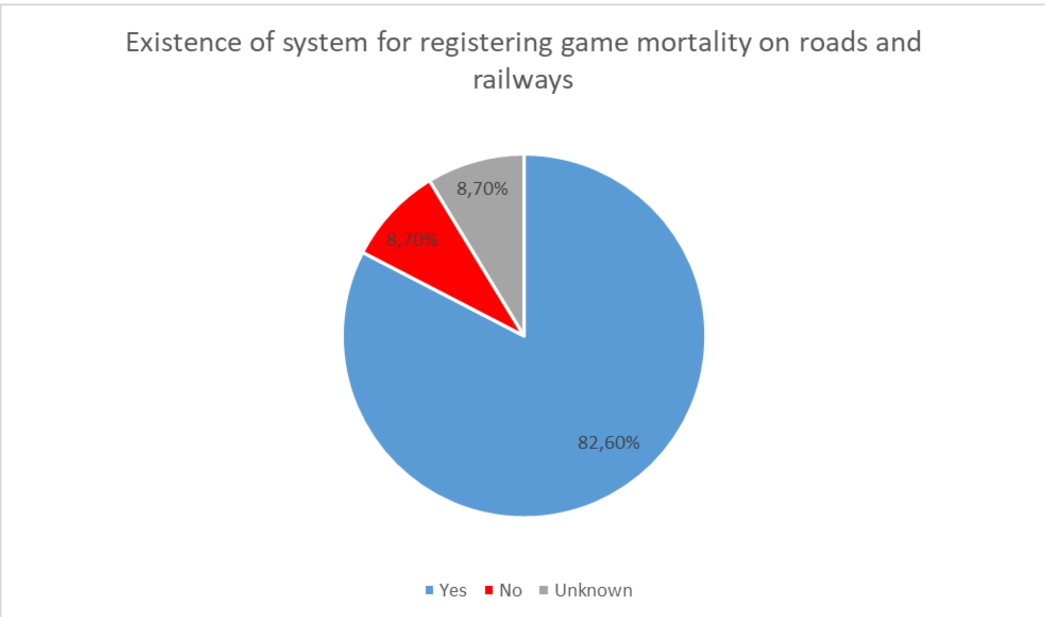
Graph no. 3: Most killed type of game species on roads and railways

Accidents in this research have been studied on both roads and railways. That being said, it was interesting to explore where more collisions with game happen. It is clear from the result that in most countries (20) accidents happen more often on the roads than on the railways. Only three countries-Iceland, Croatia and San Marino, chose the answer "I don't know."



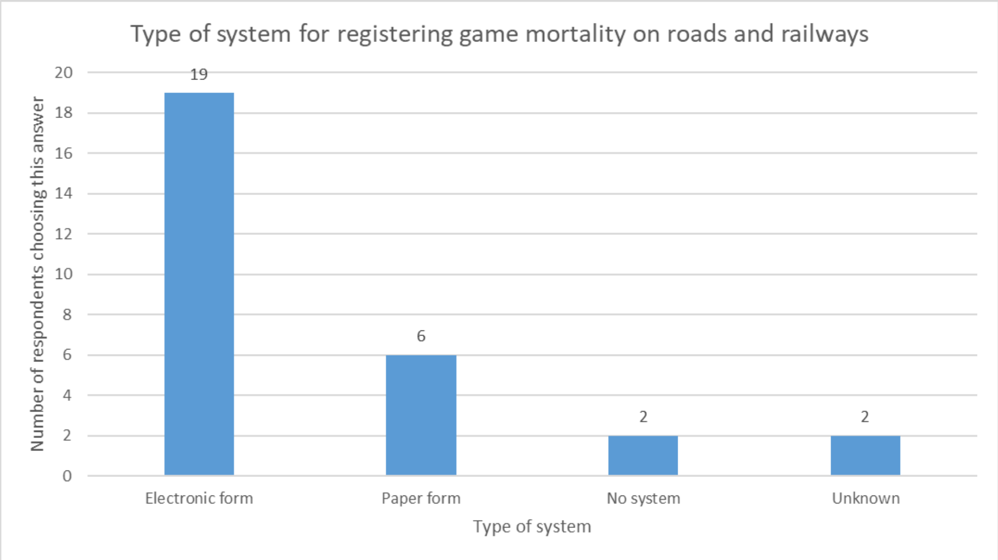
Graph no. 4: Where the most of the game-vehicle collisions occur

These accidents can be entered into special systems to register game mortality on roads and railways. But not every country has such a system. The questionnaire shows that 19 countries have a system. There is no such system in only two countries (Malta and Iceland) and two respondents did not know the answer to this question (San Marino and Andorra).



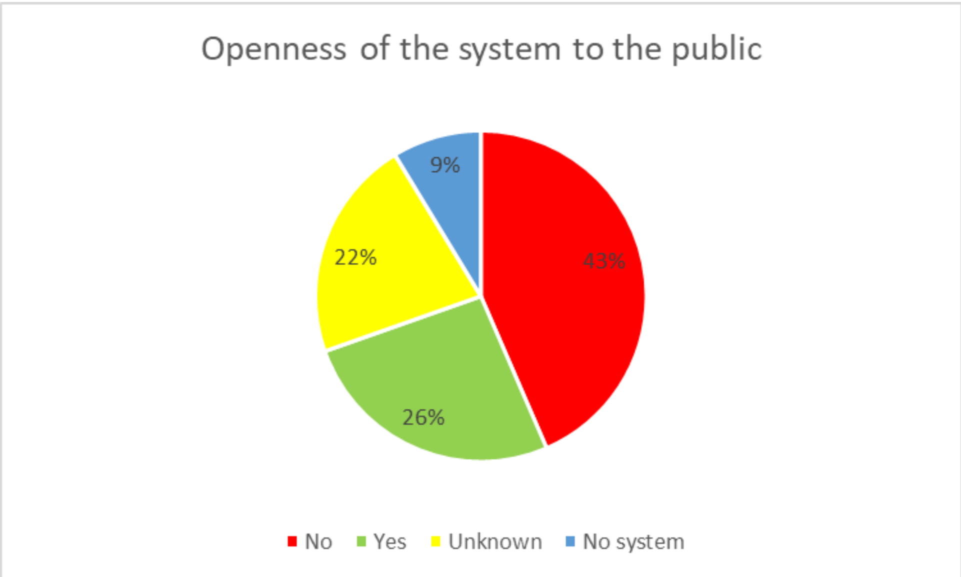
Graph no. 5: Existence of system for registering game mortality on roads and railways across Europe

Existing systems can take different forms- such as electronic and paper systems. In 19 countries, the system exists in electronic form and in six in paper form. On this issue, representatives of European countries could answer by selecting multiple answers, which showed that in all six countries where the paper form was, there was also an electronic form of the system. These countries were specifically Russia, Italy, France, Spain, Germany and Poland. In the remaining countries (13) there is only an electronic form of the system. There is no such system in Iceland and Malta, and San Marino and Andorra do not know.



