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REVIEW ARTICLE

Glyphosate in the Iberian Peninsula: Evaluating risks to Iberian wildlife

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ABSTRACT

Glyphosate [N-(phosphonomethyl)glycine] (GlyP) is an herbicide extensively used worldwide, including the Iberian Peninsula. It is mainly used in agricultural landscapes but also in urban areas, in railways, and even in water bodies. Despite glyphosate's large use, there is a paucity of research on its exposure and its potential effects on wildlife living treated environments. In recent years, an increasing number of studies have warned about the effects of this herbicide namely, on oxidative stress, and on liver and kidney in different taxa. Additionally, some studies also suggested endocrine disruption capacity in reptiles or genotoxicity in fish. Most of these studies have been carried out on experimental animals, in laboratory conditions, so the real exposure and potential effects on wildlife is largely unknown. In this context, this review is intended to help understand the ecological consequences that glyphosate may be exerting on wildlife that inhabit the Iberian Peninsula.

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Introduction

Herbicides are substances used to control undesirable plant species in gardens and crops. Their use is based on their potential benefits on global food availability, and on society development. However, the continued use of herbicides, like other pesticides, should be regularly reevaluated, and their toxicological profiles reassessed, particularly in light of emerging evidence of adverse effects on other living organisms, and their potential to cause environmental harm (Carabias Martínez et al., 2000; Gupta, 2014; Paetow et al., 2023). In this sense, the impact of different pesticides on distinct wildlife species and ecosystems has been approached since the middle of the 20th century, with the insecticide DDT (dichlorodiphenyltrichloroethane) development (Carson, 1962; Newton, 2018).

Evaluating the use and assessing the safety of herbicides (and other pesticides) is a continuous process. The Sustainable Use of Pesticides Directive (Directive 2009/128/EC) aims to achieve a sustainable use of pesticides. Based on this Directive, the decision to use and how to use a pesticide must be sustained on scientific evidence of their implications, and subjected to risk analysis (European Parliament & Council, 2009).

Glyphosate marketed since 1974 by Monsanto, became in a few years the world's most popular and most successful herbicide in history due to its high effectiveness and low cost. Glyphosate is a weak organic acid consisting of a N-phosphonomethyl-modified derivative of glycine (Bradberry et al., 2004; Mensink & Janssen, 1994; Sammons & Gaines, 2014), commercially known as Roundup®, the trade name of the first commercial product (patent expired in 2000), and now belonging to Bayer CropScience, Germany. Glyphosate-based products are commercially available with concentrations of 1% glyphosate (for domestic use) to 41% or more (for professional use). Glyphosate is extensively used as a nonselective herbicide by professional and domestic users in agricultural and nonagricultural areas worldwide, with its consumption increasing exponentially with the development of genetically modified crops. Globally, genetically engineered herbicide-tolerant crops now account for about 56% of global glyphosate use (Benbrook, 2016).

Glyphosate has a plant-specific mechanism of action, a low soil migration and volatility and suffers biotic degradation, contributing to a positive environmental safety profile (Antier et al., 2020; Bradberry et al., 2004). However, glyphosate's degradation by the microorganisms is and dependent on the diversity of microorganisms present in the soil. Its half-life in soil is approximately 2 months, but some authors have already reported resistance in vegetation, soil, and water, 1 year after application (Edge et al., 2021; Gill et al., 2018). The primary pathway of glyphosate metabolization by several

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bacteria is due to sarcosine oxidase which converts phosphate and sarcosine into glycine and formaldheyde. However, a suggested alternative pathway involves the formation of aminomethylphosphonic acid (AMPA) by the enzyme glyphosate oxidoreductase (Bradberry et al., 2004).

Biomonitoring studies have reported urinary glyphosate concentrations ranging from 0.16 to 7.6 µg/L in occupationally exposed individuals, while lower levels (typically <1 µg/L) have been detected in the general population (Gillezeau et al., 2019). Environmentally, glyphosate is frequently found in surface waters, groundwater, and soils (Battaglin et al., 2014). According to Battaglin et al. (2014), glyphosate and AMPA can occur widely in surface water, being detected at least once at 59% of 470 sites. They were detected with similar frequency in large rivers and in smaller streams. Glyphosate and AMPA also occurred in groundwater or soil water with one or both compounds being detected at least once at 8.4% of 820 sites analyzed by these authors. Moreover, glyphosate was detected in more than 50% of soil and sediment samples.

