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Research Article

IMPACT OF ANTHROPOGENIC STRESSORS IN THE MORTALITY OF ENDANGERED VERTEBRATE SPECIES: A 10-YEAR STUDY IN NORTHERN PORTUGAL

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ABSTRACT: This study was focused to gather the data available concerning the mortality of 440 wild animals admitted in the Wildlife Rehabilitation Centre in Parque Biológico de Gaia from 2008-2017. Only the species with unfavorable conservation status according to the Portuguese Red Book of Vertebrates were included. The animals belonged to the classes Mammalia (5.68%), Aves (86.14%), Reptilia (7.95%), and Amphibia (0.22%), 19 different orders. Overall, the most common cause of death was trauma (72%), mainly due to an unknown origin (75.5%) and shooting (2.5%). The non-traumatic causes were mainly of unknown origin (n= 18.4%) and due to nutritional problems (4.7%). Amongst the identified pressures, the proximity to a high density of small and medium companies was the most significant. There were high coefficients of redetermination (R2>0.8) which relates pressures with endangered animals' mortality. It is, therefore, possible to conclude that according to our results human activity has an important impact on the mortality of these species.

Key words: Endangered animals, Wildlife mortality, PLS-PM, Anthropogenic pressures, Conservation.

INTRODUCTION

According to the Portuguese Red Book of Vertebrates, 181 species of vertebrates in Portugal have an endangered conservation status (Cabral *et al.* 2005). The increasing human activity, especially in the last decades, has leading to the reorganization of the terrestrial biosphere. Agriculture fields, roads, industries or cities are the predominant landscape (Ellis and Ramankutty, 2008), with the human-dominated ecosystems covering the more land surface than wild ecosystems do (Foley *et al.* 2005). The ecosystem alterations have a negative effect on biodiversity due to habitat loss and fragmentation, both considered determinant in population decline and extinction. Likewise, climate changes, epidemics, collision with man-made structures, poisoning, pollution, illegal poaching, animal trade and environmental disasters, are some of the other anthropogenic threats that also contribute to the decline in wild populations (Butchart 2010, Loss *et al.* 2013).

So far, there is a paucity of studies on the impact of anthropogenic pressures on endangered wild populations (Brand 2013, Wilcove *et al.* 2012). Long term studies associating mortality factors and spatial location can be used for effective conservation measures and for identifying factors that retard species recovery (Kovács *et al.* 2008, Kalpakis *et al.* 2009).

The Wildlife Rehabilitation Centre (WRC) in Parque Biológico de Gaia (PBG), one of the oldest centres operating in Portugal, has one of the largest databases available for analyses. The data collected in WRCs in Northern Portugal can provide us with an insight into the health of ecosystems and populations (Mullineaux 2014).

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The purpose of this retrospective study was to examine the factors that caused mortality in threatened species admitted in WRC-PBG during the past 10 years (2008-2017). Furthermore, using the Partial Least Squares-Path Modelling (PLS-PM) model we can identify the causes of mortality that would help to devise management plans that could help in species recovery.

MATERIALS AND METHODS

Study area and animals

The admission records of endangered native species in Wildlife Rehabilitation Centre (WRC) in Parque Biológico de Gaia (41º 05' 48.50"N - 8º 33' 21.34"W) from January 2008 to December 2017 were analysed. The classification of threatened species was based on the Portuguese Red Book of Vertebrates and 2015 IUCN List of Threatened Animals. Animals were collected in municipalities from the Northern Region of Portugal.

Study design and sample selection

This study included all the individuals that were euthanized (in agreement with an unfavourable prognosis and legislation in force) and died during treatment or admission.

Individual data was categorized according to the taxonomic class, order and species. Based on their external characteristics (Loureiro *et al.* 2008, Meirinho *et al.* 2014, Bencatel *et al.* 2017), animals were classified in 2 different age classes, adult and juvenile. The geographical location of capture, the year of admission and season (spring, summer, autumn, winter) were also considered. In the majority of the records gender information was absent, therefore, not considered for this study.

The causes of mortality were defined following a previously published methodology by our research group: infectious diseases, captivity (dehydration, muscular atrophy, injuries, parasites and metabolic diseases), nutritional disorders, toxics, parasitic infections, non-trauma unknown origin, collision with vehicles, electrocution, predation, shooting and trauma of unknown origin (Garcês *et al.* 2018).

Statistical analysis

The descriptive statistics were performed using the Statistical Package for Social Sciences (SPSS), version 24, advanced Models TM 21.0 (SPSS Inc. 233 South Wacker Drive, 11th. Floor Chicago, IL 60606-6412).

For the PLS-PM dataset preparation, were used the XL Stat software (Addinsoft, 2014) and the ArcMap software (http://desktop.arcgis.com/en/arcmap/), for model implementation and to handle spatial data and produce thematic maps.