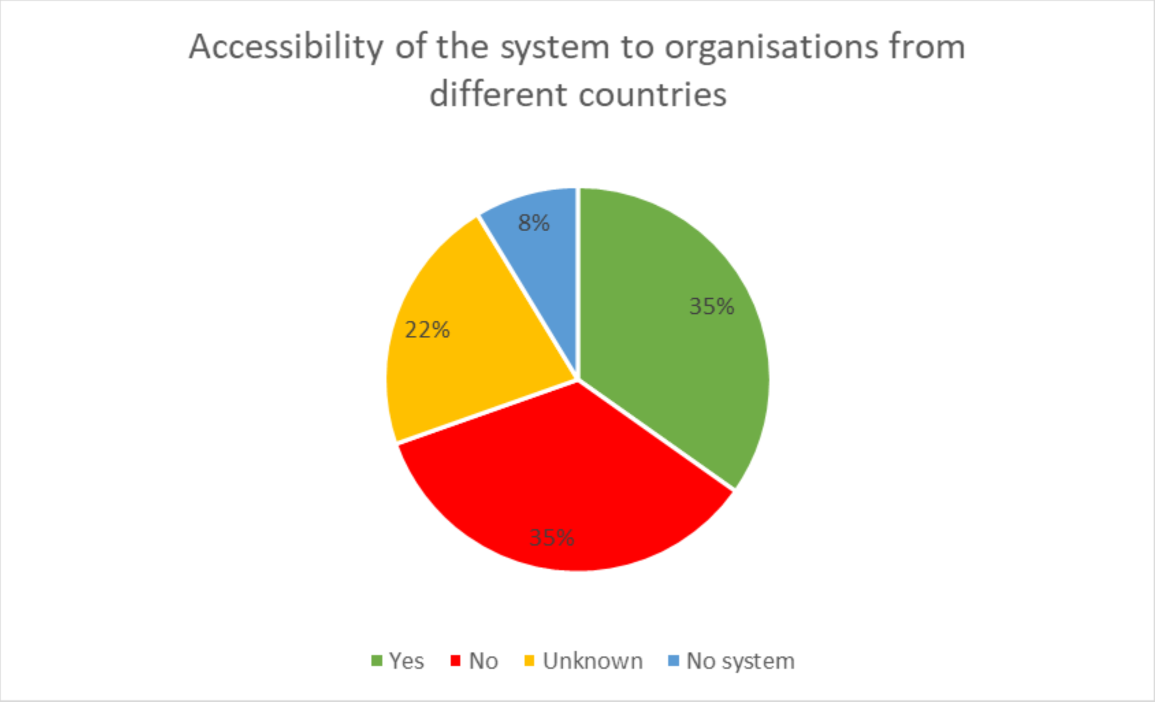
Graph no. 6: Type of the system used in European countries

Another important factor is whether the system is open to the public. In most countries (10) it is not open to the public, in other countries (6) it is. They are specifically Italy, Netherlands, France, Austria, Belgium and Germany. The answer is unknown in five countries (San Marino, Andorra, Bulgaria, Poland) and the system does not exist in two countries (Malta, Iceland).



Graph no. 7: Openness of the system to the public

The availability of data from the system for organisations from other countries is an important parameter for comparing data from individual countries. The results of the questionnaire show that eight countries provide the available data, namely: Italy, Croatia, the United Kingdom, France, Austria, Belgium, Spain, Germany. Five countries (Netherlands, San Marino, Andorra, Bulgaria, Poland) do not know the answer to this question, two countries do not have a registration system (Iceland and Malta) and information from the other eight countries is not available to organisations from other countries.



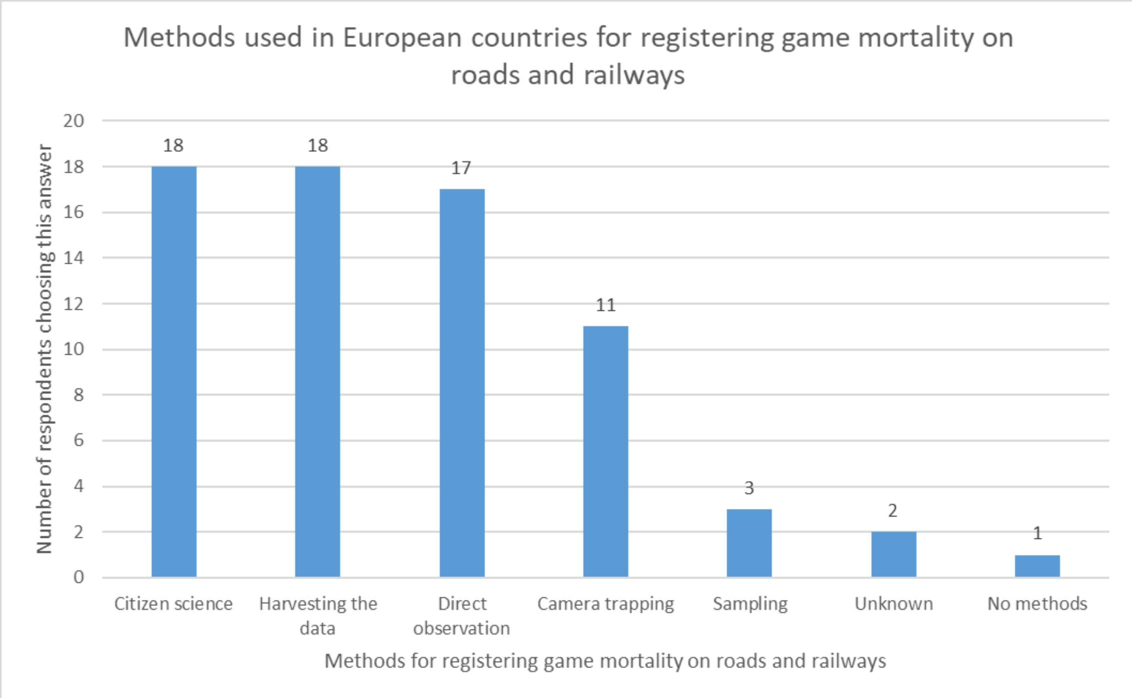
Graph no. 8: Accessibility of the system to organisations from different countries

When asked whether a system for registering game mortality on roads and railways is planned in the future, all the aforementioned countries that do not yet have the system or do not know about the existence of the system (Malta, Iceland, San Marino and Andorra) said they did not know whether it was planned to be created in the future.

In response to the question why these countries think the system does not yet exist, these countries responded that: Iceland said a similar system already exists for recording unfledged terns *(Sterna paradisea)*, in Malta wild mammals are no larger than rabbits and Andorra and San Marino are too small countries.

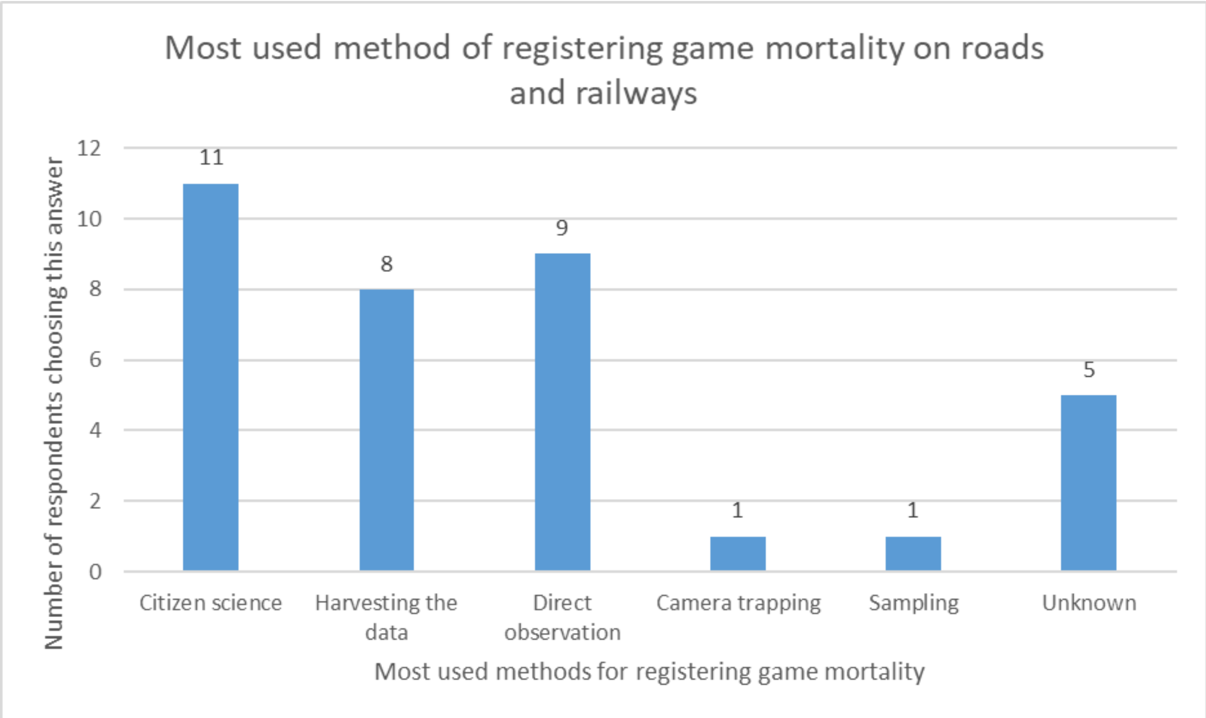
There are different methods for registering animals killed on roads and railways. These include, for example direct observation (counting dead animals in the field); harvesting the data from police, hunters; camera trapping (camera traps placed in strategic locations including infrared sensors); sampling (collecting data from random sample of animals); citizen science (reporting sighting dead animals by citizens) etc.

