PESQUISA VETERINÁRIA BRASILEIRA
Brazilian Journal of Veterinary Research
ISSN 0100-736X (Print)
ISSN 1678-5150 (Online)

Pesq. Vet. Bras. 44:e07565, 2024
DOI: 10.1590/1678-5150-PVB-7565

Review Article
Wildlife Medicine

Causes of death in companion, livestock, and wild animals: A systematic review and Garbage Codes analysis[1]

Eduardo S.S. Sousa[2], Maria E.S. Sousa[3], Ricardo A.M. Negreiros[2*], Moisés D.C.A. Pereira[2], Arthur W.L. Brasil[4], Inácio J. Clementino[5], Lilian R.C. Eloy[5], Sérgio S. Azevedo[6] and Ricardo B. Lucena[5]

ABSTRACT.- Sousa E.S.S., Sousa M.E.S., Negreiros R.A.M., Pereira M.D.C.A., Brasil A.W.L., Clementino I.J., Eloy L.R.C., Azevedo S.S. & Lucena R.B. 2024. **Causes of death in companion, livestock, and wild animals: A systematic review and Garbage Codes analysis.** *Pesquisa Veterinária Brasileira 44:e07565, 2024.* Centro de Ciências Médicas, Universidade Federal da Paraíba, Campus I Lot. Cidade Universitaria s/n, Cx. Postal 5115, João Pessoa, PB 58051-900, Brazil. E-mail: ricardoandrenegreiros@gmail.com

Companion, livestock, and wild animals have various biological, behavioral, and ecological differences that may lead to distinct pathological conditions. Moreover, unlike human medicine, there is no standardized code for classifying diseases in animals, resulting in varied presentations of findings across studies. Standardizing these data can help clinicians identify diseases and facilitate communication among veterinarians. A systematic review of the literature was conducted across five databases to identify the main causes of animal death in the domains “companion”, “livestock”, and “wild” animals. The analysis included the 31 articles provided in the evidence summary section. Subsequently, the causes of death were classified according to the International Classification of Diseases, tenth revision (ICD-10) and analyzed according to the presence of Garbage Codes. There was considerable diversity in the causes of death and how they were assessed and reported in each domain. Each species and domain demonstrated a high proportional mortality of causes uncommon in other domains. The companion domain included seven articles, livestock had nine articles, and wild animals had fifteen articles with 66.85%, 71.43 %, and 20.06% Garbage Codes, respectively. The different causes of death and their descriptions indicate a low level of uniformization in the presentation of findings in veterinary medicine. The causes varied based on the domains and species investigated, highlighting real distinctions between these populations. The application of ICD-10 for standardizing the diagnosis of animal mortality proved useful in detecting highly prevalent Garbage Codes.

INDEX TERMS: Animal welfare, causes of mortality, Garbage Code, ICD-10, One Health.

RESUMO.- [**Causas de morte em animais de companhia, produção e selvagens: revisão sistemática e análise de Códigos *Garbage*.**] Animais de companhia, produção e selvagens tem várias diferenças biológicas, comportamentais e ecológicas que podem culminar em condições patológicas distintas. Além disso, não há códigos padronizados para a classificação de doenças em animais, como é o caso dos humanos, resultando em apresentações variadas dos achados entre estudos. A padronização desses dados pode auxiliar os clínicos a identificarem doenças e facilitar a comunicação entre médicos veterinários. Uma revisão sistemática da literatura foi conduzida entre cinco bases de dados acerca das principais causas de morte de acordo com os domínios de animais de “companhia”, “produção” e “selvagens”. A análise

[1]Received on August 18, 2024.
Accepted for publication on September 16, 2024.
[2] Centro de Ciências Médicas, Universidade Federal da Paraíba (UFPB), Campus I Lot. Cidade Universitária s/n, Cx. Postal 5115, João Pessoa, PB 58051-900, Brazil. *Corresponding author: ricardoandrenegreiros@gmail.com
[3] Faculdade de Enfermagem e Medicina Nova Esperança (FACENE/FAMENE), Av. Frei Galvão 12, João Pessoa, PB 58067-698, Brazil.
[4] Centro de Ciências da Saúde, Universidade Federal da Paraíba (UFPB), Campus I Lot. Cidade Universitária s/n, Cx. Postal 5115, João Pessoa, PB 58051-900, Brazil.
[5] Centro de Ciências Agrárias, Universidade Federal da Paraíba (UFPB), Campus I Lot. Cidade Universitária s/n, Cx. Postal 5115, João Pessoa, PB 58051-900, Brazil.
[6] Centro de Tecnologia e Saúde Rural, Universidade Federal de Campina Grande (UFCG), Rua Aprígio Veloso 882, Cx. Postal 10024, Campina Grande, PB 58429-900, Brazil.

incluiu 31 artigos dispostos no sumário de evidências. Em seguida, as causas de morte foram classificadas de acordo com a Classificação Internacional de Doenças, décima revisão (CID-10) e analisada quanto a presença de Códigos *Garbage*. Verificou-se uma diversidade considerável nas causas de morte e como foram acessadas e reportadas em cada domínio. Cada espécie e domínio demonstrou uma alta mortalidade proporcional de causas que são incomuns aos outros. O domínio de animais de companhia incluiu sete artigos, o de produção nove e animais selvagens quinze artigos com 66,85%, 71,43% e 20,06% de Códigos *Garbage*, respectivamente. As diferentes causas de morte e suas descrições indicam um baixo nível de padronização para a apresentação de achados na medicina veterinária. As causas variaram bastante de acordo com os domínios e espécies investigados, mostrando distinções reais entre essas populações. A aplicação da CID-10 para a padronização de diagnósticos de mortalidade animal provou-se útil em detectar a alta prevalência de Códigos *Garbage*.

TERMOS DE INDEXAÇÃO: Bem-estar do animal, causas de mortalidade, Códigos Garbage, CID-10, Saúde Única.

INTRODUCTION

The concept that human health is interconnected with animal and environmental health, known as One Health, has prompted several strategies and approaches to improve animals' life expectancy and health span (Douphrate 2021). Strategies based on One Health comprise collaborative activities capable of having an impact on health threats shared among humans, animals and the environment, such as zoonotic diseases (Sinclair 2019). Understanding the causes of animal death is crucial for developing such approaches. However, given the unique characteristics of each species and the absence of a standardized system to classify the causes of death, identifying the most important intervention points is challenging.

There are biological, behavioral, and ecological characteristics that differentiate companion, production, and wild animals, the latter being more challenging to have their causes of death precisely diagnosed due to delays in carcass collection and evaluation (Ryser-Degiorgis 2013). Even under human care, wild animals may present unique diseases that require etiological investigation and screening methods to ensure their preservation and survival (Peck et al. 2019, Krol et al. 2020).

Livestock farmers are adapting their production models by implementing interventions such as providing comfortable living environments to enhance production and improving husbandry practices to minimize stress and pain, which influences the quality of animal products (Duncan 2005, Douphrate 2021, Vigors et al. 2021). Livestock animals' deaths represent a financial loss and negatively affect the welfare of the other animals on the farm. However, the causes of death and accurate diagnoses in this group of animals remain unclear, lack documentation, and are frequently only investigated when productivity is compromised. Understanding their pathological conditions can help improve management and production efficiency (Christensen & Svensmark 1997, Thomsen et al. 2004, McConnel et al. 2019).

Companion animals also possess unique characteristics that can predispose or lead to death (Pegram et al. 2021). Age, breed, and environment are key epidemiological factors for companion animals that may be accounted for when investigating their causes of death (Nascimento et al. 2022). Zoonotic diseases are of great importance when assessing the causes of death in companion animals, given the potential that some infectious diseases have to be transmitted from animals to humans, especially when they co-exist in the same environment. This reinforces the necessity of reliable reporting mechanisms, robust data collection and surveillance (Cross et al. 2019, Kimani et al. 2019).