The PLS-PM software was run twice, in order to investigate the non-traumatic and traumatic mortality. The measurable variables (MV) were viewed as causes of the latent variables (LV), defined as "anthropogenic pressures" (exogenous variable) and "mortality" (endogenous variable) (Sanches-Fernandes *et al.* 2018). The data collected was assembled into a worksheet comprising n rows (size samples) and p columns (characterization of the sample). The sample size designates the number of municipalities from Northern Portugal where animals were collected. The anthropogenic pressures selected were: burnt areas, number of domestic landfills, water reservoirs, road density, wind farms (number and total power), residential buildings, non-residential buildings, small companies (with < 10 employees), human, population, medium companies (with 10-250 employees), large companies (with > 250 employees) and farm density. The associations between the two LV were quantified through path coefficients (R^2) which provide us information regarding the influence of the anthropogenic pressures on mortality. The association among LV and MV were quantified by weights, which represent the contribution of each MV to its LV.

RESULTS AND DISCUSSION

Sample and mortality cause

A total of 440 endangered animals was admitted to the WRC from 2008 to 2017. The animals were categorized in 4 different classes: Class Amphibia (n=1, 0.2%), Class Aves (n= 379, 86.1%), Class Mammalia (n=25; 5.7%) and Class Reptilia (n=35, 8.0%). They were distributed over 19 different orders: Order Accipitriformes (n=108, 24.5%), Order Charadriiformes (n=105,23.7%), Order Caprimulgiformes (n=74, 16.8%), Order Testudinata (n=27, 6.1%), Order Strigiformes (n=21, 4.8%), Order Lagomorpha (n=21, 4.8%), Order Anseriformes (n=21, 4.8%), Order Passeriformes (n=15, 3.4%), Order Falconiformes (n=16, 3.6%), Order Squamata (n=9, 2.0%), Order Piciformes (n=3, 0.7%), Order Procellariiformes (n=3, 0.7%), Order Phoenicopteriformes (n=3, 0.7%), Order Carnivora (n=3, 0.7%), Order Cuculiformes (n=2, 0.5%), Order Pelecaniformes (n=2, 0.5%), Order Otidiformes (n=2, 0.5%), Order Anura (n=1, 0.2%) and Order Chiroptera (n=1, 0.2%)

From those 440 animals, 404 (91.8%) were adult and 34 (7.7%) juveniles. The majority was admitted during the summer (n=186, 42.3%) and autumn (n=124, 28.2%),

Table 1. Characterization of the sample population considered for the present study (2008-2017). (CR-critically in danger; EN-endangered; DD-insufficient information; VU-vulnerable; NT-near threatened).

Species	Cases	Age		Conservation status	Species	Cases	Age		Conservation status
	N (%)	Adult	Juvenile			N (%)	Adult	Juvenile	
Discoglossus galganoi	1 (0.2)	1 (0.2)	0 (0.0)	NT	*Sterna hirundo*	2 (0.5)	2 (0.5)	0 (0.0)	EN
Accipiter gentilis	82 (18.6)	77 (17.5)	5 (1.2)	VU	*Sterna sandvicensis*	3 (0.7)	3 (0.7)	0 (0.0)	NT
Aegypius monachus	1 (0.2)	1 (0.2)	0 (0.0)	CR	*Tringa totanus*	4 (0.9)	3 (0.7)	1 (0.2)	CR
Gyps fulvus	1 (0.2)	1 (0.2)	0 (0.0)	NT	*Actiti shypoleucos*	1 (0.2)	1 (0.2)	0 (0.0)	VU
Circaetus gallicus	3 (0.7)	3 (0.7)	0 (0.0)	NT	*Burhinus oedicnemus*	2 (0.5)	2 (0.5)	0 (0.0)	VU
Circus aeruginosus	4 (0.9)	4 (0.9)	0 (0.0)	VU	*Calidris canutus*	1 (0.2)	1 (0.2)	0 (0.0)	VU
Elanus caeruleus	6 (1.4)	6 (1.4)	0 (0.0)	NT	*Gallinago gallinago*	6 (1.4)	6 (1.4)	0 (0.0)	CR
Pandion haliaetus	1 (0.2)	1 (0.2)	0 (0.0)	CR	*Larus fuscus*	39 (8.9)	39 (8.9)	0 (0.0)	VU
Pernis apivorus	9 (2.0)	9 (2.0)	0 (0.0)	VU	*Tringa nebularia*	1 (0.2)	1 (0.2)	0 (0.0)	VU
Melanitta nigra	21 (4.7)	21(4.7)	0 (0.0)	EN	*Uria aalge*	10 (2.3)	10 (2.3)	0 (0.0)	CR
Caprimulgus europaeus	74 (16.8)	61(13.9)	13 (3.0)	VU	*Scolopax rusticola*	13 (3.0)	13 (3.0)	0 (0.0)	DD
Falco peregrinus	12 (2.7)	12 (2.7)	0 (0.0)	VU	*Corvus corax*	1 (0.2)	1 (0.2)	0 (0.0)	NT
Falco subbuteo	4 (0.9)	4 (0.9)	0 (0.0)	VU	*Fringilla montifringilla*	1 (0.2)	1 (0.2)	0 (0.0)	DD
Tetrax tetrax	2 (0.5)	0 (0.0)	2 (0.5)	VU	*Turdus philomelos*	3 (0.7)	2 (0.5)	1 (0.2)	NT
Clamator glandarius	2 (0.5)	2 (0.5)	0 (0.0)	VU	*Corvus corax*	2 (0.5)	2 (0.5)	0 (0.0)	NT
Ixobrychus minutus	2 (0.5)	2 (0.5)	0 (0.0)	VU	*Locustella luscinioides*	2 (0.5)	2 (0.5)	0 (0.0)	VU
Ardea purpurea	2 (0.5)	2 (0.5)	0 (0.0)	EN	*Turdus philomelos*	5 (1.1)	5 (1.1)	0 (0.0)	NT
Ixobrychus minutus	1 (0.2)	1 (0.2)	0 (0.0)	VU	*Jynx torquilla*	3 (0.7)	0 (0.0)	3 (0.7)	DD
Plegadis falcinellus	1 (0.2)	1 (0.2)	0 (0.0)	CR	*Calonectris diomedea*	1 (0.2)	1 (0.2)	0 (0.0)	VU
Phoenicopterus roseus	3 (0.7)	3 (0.7)	0 (0.0)	VU	*Oceanodroma castro*	1 (0.2)	1 (0.2)	0 (0.0)	VU
Bubo bubo	4 (0.9)	4 (0.9)	0 (0.0)	NT	*Calonectris diomedea*	1 (0.2)	1 (0.2)	0 (0.0)	VU
Otus scops	5 (1.1)	2 (0.5)	3 (0.7)	DD	*Mustela putorius*	2 (0.5)	2 (0.5)	0 (0.0)	DD
Asio flammeus	7 (1.6)	7 (1.6)	0 (0.0)	EN	*Martes martes*	1 (0.2)	1 (0.2)	0 (0.0)	DD
Otus scops	4 (0.9)	4 (0.9)	0 (0.0)	DD	*Oryctolagus cuniculus*	21 (4.8)	19 (4.3)	2 (0.5)	NT
Plecotus auritus	1 (0.2)	1 (0.2)	0 (0.0)	DD	*Vipera latastei*	9 (2.0)	7 (1.6)	2 (0.5)	VU
Mauremys leprosa	24 (5.5)	24 (5.5)	0 (0.0)	VU	*Emys orbicularis*	3 (0.7)	1 (0.2)	2 (0.5)	EN