The widespread use of glyphosate combined with its detection difficulties, has led to what is known as the 'Glyphosate Paradox'—it is both the most commonly used herbicide and one of the most difficult to detect. The challenges in quantifying and demonstrating the toxicity of glyphosate likely stem from its metal-chelating properties, the interference of environmental organic compounds, and its similarity to its degradation products (Valle et al., 2019). Despite the availability of standardized immunoassay kits, a more detailed quantification laboratory determination of glyphosate (and AMPA) is usually complex, and costly. Determination is usually carried out with chromatographic techniques, such as high-performance liquid chromatography (HPLC) or gas-liquid chromatography (GC), both coupled with mass spectrometry (MS/MS) (Mensink & Janssen, 1994; Valle et al., 2019).

Globally, glyphosate and its active metabolites have been pointed out as endocrine-disruptive chemicals (EDCs), although their effects extend to non-endocrine organs. Glyphosate toxicity has gained attention during the last few decades, leading to some studies in different taxonomic groups (Gill et al., 2018). For human populations, glyphosate enters the food chain due to contaminated agricultural soils and drinking water. In addition, a more intense exposure has been described in occupational exposed workers (Gillezeau et al., 2019). Exposure to glyphosate-based products is more likely to occur at sublethal levels and lead to chronic effects, with multiple contacts and events occurring in urban, natural, and agricultural habitats (Kissane & Shephard, 2017). However, these levels may change depending on the considered species. In freshwater invertebrates and fish, the median lethal concentration (LC50) values reported for glyphosate exceed 55 mg/L, while the no observed effect level (NOEL) over a 21-day exposure period has been documented at 100 mg/L (Mensah et al., 2015). Mesnage et al. (2013) observed with negative dose-dependent effects on cellular respiration and membrane integrity from 1 ppm, at environmental/occupational doses in human cells. Several researchers have demonstrated the consequences of exposure, including changes in the activity of enzyme aromatase in the placenta (Richard et al., 2005), cytotoxic and genotoxic effects in buccal epithelial cells (Koller et al., 2012), increase in the cell number or cytosolic lipid accumulation in fibroblast (3T3-L1) (Martini et al., 2016), and interference in cytochrome P450 enzymes and biosynthesis of aromatic amino acids by intestinal bacteria (Samsel & Seneff, 2013). At a systemic level, researchers have mentioned increased predisposition to cancer, gastrointestinal and heart diseases, obesity, depression, diabetes, infertility, and autism in humans (Gill et al., 2018; Samsel & Seneff, 2013; Thongprakaisang et al., 2013). Overall, studies have shown chronic exposure effects altering the mechanisms of oxidative stress and inducing immune suppression, endocrine disruption, and cell damage (Van Bruggen et al., 2018; Wang et al., 2022). Glyphosate has been associated to signs of liver and kidney injury by morphological and biochemical changes in rats (Séralini et al. 2014). Moreover, disturbances in metabolome and proteome revealed a substantial overlap with biomarkers of nonalcoholic fatty liver disease and its progression to steatohepatosis due to chronic and low doses of glyphosate-based herbicides (Mesnage et al., 2017). Similarly, Mesnage et al. (2022) suggested an association between exposure to glyphosate formulations and deep changes in cecum microbiome composition in rats. More recently, the same authors presented a project (GlyphoMix®) that consist in a multisystem study that will evaluate the impact on the antioxidant machinery, oxidative stress, DNA damage, and tissue histology in various organs (bone marrow, liver, kidneys, brain, gastrointestinal tract) (Mesnage et al., 2023). Romualdo et al. (2023) reported that glyphosate exposure – in a dose within the toxicological limits - impairs hepatic inflammation/redox dynamics in a NAFLD microenvironment. Finally, the International Agency of Research in Cancer (International Agency for Research on Cancer, 2017) mentioned that there is sufficient evidence in experimental animals for the carcinogenicity of glyphosate, with a positive association for non-Hodgkin lymphoma in humans, leading to a classification of 'probably carcinogenic to humans.' Comparing to these human and experimental animals' data, there is a considerable lack of research on the impact of glyphosate on wildlife (Kissane & Shephard, 2017). Nevertheless, the European Commission formally asked their members to pay particular attention to 'the risk to terrestrial vertebrates and non-target terrestrial plants,' and 'the risk to diversity and abundance of non-target terrestrial arthropods and vertebrates via trophic interactions' (European Commission, 2017).