The *post mortem* examination acts as a versatile tool to help analyze the causes of death and verify the influence of epidemiological factors on dead animals, thus enabling the monitoring of possible causes of illness (Küker et al. 2018, Pereira et al. 2020). However, *post mortem* procedures, record-keeping practices, and terminology are not standardized and vary greatly among different institutions (Strong et al. 2017, Heaver & Waters 2019).

When evaluating the health of human beings, the standardization of medical and clinical conditions is achieved through the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10) World Health Organization (WHO 2004) and recorded on human death certificates. However, despite providing rules and classifying health conditions, some codes are considered "Garbage Codes", which are non-specific and inaccurate causes of death that have low informational value and do not help in the development of health intervention strategies (Naghavi et al. 2010, Eng et al. 2024). Erroneous classification caused by the use of Garbage Codes can affect the statistical accuracy of the health system, leading to the underestimation of certain medical issues (França et al. 2022). Causes of death recorded as Garbage Codes constitute approximately 25% of all causes of human deaths in Korea (Lee et al. 2016), 29% in Norway (Ellingsen et al. 2022) and 30% in Brazil (Lima et al. 2019), representative ratios that should not be ignored. When detailing the reported causes of death in animals, in addition to the lack of an international reporting method, the diversity of domains, species and means of investigation can influence the presence of Garbage Codes, making it difficult to classify the deaths correctly.

Therefore, we conducted a systematic review to identify the main causes of animal death across wild, livestock, and companion animal domains and to compare the *post mortem* examination findings among various species. We also analyzed intraspecific factors to determine if they affected the onset of health problems. The causes of death were classified using the ICD-10 and evaluated for Garbage Codes. The aim of this study was to quantify and classify the causes of animal deaths and assess the utility of this classification to improve the dialogue between veterinarians and researchers.

MATERIALS AND METHODS

Ethical approval. Since all the data were obtained from database literature searches, this study did not perform any animal experiments. The submission to the Ethics Committee on Animal Use (CEUA) was unnecessary.

Search strategy. A systematic literature review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al. 2021). The study included the PubMed/MEDLINE, EMBASE, LILACS, SciELO, and BVS Salud databases and retrieved articles in any language without time restrictions published until August 26, 2023. The following search terms and Boolean operators were applied: (death diagnosis) AND (epidemiology) AND (determination of death) AND (animal) AND (veterinary) NOT (marine animals).

zzData extraction. Two independent researchers (M.S. and R.N.) collected and stored the data in electronic files. Discrepancies arising from the extracted information were resolved by a third researcher (E.S.). After a thorough review of the full text and application of the inclusion and exclusion criteria, the following information was extracted from the included articles: author(s), date of publication, country, type of study, entity where the study was conducted, species investigated, sample size, animal housing environment, *post mortem* examination methods, and main causes of death.

ICD-10 and Garbage Code analysis. The primary causes of death verified in this study were mapped using the closest corresponding codes according to the ICD-10 by two independent researchers (E.S. and R.L.). In cases of disagreement between the codes, a third researcher (S.A.) provided their classifications. The four main codes obtained in each domain were arranged as a percentage relative to the total deaths, while the remaining codes comprised the "others" variable. The Garbage Codes verified in each study were inserted into the tables. Garbage Codes were considered as the nonspecific causes of death that can be redistributed into smaller groups, intermediate causes of death, immediate causes of death that are the final consequences of diseases, and codes that are not the primary causes of death (Naghavi et al. 2010).

RESULTS

Systematic review and summary of evidence. After selection, 31 articles were included in the qualitative analysis and systematic review, including 68,114 animals whose causes of death were investigated. Details of the complete study selection process are provided in the PRISMA flowchart (Fig.1).

Companion animals. Table 1 summarizes the characteristics and key findings data from the companion animal articles, four of which included dogs (*Canis lupus familiaris*) and data obtained from surveys of owners (Proschowsky et al. 2003, Mandigers et al. 2006, Adams et al. 2010, Inoue & Sugiura 2021), which contributed to memory and classification biases. Adams (2010) was the only author who used questionnaires to ascertain the number of dogs that underwent *post mortem* examinations, which represents a small sample size, emphasizing the subjectivity of verifying causes of death in these studies. The only study that performed necropsies to determine the causes of death in dogs categorized them by systemic groups, and by doing so, it did not specify causes, failing to describe the disease itself that caused the death (Dias-Pereira 2022).

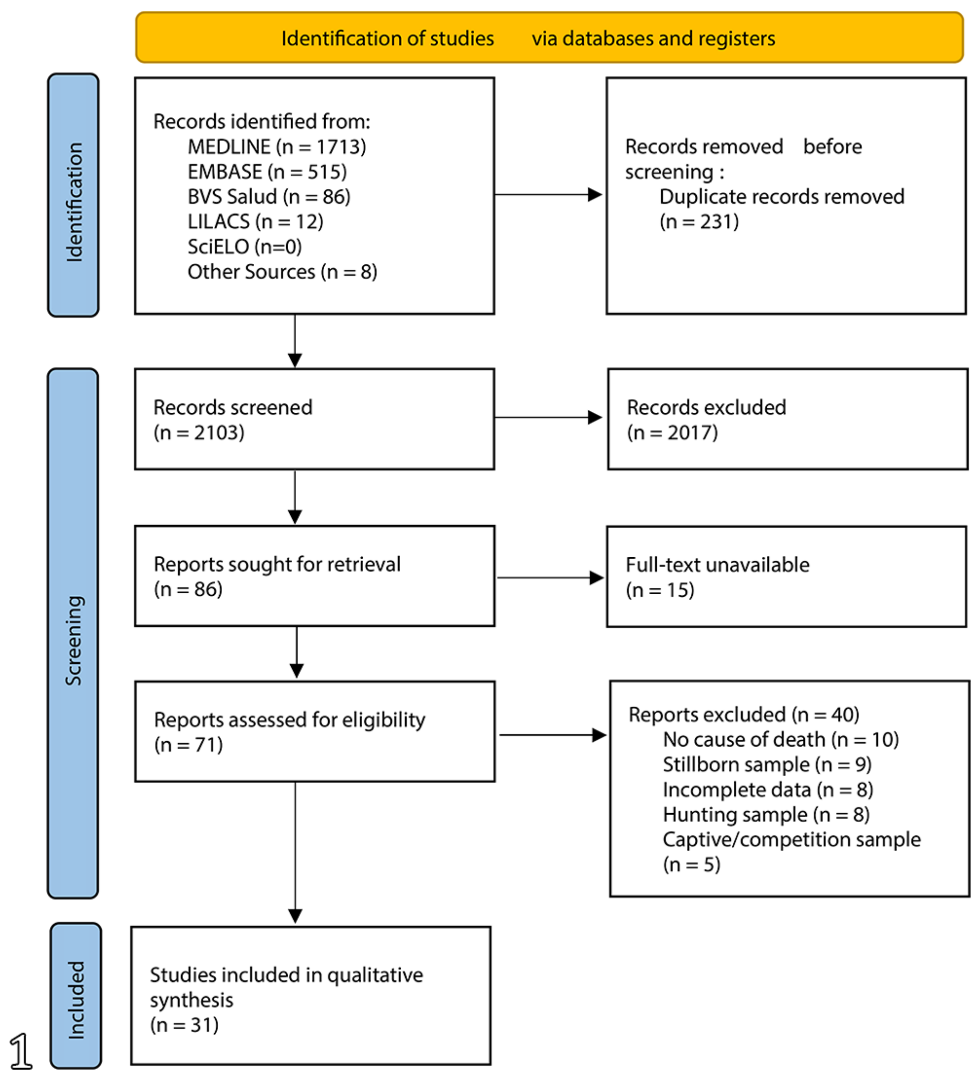

Fig.1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart for study selection and inclusion.

