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Review Article

A review of the mortality of wild fauna in Europe in the last century: the consequences of human activity

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Abstract

The exponential growth of the human population and their activity in the last decades have adverse effects on biodiversity. The main objective of this review was to present a compilation of works on causes of mortality of native wildlife in Europe, in the last decades linked to human activity. Here, a total of 130 peer-reviewed publications were reviewed for the period between 1942 to 2017 from thirty-eight countries. Sixty-five percent of the studies were focused on the bird's species. Our results showed that the leading cause of mortality was due to traumatic origin, particularly collision with infrastructures and motor vehicles. Based on the papers analysed in the present study, it is possible to conclude that human development and its anthropogenic pressures have a negative effect on some species of wildlife, while the potential impact on the vast majority of other species is still unknown. This study provided an insight into the effects of the different anthropogenic pressures on the European fauna, giving valuable information on its main threats and raising important questions on rehabilitation management practices.

Keywords: Anthropogenic pressures, Europe, mortality, urban, wild fauna

Introduction

Europe has a long and rich cultural history, being the background of some of the greatest deeds of humanity. The human population in the continent has been growing in the last centuries, including not only natives but also emigrants and refugees from other countries, with an estimated population of around 740 million (FAOSTAT 2013). The European continent is also home to large biodiversity of fauna and flora, with 219 terrestrial mammals', 41 marine mammals, and 530 bird species (Temple and Terry 2007, Deinet *et al.* 2013, IUCN Red List of Threatened Species 2014).

Unfortunately, with the increase of the human population (UNFPA 2011), its ecological footprint is accompanied by negative influences on biodiversity. One example is the case of one of the most common birds in Europe, the house sparrow (*Passer domesticus*). The data from the European Bird Census Council shown a reduction of about 60% of their population since 1978 (Gaston 2010). Europe has undergone great changes in the environment, particularly over the past 200 years, with the destruction of wild habitat for conversion to agricultural fields, grazing pasture, urban areas, the logging of forests for timber and firewood, industrial revolution and wars (Willis and Birks 2006, Gordon 2009, Kümmerle *et al.* 2012). Some examples of some activities that contributed indirectly to the decline of wild populations as a consequence of human development are climatic changes, environmental disasters, collisions with man-

made structures, poisoning, pollution or introduction of exotic species (Morishita *et al.* 1998, Bradley and Altizer 2000, Butchart 2010, Loss *et al.* 2013). Likewise, illegal poaching for meat consumption or animal trade and direct persecution, particularly large carnivores due to livestock depredation and fear of attacks on humans, led to the extinction of some species, in different periods of the history, locally or Europe-wide. Some examples are Brown Bear (*Ursus actos*), Wolf (*Canis lupus*), Eurasian Beaver (*Castor fiber*), European Bison (*Bison bonasus*), Iberian lynx (*Lynx pardinus*), Alpine Ibex (*Capra ibex*), Wild Boar (*Sus scrofa*) and Wolverine (*Gulo gulo*) (Deinet *et al.* 2013).

All these pressures have led to a great loss of biodiversity (Butchart *et al.* 2010, Inger *et al.* 2015). Vertebrate populations have suffered a decline of around 30%, since 1970, with mammal populations, have declined on average by 25% and birds by 8% (Baillie *et al*. 2010). Numerous species are at the risk of extinction, with 15% of mammals (Temple and Terry 2007), 23% of amphibians and 19% of reptiles being threatened (IUCN Red List of Threatened Species 2014). However, biodiversity trends are not universally negative, and within the broad scale of declines we see today, there are both winners and losers. For example, in Palearctic (where Europe is inserted), vertebrates have exhibited an average 6% increase since 1970 (Deinet *et al.* 2013).

The main objective of the authors in this review was to present a compilation of works that have been performed in the different countries of Europe in the last decades on causes of mortality related to anthropogenic causes of native wild animals related. It will be analysed which cause of death from the anthropogenic origin is predominant on the different classes of vertebrates (mammals, birds, reptiles, amphibians) existent in Europe and which patterns have observed the last decades.

Web-based literature search

For this review, we conducted a literature search through the main web search engines, including Google Web, Google Scholar, Web of Knowledge, Research Gate, and PubMed, as well as in the more relevant ecological, veterinary and similar subject journals. To collect articles related with the causes of mortality in native vertebrates in Europe in the last decades, our search terms included combinations of mortality, Europe, wildlife, wild animals, wild birds, wild reptiles, wild mammals, wild amphibians and names of European countries individually. As inclusion criteria, only works that describe the species, the period of study, spatial location, number of animals, and the main cause of mortality (descriptive analyse with absolute and relative frequencies) were included. In supplementary file 1, is a list of the journal in which information for this review was collected.