Therefore, this review intends to provide a summary regarding the current knowledge on the impact of glyphosate on wildlife health, focusing on the Iberian Peninsula.

The vast use in the Iberian Peninsula

Globally, 72% of total glyphosate use occurred between 1974 and 2014, reflecting a sharp increase in reliance on this herbicide in modern agricultural practices. A similar trend, corresponding to two-thirds of the glyphosate used from the very beginning, is observed in the United States. In the U.S., over 1.6 billion kilograms of glyphosate active ingredient have been applied, accounting for approximately 19% of the estimated global total of 8.6 billion kilograms (Benbrook, 2016). In Europe, pesticide sales (including glyphosate) remained relatively stable between 2011 and 2023 across most EU countries, with some nations showing increases and others decreases. The European Commission reports that glyphosate is one of the most widely used herbicides in the EU, applied in agriculture, horticulture, forestry, and non-cultivated areas such as railways (European Commission, 2025; Eurostat, 2025).

Spain is the second European country with the highest volume of pesticides sold in 2017, with 16% of the total European pesticide sales, preceded only by France (17%) (Eurostat, 2020). Considering herbicides in particular, Spain came in third place (11%), after France (21%) and Germany (12%) (Antier et al., 2020). Even though official authorities in Spain have claimed that the use of glyphosate and its active metabolites need to be controlled, it was the most used herbicide in barley, nuts, sunflower, olive, and wheat agricultural lands in 2023. In Spain, glyphosate consumption in agricultural lands during 2018/2019 agricultural campains was around 3280 tones (Ministerio de Agricultura, Pesca y Alimentación, 2019).

In Portugal, glyphosate-based herbicides have been also widely used in agricultural lands, with more than 0.32 kg of active principle per hectare (Antier et al., 2020). In 2020, glyphosate-based products were the most sold herbicides in Portugal, with a total of 1809 tones, which is equivalent to 75% of the herbicides' sales (Direção-Geral de Alimentação e Veterinária, 2020).

According to a recent report, 31% and 22% of drinking water samples collected in Spain and Portugal, respectively, contained glyphosate (or its relevant metabolites) at levels higher than 0.1 µg/L, the maximum safety limit for drinking water (Ministerio para la Transición Ecológica y el Reto Demográfico, 2023). Particularly in Portugal, a sample from the Idanha-a-Nova region (Castelo Branco district) contained 3 µg/L of glyphosate, which is 30 times above the safety limit for human consumption (Gergely Simon, 2023). Since humans share the environment and water resources with animal species, glyphosate toxicity, and contamination is expected to affect both human and wildlife populations.

Methodology

Scopus® and Google Scholar® were used as search tools for this narrative review. A string of keywords [(glyphosate OR glifosato) AND (Portugal OR Spain OR Iberia OR Iberian) AND (wildlife OR wild OR fauna)] was used to obtain the first list of papers on the subject. Then, a second search was conducted using 'glyphosate' and the scientific name of every terrestrial and freshwater animal species in the Iberian Peninsula, based on the IUCN Red List. All types of publications were considered, namely articles, book chapters, scientific abstracts, and official reports, written in English, Portuguese, or Spanish. Papers unrelated to the subject, or mentioning too detailed aspects of the technical use of glyphosate herbicides in agriculture have been excluded (Figure 1). The list of papers obtained from this methodology is presented as supplementary material. The published data on the subject was considered heterogeneous and insufficient to perform a formal systematic review about the subject, leading the authors to choose to develop a narrative review, following the Cochrane® principles (Cochrane, n.d.).