All the studies involving dogs have shown a high prevalence of neoplasia/cancer as a cause of death. Other causes of death in some of them, such as behavior (Mandigers et al. 2006) and car accidents (Bonnett et al. 2005), were not variables measured, or their frequencies were not similar in all studies. Furthermore, Proschowsky (2003) demonstrated that breed has a distinctive role in factors related to dog deaths (Proschowsky et al. 2003).

The only selected study investigating causes of death in cats (*Felis catus*) used an animal health surveillance system to extract clinical information from the study participants (O'Neill et al. 2015). The studies regarding dogs showed that the more prevalent cause of death was neoplasia; however, the cat study stated that there is a higher frequency of deaths due to trauma and renal disease, which were rarely observed in the mentioned studies on dogs.

Livestock animals. Table 2 compiles the article characteristics and key findings regarding livestock animals, including six studies on *Bos* sp. (Mulei et al. 1995, Svensson et al. 2006, McConnel et al. 2009, Waldner et al. 2009, Fusi et al. 2017, Molossi et al. 2021), one on *Sus domesticus* (Engblom et al. 2008) and two studies on bird species (Brochu et al. 2019, Cadmus et al. 2019). Data collection varied among studies, using university records (Mulei et al. 1995, Molossi et al. 2021), monitoring program databases (Engblom et al. 2008), necropsies performed by researchers (Svensson et al. 2006, Waldner et al. 2009, Brochu et al. 2019, McConnel et al. 2019), and partner veterinarians' records (Fusi et al. 2017, Cadmus et al. 2019).

Engblom et al. (2008) reported that *Sus scrofa domesticus* had a high frequency of arthritis and osteochondrosis, which was not reported in the species by other authors.

Cadmus et al. (2019) and Brochu et al. (2019) conducted studies on several species kept in small poultry farms and divided the causes of death into infectious and noninfectious. The discrepancy between the causes of death in the two studies can be attributed to the sample size, differences in standardization and data collection methods. However, the proportions of infectious and noninfectious causes of death were similar.

Research on the causes of death in calves (*Bos taurus*) found that the most frequent causes were related to respiratory illnesses, especially pneumonia. Other causes, such as feeding, trauma, and tick-borne diseases, were also reported (Mulei et al. 1995, Svensson et al. 2006). The authors approached categorization differently.

As for dairy cows, Fusi et al. (2017) and McConnel et al. (2009) reported the causes of death in contrasting stances, although the studies share some similarities. Both evaluated diseases related to the consequences of conception, specifically metritis (McConnel et al. 2009) and calving problems (Fusi et al. 2017). The two studies used different data collection methods.

As to the causes of death in beef cattle (Waldner et al. 2009, Molossi et al. 2021), there was a high diversity among the groups with interesting findings, such as intoxication by poisonous plants.

Wildlife. Table 3 outlines the data containing the articles' characteristics and key findings on wildlife animals. LaRose

Table 1. Summary of evidence with relevant data found in companion animals articles systematic review

Author (year)	Country	Study type	Study setting	Species	Sample size	Methods of evaluation	Main causes of death	Garbage Codes
Proschowsky et al. (2003)	Denmark	Cross-sectional	Danish Kennel Club	Diverse breeds of dogs (*Canis lupus familiaris*)	2928	Questionnaire	Old age (n=609) Cancer (n=425) Combinations (n=380) Behavior problems (n=188)	R54 C80 R68.8 F91
Bonnet et al. (2005)	Sweden	Cohort	-	Diverse breeds of dogs (*Canis lupus familiaris*)	31057	Insurance company registry	Car accident (n=2342) Idiopathic epilepsy (n=968) Hip dysplasia (n=844) Signs of heart failure (n=723)	Y33 I50.9
Mandigers et al. (2006)	Netherlands	Cross-sectional	-	Dobermann (*Canis lupus familiaris*)	81	Questionnaire	Behavior (n=16) Heart failure (n=12) Tumors (n=11) Accident (n=7)	F91 I50 C80 X59.9
Adams et al. (2010)	United Kingdom	Cross-sectional	-	Diverse breeds of dogs (*Canis lupus familiaris*)	15881	Questionnaire	Cancer (n=4282) Old age (n=2829) Cardiac (n=1770) Urologic (n=783)	C80 R54 I50.9
Inoue & Sugiura (2021)	Japan	Cohort	-	Diverse breeds of dogs (*Canis lupus familiaris*)	5115	Questionnaire	Senility (n=1322) Neoplasia (n=1117) Unknown (n=893) Cardiovascular (n=495)	R54 C80 X59 I50.9
Dias-Pereira (2022)	Portugal	Cohort	University of Porto	Diverse breeds of dogs (*Canis lupus familiaris*)	259	Necropsy Histopathology	Neoplasia (n=120) Old age (n=47) Cardiovascular failure (n=44) Inflammation (n=38)	C80 R54 I50.9 A41
O'Neill et al. (2015)	England	Cross-sectional	-	Cat (*Felis catus*)	3309	Epidemiological analysis of electronic patient records	Trauma (n=405) Renal disorder (n=399) Neoplasia (n=356) Mass lesion disorder (n=336)	C80

et al. (2010) and Simpson et al. (2013) conducted studies on red squirrels (*Sciurus vulgaris*) at locations with similar environmental conditions, providing greater homogeneity between the samples. Both studies identified road traffic accidents (RTA) as the most common cause of death. Death due to trauma (LaRose et al. 2010) and predation (Simpson et al. 2013) have also been observed. The presence of species-specific diseases, such as the squirrel pox virus (LaRose et al. 2010), at certain periods, has a great impact on the causes of death of wild animals.

Table 2. Summary of evidence with relevant data found in livestock animals articles systematic review

Author (year)	Country	Study type	Study setting	Species	Sample size	Methods of evaluation	Main causes of death	Garbage Codes
Mulei et al. (1995)	Kenya	Cross-sectional	Faculty of Veterinary Medicine, Kabete	Dairy calf (*Bos taurus*)	345	Necropsy Histopathology Microbiology Parasitology	Alimentary tract diseases (n=108) Respiratory tract diseases (n=58) Tick-borne diseases (n=46) Musculoskeletal system (n=24)	R29
Svensson et al. (2006)	Sweden	Longitudinal	Latnmännen Analycen AB	Dairy calf (*Bos taurus*)	421	Necropsy Histopathology Microbiology	Pneumonia (n=64) Trauma (n=42) Enteritis (n=39) Malformations (n=11)	
Waldner et al. (2009)	Canada	Longitudinal	-	Dairy calf (*Bos taurus*)	184	Necropsy Histopathology	Traumatic reticuloperitonitis (n=15) Malignant neoplasia (n=13) Calving-associated injury (n=12) Rumen tympany (n=11)	C80
McConnel et al. (2009)	United States	Longitudinal	Veterinary Diagnostic Laboratory, Colorado State University	Dairy calf (*Bos taurus*)	94	Necropsy Histopathology	Severe limb injury (n=7) Gastrointestinal ulceration (n=6) Metritis (n=6) Spinal injury (n=6)	
Fusi et al. (2017)	Italy	Longitudinal	-	Dairy calf (*Bos taurus*)	251	Questionnaire	Metabolic/digestive disorders (n=56) Mastitis/udder problems (n=43) Calving problems (n=35) Lameness/locomotor disorders (n=31)	F82
Molossi et al. (2021)	Brazil	Cross-sectional	Department of Veterinary Pathology, Federal University of Rio Grande do Sul	Dairy calf (*Bos taurus taurus*) (*Bos taurus indicus*)	1277	Necropsy Microbiology Histopathology Immunohistochemical Parasitology	Inconclusive(n=272) Hemoprotozoal infection (n=183) Senecio sp. intoxication (n=86) Rabies (n=83)	R99
Engblom et al. (2008)	Sweden	Longitudinal	National Veterinary Institute	Sow (*Sus domesticus*)	96	Necropsy Histopathology Microbiology	Arthritis (n=35) Osteochondrosis (n=13) Fracture (n=10) Abscess in spinal cord (n=7)	
Cadmus et al. (2019)	United States	Cross-sectional	-	Chicken (*Gallus gallus domesticus*) Turkey (*Meleagris gallopavo*) Duck (Anatidae) Geese (Anser)	2687	Multiple veterinary records	Neoplastic/lymphoproliferative (n=1131) Infectious (n=970) Noninfectious (n=463) Undetermined (n=123)	C80 A41.9 R99
Brochu et al. (2019)	Canada	Cross-sectional	Animal Health Laboratory	Chicken (*Gallus gallus domesticus*) Turkey (*Meleagris gallopavo*) Duck (Anatidae) Quail (*Coturnis coturnis*) Peafowl (*Pavo cristatus*) Pheasant (*Phasianus colchicus*)	245	Necropsy Histopathology Microbiology Parasitology Immunohistochemistry	Mixed respiratory infection (n=52) Bacterial (n=42) Viral (n=30) Metabolic or nutritional (n=28)	A41.9