The results were expressed in absolute and relative frequencies, considering the class of animals the geographical distribution of the studies and the main cause of death (which was categorized into traumatic and non-traumatic, in order to facilitate the exposure of the results). Even when a paper presented multiple causes, only the main cause of mortality was selected for this study to simplify its presentation. The methodology used in this paper followed what has been described by Koutsos *et al.* 2019.

All data collected were organized in Excel-sheets and the descriptive statistics was performed using SPSS Advanced Models TM 21.0 (SPSS Inc. 233 South Wacker Drive, 11th Floor Chicago, IL60606-6412). For the elaboration of the maps and graphics, it was used the tools from Microsoft Excel and PowerPoint.

Results obtained from the consulted papers

Overall, we analysed a total of 130 works, from 38 countries, between the years of 1942 to 2017. In this review, only peer-reviewed papers were included.

Class of the animals and geographical distribution of the studies

Sixty-five percent of the studies were focused on bird species, 27.5% in mammals, 4.5% in amphibians, and 1% in reptiles. The remaining i.e., 6.5% were studies that focused on a diverse class of vertebrates simultaneously. Figure 1 represents the research frequency in the different classes by different European countries. The map shows that the countries with the greatest number of studies were Spain (n=35), England (n=18), Portugal (n=10), and Poland (n=9). The countries with fewer studies (only one paper found) were Iceland, Ireland, Ukraine, Czech Republic, Romania, Hungary, and Montenegro.

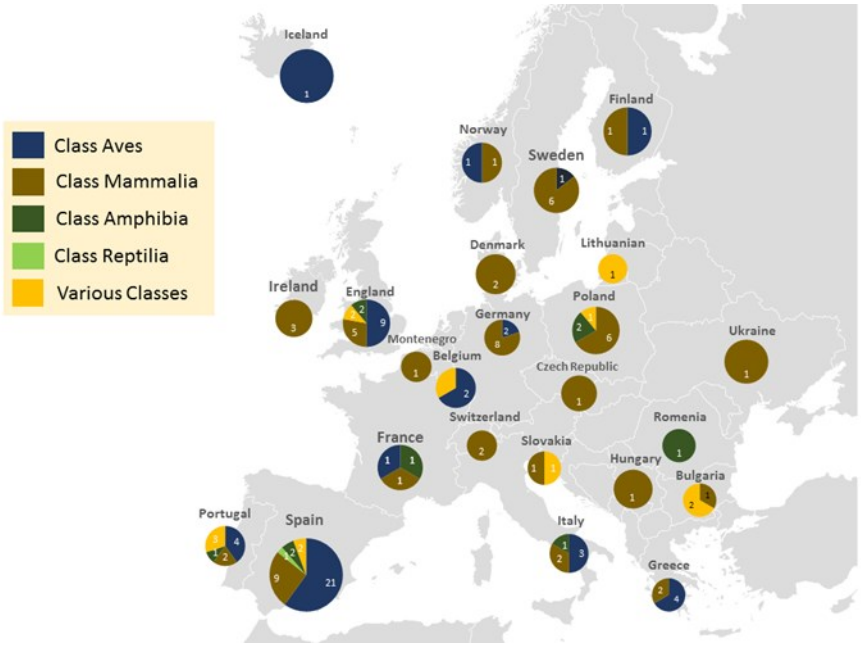

Figure 1. Representation of the 130 works, from 38 different European countries included in the review, by the different classes of vertebrates (blue- class Aves, brown- class Mammalia, dark green – class Amphibia, light green – class Reptilia, yellow – various classes in the same study)

Studies on the Class Mammalia were predominant in countries as Sweden, Denmark, Ireland, Germany, Poland, Ukraine, Czech Republic, Montenegro, Switzerland, and Hungary. Class Aves was the main focus of researches in Iceland, England, Italy, Greece, Belgium, Spain, and Portugal. In Romania, the only study performed was involved in Class Amphibia. Studies on numerous classes of vertebrates were completed in Portugal, Spain, Lithuanian, Poland, England, Belgium, Slovakia, and Bulgaria.