and the remaining in winter (63, 14.3%) and spring (n=66, 15%). Regarding the conservation status, 23 animals (5.2%) were critically endangered (CR), 36 (8.2%) were endangered (EN), 30 (6.8%) data deficient (DD), 300 (68.2%) were vulnerable (VU) and 51 (11.6%) near threatened (NT) (Table 1).

The animals were collected in 47 municipalities from Northern Portugal (Fig. 2). The municipalities with a higher number of events were Vila Nova de Gaia (n= 122), Porto (n= 39), Matosinhos (n= 38) and Santa Maria da Feira (n=20).

In 123 cases, death occurred due to non-traumatic origin: 2 cases (0.5%) due to parasitic diseases, 21 (4.7%) with nutritional disorders, 10 (2.3%) due to captivity, 9 (2.05%) due to infectious diseases and the remaining 81 (18.4%) of unknown origin. In 317 animals the cause of death was trauma: 1 animal (0.2%) with fish hooks and nets, 2 (0.5%) due to collision with vehicles, 8 (1.8%) predation, 9 (2.0%) by gunshots and the remaining 296 (75.5%) to unknown traumatic cause (Table 2).

In Fig. 1, the spatial distribution of non-traumatic mortality causes is displayed by locality. Localities with a higher density of cases are marked in red. The municipalities ranked in the top position (Figures 1a-f), are: a) for captivity, Porto (n = 3); b) for nutritional disorders Vila Nova de Gaia (n = 7), c) for parasitic diseases, Matosinhos (n=1); d) for infectious diseases, Vila Nova de Gaia (n = 3) and e) non-traumatic causes of

Table 2. Mortality causes distributed over the different orders of threatened animals admitted into the Wildlife Rehabilitation Centre of Parque Biológico de Gaia, from 2008-2017.

	NON-TRAUMA: Number of cases (%)					TRAUMA: Number of cases (%)				
Order	**Nutritional**	**Parasitic diseases**	**Captivity**	**Infectious diseases**	**Unknow non-traumatic**	**Fish woks and nets**	**Collision vehicles**	**Predation**	**Gunshot**	**Unknow trauma**
Anura	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(0.2)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Accipitriformes	0(0.0)	1(0.2)	2(0.5)	0(0.0)	6(1.4)	0(0.0)	0(0.0)	0(0.0)	6(1.4)	93 (21.1)
Anseriformes	0(0.0)	0(0.0)	0(0.0)	0(0.0)	14(3.2)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	7(1.6)
Caprimulgiformes	0(0.0)	1(0.2)	0(0.0)	1(0.2)	8(1.8)	0(0.0)	0(0.0)	2(0.5)	0(0.0)	49(11.1)
Charadriiformes	9(2.0)	0(0.0)	0(0.0)	6(1.4)	26(5.9)	0(0.0)	0(0.0)	2(0.5)	0(0.0)	67(15.2)
Cuculiformes	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	2(0.5)
Falconiformes	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(0.2)	0(0.0)	0(0.0)	0(0.0)	3(0.7)	12(2.7)
Otidiformes	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	(0.5)
Passeriformes	2(0.5)	0(0.0)	2(0.5)	0(0.0)	3(0.7)	0(0.0)	0(0.0)	2(0.5)	0(0.0)	8(1.8)
Pelecaniformes	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	2(0.5)
Phoenicopteriformes	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(0.7)
Piciformes	3(0.7)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Procellariiformes	0(0.0)	0(0.0)	0(0.0)	0(0.0)	2(0.5)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(0.2)
Strigiformes	3(0.7)	0(0.0)	0(0.0)	0(0.0)	3(0.7)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	15(3.4)
Carnivora	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(0.2)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	2(0.5)
Chiroptera	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(0.2)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)
Lagomorpha	2(0.5)	0(0.0)	0(0.0)	0(0.0)	4(0.9)	0(0.0)	1(0.2)	1(0.2)	0(0.0)	13(3.00)
Squamata	0(0.0)	0(0.0)	1(0.2)	1(0.2)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	7(1.6)
Testudinata	2(0.5)	0(0.0)	5(1.1)	1(0.2)	2(0.5)	1(0.2)	1(0.2)	1(0.2)	0(0.0)	14(3.2)