Table 3. Summary of evidence with relevant data found in wildlife animals articles systematic review

Author (year)	Country	Study type	Study setting	Species	Sample size	Methods of evaluation	Main causes of death	Garbage Codes
Gallagher & Nelson (1979)	England	Cross-sectional	Gloucester Veterinary Investigation Centre	European badger (*Meles meles*)	530	Autopsy Mycobacterial isolations Bacteriology Histopathology	RTA (n=460) Tuberculosis (n=26) Bite wounds (n=11) Starvation (n=10)	
Akdesir et al. (2018)	Switzerland	Cross-sectional	University of Bern	Stone marten (*Martes foina*) Badger (*Meles meles*) Polecat (*Mustela putorius*) Pine marte (*Martes martes*) Stoat (*Mustela erminea*) Weasel (*Mustela nivalis*) Otter (*Lutra lutra*)	566	University of Bern records	Trauma (n=102) Undetermined (n=98) Distemper virus (n=60) Streptococcus sp (n=32)	R99
Sileo et al. (1990)	United States	Cross-sectional	Sand Island of Midway Atoll	Laysan albatross (*Diomedea immutabilis*)	137	Dissection Necropsy Ancillary examination	Dehydration (n=46) Suspect dehydration (n=24) Lead poisoning (n=15) Trauma (n=15)	
Work & Hale (1996)	United States	Cross-sectional	Natural Wildlife Health Center, Honolulu Field Station	Barn owls (*Tyto alba*) Hawaiian owls (*Asio flammeus sandwichensis*)	81	Necropsy Histopathology Microbiology	Trauma (n=40) Infectious disease (n=22) Emaciation (n=17) Undetermined (n=7)	B99 R99
Pennycott et al. (1998)	Scotland	Cross-sectional	Highland Region Strathclyde Region Grampian Region	Chaffinch (*Fringilla coelebs*) Greenfinch (*Carduelis chloris*) Bullfinch (*Pyrrhula pyrrhula*) Bramblefinch (*Fringilla montifringilla*) Siskin (*Carduelis spinus*) Goldfinch (*Carduelis carduelis*) Lesser redpoll (*Acanthis flammea*)	116	Necropsy Microbiology Parasitology Histopathology	Salmonellosis (n=50) O86 colibacillosis (n=45) Trauma (n=7) Other or no diagnosis (n=14)	R99
Fanke et al. (2011)	Germany	Cross-sectional	Leibniz Institute for Zoo and Wildlife Research	Eurasian cranes (*Grus grus*)	167	Necropsy Histopathology Microbiology Parasitology	Trauma (n=105) Zinc phosphide intoxication (n=28) Infection (n=17) Parasitosis (n=7)	B99
Baker & Britt (1990)	Scotland	Cross-sectional	North Ronaldsay Island	Lamb (*Ovis aries*)	35	Necropsy Fleece ectoparasitological	Trauma (n=11) Hypothermia (n=8) Starvation (n=5) Gastroenteritis/enteritis (n=4)	
Britt & Baker (1990)	Scotland	Longitudinal	North Ronaldsay Island	Sheep (*Ovis aries*)	71	Necropsy Histopathology Parasitology	Dental disease/starvation (n=25) Starvation/malnutrition (n=17) Parasitic gastroenteritis (n=9) Pneumonia (n=7)	
Aguirre et al. (1999)	Sweden	Cross-sectional	National Veterinary Institute	Roe deer (*Capreolus capreolus*)	985	Necropsy Histopathology Microbiology Parasitology Toxicology	Trauma (n=189) Starvation (n=173) Gastroenteritis (n=144) Systemic disease (n=114)	R99

Author (year)	Country	Study type	Study setting	Species	Sample size	Methods of evaluation	Main causes of death	Garbage Codes
Nettles et al. (2002)	United States	Cross-sectional	National Key Deer Refuge	Key deer (*Odocoileus virginianus clavium*)	170	Necropsy Microbiology Parasitology	RTA (n=127) Chronic purulent infections (n=33) Haemonchosis (n=5) Enteric infections (n=2)	B99
Buergelt et al. (2002)	United States	Cross-sectional	University of Florida	Florida panther (*Felis concolor coryi*)	55	Necropsy Radiography Toxicology Parasitology Histopathology	RTA (n=24) Aggression (n=9) Respiratory (n=7) Cardiac (n=6)	J98.9 I50.9
Williams et al. (2008)	Tanzania	Cross-sectional	Gombe National Park	Chimpanzee (*Pan troglodytes*)	130	Gombe National Park records	Illness (n=50) Unknown (n=38) Intraspecific aggression (n=17) Orphaning (n=6)	B99 R99
LaRose et al. (2010)	Scotland	Cross-sectional	University of Edinburgh	Red squirrel (*Sciurus vulgaris*)	245	Necropsy Histopathology Microbiology	RTA (n=105) Squirrelpox virus infection (n=35) Trauma (n=27) Starvation (n=24)	
Simpson et al. (2013)	Great Britain	Cross-sectional	-	Red squirrel (*Sciurus vulgaris*)	163	Necropsy Microbiology Parasitology	RTA (n=68) Predation (n=15) Toxoplasmosis (n=12) Exudative dermatitis (n=5)	
Mühldorfer et al. (2011)	Germany	Cross-sectional	Leibniz Institute for Zoo and Wildlife Research	Bats of European verpertilionid species (Vespertilionidae)	433	Necropsy Histopathology Microbiology Parasitology	Disease of unknown etiology (n=81) Unknown trauma cause (n=71) Cat predation (n=66) Bacterial infection (n=54)	B99

Intraspecific aggression has been observed in studies involving Florida panthers (*Felis concolor coryi*) (Buergelt et al. 2002) and chimpanzees (*Pan troglodytes*) (Williams et al. 2008). However, in the latter, in addition to those related to territorial dominance, adult chimpanzees were also observed killing baby chimpanzees and abandoning them.

Trauma, including predation and deer-vehicle collisions (DVC), is the most prevalent cause of death in roe deer (*Capreolus capreolus*) (Aguirre et al. 1999). Another study with Key deer (*Odocoileus virginianus clavium*) also depicted RTA as the main cause of death; however, this category was separated from other traumatic causes (Nettles et al. 2002). Other findings diverged among these studies.

Evaluating two studies on wild sheep (*Ovis aries*) in the same ecosystem, one focusing on lambs (Baker & Britt 1990) and the other on adult sheep (Britt & Baker 1990), many causes of death differed. However, both studies identified starvation and gastroenteritis as the most prevalent causes of death.

Two studies investigated the cause of death in mustelids (Gallagher & Nelson 1979, Akdesir et al. 2018). Both studies highlighted the prevalence of trauma as the main cause of death in the Mustelidae family despite the different terminological terms used in each study, including any traumatic events or, specifically, RTA and bites.