Causes of mortality

Traumatic and non-traumatic causes of mortality

Considering the leading causes categorized as traumatic and non-traumatic, in 10% (n=13), the primary cause of mortality was non-traumatic and in 90% (n=117) of the studies was traumatic. Figure 2 represents the leading causes of mortality by the different countries related to its traumatic and non-traumatic origin.

Figure 2 illustrates studies in which mortality was due to traumatic reason in (blue colour), which were classified based on the studied country. In a total of 18 countries (Portugal, Greece, Bulgaria, Hungary, Czech Republic, Slovakia, Switzerland, Germany, Montenegro, Ireland, Iceland, Finland, Norway, Denmark, Ukraine, Lithuanian, Poland and Romania) which the papers analysed these pointed to trauma as the main cause of death. Papers, where non-trauma was the main cause of mortality was only observed in 5 countries: Spain (n=4), Belgium (n=2), England (n=2), Sweden (n=1), France (n=1) and Italy (n=2).

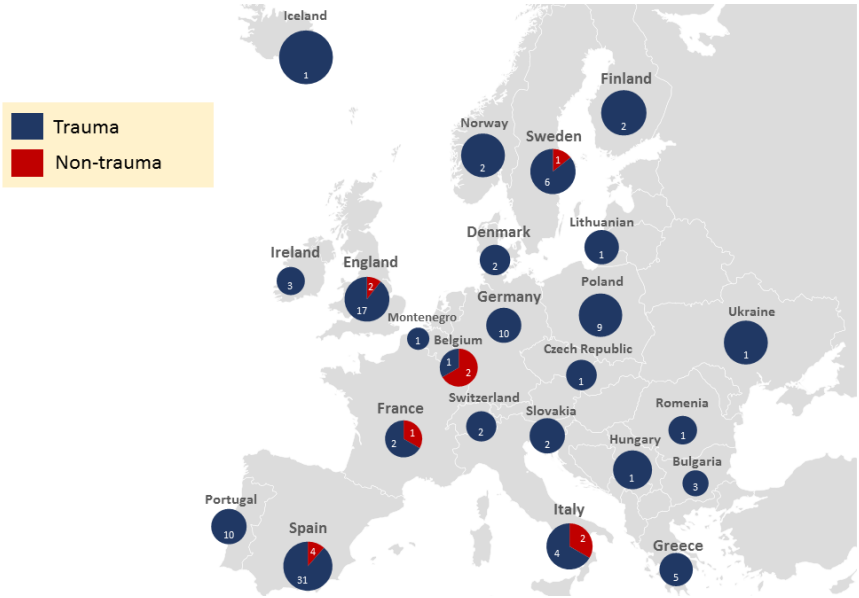

Figure 1. Representation of the 130 works, from 38 different European countries, by the various causes of mortality (blue- trauma, red-non-trauma)

Major causes of mortality

The major causes of mortality described in the different papers, were as follow: oiling (n=1), light pollution (n=1), poisoning (n=3), nutritional disorders (n=4), infectious diseases (n=5), trapped or stranded (n=5), gunshot (n=7), predation or cannibalism (n=7), trauma (n=14) (from non-specified cause) and collision with infrastructures or vehicles (n=82) (Table 1, Figure 3).

Table 1. Distribution of the causes of mortality and morbidity by the different countries inserted in this study

Country	Causes of mortality and morbidity										Ref.
	Trauma unknown	Gunshot	Infectious diseases	Poison	Oiling	Light pollution	Collisions	Predation/ Cannibalism	Traps and Stranded	Nutritional disorders	
Belgium					1		1			1	(Debacker *et al.* 1997, Jauniaux *et al.* 1998, Morelle *et al.* 2013)
Bulgaria							3				(Seiler 2003, Kambourova-Ivanova *et al.* 2012, Gruychev 2018)
Czech Republic							1				(Gaisler *et al.* 2010)
Denmark							2				(Bomadsen *et al.* 1999, Madsen *et al.* 2018)
England	2	1	1	1			9	3	2	1	(Hodson 1960, Jennings 1961, Hodson and Snow 1965, Churcher and Lawton 1987, Cooke 1995, Clarke *et al.* 1998, Newton *et al.* 1999, Philcox *et al.* 1999, Bunnell 2001, Slater 2002, Warren *et al.* 2002, Etheridge *et al.* 2006, Kelly and Bland 2006, Bowker *et al.* 2007, Robinson *et al.* 2010, Dowding *et al.* 2010, Kelly *et al.* 2010, Allain and Smith 2016, Simpson and Fisher 2017)