Most of the representatives of the countries responded by selecting several of the previously mentioned options. San Marino and Andorra replied that they did not know, and Iceland replied that no method was used in their country.



Graph no. 9: Methods used in European countries for registering game mortality on roads and railways

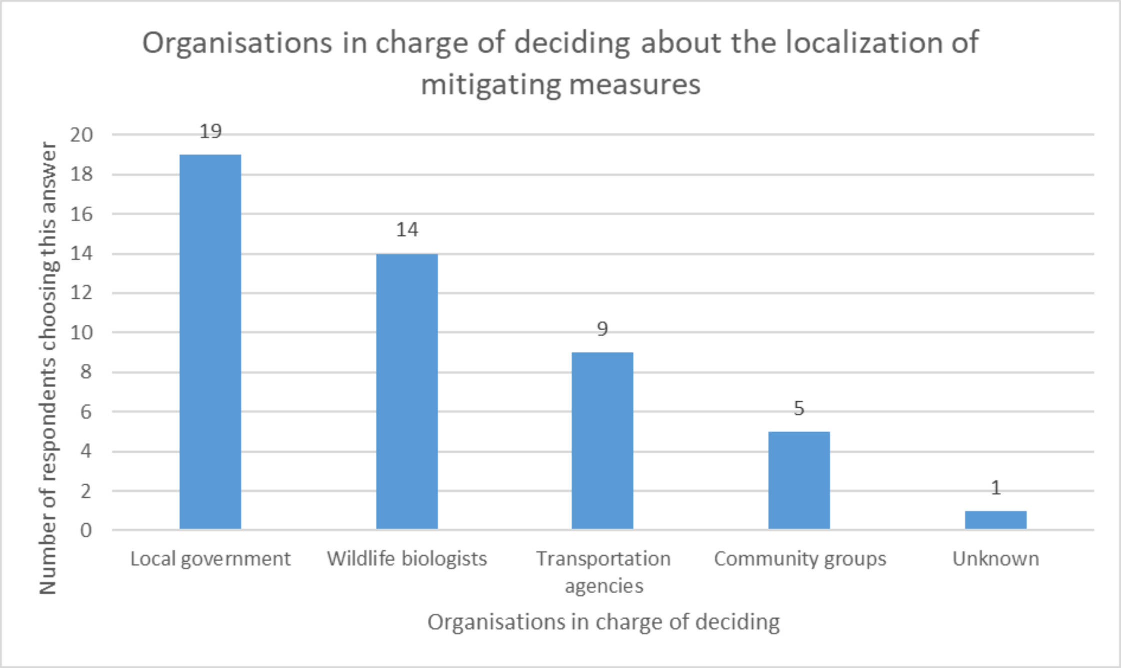
In order to narrow the choice of methods of registering animal mortality on the roads, a question was also asked about which of these methods of registration is most common in these countries. The explanations for this graph remain the same, it is only a measure of the methods used and the most frequently used methods.



Graph no. 10: Most used methods for registering animal mortality on roads and railways

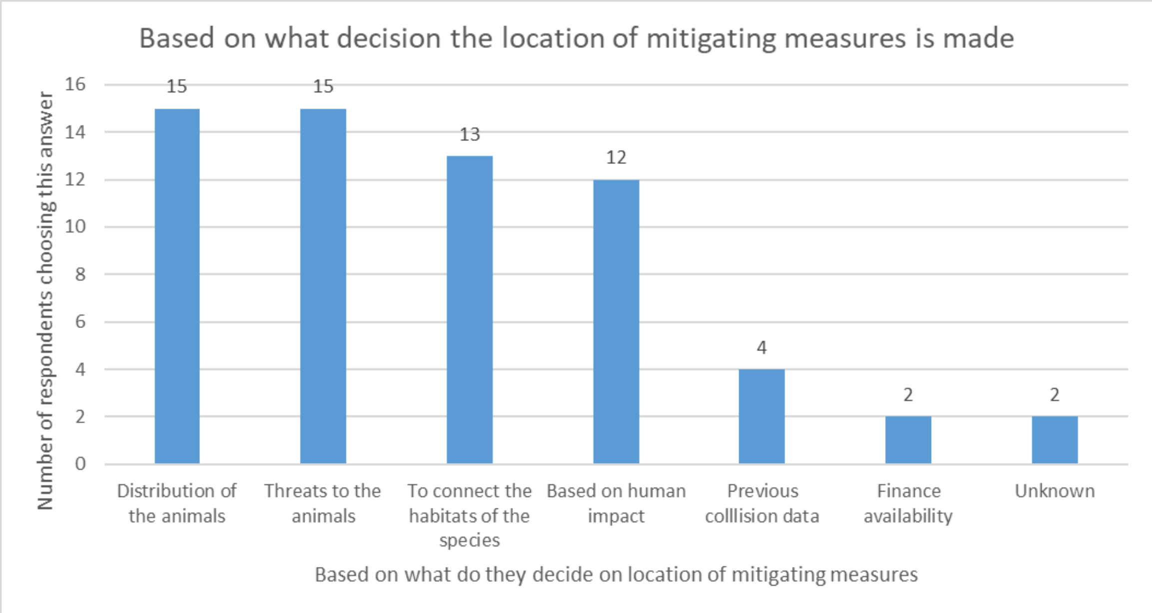
5.3 Deciding on the location of mitigating measures

In different parts of Europe, different organisations and companies decide on the location of mitigating measures. From the data, we have the opportunity to learn that it is mostly a combination of several organizations. We learn from the results that local governments, wildlife biologists, and transportation agencies are the most likely to choose the location of mitigating measures. Only in Poland they did not know the answer to that question.



Graph no. 11: Organisations in charge of deciding about the localization of mitigating measures

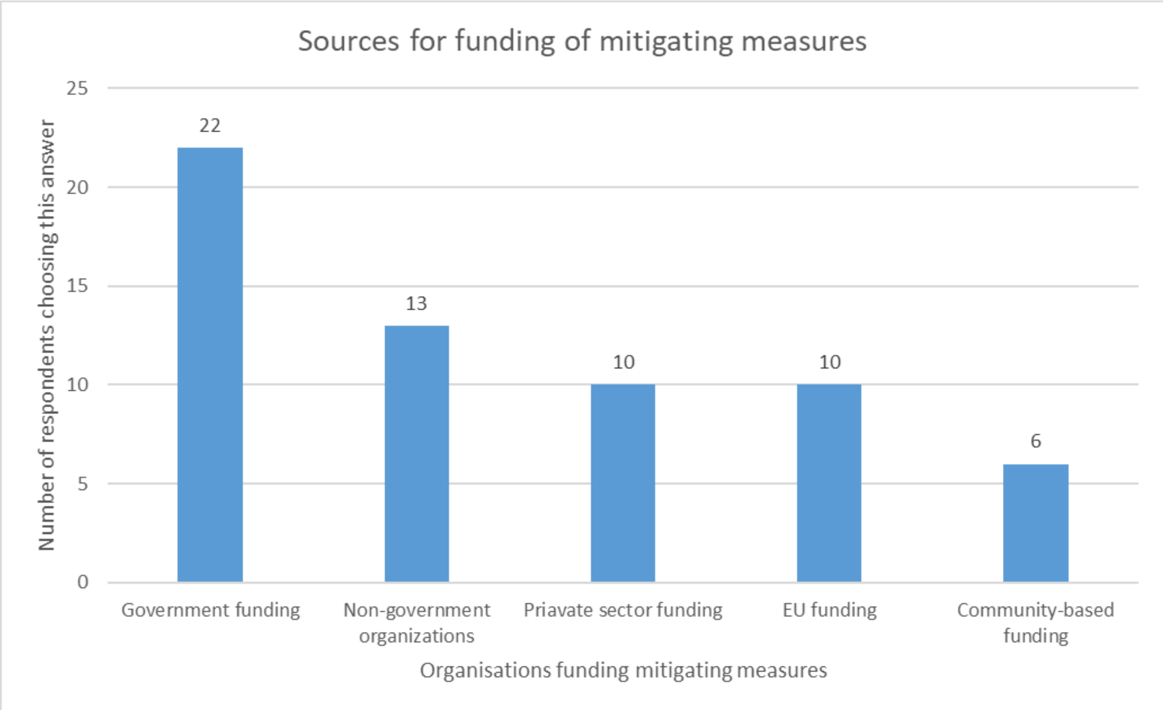
Localization of mitigating measures is an important parameter. Countries are most likely to make decisions based on distribution of animals, threats to the animals, to connect the habitat of the species or based on human impact. Other factors could be data from previous years and sources of funding for the specific location. Serbia and France did not know answer to this question.