unknown origin, Vila Nova de Gaia (n = 34).

The spatial distribution of traumatic causes of death is displayed in Fig. 2. The municipalities ranked in the top position (Fig. 1a - 1e), are: a) for collision with vehicles, Vila Nova de Gaia (n = 1), b) for predation, Vila Nova de Gaia (n = 2), c) for gunshot, Viana do Castelo (n=24); d) for fish hooks and nets, Maia (n = 1) and e) for trauma of unknown origin, Vila Nova de Gaia (n = 71).

Anthropogenic pressures vs mortality

A variance in the anthropogenic pressure's distribution is observed between northwest and northeast regions of Portugal. In the northwest region of the territory, burnt areas, domestic landfills, population density, residential buildings, non-residential buildings, medium companies and large companies are predominant. In northeast region, the wind farms, small companies, farms and water reservoirs are the prevailing anthropogenic pressures. The road density seems to be distributed equally in both study areas.

The spatial distribution of non-trauma and trauma mortality based on the measured number of cases is represented in Fig.3a and 3b and the results of PLS-PM in Figs. 3c and 3d. The applicability of PLS-PM in this study is favoured by the noticeable communication between the measured and modelled distributions.

The relation between anthropogenic pressures and non-traumatic and traumatic causes of mortality provided by PLS-PM, is shown in Fig. 4A and 4B. The corresponding path coefficients are 0.863 (non-trauma case) and 0.830 (trauma-case).

According to non-traumatic mortality PLS-PM model (panel A), the mortality related other non-traumatic causes of unknown origin, were the main causes of death. The main anthropogenic pressures responsible for the non-traumatic mortality of endangered animals were small companies (w= 1.40), medium companies (w=1.45) and residential building density (w = - 1.12), followed by roads density (w = - 0.45) and human population density