Continued table 1. Distribution of the causes of mortality and morbidity by the different countries inserted in this study

Country	Causes of mortality and morbidity										References
	Trauma unknown	Gunshot	Infectious diseases	Poison	Oiling	Light pollution	Collisions	Predation/ Cannibalism	Traps and Stranded	Nutritional disorders	
Finland							2				(Krone *et al.* 2006, Rautio *et al.* 2016)
France			1				2				(Capo *et al.* 2006, Meek 2012, Gourlay *et al.* 2014)
Germany	2						8				(Haensel and Rackow 1996, Hauer *et al*. 2002, Muller *et al*. 2007, Muhldorfer *et al*. 2011, Jancke and Giere 2011, Stenkat *et al*. 2013, Voigt *et al*. 2015, Seidel *et al*. 2018)
Greece	1	2					2				(Crivelli et al. 1988, Komnenoud *et al.* 2005, Mazaris *et al.* 2008, Kalpakis *et al.* 2009b, Georgiakakis *et al.* 2012)
Hungary							1				(Lanszki *et al.* 2008)
Iceland		1									(Clausen 1981)
Ireland							3				(Haigh *et al.* 2014, Liu and Nieuwenhuis 2019)
Italy			2				3		1		(Meriggi *et al.* 2009, Manarolla *et al.* 2010, Casalone *et al.* 2014, Manzia *et al.* 2016, Gianluca 2016)
Lithuanian							1				(Blaciauskas and Balciauskiené 2008)
Montenegro							1				(Iković *et al.* 2014)
Norway							1	1			(Morner *et al.* 2005, Lie Dahl *et al.* 2012)
Poland							7	2			(Kamler *et al.* 2007, Kamler *et al.* 2007, Lesiński 2008, Gryz and Krauze 2008, Elzanowski and Ciesio 2009, Lesiński *et al.* 2010, Misiorowska and Wasilewski 2012, Budzik and Budzik 2014)
Portugal	4						5				(Carvalho and Mira 2011, Matos *et al.* 2012, Silva *et al.* 2012, Silva *et al.* 2014, Garcês *et al*. 2017, Garcês *et al.* 2018, Garcês *et al*. 2018)
Romania							1				(Hartel and Moga 2009)
Slovakia							2				(Hell *et al.* 2005, Skuban *et al.* 2017)

Continued table 1. Distribution of the causes of mortality and morbidity by the different countries inserted in this study

Country	Causes of mortality and morbidity											Reference
	Trauma unknown	Gunshot	Infectious diseases	Poison	Oiling	Light pollution	Collisions	Predation/ Cannibalism	Traps and Stranded	Nutritional disorders		
Spain	3	2		2		1	21		3	2		(Hernandez 1988, Ferreras *et al.* 1989, Gonzalez-Prieto *et al.* 1993, Frías 1999, Huerta *et al.* 2000, Janss 2000, Fajardo 2001, Real *et al.* 2001, Camphuysen *et al.* 2002, Orós *et al.* 2005, Martínez *et al.* 2006b, González *et al.* 2007a, González *et al.* 2007b, Sillero 2008, Margalida *et al.* 2008, Rodríguez *et al.* 2010, Tintó *et al.* 2010, Colino-Rabanal *et al.* 2011, Molina-López *et al.* 2011, Molina-López and Darwich 2011, Palazón *et al.* 2012, Lagos *et al.* 2012, Tavecchia *et al.* 2012b, Casal *et al.* 2013, Rodríguez-Morales *et al.* 2013, Zuberogoitia *et al.* 2014, Martínez *et al.* 2014, Martínez-Silvestre *et al.* 2014, D'Amico *et al.* 2015, Jorge Orós *et al.* 2016, Montesdeoca *et al.* 2016, González-Astudillo *et al.* 2016, Montesdeoca *et al.* 2017, Canal *et al.* 2018)
Sweden	2	1	1				2	1				(Angelstam 1984, Kristiansson 1990, Aguirre and Bro 1999, Huerta *et al.* 2000, Harkonen *et al.* 2007, Bischof *et al.* 2009, González-Astudillo *et al.* 2016)
Switzerland							2					(Schmidt-Posthaus *et al.* 2002, Roedenbeck and Voser 2008)
Ukraine							1					(Volokh and Rozhenko 2013)
TOTAL	14	7	5	3	1	1	82	7	6	4		

On the seven papers where the main cause of death was predation, in 1 work the predators were domestic animals (Churcher and Lawton 1987), in the one other study were individuals from the same species (infanticide and cannibalism (Momer *et al.* 2005) and in the rest of papers predation was attributed to specific natural predators e.g. birds of prey, foxes, mustelids (Angelstam 1984, Kamler *et al*. 2007, Bowker *et al.* 2007, Misiorowska and Wasilewski 2012, Soue *et al.* 2015).