Graph no. 12: Factors influencing location of mitigating measures

5.4 Sources of financing of these measures

Funding for mitigating measures is a costly proposition. As a result, several organisations are mostly involved, according to the questionnaire. This is particularly the case of government funding (budgets for wildlife and biodiversity protection), non-government organizations (private donations and funds), EU funding (different funding programs from European Union), private sector funding (compensation mechanisms, corporate responsibility funding, …) and community-based funding (community-based initiatives).



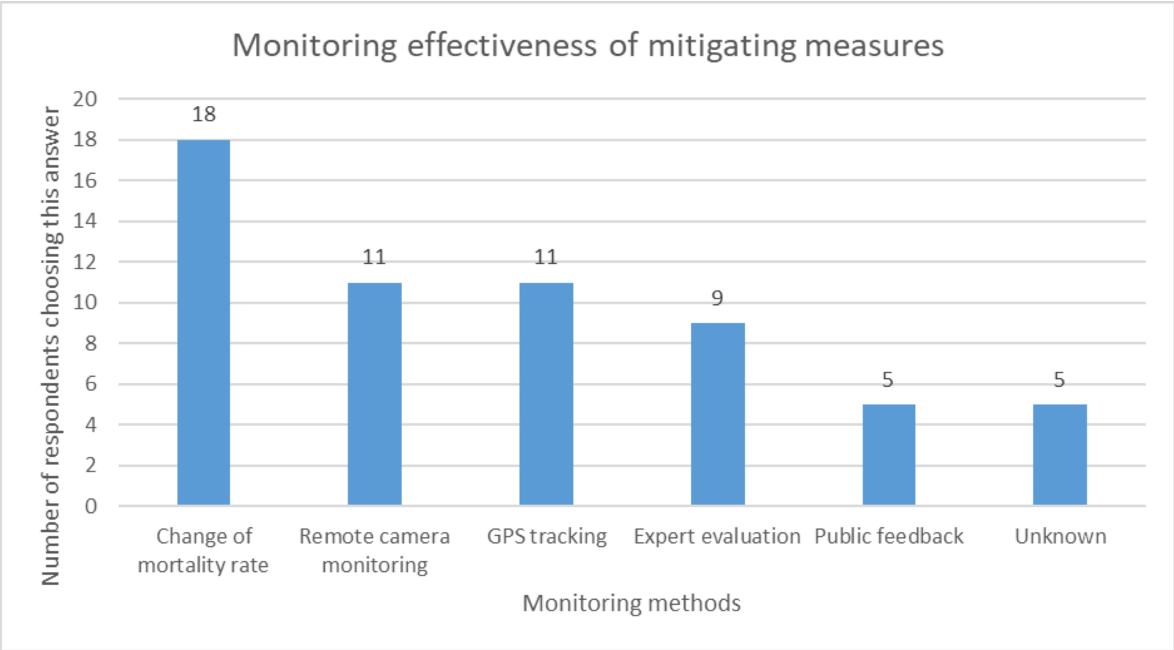
Graph no. 13: Sources for funding of mitigating measures

The price of the mitigating measures varies and cannot be set uniformly or in general, as every private supplier has its own prices. We did not get that answer in most countries.

Most representatives of the countries said they did not have an answer to this question, others said it depended on the size and length of mitigating measures. Italy replied that the overpass on the A1 to Florence cost €10 million. Slovenia replied that the overpasses cost several million and the fencing around 10 - 20 thousand euros per kilometre. Sweden replied that 1780000 euros, the UK 19.8 million euros, Germany 10 million euros without repairs or maintenance. The rest of the countries replied that they either didn't know or depended on many factors.

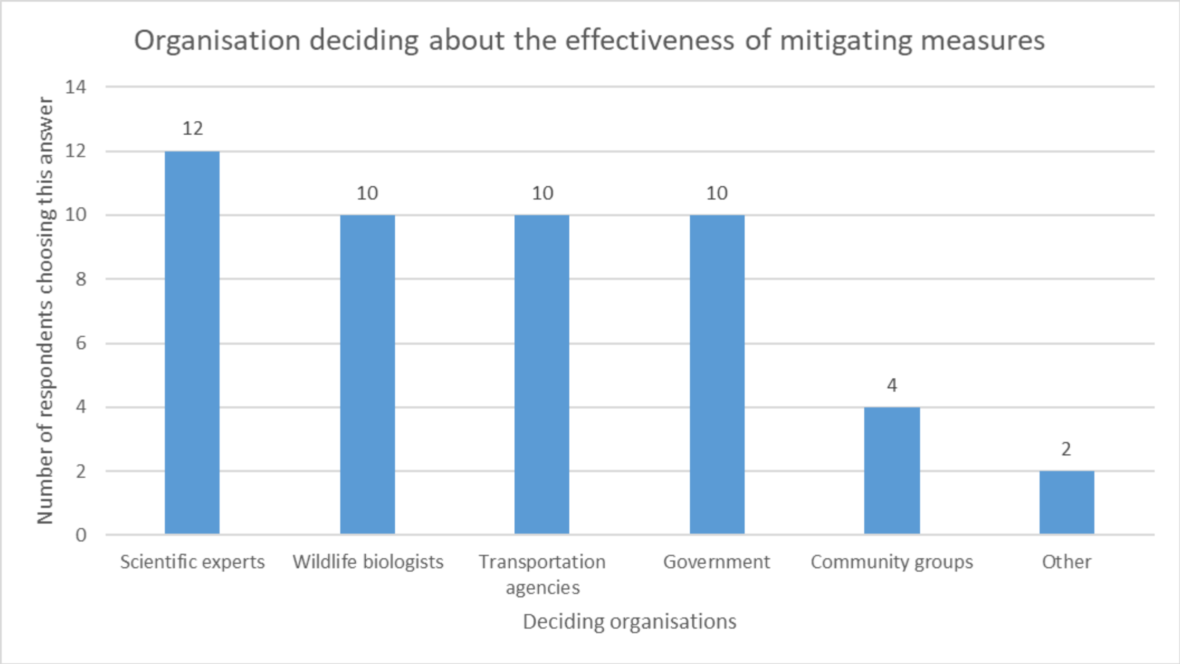
5.5 Monitoring of effectiveness of mitigating measures

The most commonly used methods for monitoring the effectiveness of mitigating measures are changes of mortality rate in the area (18 countries), remote camera monitoring set up along roadways (11 countries) and GPS tracking of animal movement (11 countries). Other used methods are expert evaluation (9 countries) and public feedback (5 countries). In five countries this information is unknown.