A study on European vespertilionid species (Vespertilionidae) of bats listed unspecified causes of death, mainly disease or trauma of unknown etiology (Mühldorfer et al. 2011).

Four studies investigated the causes of death in wild birds (Sileo et al. 1990, Work & Hale 1996, Pennycott et al. 1998, Fanke et al. 2011). Trauma was a highly prevalent etiology in studies on adult birds. While other causes, such as poisoning or intoxication, were rarely reported in studies with other wild animals, they occupied an important place in the causes of death in the birds. The authors also presented a wide variety of descriptions regarding nutritional causes of death, such as dehydration and emaciation.

Summing up, researches involving wild animals present traumatic etiologies as the main cause of death, subdividing them into road traffic accidents (RTA), predation, and intraspecific aggression.

Garbage Code diagnoses. The prevalence of the main causes of animal death according to the ICD-10, grouped by domain, is shown in Figure 2.

According to the definitions and list of Garbage codes, among the main causes of death identified in this study, only A09 (other gastroenteritis and colitis of infectious and unspecified origin), T07 (unspecified multiple injuries) and T73.0 (effects of hunger) were not considered. Diagnoses grouped as “other” excluded, the proportion of diagnoses considered as Garbage Codes was 66.85% in the companion animals’ group, 71.43% in the livestock animals’ group, and 20.06% in the wildlife animals’ group.

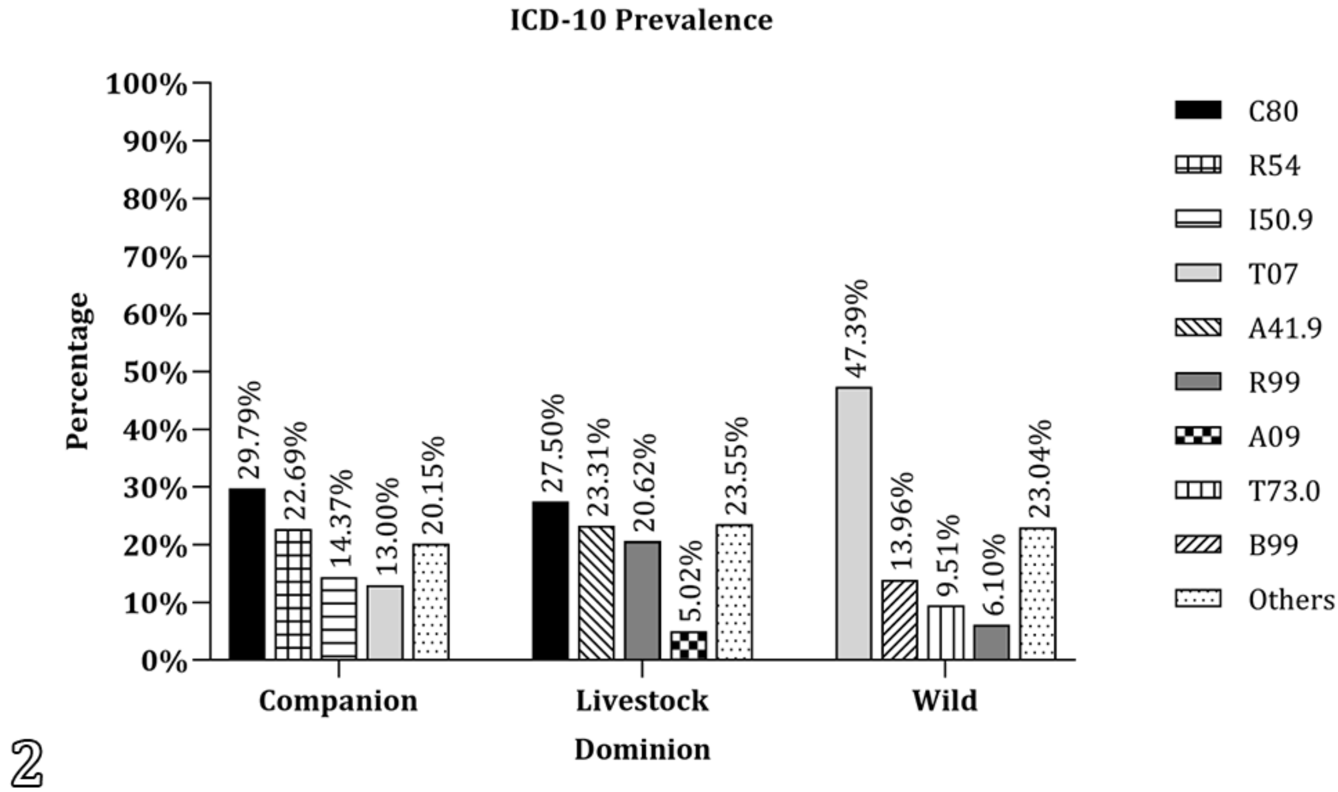

Fig.2. Main causes of animal death according to the International Classification of Diseases, tenth revision (ICD-10) grouping by domain. C80 = Malignant neoplasm, without specification of site; R54 = Senility; I50.9 = Hearth failure, unspecified; T07 = Unspecified multiple injuries; A41.9 = Sepsis, unspecified; R99 = Other ill-defined and unspecified causes of mortality; A09 = Other gastroenteritis and colitis of infectious and unspecified origin; T73.0 = Effects of hunger; B99 = Other and unspecified infectious diseases.

DISCUSSION

There was considerable heterogeneity in the causes of death and the means used to assess and report the data. The diversity of specimens from different habitats allowed us to establish the events that led to their death. Although the causes of death were described differently, they can be grouped and standardized for better monitoring and inspection by entities interested in promoting the health and standard of living of domestic animals, increasing the quality of farm animal products, and contributing to the conservation of wildlife species in nature. Notably, it is important to highlight the high prevalence of diagnoses categorized as garbage codes, especially in the livestock and companion animal domains.

The cause of advanced age or senility, highlighted in this review and classified as Garbage Codes, highlights the subjectivity associated with interpreting the cause of death of dogs, as an investigation into the cause of death may have been inadequate. Although age groups are risk factors for specific diseases, for example, the pathological distress of newborn kittens is quite distinct from those of post-weaning kittens (Cave et al. 2002), and therefore, using age as a risk factor for the underlying cause of death is not ideal. Furthermore, in studies that analyzed companion animals, *post mortem* examinations were absent.

In studies involving human data, upon revisiting the underlying causes of death and investigating the causes of death attributed to Garbage Codes, a significant shift in the underlying cause of death was noticed, accompanied by a substantial decrease in the percentage of Garbage Codes (Benedetti et al. 2019). The redistribution of Garbage Codes can substantially alter the demographic characteristics within a population and provide a more accurate reference for the development of health policies (Ng et al. 2020). In this context, actions taken for animal care would be better directed following a re-evaluation of the diagnostic concepts used in evaluating causes of death. The results can be further improved by applying specific codes for the classification of fatal conditions, which will significantly reduce the frequency of Garbage Codes (Park & Kim 2022).

In addition to the consequences of the lack of standardization in coding, the methods used to conduct studies can also affect the reported causes of death. On account of the nature of data collection via questionnaires, the results of the studies on dogs were susceptible to their owners' memory bias, as they may or may not have contacted their veterinarians for help.

We believe that the disparity in Garbage Codes diagnoses among the studied domains is primarily due to the fact that nearly half of the causes of death in wild animals fall under the category of 'trauma', a variable that may be associated with accidental human intervention, such as RTA.

There are two limitations associated with the study. Firstly, there is a limited theoretical framework available, and multiple forms of categorization and descriptions of the causes of animal death exist. Despite the different demands for the diagnosis of each group addressed in the present study, we recommend creating a standardized system that allows researchers to efficiently compare causes of death. This has already been proven useful in whale hunting, enabling better logistics and control (Knudsen 2005). Secondly, data collection on wild animals depends on the probability of finding a deceased animal, which can result in overestimated or underestimated causes of death. Additionally, causes such as RTA may be influenced by underlying conditions that lead wild animals onto roads, such as rabies, which neurologically alters the behavioral patterns of certain species (Gomes et al. 2012).