From the six studies in which trapped or stranded animals was the major cause of death or disease, in the two works, the animals were found in traps (Ferreras *et al.* 1989, Palazón *et al.* 2012), in two others, the animals were entangled in fishing gear or plastic (Jorge Orós *et al.* 2016, Simpson and Fisher 2017) and the two others were stranded marine animals in the beach (Casalone *et al.* 2014, Orós *et al.* 2016).

On the 82 works in which collision with infrastructures or vehicles was the main cause of death, 62 studies described the collision with motorized vehicles (e.g., cars, motorbikes). The primary cause of death identified in 10 studies was electrocution/collision with powerlines (Crivelli *et al.* 1988, Janss 2000, Krone *et al.* 2002, Kalpakis *et al.* 2009a, Tintó *et al.* 2010,

Martínez *et al.* 2016, González-Astudillo *et al.* 2016). In five papers, mortality was due to collision with wind turbines (Erickson *et al.* 2002, Rydell *et al.* 2010, Lie Dahl *et al.* 2012, Georgiakakis *et al.* 2012, Voigt *et al.* 2015), and in one paper (Allain and Smith 2016) collision with bikes was identified as the primary cause of death. Figure 3 displays a circular graphic with a representation of the different causes of mortality.

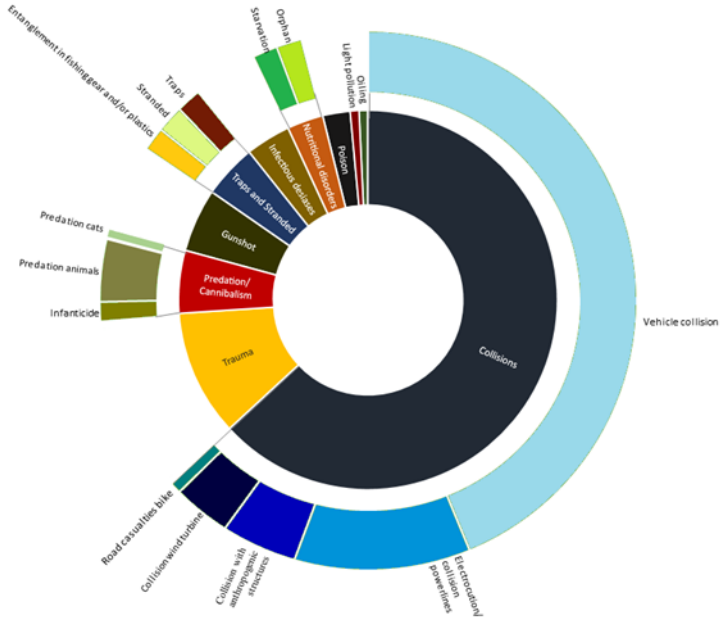

Figure 3. Distribution of the main causes of mortality in the 130 works included in the review

Considering the distribution of the main causes of mortality of each work by the different countries (Table 1), collision was the main cause of death in Spain (n=21), England (n=9), Portugal (n=5), Germany (n=8) and Poland (n=7). Mortality due to collision was present in all countries, with exception of Iceland. Gunshot as main cause of death was observed in England (n=1), Greece (n=2), Iceland (n=1), Spain (n=2) and Sweden (n=1). Infectious diseases were observed in England (n=1), France (n=1), Italy (n=2) and Sweden (n=1). Poison only was observed as main cause of death in 2 countries, England (n=1) and Spain (n=2). Predation and cannibalism were observed in England (n=3), Norway (n=1), Sweden (n=1) and Poland (n=2).

Traps and stranded was observed in England (n=2), Italy (n=1) and Spain (n=3). Nutritional disorders occurred in Belgium (n=1), England (n=1) and Spain (n=2). Oiling and light pollution were observed in Belgium (n=1) and Spain (n=1), respectively. Trauma from unknown origin was observed in England (n=2), Germany (n=2), Greece (n=1), Portugal (n=4), Spain (n=3) and Sweden (n=2).