Impact on wildlife, with special focus on the Iberian Peninsula

Table 1 summarizes the different effects of glyphosate in distinct taxa, including both invertebrate and vertebrate species. Considering the wide use of glyphosate in the Iberian Peninsula and the variety of species inhabit this area, describing the impacts on biodiversity should be considered a priority for environmental scientists, biologists, and wildlife veterinarians. Most Iberian species have not been used to evaluate the effects of glyphosate-based herbicides, except for some freshwater species. However, some helped to provide a general idea of the impact of this toxicant in Iberian habitats.

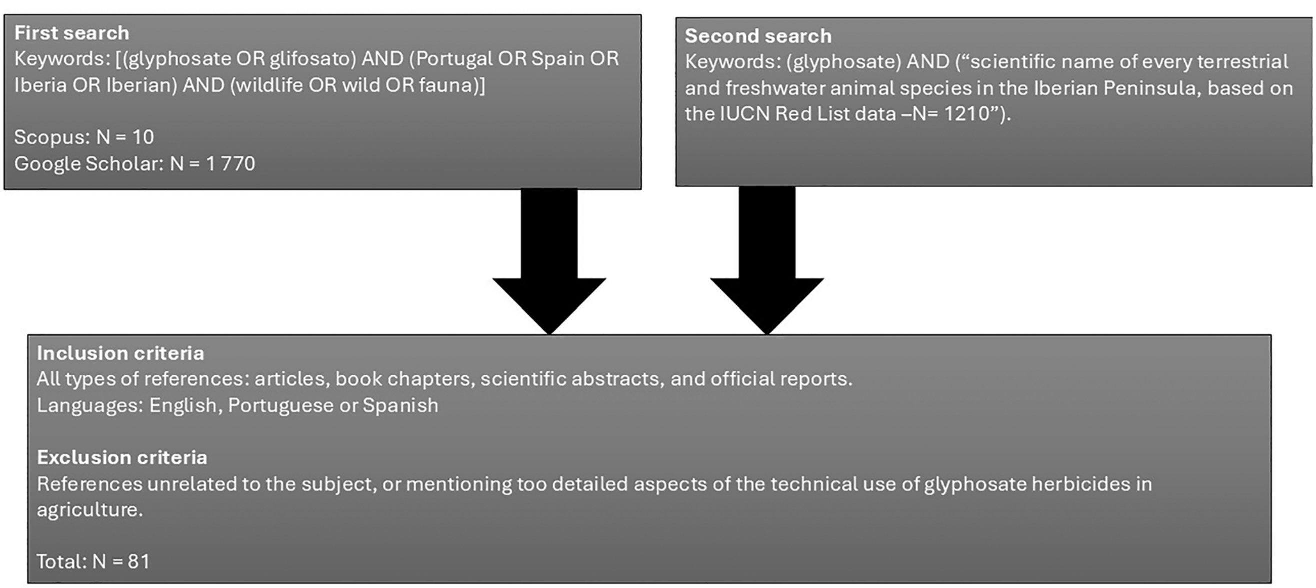

Figure 1. Illustration of the search methodology used to produce this review.

Table 1. Summary of relevant effects of glyphosate exposure in wildlife species that inhabit the Iberian Peninsula.