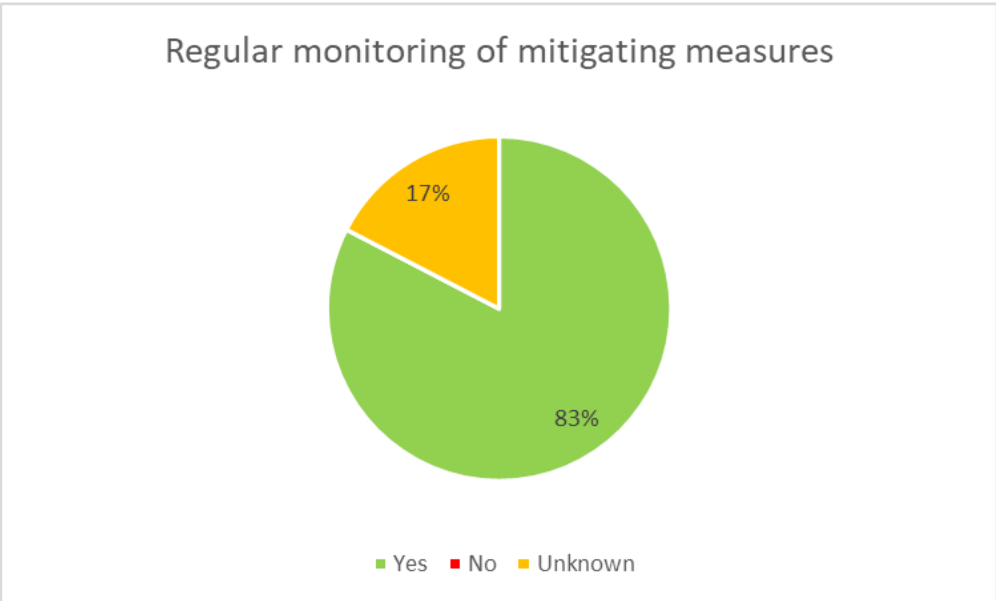
Graph no. 14: Methods for monitoring effectiveness of mitigating measures in European countries

In most countries, scientific experts (12), wildlife biologists (10), transportation agencies (10), government (10), community groups (4), and others (2) decide whether mitigating measures are effective.



Graph no. 15: Who decides about the effectiveness of mitigating measures

For these measures to be operational in the long term, they need to be checked regularly. Based on the results of the questionnaire, 19 countries have regular inspections and four countries do not have answers (Malta, Iceland, San Marino and Andorra).



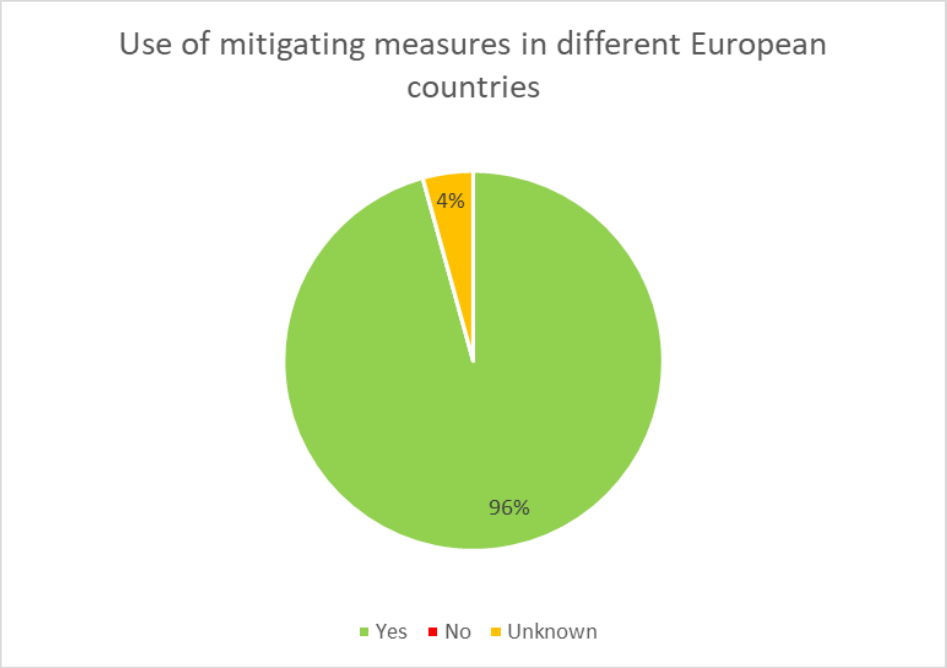
Graph no. 16: Regular monitoring of mitigating measures in European countries

In 17 countries, a reduction in game mortality has been observed in locations where mitigating measures have been installed. In six countries, respondents did not know the answer (Malta, Iceland, San Marino, Andorra, Greece and Bulgaria).

Graph no. 17: Reduction in game mortality on roads and railways with installed mitigating measures in European countries

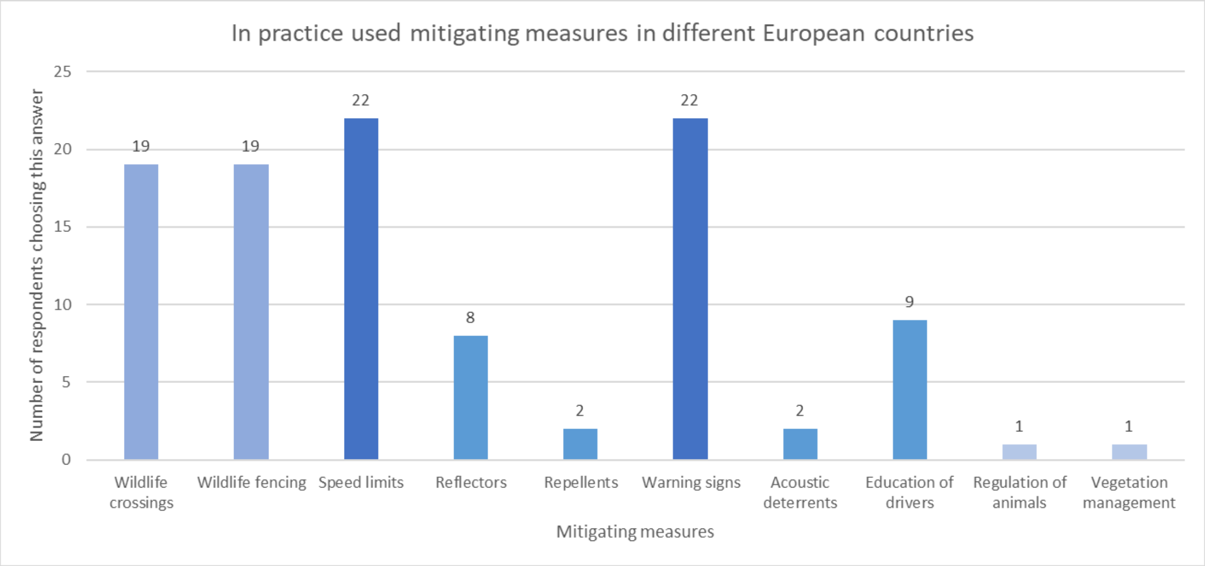
5.6 The actual measures used

Mitigatory devices are used in the states of 22 respondents. Only San Marino did not know the answer to that question.