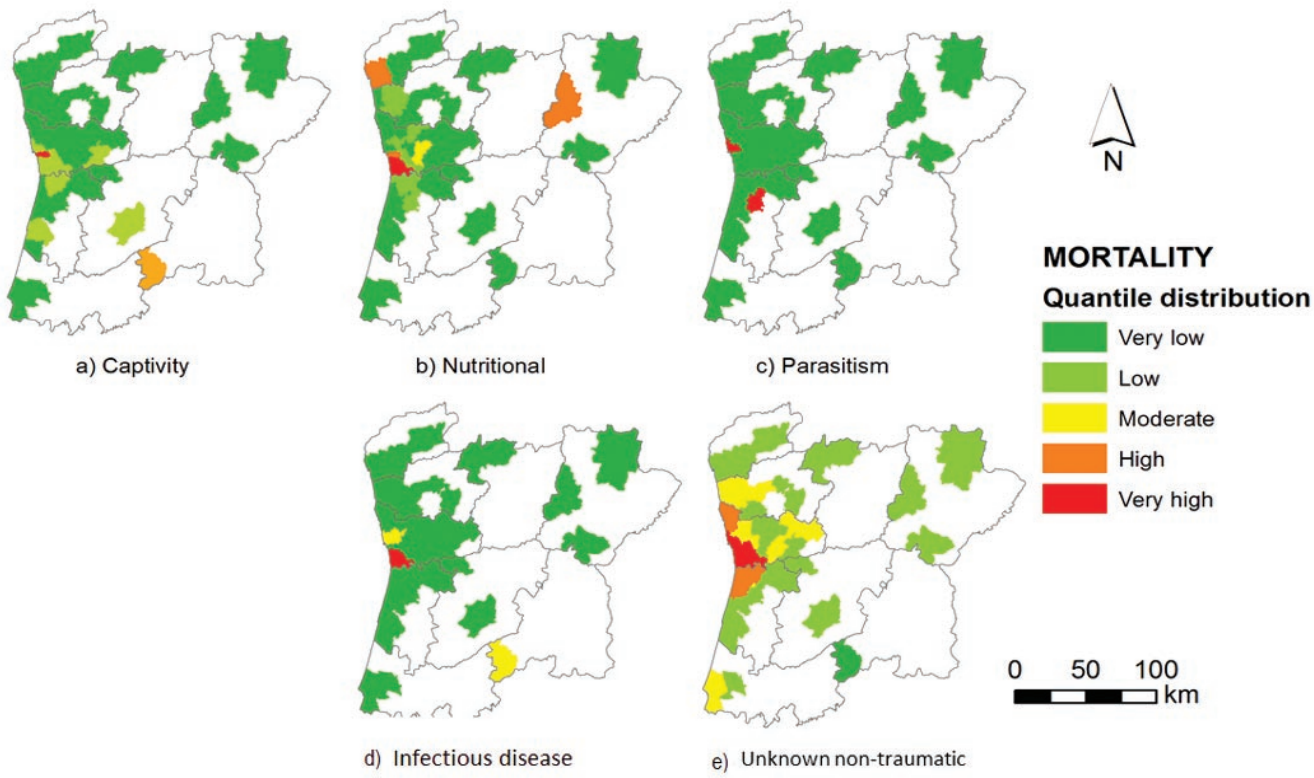

Fig. 1. Spatial distribution of non-traumatic mortality causes of the animals admitted in the Wildlife Rehabilitation Centre of Parque Biológico de Gaia across the different municipalities in Northern of Portugal (2008-2017).

(w = 0.41). Some pressures were apparently less important considering their smaller absolute weights: non-residential buildings (w = 0.26) and burnt areas (w = 0.15). The remaining pressures (water reservoirs, wind farms, domestic landfills, large companies, and farms) had a residual impact on these animals' death.

The traumatic mortality PLS-PM model represented in the panel B, identified predation, shooting, and trauma of unknown origin as the predominant causes of death. The foremost anthropogenic pressures associated with traumatic mortality, according to the results, were also small companies (w = 6.41) and medium companies (w = 6.32). Residential building density (w = 1.19), non-residential buildings density (w = 0.42) and human population density (w = -0.41) were also considered as impacting pressures. The remaining ones had insignificant impact.

In both models it is possible to observe that some weights are positive, and others are negative. This phenomenon can relate to the reverse coding of variables linked to divergences in their spatial dispersal tendencies. In the PLS-PM, negative signs can be linked to many motives, as the variability caused by collinearity (Kock and Lynn 2012) or the presence of unlikely causal relation (Pearl 2009), denominated Simpson's paradox. The opposing signs of the weights are more likely to be related to a similar influence in different regions within the study area, and not necessarily associated to despair influences on mortality.

The PLS-PM coefficients of determination (R^2) obtained, were for the non-traumatic model of $R^2 = 0.863$ and a traumatic model of $R^2 = 0.83$. These results were significant since the Rho > 0.9 according to Cronbach's alpha and Dillon-Goldstein's. The relation between LV and MV results were satisfactory because their GoF and corresponding bootstrap values are moderate.

The species extinction rate has been accelerated by human activities. Some authors estimate that around 1000 to 100,000 species extinct every year. Yearly, worldwide, millions of wild animals die, mostly due to anthropogenic factors (Burton and Doblar 2004, Garcês *et al.* 2018a). Large species, rare species, and those which are habitat specialists, are particularly susceptible. Species extinction can disrupt vital ecological processes such as pollination or seed dispersal. This can lead to loss of ecosystem functionality, and finally to ecosystem collapse and species extinction (Sodhi *et al.* 2019).

Studies focusing on the establishment of spatial correlations between causes of death and anthropogenic pressures on endangered species, have not yet been