Major causes of mortality by animal classes

In 14 studies (11%) more than one class of vertebrates were included. In 12 of 14 of these works the main cause of mortality was due to collision with vehicles (Hodson 1960, Hell *et al.* 2005, , Gryz and Krauze 2008, Balčiauskas 2009, Carvalho and Mira 2011, Kambourova-Ivanova *et al.* 2012, Godinho and Onofre 2013, Morelle *et al.* 2013, D'Amico *et al.* 2015, Gruychev 2018, Canal *et al.* 2018). In the remaining two works which one study was performed in amphibians, mammals and reptiles the main cause of mortality was due to trauma of unknown cause (Garcês *et al.* 2018a) and the other studied mammals and bird, it was due to predation of domestic animals (cats).

Moreover, in the next parts we present the main causes of mortality by the main Classes of

Vertebrates – Mammalia, Aves, Amphibia and Reptilia.

Class Mammalia

In 56 studies that only included mammal's species, the majority of the causes of death was related to trauma. In 14 works performed in bats species, the main causes of mortality in 12 papers was due to collision with vehicles and other human infrastructure associated to roads (Gonzalez-Prieto *et al.* 1993, Haensel and Rackow 1996, Capo *et al.* 2006, Lesiński 2008, Gaisler *et al.* 2010, Lesiński *et al.* 2010, Mühldorfer *et al.* 2011, Iković *et al.* 2014) and in the rest of papers, it was due to collision with wind turbines (Georgiakakis *et al*. 2012, Voigt *et al.* 2015,). In large carnivores, such as brown bear (*Ursus arctos*) the main cause of mortality was due to illegal hunting (Bischof *et al.* 2009), infanticide by males (Skuban *et al.* 2017) and road casualties (Morner *et al.* 2005), in Eurasian Lynx (*Lynx lynx*) mortality was due to road kill (Schmidt-Posthaus *et al.* 2002) in Iberian Lynx (*Felis pardina*) was due to confine of animals in illegal traps (Ferreras *et al.* 1989). In Wolves (*Lupus canis*) it was due to road kills (Skuban *et al.* 2017, Colino-Rabanal *et al.* 2011) and in wolverines (*Gulo gulo*) was related to infanticide by the males (Skuban *et al.* 2017). Regarding the smaller carnivores, such the case of the European Otter (*Lutra lutra*) the main cause of death was due to road kill (Bomadsen *et al.* 1999, Philcox *et al.* 1999, Hauer *et al.* 2002, Lanszki *et al.* 2008, Jancke and Giere 2011) and illegal hunting (Hauer *et al.* 2002). In ungulates - Red Deer (*Cervus elaphus*), Fallow Deer (*Dama dama*), Sika Deer (*Cervus nippon*), Roe Deer (*Capreolus capreolus*) and Wild Boar (*Sus scrofa*) –in six papers the main causes of death were because of collision with vehicles (Rodríguez *et al.* 2010, Lagos *et al.* 2012, Seidel *et al.* 2018, Madsen *et al.* 2018, Liu and Nieuwenhuis 2019), but in two papers it was due to infectious diseases (Aguirre and Bro 1999). Trauma from diverse origins appeared in two works that in one study mortality was due to predation by large predators (wolf) (Kamler *et al.* 2007). In the two works performed in marine mammals (cetaceans and European Harbour Seals (*Phoca vitulina*)) the main causes of death were due to infectious diseases and stranded animals in the beach (Harkonen *et al*. 2007, Casalone *et al*. 2014). In European Hedgehog (*Erinaceus europeus*) the main cause of mortality was due to road kill (n=5) (Kristiansson 1990, Haigh *et al.* 2014, Rautio *et al.* 2016), poisoning (n=1) (Dowding et al. 2010) and nutritional disorders (in particular admittance of orphans) (n=2) (Bunnell 2001, Martínez *et al.* 2014). In the remaining studies that include a collection of a large variety of mammal species (Seiler 2003, Volokh and Rozhenko 2013,), or small animals such as Brown Hare (*Lepus europaeus*) (Roedenbeck and Voser 2008), European Badger (*Meles meles*) (Clarke, *et al.* 1998, Seiler 2003) or European Polecat (*Mustela putorius*) (Kelly *et al.* 2010) the main cause of death and admission to the Centres was because of collision with vehicles (n=7).