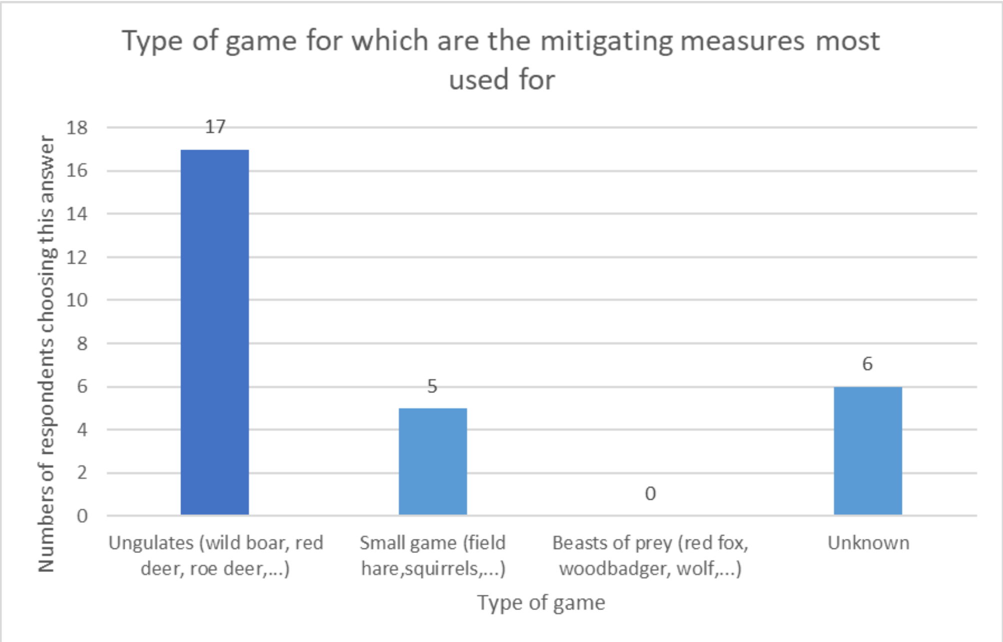
Graph no. 18: Use of mitigating measures in different European countries

In Europe, the most commonly used mitigating measures include speed limits (22), warning signs (22), wildlife crossing (overpasses and underpasses) (19) and fencing (19). Another common way to reduce wildlife animal mortality on roads and railways is education of drivers, repellents, reflectors, acoustic deterrents, regulation of animals and roadside vegetation management.



Graph no. 19: Actual used mitigating measures in different European countries

17 countries reported that these measures are most commonly used for ungulates, 5 for small game (Slovenia, The Netherlands, Greece, France and Malta). No country listed the beasts of prey, and six countries did not know the answer to the question (Lithuania, Iceland, Croatia, San Marino, Belarus and Andorra).



Graph no. 20: Type of game for which the mitigating measures are most used in European countries

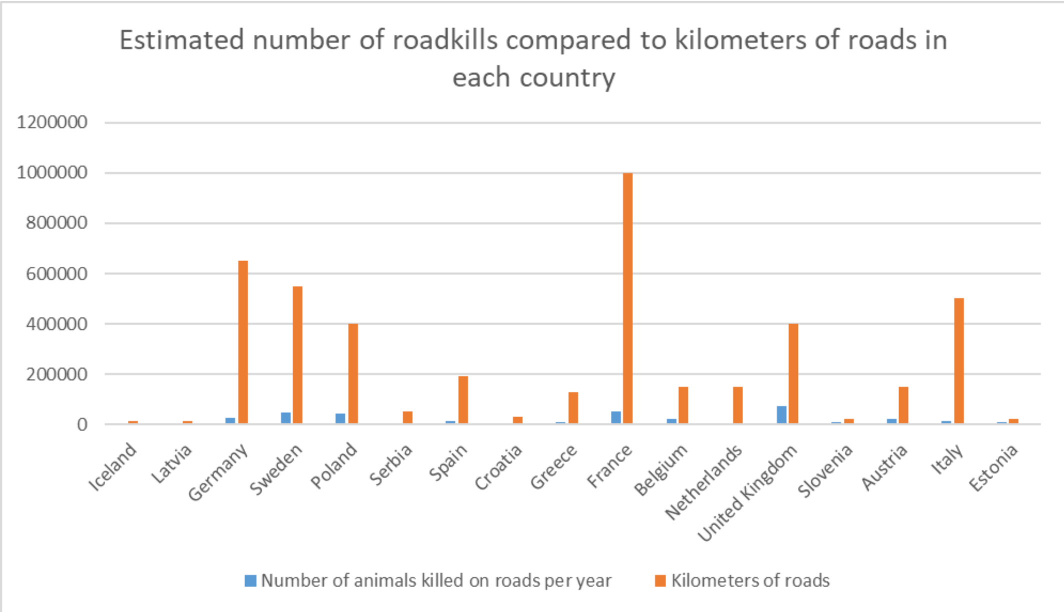
5.7 Number of wildlife animal mortality on roads and railways

5.7.1 Roads

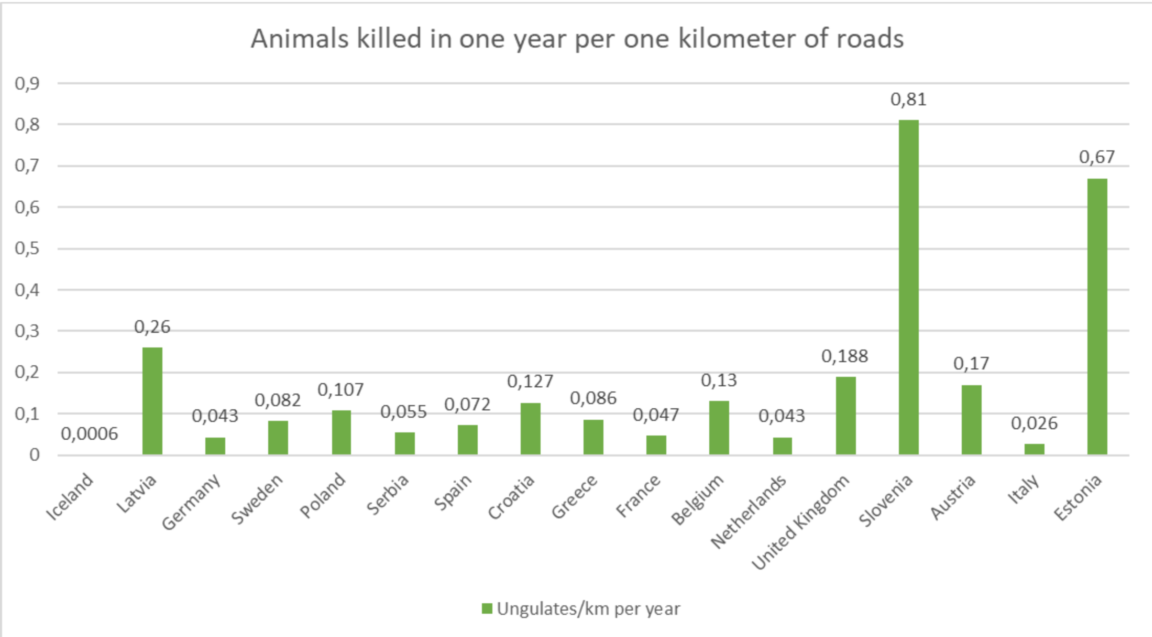
Different European countries gave us an estimated number of animals killed on the roads in their country. We then relied on Eurostat data *(ec.europa.eu/eurostat)* to convert this data into the number of game killed per kilometre of road in a given country. The table data illustrates the Graph no. 21 and Graph no. 22 below.