Creating systems that integrate and enable mapping the causes of animal deaths can benefit future research and facilitate strategies for conservation, optimize production, and enhance the care of domestic animals. In Brazil, a software application called "Sistema Urubu" collects and manages input data on vehicle collisions involving wildlife (Castro & Bager 2019). In the United States, an instrument was developed to gather information reported by owners of companion dogs regarding the death of their animals, which has been noted as a valuable tool for data collection, guiding the actions of veterinarians (McNulty et al. 2023). However, there are currently no complete tools available in the veterinary practice that incorporate a complex classification system, such as the ICD-10, and allow data standardization of causes of death.

We propose the development of an application that integrates ICD-10 into the diagnosis of animals' causes of death in order to enhance the development of approaches to animal health. As the Garbage Codes concept is mostly used in human medicine, adaptations to veterinary medicine are necessary, which can be challenging, especially considering the particularities of each species and requires the evaluation of more variables, such as the living environment. Likewise, we recommend adapting ICD-10 to veterinary medicine or creating its own classification code. Such decision-making requires investment in professional veterinary training to ensure accurate and consistent causes of death characterizations, allowing for higher quality data collection and more robust analyses.

CONCLUSIONS

This study details the various causes of death of companion, production, and wild animals. We identified a wide variety of causes and authors' descriptions based on the most distinct species and domains studied. This highlights the lack of standardization of data collection methods and of presentation of the results.

We recommend the ICD-10, despite its limitations, as a possible classification method for causes of death in animals, enabling standardization and, consequently, the detection of Garbage Codes, which are highly prevalent in the domains of companion animals and livestock. Therefore, a system that allows adequate mapping and analysis of these data is required in order to take animal health actions more effectively.

Authors' contributions.- Eduardo S.S. Sousa: review and editing, writing – original draft, visualization, validation, supervision, project administration, methodology, investigation, formal analysis, data curation. Maria E.S. Sousa: review and editing, writing – original draft, visualization, validation. Ricardo A.M. Negreiros: writing – review and editing, writing – original draft, investigation, software, formal analysis, data curation. Moisés D.C.A. Pereira: writing – review and editing, writing – original draft. Arthur W.L. Brasil: visualization, validation, supervision. Inácio J. Clementino: review and editing, supervision, methodology. Lilian R.C. Eloy: writing – review, translation and editing. Sérgio S. Azevedo: visualization, validation, supervision. Ricardo B. Lucena: conceptualization, visualization, validation, supervision, project administration, methodology, investigation, data curation.

Conflict of interest statement.- The authors declare that there are no conflicts of interest.

REFERENCES

Adams V.J., Evans K.M., Sampson J.L. & Wood J.L.N. 2010. Methods and mortality results of a health survey of purebred dogs in the UK. J. Small Anim. Pract. 51(10):512-524. <https://dx.doi.org/10.1111/j.1748-5827.2010.00974.x> <PMid:21029096>

Aguirre A.A., Bröjer C. & Mörner T. 1999. Descriptive epidemiology of roe deer mortality in Sweden. J. Wildl. Dis. 35(4):753-762. <https://dx.doi.org/10.7589/0090-3558-35.4.753> <PMid:10574535>

Akdesir E., Origgi F.C., Wimmershoff J., Frey J., Frey C.F. & Ryser-Degiorgis M.-P. 2018. Causes of mortality and morbidity in free-ranging mustelids in Switzerland: Necropsy data from over 50 years of general health surveillance. BMC Vet. Res. 14(1):195. <https://dx.doi.org/10.1186/s12917-018-1494-0> <PMid:29921290>

Baker J.R. & Britt D.P. 1990. Causes of death in the native sheep of North Ronaldsay, Orkney. II. Lambs. Br. Vet. J. 146(2):143-146. <https://dx.doi.org/10.1016/0007-1935(90)90006-O> <PMid:2331591>

Benedetti M.S.G., Saraty S.B., Martins A.G., de Miranda M.J. & Abreu D.M.X. 2019. Evaluation study of the garbage codes research project in the northern region of Brazil. Revta Bras. Epidemiol. 22(Supl.3): e190006.supl.3. <https://dx.doi.org/10.1590/1980-549720190006.supl.3> <PMid:31800858>

Bonnett B.N., Egenvall A., Hedhammar Å. & Olson P. 2005. Mortality in over 350,000 insured Swedish dogs from 1995-2000: I. Breed-, gender-, age- and cause-specific rates. Acta Vet. Scand. 46(3):105-120. <https://dx.doi.org/10.1186/1751-0147-46-105> <PMid:16261924>

Britt D.P. & Baker J.R. 1990. Causes of death and illness in the native sheep of North Ronaldsay, Orkney I. Adult sheep. Br. Vet. J. 146(2):129-142. <https://dx.doi.org/10.1016/0007-1935(90)90005-N> <PMid:2331590>

Brochu N.M., Guerin M.T., Varga C., Lillie B.N., Brash M.L. & Susta L. 2019. A two-year prospective study of small poultry flocks in Ontario, Canada, part 2: causes of morbidity and mortality. J. Vet. Diagn. Investig. 31(3):336-342. <https://dx.doi.org/10.1177/1040638719843575> <PMid:30973078>

Buergelt C.D., Homer B.L. & Spalding M.G. 2002. Causes of mortality in the Florida panther (*Felis concolor coryi*). Ann. N. Y. Acad. Sci. 969:350-353. <https://dx.doi.org/10.1111/j.1749-6632.2002.tb04403.x> <PMid:12381616>

Cadmus K.J., Mete A., Harris M., Anderson D., Davison S., Sato Y., Helm J., Boger L., Odani J., Ficken M.D. & Pabilonia K.L. 2019. Causes of mortality in backyard poultry in eight states in the United States. J. Vet. Diagn. Investig. 31(3):318-326. <https://dx.doi.org/10.1177/1040638719848718> <PMid:31084344>

Castro É.P. & Bager A. 2019. Sistema Urubu: a ciência cidadã em prol da conservação da biodiversidade. Revta. Bras. Tecnol. Sociais 6(2):1-20. <https://dx.doi.org/10.14210/rbts.v6n2.p111-130>

Cave T.A., Thompson H., Reid S.W.J., Hodgson D.R. & Addie D.D. 2002. Kitten mortality in the United Kingdom: A retrospective analysis of 274 histopathological examinations (1986 to 2000). Vet. Rec. 151(17):497-501. <https://dx.doi.org/10.1136/vr.151.17.497> <PMid:12430997>

Christensen J. & Svensmark B. 1997. Evaluation of producer-recorded causes of preweaning mortality in Danish sow herds. Prev. Vet. Med. 32(3/4):155-164. <https://dx.doi.org/10.1016/S0167-5877(96)01147-6> <PMid:9443324>

Cross A.R., Baldwin V.M., Roy S., Essex-Lopresti A.E., Prior J.L. & Harmer N.J. 2019. Zoonoses under our noses. Microbes Infect. 21(1):10-19. <https://dx.doi.org/10.1016/j.micinf.2018.06.001> <PMid:29913297>

Dias-Pereira P. 2022. Morbidity and mortality in elderly dogs – a model for human aging. BMC Vet. Res. 18(1):457. <https://dx.doi.org/10.1186/s12917-022-03518-8> <PMid:36581919>

Douphrate D.I. 2021. Animal Agriculture and the One Health Approach. J. Agromed. 26(1):85-87. <https://dx.doi.org/10.1080/1059924X.2021.1849136> <PMid:33502961>

Duncan I.J.H. 2005. Science-based assessment of animal welfare: farm animals. Revta Sci. Tech. 24(2):483-492. <PMid:16358502>