Class Aves

A total of 50 works was performed in bird species only. Twenty-five were performed in birds of prey, such as the Eurasian Sparrowhawks (*Accipiter nisus*), Imperial Eagle (*Aquila adalberti*), Red Kites (*Milvus milvus*), barn owl (*Tyto alba*), White-Tailed Sea Eagles (*Haliaeetus albicilla*) and many others. From those of 25 papers, in four the main cause of mortality was due to trauma (from unknown origin or multiple causes) (Komnenoud *et al.* 2005, Kelly and Bland 2006, Molina-López *et al.* 2011, Casal *et al.* 2013), in six was due to collision with power lines and electrocution (Ferrer and Hiraldo 1992, Real *et al.* 2001, Krone *et al.* 2006, Martínez *et al.* 2006a, González *et al.* 2007a), in three it happened due to collision with anthropogenic structures (Muller *et al.* 2007), in three by collision with vehicles (Hernandez 1988, Newton *et al.* 1999, Fajardo 2001), in three by shooting (Clausen 1981, Etheridge *et al.* 2006, Kalpakis *et al.* 2009a), in two by poisoning (Margalida *et al.* 2008, Tavecchia *et al*. 2012a), in one by infectious diseases

(Manarolla *et al.* 2010), in one by nutritional disorders (Molina-López and Darwich 2011) and one by collision with wind turbines (Lie Dahl *et al*. 2012).

In the five studies performed in seabirds the main cause of mortality was due to nutritional disorders (mainly starvation) (Jauniaux *et al.* 1998), oiled birds (Debacker *et al.* 1997), gunshot (Camphuysen *et al.* 2002), light pollution (Montesdeoca *et al.* 2017) and drowning in fishing nets (Simpson and Fisher 2017).

The remaining 20 studies were performed in several species of birds, in large majority including Passeriformes. The main causes of mortality in five of these studies was due to electrocution and collision with power lines (Crivelli *et al.* 1988, Janss 2000, Kalpakis *et al*. 2009a, Tintó *et al.* 2010, Silva *et al.* 2014), in three by predation by other animals as birds of prey and small carnivores (Angelstam 1984, Warren et al. 2002, Bowker *et al.* 2007), in 5 due to trauma of variety or unknown origin (Jennings 1961, Montesdeoca *et al.* 2016, Stenkat *et al.* 2013, Garcês *et al.* 2018a, Garcês *et al.* 2018), in two due to shooting (Frías 1999, Mazaris *et al.* 2008,), in two due to infectious diseases (Robinson *et al.* 2010, Gourlay *et al*. 2014), in two due to collision with vehicles (Hodson and Snow 1965, Frías 1999) and two collision with anthropogenic structures (Jennings 1961, Kalpakis *et al*. 2009a).

Class Amphibia and Class Reptilia

In the Class Amphibia in a total of nine works, the main cause of mortality was due to road casualties, with motorized vehicles and bikes (Cooke 1995, Sillero 2008, Elzanowski and Ciesio 2009, Hartel and Moga 2009, Meek 2012, Matos *et al.* 2012, Budzik and Budzik 2014, Gianluca 2016, Allain and Smith 2016). The two studies performed in reptiles only, loggerhead turtles (*Caretta caretta*), the main causes of mortality was due to stranded animals in the beach and entanglement in fishing gear and/or plastics (Orós *et al*. 2005, Orós *et al.* 2016).

Discussion

There are numerous Wildlife Rehabilitation Centres and Wildlife Sanctuaries distributed across the different countries of Europe. Their main objective is to provide treatment and temporary care of injured, unhealthy and displaced native wild animals with the ultimate purpose of restoring them to their natural habitat. These centres work with a remarkable diversity of wild animals species, management protocols, laws and resources (equipment's, installations, etc.) depend ending in which country they are located (Sainsbury *et al.* 2001, Molina-López *et al.* 2011, Gourlay *et al*. 2014, Mullineaux 2014). These centres can collect a prodigious diversity of data at long of the years that can offer, an insight into the health and main threatens that ecosystems and populations face, not only to other rehabilitators but also to investigators (Mullineaux *et al.* 2003, Mullineaux 2014). The analyse of this data can provide us with information regarding the health population and be a useful tool to identify which are the main hazards from human activity.