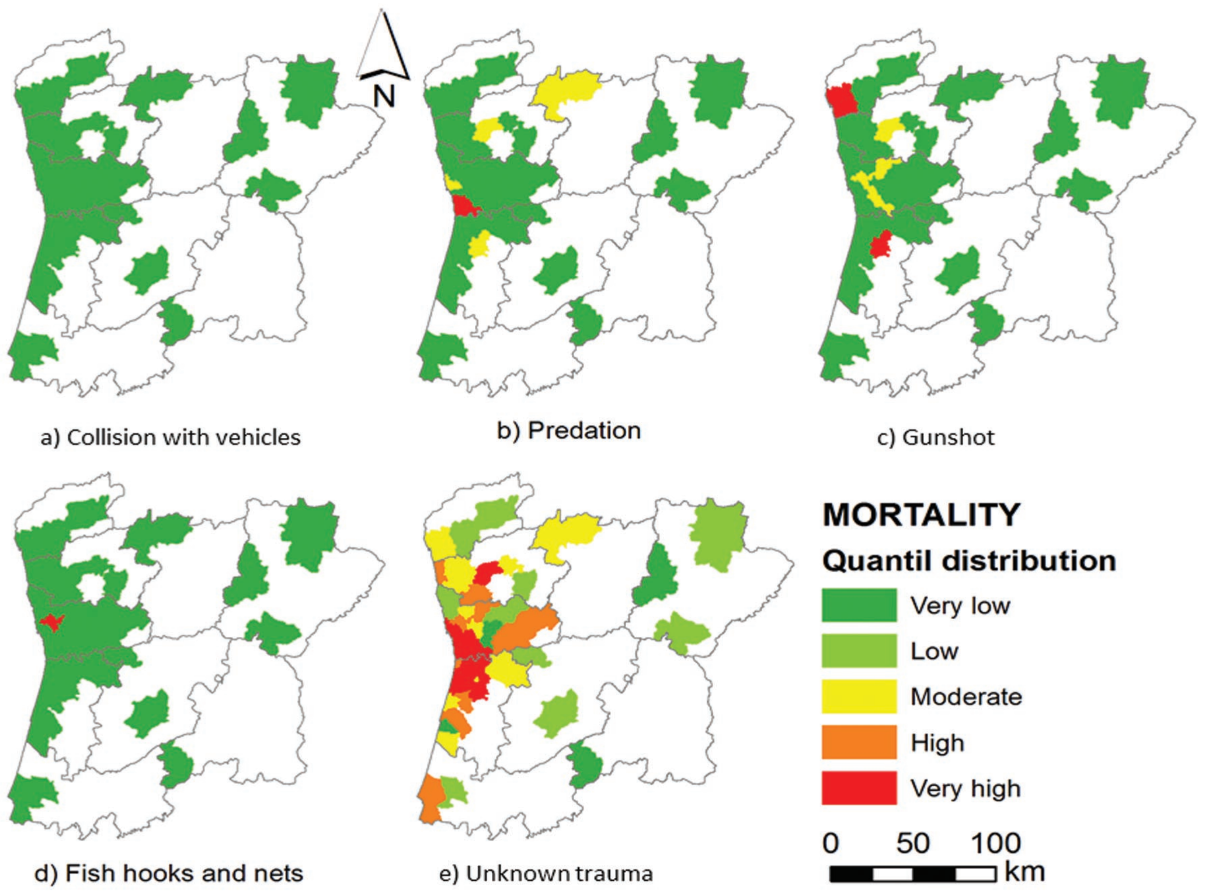

Fig. 2. Spatial distribution of traumatic mortality causes of the animals admitted in the Wildlife Rehabilitation Centre of Parque Biológico de Gaia across the different municipalities in Northern of Portugal (2008-2017).

carried out according to the authors' best knowledge. Mortality studies on endangered species such as the Bonelli's eagle (*Hieraaetus fasciatus*) in Spain (Real *et al.* 2001) or the Bald eagle (*Haliaeetus leucocephalus*) in the United States (Cole *et al.* 2009) are available, even though with a very small sample size.

The vast majority of the animals belonged to the Class Aves (n = 379). This can be explained by the fact that birds are the most representative group of terrestrial vertebrates. They are extremely adaptable to different environments and its ability to fly in open spaces makes them easier to find when injured (Cunningham *et al.* 2014). In the case of mammals, reptiles and amphibians, most species have nocturnal habits, occupy small territory areas, and tend to take refuge in burrows or shelters whenever in threatening situations. This behaviour makes injured individuals more difficult to find (Loureiro *et al.* 2008, Loureiro *et al.* 2012).

Regarding the conservation status, it is important to highlight 23 animals with CR status and 36 with EN. The main cause of death of these critically endangered animals was of traumatic origin, which is in compliance with the reported observations in the aforementioned papers.

Concerning the Class Reptilia, 3 *Emys orbicularis* specimens considered as EN were presented. All died from nutritional disorders. This condition is very common in animals that were kept in illegal captivity which was the case (Brown and Sleeman 2002, Garcês *et al.* 2018b).

A large percentage of animals in this study, presented an unidentified cause of death. This is due to the lack of clinical information in the admittance form. It is also possible that scarce human and financial resources might have played a role in some of the missing data.

The use of PLS-PM evidenced the existence of a high relation between endangered species mortality and anthropogenic pressures in the study area, as shown by the high coefficients of determination (R^2) obtained (close to 1).

Small and medium-sized companies seem to be the main anthropogenic pressure related to mortality in endangered animals in both models, traumatic and non-traumatic. This result is similar to what we have observed in a previous study performed in wild birds (Garcês *et*