Ellingsen C.L., Alfsen G.C., Ebbing M., Pedersen A.G., Sulo G., Vollset S.E. & Braut G.S. 2022. Garbage codes in the Norwegian cause of death registry 1996-2019. BMC Publ. Health 22(1):1301. <https://dx.doi.org/10.1186/s12889-022-13693-w> <PMid:35794568>

Eng H.M., Ellingsen C.L., Pedersen A.G. & alfsen G.C. 2024. Cause of death certificates in nursing homes: Does quality matter? A retrospective review from two counties in Norway. Scand. J. Public Health 52(6):711-717. <https://dx.doi.org/10.1177/14034948231187512> <PMid:37491994>

Engblom L., Eliasson-Selling L., Lundeheim N., Belák K., Andersson K. & Dalin A.-M. 2008. *Post mortem* findings in sows and gilts euthanised or found dead in a large Swedish herd. Acta Vet. Scand. 50:25. <https://dx.doi.org/10.1186/1751-0147-50-25> <PMid:18593470>

Fanke J., Wibbelt G. & Krone O. 2011. Mortality factors and diseases in free-ranging Eurasian cranes (*Grus grus*) in Germany. J. Wildl. Dis. 47(3):627-637. <https://dx.doi.org/10.7589/0090-3558-47.3.627> <PMid:21719827>

França E.B., Ishitani L.H., Abreu D.M.X., Teixeira R.A., Corrêa P.R.L., Jesus E.S., Marinho M.A.D., Bahia T.V., Bierrenbach A.L., Setel P. & Marinho F. 2022. Measuring misclassification of Covid-19 as garbage codes: results of investigating 1,365 deaths and implications for vital statistics in Brazil. PLOS Glob. Public. Health 2(5):e0000199. <https://dx.doi.org/10.1371/journal.pgph.0000199> <PMid:36962159>

Fusi F., Angelucci A., Lorenzi V., Bolzoni L. & Bertocchi L. 2017. Assessing circumstances and causes of dairy cow death in Italian dairy farms through a veterinary practice survey (2013-2014). Prev. Vet. Med. 137(Pt A):105-108. <https://dx.doi.org/10.1016/j.prevetmed.2017.01.004> <PMid:28089290>

Gallagher J. & Nelson J. 1979. Cause of ill health and natural death in badgers in Gloucestershire. Vet. Rec. 105(24):546-551. <PMid:394469>

Gomes A.A.B., Silva M.L.C.R., Bernardi F., Sakai T., Itou T. & Ito F.H. 2012. Molecular epidemiology of animal rabies in the semiarid region of Paraíba, Northeastern Brazil. Arq. Inst. Biol. 79(4):611-615. <https://dx.doi.org/10.1590/s1808-16572012000400020>

Heaver J. & Waters M. 2019. A retrospective study of mortality in Eurasian lynx (*Lynx lynx*) in UK zoos. Zoo Biol. 38(2):200-208. <https://dx.doi.org/10.1002/zoo.21476> <PMid:30672008>

Inoue M. & Sugiura K. 2021. Identifying causes of death of companion dogs in japan using data from pet cemeteries. J. Vet. Med. Sci. 83(7):1039-1043. <https://dx.doi.org/10.1292/jvms.21-0171> <PMid:33994429>

Kimani T., Kiambi S., Eckford S., Njuguna J., Makonnen Y., Rugalema G., Morzaria S.P., Lubroth J. & Fasina F.O. 2019. Expanding beyond zoonoses: the benefits of a national One Health coordination mechanism to address antimicrobial resistance and other shared health threats at the human-animal-environment interface in Kenya. Rev. Sci. Tech. 38(1):155-171. <https://dx.doi.org/10.20506/rst.38.1.2950> <PMid:31564733>

Knudsen S.K. 2005. A review of the criteria used to assess insensibility and death in hunted whales compared to other species. Vet. J. 169(1):42-59. <https://dx.doi.org/10.1016/j.tvjl.2004.02.007> <PMid:15683763>

Krol L., Moore R.P., Mutlow A.G., Brady S.M. & Dorsa II D. 2020. A retrospective analysis of mortality in captive Magellanic penguins (*Spheniscus magellanicus*) in the United States, 2008-2018. Zoo Biol. 39(6):405-410. <https://dx.doi.org/10.1002/zoo.21561> <PMid:33220009>

Küker S., Faverjon C., Furrer L., Berezowski J., Posthaus H., Rinaldi F. & Vial F. 2018. The value of necropsy reports for animal health surveillance. BMC Vet. Res. 14:191. <https://dx.doi.org/10.1186/s12917-018-1505-1> <PMid:29914502>

LaRose J.P., Meredith A.L., Everest D.J., Fiegna C., McInnes C.J., Shaw D.J. & Milne E.M. 2010. Epidemiological and postmortem findings in 262 red squirrels (*Sciurus vulgaris*) in Scotland, 2005 to 2009. Vet. Rec. 167(8):297-302. <https://dx.doi.org/10.1136/vr.c4196> <PMid:20729517>

Lee Y.R., Kim Y.A., Park S.Y., Oh C.M., Kim Y.E. & Oh I.H. 2016. Application of a modified garbage code algorithm to estimate cause-specific mortality and years of life lost in Korea. J. Korean Med. Sci. 2(Supl.2):S121-S128. <https://dx.doi.org/10.3346/jkms.2016.31.S2.S121> <PMid:27775249>

Lima R.B., Frederes A., Marinho M.F., Cunha C.C., Adair T. & França E.B. 2019. Investigation of garbage code deaths to improve the quality of cause-of-death in Brazil: results from a pilot study. Revta Bras. Epidemiol. 22(Supl.3):e19004.supl.3. <https://dx.doi.org/10.1590/1980-549720190004.supl.3> <PMid:31800856>

Mandigers P.J.J., Senders T. & Rothuizen J. 2006. Morbidity and mortality in 928 Dobermanns born in the Netherlands between 1993 and 1999. Vet. Rec. 158(7):226-229. <https://dx.doi.org/10.1136/vr.158.7.226> <PMid:16489159>

McConnel C.S., Garry F.B., Lombard J.E., Kidd J.A., Hill A.E. & Gould D.H. 2009. A necropsy-based descriptive study of dairy cow deaths on a Colorado dairy. J. Dairy Sci. 92(5):1954-1962. <https://dx.doi.org/10.3168/jds.2008-1505> <PMid:19389952>

McConnel C.S., Nelson D.D., Burbick C.R., Buhrig S.M., Wilson E.A., Klatt C.T. & Moore D.A. 2019. Clarifying dairy calf mortality phenotypes through postmortem analysis. J. Dairy Sci. 102(5):4415-4426. <https://dx.doi.org/10.3168/jds.2018-15527> <PMid:30879809>

McNulty K.E., Creevy K.E., Fitzpatrick A., Wilkins V., Barnett B.G., Dog Aging Project Consortium. & Ruple A. 2023. Development and validation of a novel instrument to capture companion dog mortality data: the Dog Aging Project End of Life Survey. J. Am. Vet. Med. Assoc. 261(9):1326-1336. <https://dx.doi.org/10.2460/javma.23.02.0078> <PMid:37179051>

Molossi F.A., Cecco B.S., Pohl C.B., Borges R.B., Sonne L., Pavarini S.P. & Driemeier D. 2021. Causes of death in beef cattle in southern Brazil. J. Vet. Diagn. Investig. 33(4):677-683. <https://dx.doi.org/10.1177/10406387211007952> <PMid:33834923>

Mühldorfer K., Speck S., Kurth A., Lesnik R., Freuling C., Müller T., Kramer-Schadt S. & Wibbelt G. 2011. Diseases and causes of death in European bats: Dynamics in disease susceptibility and infection rates. PLoS One 6(12):e29773. <https://dx.doi.org/10.1371/journal.pone.0029773> <PMid:22216354>