Country	Number of animals killed on roads per year	Kilometres of roads	Ungulates/km per year
Iceland	8	13034	**0,0006**
Lithuania	4000	15242	**0,26**
Germany	27500	644480	**0,043**
Sweden	47000	573906	**0,082**
Poland	45000	419236	**0,107**
Serbia	2500	45419	**0,055**
Spain	12000	166375	**0,072**
Croatia	3750	29514	**0,127**
Greece	10000	116100	**0,086**
France	50000	1058630	**0,047**
Belgium	20000	154012	**0,13**
Netherlands	6000	139000	**0,043**
United Kingdom	74000	394428	**0,188**
Slovenia	9000	11101	**0,81**
Austria	23000	134800	**0,17**
Italy	12500	487700	**0,026**
Estonia	11000	16460	**0,67**
Summary	357258	4420242	**0,081**

Table no. 1: Estimated number of ungulate's road kills per year in different European countries, kilometres of roads in different countries and ungulates killed per year on one kilometres of road per year (data from: ec.europa.eu/eurostat)



Graph no. 21: Estimated number of ungulates killed on roads compared to kilometres of roads in each country



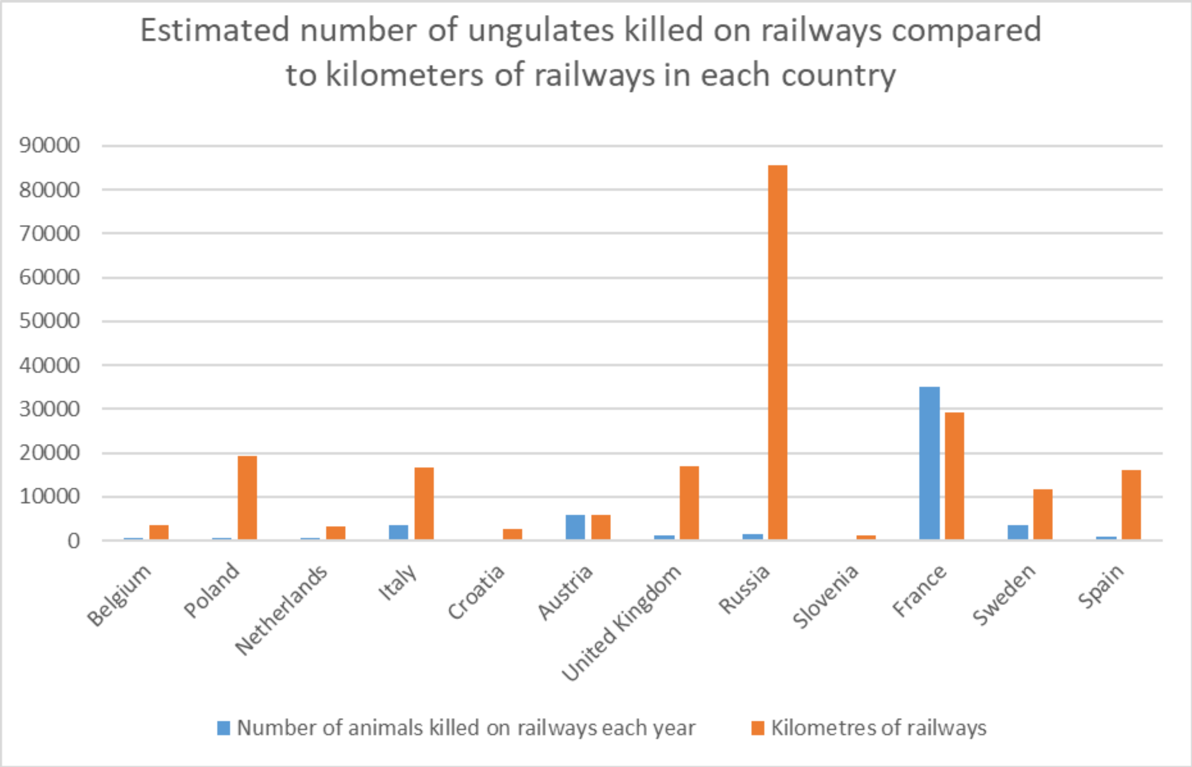
Graph no. 22: Ungulates killed in one year per one kilometre of roads in different European countries

5.7.2 Railways

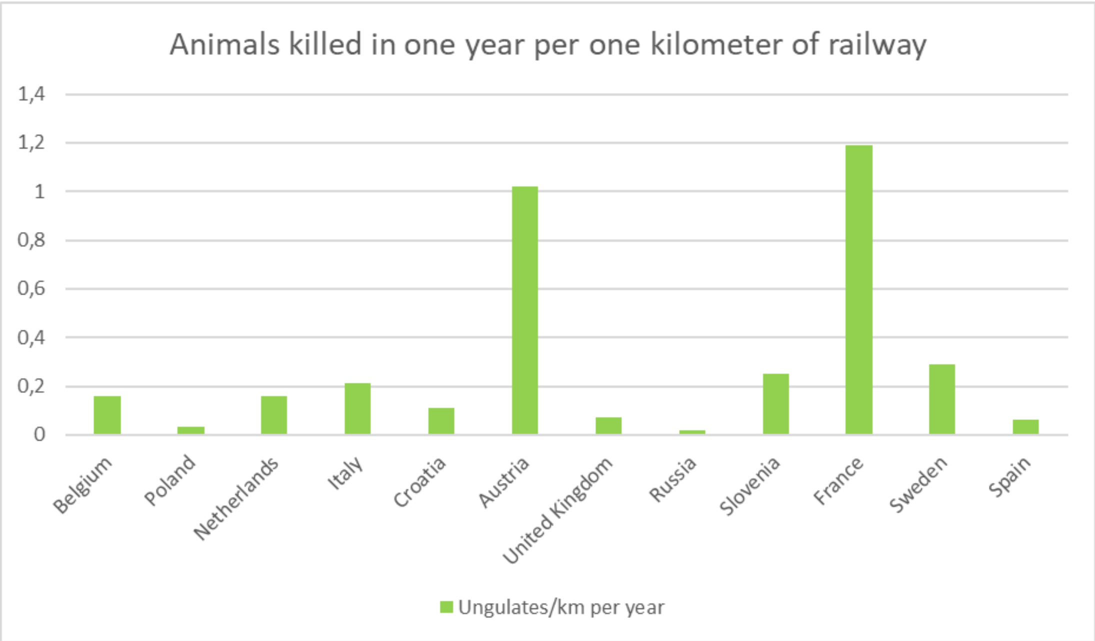
Different European countries gave us an estimated number of animals killed on the railways in their country. We then relied on Eurostat data *(ec.europa.eu/eurostat)* to convert this data into the number of game killed per kilometre of railway in a given country. The table data illustrates the Graph no. 23 and Graph no. 24 below.

Country	Number of animals killed on railways each year	Kilometres of railways	Ungulates/km per year
Belgium	579	3602	**0,16**
Poland	640	19376	**0,033**
Netherlands	500	3223	**0,16**
Italy	3500	16700	**0,21**
Croatia	308	2776	**0,11**
Austria	6000	5910	**1,02**
United Kingdom	1148	16837	**0,07**
Russia	1563	85500	**0,018**
Slovenia	300	1200	**0,25**
France	35000	29273	**1,19**
Sweden	3433	11633	**0,29**
Spain	1000	16067	**0,062**
Summary	53971	212097	**0,254**

Table no. 2: Estimated number of ungulates killed on railways per year in different European countries, kilometres of railways in different countries and ungulates killed per year on one kilometres of railway per year (data from: ec.europa.eu/eurostat)



Graph no. 23: Estimated number of ungulates killed on railways compared to kilometres of railways in each country



Graph no. 24: Ungulates killed in one year per one kilometre of railways in different European countries

6 Discussion

The aim of this work was to create a literature research and questionnaire investigation with several types of questions concerning, in particular, the registration of animal mortality on roads, mitigating measures, their effectiveness, sources of funding and decisions on their location. These data are intended to provide more information on the conditions of game collisions across Europe and to make recommendations for the Czech Republic based on them.

A total of 23 countries from different parts of Europe were part of the research. Most respondents were from the private sector. In their country, government organizations, such as the police, most often registered animal mortality on roads. Most accidents happened on roads with ungulates. In most countries it was found that there was a system for registering in electronic form, but it was not open to the public and for access to organisations from other countries the answers were half yes/no. For the most part, the reason respondents thought there was no system in their country was because their country was too small. The most commonly used method for collecting data was citizen science and then harvesting the data (from police, hunters, ...). Local government authorities were most likely to decide on the location of mitigating measures based on distribution and threats to animals. Government funds were the most common source of funding, and the price of individual devices depended on the private contractor, and therefore respondents mostly did not know the answer to this question. The effectiveness of mitigating measures was evaluated based on the change of mortality rate. Their effectiveness was decided by scientific experts, checked regularly, and in most cases have been shown to have a positive effect on reducing game mortality. Most respondents answered that mitigating measures were used in their country. Most commonly these were warning signs, speed limits, wildlife crossings and fencing for ungulates. In total, there were 0,081 animal collisions per kilometre of roads and 0,254 animal collisions per kilometre of railways in all countries where the respondents came from.