The vast majority of works that were used belonged to animals from the Class Aves. A total of 50 papers only focusses in a determined bird's species (e.g. *Buteo buteo*) and the remaining six analysed a sample that was constituted by a large variety of species that existed in a determined region of the country. This fact can be related to many factors: 1) they are the most representative group of terrestrial vertebrates (Matias *et al*. 2007, Inger *et al*. 2016), 2) they are extremely adaptable to different environments (Wenny *et al*. 2011, Inger *et al*. 2016), 3) the ability to fly makes them cover large areas of territory and makes them easier to find when wounded (Matias *et al*. 2007, Cunningham *et al*. 2014, Ellison *et al.* 2015, Inger *et al*. 2016), 4) some species are important sentinels of the ecosystem's quality status (e.g. Passeriformes). (Stuart and Butchart 2010, Cunningham *et al*. 2014, Ellison *et al.* 2015).

The countries with more published works were Spain, England, Germany, Portugal and Poland. The predominance of works in these countries can be related to many factors: 1) our methodology considered no works published in other languages other than English, French,

Spanish or Portuguese, 2) the majority of the centres that publish their data as annual reports, rarely make it available to general public (e.g. the report of activities 1985-2010 Wildlife Rehabilitation Centre of Parque Biológico de Gaia, Portugal (Anonimus 2010).

In this review, we inspected the main causes of mortality and conclude that trauma was the main cause of death. This prevalence of trauma was also observed in other countries and continents, such USA (Augspurger *et al*. 1996, Work and Hale 1996, Brown and Sleeman 2002, Wendell *et al.* 2002, Lima *et al*. 2004, Schenk 2017, White *et al.* 2018), Canada (Wiese and Robertson 2004, Devineau *et al.* 2010, Longcore *et al.* 2013, Bishop and Brogan 2013, Smith *et al*. 2017), Brazil (Bager and Da Rosa 2011, Mestre *et al.* 2012, Corrêa *et al*. 2017, Regnet and Loebmann 2019), India (Lista *et al.* 2007, Dutta *et al.* 2016) or Australia (Hocken 2000, Hocken 2005, Brendan *et al.* 2010, Soue *et al.* 2015, Scheelings 2015) where the major cause of death of wild fauna was related to traumatic causes. Our study showed that the main cause of mortality was related to collision, mainly with motorized vehicles, in all classes of vertebrates that were involved in our analysis.

In our work, it is important to refer to the presence of some limitations and possible bias. Although systematic reviews searches for grey literature are a vital method of mitigating publication bias, they are very difficult to access, and many times not accessible to the public (Haddaway *et al.* 2017). This grey literature is much less transparent and the data many times is not complete or statistical treated, and there is a great diversity between the different centres and organizations. Also, there is the case that part of the data is used in peer-reviewed publications, which in many cases is impossible to determine which one, and there is a risk of duplication of data. For all these reasons, the authors, agreed that was the best choice not to use any grey literature in the compilation of material for review.

The data present in papers was not originated from the same sources, the wildlife rehabilitation centres. Some data was collected during census from infectious diseases or epidemiologic census of populations. For this review, in which one of the papers selected only the main cause of mortality related to anthropogenic sources (when there was a list of many causes of death described in a determined sample) had been added to the statistical analyses. Not only to simplify the analyse the information but also, due to the fact that in the majority of the papers only a specific cause of death (e.g. roadkill, shot) was studied in a determined population or area.

These results and our experience in the analyse of this kind of data, show that is important in the future improvement on the standardization of the databases and collection of data. As a result, many information is not available, that could be essential to understand determined patterns. This occurred in our works (Garcês et al. 2018a, 2018b and 2019), where a large percentage of the traumatic deaths were from an unknown origin. This would not only facilitate its use in surveillance programmes of wildlife diseases and others, but also increase the information exchange amongst these institutions, in order to improve the treatment or rehabilitation of these animals. Likewise, it would facilitate the sharing of information with governmental institutions and conservation agencies, in order to establish more efficient conservation measures and laws in the future.

Conclusion

The studies on causes of mortality can provide an elucidating view of the human impacts on wildlife. Based in the papers analysed in the present study, it is possible to conclude that human development (e.g. building construction, road networks, energy supplier infrastructures) and its anthropogenic pressures have a negative effect in some species of wildlife, while the potential effects on the vast majority of other species are still unknown. It is important to collect more information regarding the anthropogenic impact on the mortality of European wildlife, so that in a near future the land managers can prevent structure development (e.g. roads, wind farms, and industries) near important areas, such as breeding areas or migration corridors. Efforts

should be made to reduce the density of anthropogenic structures established in unfragmented habitats when all other options have not yet been exhausted.

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