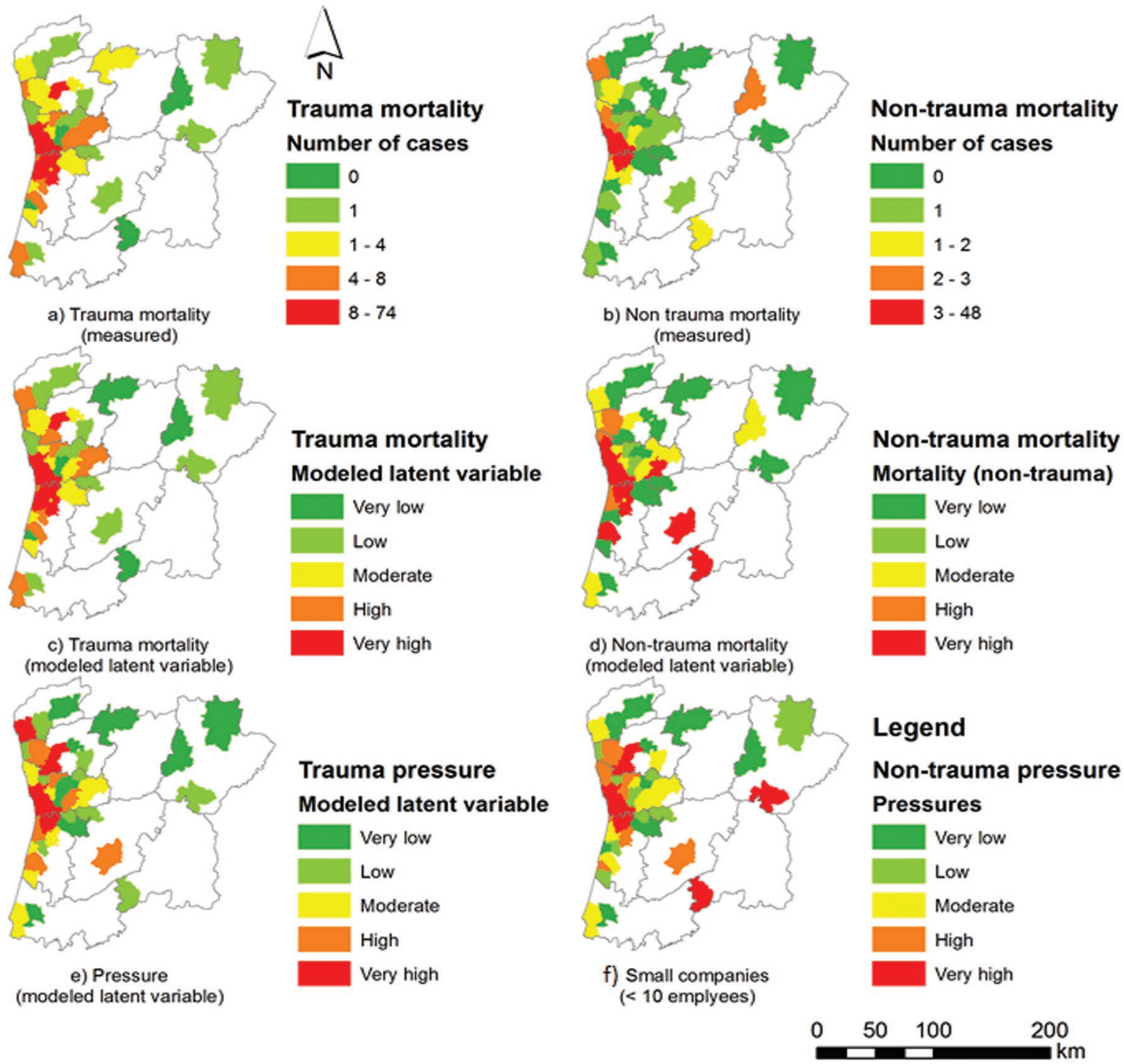

Fig. 3. Spatial distribution of modelled and measured total trauma and non-trauma mortality model in the endangered animals admitted to the Wildlife Rehabilitation Centre of Parque Biológico de Gaia from municipalities of northern Portugal (2008-2017).

al. 2019). There are some arguments that can support the greater impact of the small and medium companies on mortality if compared with other pressures. It is important to mention that 99.9% of the Portuguese enterprises (since 2004) are mainly small and medium companies. The majority of these industries are located in the coast and the country´s northern region (Portada 2018). The concentration of people in cities, the increase in traffic, and all the infrastructures built and respective design (large clear glass windows, chimneys, etc.) are concurrent to the occurrence of accidents specially with birds, which is the most representative group within the sample (Silva *et al.* 2014). Furthermore, the pollution generated from these industries can indirectly have an impact on these animals' mortality.

Habitat destruction and fragmentation are the staple threats that underline the importance of small and medium companies' impact on biodiversity loss. The destruction of habitat by the industries is not only associated with the destruction of large areas of construction of infrastructures or environmental pollution, but in large part is due to the construction of access roads for the movement of people, raw materials and products. Several authors established a link between these threats and the decline and extinction of some populations (Destro *et al.* 2018, Gibbons *et al.* 2018). The conversion of wild areas