Mulei C.M., Gitau G.K. & Mbuthia P.G. 1995. Causes of calf mortality in Kabete area of Kenya. Onderstepoort J. Vet. Res. 62(3):181-185. <PMid:8628571>

Naghavi M., Makela S., Foreman K., O'Brien J., Pourmalek F. & Lozano R. 2010. Algorithms for enhancing public health utility of national causes-of-death data. Popul. Health Metr. 8:9. <https://dx.doi.org/10.1186/1478-7954-8-9> <PMid:20459720>

Nascimento D.C., Costa Neto J.M., Solcà M.S., Estrela-Lima A. & Barbosa V.F. 2022. Clinicoepidemiological profile and risk factors associated with mortality in traumatized cats admitted to a veterinary teaching hospital in Brazil. J. Feline Med. Surg. 24(4):381-388. <https://dx.doi.org/10.1177/1098612X211028027> <PMid:34259571>

Nettles V.F., Quist C.F., Lopez R.R., Wilmers T.J., Frank P., Roberts W., Chitwood S. & Davidson W.R. 2002. Morbidity and mortality factors in Key deer (*Odocoileus virginianus clavium*). J. Wildl. Dis. 38(4):685-692. <https://dx.doi.org/10.7589/0090-3558-38.4.685> <PMid:12528433>

Ng T.-C., Lo W.-C., Ku C.-C., Lu T.-H. & Lin H.-H. 2020. Improving the use of mortality data in public health: A comparison of garbage code redistribution models. Am. J. Publ. Health 110(2):222-229. <https://dx.doi.org/10.2105/AJPH.2019.305439> <PMid:31855478>

O'Neill D.G., Church D.B., McGreevy P.D., Thomson P.C. & Brodbelt D.C. 2015. Longevity and mortality of cats attending primary care veterinary practices in England. J. Feline Med. Surg. 17(2):125-133. <https://dx.doi.org/10.1177/1098612X14536176> <PMid:24925771>

Page M.J., McKenzie J.E., Bossuyt P.M., Boutron I., Hoffmann T.C., Mulrow C.D., Shamseer L., Tetzlaff J.M., Akl E.A., Brennan S.E., Chou R., Glanville J., Grimshaw J.M., Hróbjartsson A., Lalu M.M., Li T., Loder E.W., Mayo-Wilson E., McDonald S., McGuinness L.A., Stewart L.A., Thomas J., Tricco A.C., Welch V.A., Whiting P. & Moher D. 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021(71):372. <https://dx.doi.org/10.1136/bmj.n71> <PMid:33782057>

Park S. & Kim S.H. 2022. Does the application of International Classification of Disease Codes for the cause of death on death certificates reduce garbage codes? Inquiry 59:1-9. <https://dx.doi.org/10.1177/00469580221081433> <PMid:35384751>

Peck S.J., Michael S.A., Knowles G., Davis A. & Pemberton D. 2019. Causes of mortality and severe morbidity requiring euthanasia in captive Tasmanian devils (*Sarcophilus harrisii*) in Tasmania. Aust. Vet. J. 97(4):89-92. <https://dx.doi.org/10.1111/avj.12797> <PMid:30919442>

Pegram C., Gray C., Packer R.M.A., Richards Y., Church D.B., Brodbelt D.C. & O'Neill D.G. 2021. Proportion and risk factors for death by euthanasia in dogs in the UK. Sci. Rep. 11:9145. <https://dx.doi.org/10.1038/s41598-021-88342-0> <PMid:33947877>

Pennycott T.W., Ross H.M., McLaren I.M., Park A., Hopkins G.F. & Foster G. 1998. Causes of death of wild birds of the family Fringillidae in Britain. Vet. Rec. 143(6):155-158. <https://dx.doi.org/10.1136/vr.143.6.155> <PMid:9746945>

Pereira A.A.B.G., Dias B., Castro S.I., Landi M.F.A., Melo C.B., Wilson T.M., Costa G.R.T., Passos P.H.O., Romano A.P., Szabó M.P.J. & Castro M.B. 2020. Electrocutions in free-living black-tufted marmosets (*Callithrix penicillata*) in anthropogenic environments in the Federal District and surrounding areas, Brazil. Primates 61(2):321-329. <https://dx.doi.org/10.1007/s10329-019-00760-x> <PMid:31564005>

Proschowsky H.F., Rugbjerg H. & Ersbøll A.K. 2003. Mortality of purebred and mixed-breed dogs in Denmark. Prev. Vet. Med. 58(1/2):63-74. <https://dx.doi.org/10.1016/S0167-5877(03)00010-2> <PMid:12628771>

Ryser-Degiorgis M.-P. 2013. Wildlife health investigations: Needs, challenges and recommendations. BMC Vet. Res. 9:223. <https://dx.doi.org/10.1186/1746-6148-9-223> <PMid:24188616>

Sileo L., Sievert P.R. & Samuel M.D. 1990. Causes of mortality of albatross chicks at Midway Atoll. J. Wildl. Dis. 26(3):329-338. <https://dx.doi.org/10.7589/0090-3558-26.3.329> <PMid:2167393>

Simpson V.R., Hargreaves J., Butler H.M., Davison N.J. & Everest D.J. 2013. Causes of mortality and pathological lesions observed post-mortem in red squirrels (*Sciurus vulgaris*) in Great Britain. BMC Vet. Res. 9:229. <https://dx.doi.org/10.1186/1746-6148-9-229> <PMid:24238087>

Sinclair J.R. 2019. Importance of a One Health approach in advancing global health security and the Sustainable Development Goals. Rev. Sci. Tech. 38(1):145-154. <https://dx.doi.org/10.20506/rst.38.1.2949> <PMid:31564744>

Strong V., Baiker K., Brennan M.L., Redrobe S., Rietkerk F., Cobb M. & White K. 2017. A retrospective review of western lowland gorilla (*Gorilla gorilla gorilla*) mortality in European zoologic collections between 2004 and 2014. J. Zoo Wildl. Med. 48(2):277-286. <https://dx.doi.org/10.1638/2016-0132R.1> <PMid:28749273>

Svensson C., Linder A. & Olsson S.-O. 2006. Mortality in Swedish dairy calves and replacement heifers. J. Dairy Sci. 89(12):4769-4777. <https://dx.doi.org/10.3168/jds.S0022-0302(06)72526-7> <PMid:17106108>

Thomsen P.T., Kjeldsen A.M., Sørensen J.T. & Houe H. 2004. Mortality (including euthanasia) among Danish dairy cows (1990-2001). Prev. Vet. Med. 62(1):19-33. <https://dx.doi.org/10.1016/j.prevetmed.2003.09.002> <PMid:15154682>

Vigors B., Ewing D.A. & Lawrence A.B. 2021. The importance of farm animal health and natural behaviors to livestock farmers: Findings from a factorial survey using vignettes. Front. Anim. Sci. 2:638782. <https://dx.doi.org/10.3389/fanim.2021.638782>

Waldner C.L., Kennedy R.I., Rosengren L. & Clark E.G. 2009. A field study of culling and mortality in beef cows from western Canada. Can. Vet. J. 50(5):491-499. <PMid:19436634>

WHO 2004. International statistical classification of diseases and related health problems. 10th revision. World Health Organization, Geneva.

Williams J.M., Lonsdorf E.V., Wilson M.L., Schumacher-Stankey J., Goodall J. & Pusey A.E. 2008. Causes of death in the Kasekela chimpanzees of Gombe National Park, Tanzania. Am. J. Primatol. 70(8):766-777. <https://dx.doi.org/10.1002/ajp.20573> <PMid:18506732>

Work T.M. & Hale J. 1996. Causes of owl mortality in Hawaii, 1992 to 1994. J. Wildl. Dis. 32(2):266-273. <https://dx.doi.org/10.7589/0090-3558-32.2.266> <PMid:8722264>