From the research we obtained estimated annual numbers of game collisions on roads and railways across Europe. From this point of view, it is interesting to compare these data with existing literature. In some cases the numbers agreed, others were vastly undervalued or overvalued, and elsewhere such data could not be obtained from official sources.

For example, respondents from Belgium reported that around 20,000 ungulates die on their roads each year, while in data from Lehaire et al., 2012 we learn that around 3,899 ungulates die on roads in the Belgian province of Wallonia each year. As this is a comparison of data from all over the country and from one province, no result can be obtained. Poland said that there were collision with 45,000 ungulates on its roads each year, while Krukowicz et al., 2022 said that in 2020 there were only 26,930 ungulates killed on roads and this may therefore seem undervalued. Spain answered to the questionnaire with estimated 12,000 ungulates killed per year on roads, while research carried out between years 2003-2007 stated very underrated number of 11069 even in the space of four years (Colino-Rabanal et al., 2018). A number of 47,000 was estimated from Sweden, while Apollonio et al., 2010 claims that there were already 61,000 game-vehicle collisions with ungulates in 2005 in Sweden with a growing tendency. Slovenia replied that on their roads happens 9,000 collisions per year, while Pokorny, 2006 says 6,000-8,000, but this information may be out of date. Lithuania put the estimated number at 4,000, while Balčiauskas, 2009 puts it at only 913, a significantly lower figure. However, the biggest difference was shown in Germany, where the respondent's estimate was 27,500, which is several times lower than Hothorn et al., 2012 figure of 200,000.

We learned from the questionnaire investigation that only around 8 ungulates are killed on roads in Iceland annually, which is because only reindeers *(Rangifer tarandus)* live there as stated in the questionnaire. There is no scientific comparison for this number. In other countries comparison data could not be found or were out of date.Data in Germany can be so fragmented because their animal mortality registration on roads and railways works on a single state basis.

The same comparison could be made for railways, but there is not as much available data to do so. Poland, for example, has said that 640 animal accidents occur on railways each year in Poland, while Krauze-Gryz et al., 2017, reports that 1458 animal collisions occurred on Polish railways in 2015. In Malta and Iceland, the questionnaire found that they did not have railways.

The data obtained from the survey on the number of game collisions with trains are visually much more specific than the data obtained from the roads. This may be due to more road users making it hard to register every single collision unless the driver reports it.

We can see from the results that respondents reported that more game collisions happen on the roads than on the railways. However, the results show that according to the numbers reported in the question for estimated numbers of collisions per kilometre, more game collisions are reported on railways. This may be due to the fact that there are more roads in countries than railways. Moreover, there are only a few people on the railways than on the roads, where most of the people living in the country move, which may cause fewer registrations of the killed animals.

From the data obtained through the questionnaire survey, we can see that respondents think that the most frequent collisions on the roads occur with ungulates, but this is disproved by Tajchman et al., 2010, which claims that small mammals such as hedgehog, fox, hare, etc. are the most likely to die on the roads in Poland. This difference in claims may be due to poor visibility of these small mammals and to the fact that there is normally no damage to vehicles following a collision with them.

We can see from the results that the most road collisions with ungulates per kilometre happen in Slovenia, Estonia and Lithuania. Interestingly, Estonia and Lithuania are both Baltic countries located in the northeast of Europe. Slovenia is also in the east of Europe. An interesting link to these facts might be that all of these countries have large landscapes and a large number of forests (Rytter et al., 2016; Hladnik, 2005). According to research, it also turns out that there are poor quality mitigation measures in these countries, or they are hardly there at all (Pokorny, 2006; Kučas et Balčiauskas, 2020). But in the questionnaire investigation, all countries responded that they use mitigating measures.

In contrast, railways have shown higher numbers of rail collisions with ungulates, particularly in developed countries from the western and northern Europe. These were notably France, Austria, Sweden, Belgium and Italy. This can be due to the high speed of trains in these countries or the large number of lines (Dorsey et al., 2015).

Countries that have a system for registering animal mortality have shown no greater accuracy in wildlife mortality data on roads and railways, as they are mostly not accessible to the public or organizations from other countries. It would be a good idea for this system to be open to the public and organisations from other countries, so that this data can be used to do more research across the country and warn drivers about threats on roads and railways. This claim is refuted by Ruusila et Pellika, (2016), who argue that since the introduction of the animal mortality registration citizen science system on roads and railways, the number of animal collisions in northern European countries has increased.

The possibility of better collision registration options is also growing with the fact that the most used input system turned out to be an electronic form that exceeds the paper one these days. From the fact that all the countries that had the paper form of the system also had the electronic form, it may appear that this is just a relic of the past. Thanks to the electronic system, we can enter data in the field and not be restricted by paper forms. To a large extent, this also makes it possible to conduct citizen science. This could also mean that civil servants would not be needed to register collisions such as police officers or hunters.

The organisation that most often registers animal mortality on roads and railways in various European countries has proved to be government agencies. This may mean that the authorities are involved, for example, but they do not have the ability to capture all the collisions. It is therefore good that the questionnaire showed that several organisations are in charge of registration in most countries at the same time.

Interestingly, in most countries, decisions on the effectiveness of mitigating measures have been proven to be made by scientific experts. Such individuals have an expert perspective and see results based on research that they are even able to do themselves. This is very important for the future of building new mitigating measures.

Speed limits, warning signs, wildlife fencing and crossings were found to be among the most common mitigating measures. The responses also show that all countries that used these measures were found to be effective and to reduce the number of animal mortality rates on roads and railways. This is confirmed by the Ritwinski et al., (2016) study, which states that the four facilities mentioned above are among the most effective.

The shortcoming of this questionnaire was that the questions were mainly answered by organisations that were from the private sector (20 out of 23), which could mean that they may not always have access to internal information that is only available to state organisations. However, this fact was offset by the fact that the majority of respondents were FACE (European Federation for Hunting and Conservation) members. On the contrary, this may have helped in the coherence of facts across Europe.

7 Conclusion

- A questionnaire investigation was conducted to which 24 representatives from 23 countries responded. Based on this, we learned that most countries register game mortality through the system in electronic form and citizen science is among the most commonly used methods, which can maximize the data accuracy. We learned that among the most effective methods are speed limits, warning signs, wildlife fencing and crossings. The data obtained in the questionnaire on mortality on roads and railways often disagreed with the data from scientific articles. This was particularly confirmed in Germany, where the number of game-vehicle collisions on the roads was many times lower than the numbers in scientific articles. The questionnaire also revealed that the most collisions with vehicles are mainly in the eastern and Baltic countries, as they have a lot of countryside and forests and little or almost none mitigating measures. The opposite were railway collisions, where western and advanced countries scored worst due to high train speeds and large areas of railways. Scientific experts should be in charge of evaluating the effectiveness of mitigating measures, as they have an expert point of view.
- The recommendation for the Czech Republic is the establishment of an electronic system for mandatory entry of game mortality, so that every accident does not involve police or hunters. This could also mean improvements to the application *srazenazver.cz*, so that it can largely serve the public for entering animal mortality on roads and railways. Data entry should be through using citizen science, so it would be better if the system was open to the public and accessible to organisations from other countries. Data can serve as an important statistic across Europe. Furthermore, it would be advisable to build mitigating measures as they have proven to be effective, placing warning signs and speed limits on lower-class roads and crossings and fencing on higher-end roads in particular. Given that most organisations think there are more collisions with ungulates than with small mammals, is the reason why most of the mitigating measures are for ungulates, it would be advisable to pay more attention to mitigating measures for small mammals and vertebrates, such as hedgehogs and hares, since most of them are for ungulates. These facilities should be built in the locations where the most animals are found and where they are most at risk of being killed during game-vehicle collision. Paying for these facilities should be co-financed by different sectors, but in particular by the government. Mitigating measures should be regularly inspected to ensure their functionality and safety for game by scientific experts.

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