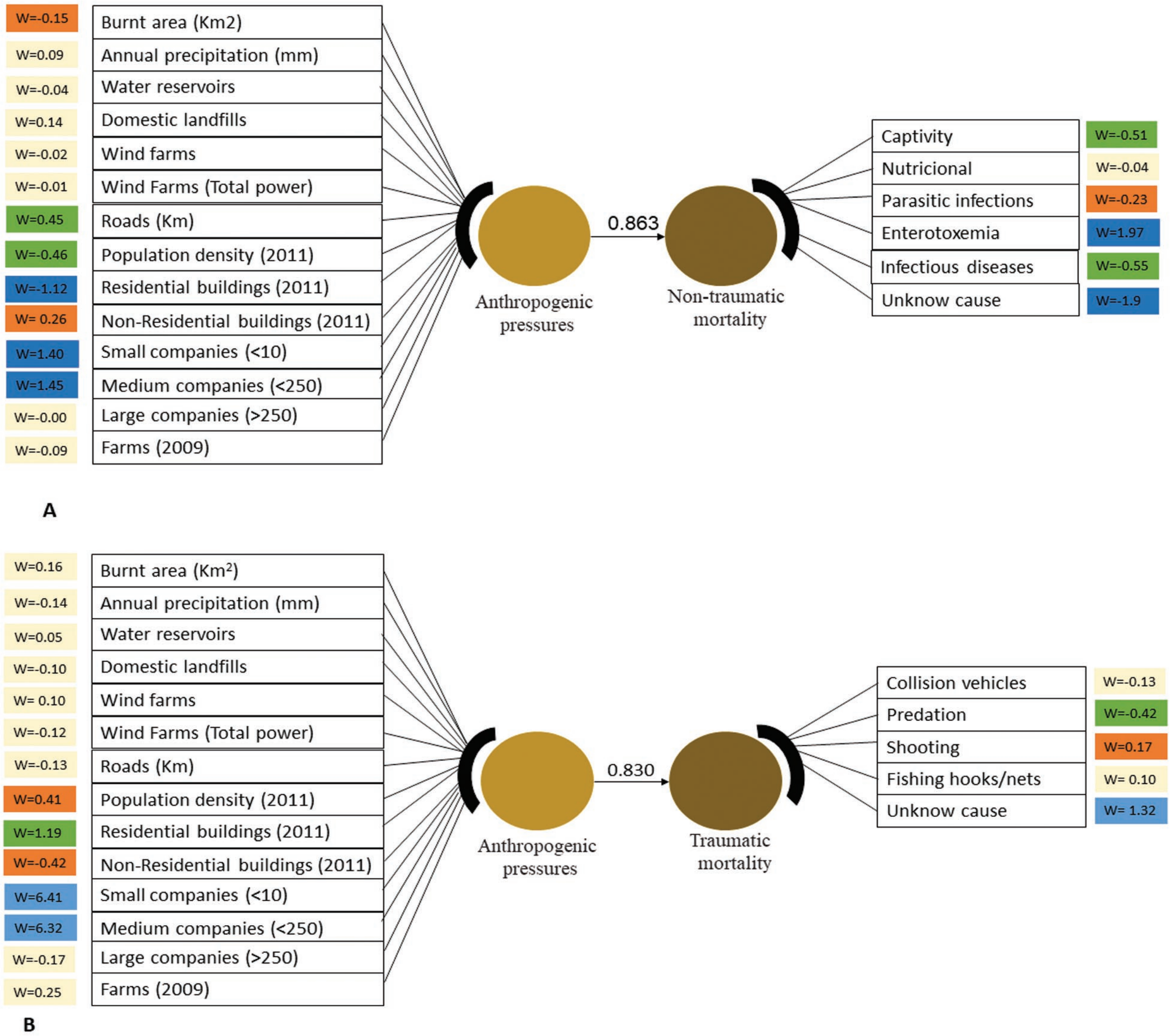

Fig. 4. Diagrams representing the PLS-PM reduced model for non-traumatic (panel A) and traumatic (panel B) mortality. The lighter circle represents the measurable variable anthropogenic pressures. The arrow represents the link between latent variables. Arrow labels are weights and path coefficients that quantify those links. Those portrayed in blue are the ones with a higher impact on mortality, followed by those in green and orange. The ones portrayed in yellow have some impact in the model even though residual.

into agriculture fields, industrial or urban areas can lead to an increase in the rate of vector-borne disease transmission. Land use changes can also amplify climate changes, reduce resources due to the disruption of pollination systems, may increase the barrier effect to the migration/hunting and reproduction sites, heightens the risk of environmental disasters (*e.g.*, oil spill or fires) and of competition with introduced species (Destro *et al.* 2018). Some species seem to be more susceptible to habitat fragmentation. These are characterised by a large body size, an intermediate mobility, specialized diet (high trophic level), and habitat pre-fragmentation smallest population, low reproductive output and limited geographical distribution (Ewers and Didham 2007, Dixo *et al.* 2009). These characteristics are more likely to be found in wild mammal, amphibian or reptile populations with a threatened conservation status. Furthermore, habitat fragmentation aggravates the risk of mortality, particularly in small populations with lower genetic diversity due to inbreeding, cumulative effect of mutations and lower evolutionary potential (Goossens *et al.* 2016).

CONCLUSION

The long-term data from Parque Biológico de Gaia allowed us to determine the main causes of mortality in endangered animals in its influence area. Trauma was the leading cause of death. Based on our results it is possible to conclude that human activity (directly or indirectly), has a strong impact on the mortality of endangered species. These results are in compliance with previous studies related to other endangered species where the predominant cause of death was associated anthropogenic threats (Palazón *et al.* 2012, Stenkat *et al.* 2013).

Small and medium-sized companies seem to be the main anthropogenic pressures associated with mortality. Despite the hazard provided by their structure design and pollution, habitat fragmentation and destruction are probably the most influencing factors concerning biodiversity loss. In the future, more comprehensive studies should be enhanced within other regions of the national territory comprising different populations in order to identify the main anthropogenic pressures in different study areas. With the integration of other knowledge areas such as population genetics, diseases, climate changes and pollutants, it might be possible to establish in the near future the efficient conservation measures. These will probably compel to the suppression of the major threats identified leading to the recovery of endangered populations and their natural habitat.

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