Animal	Exposure concentration	Effects	Reference
Invertebrates			
Apis mellifera	Three sublethal concentrations of GLY (2.5, 5, and 10 mg/L)	Reduced sensitivity to sucrose; worse learning performance and cognitive capacities; spent more time performing homeward flights.	(Balbuena et al., 2015; Herbert et al., 2014)
Eisenia foetida	1; 10; 100; 500 and 1000 mg/kg in soil (chronic exposure)	Gradual but significant weight reduction; effects on development and reproduction for different concentrations and exposure times. 100% mortality was observed in soil treated with 500 and 1000 mg/kg.	(Correia & Moreira, 2010)
Helix aspersa	3 mg/kg in soil (168 days)	Decreased development of the albumen gland.	(Druart et al., 2011)
Lumbricus terrestris	Soil treated with 0.59 g/m^2; 2.9 g/m^2; 5.79 g/m^2; 11.59 g/m^2 of Roundup 360.	Decreasing survival rate and a sharp decline in the number of cocoons (after 21 days and 42 days of exposure).	(Stellin et al., 2018)
Sphaerechinus granularis	Water with 8 mM glyphosate (a), 0.2% Roundup® (b), and 0.2% Roundup® supplemented with 8 mM of glyphosate (c).	Delayed hatching process (min). 33 ± 6128 ± 30205 ± 30	(Marc et al., 2005)
Trichogramma pretiosum	(Not mentioned)	Harmfull for the eggs	(Bueno et al., 2008; Gill et al., 2018)
Fish			
Anguilla anguilla	Water with Roundup® (58 and 116 µg/L, corresponding to 18 and 36 µg L − 1 of glyphosate, respectively) for 3 days.	Genotoxicity, oxidative damage of DNA repair system.	(Marques et al., 2014)
Cyprinus carpio	Roundup® at 3.5, 7 and 14 ppm for 16 days. LC50-96 h: 22.19 ppm	Significant decrease in the acetylcholisnesterase (AchE) activity of brain, muscle and liver after 5 days of exposure. Significant decrease of hemoglobin, hematocrit and both red and white blood cell count. Increased the activities of aspartate aminotransferase (AST), alanine aminotransferase (ALT) and lactate dehydrogenase (LDH).	(Gholami-Seyedkolaei et al., 2013)
Salmo trutta	(Not mentioned)	Increased cellular proliferation and turnover.	(Gill et al., 2018; Uren Webster & Santos, 2015)
Amphibians			
Discoglossus pictus	Water with 1 ppm and 2 ppm of nominal concentrations of glyphosate	Malformations of the head and eyes	(Wagner et al., 2017)
Bufo bufo	0, 2 and 6.5 mg acid equivalent (a.e.) / L)	Lethality depending on pH and stress. At 6.5 mg a.e/L, they showed decreased and more tadpoles were hiding	(Mikó et al., 2017)
Reptiles			
Podarcis bocagei	(Not mentioned)	Changes in follicular anatomy, thecal fibrosis, fewer oocytes; collagen deposition and fibrosis of the testis, loss of cellular junctions, and impairment in spermatogenesis. Oxidative stress and increased glycogen, lipofuscin granules, and melanin in the liver	(Bicho et al., 2013)
Trachemys scripta	Single applications ranging from 0 to 11,206 ppm wet weight during 14 days	Dose-response relationships in the ability of hatchlings to right themselves when turned on their backs. Lower egg weight, genetic damage.	(Sparling et al., 2006)
Birds			
Anas platyrhynchos	Roundup® diluted in distilled water, at 5 mg/kg and 100 mg/kg of body weight for 15 days	Damage of the male reproductive organs	(Oliveira et al., 2007)
Mammals			
Lepus granatensis	Concentrations detected in the gastric content ranged from 0.11 to 16 µg/g	Unknown but possibly influencing mortality	(Martinez-Haro et al., 2022)

Invertebrates

Regarding invertebrates, there have been studies addressing the effect on bees, earthworms, snails, and urchins. Earthworms, for instance, are an essential component of soil biota, so changes related to the use of different chemical components can directly or indirectly interfere with their life and balance (Gill et al., 2018). The general effects described include a significant decrease in body weight and reproduction (Correia & Moreira, 2010). Some soil invertebrates with a worldwide presence, as *Enchytraeus crypticus*, have been used as bioindicators of soil pollution, and Yang et al. (2025) referred that glyphosate influenced the gut bacteria of this organism, reducing diversity and inducing oxidative stress. Moreover, specifically in honey bees (*Apis mellifera*), glyphosate has been associated with a reduced sensitivity to sucrose and a worse cognitive capacity, leading to bees spending more time performing homeward flights (Balbuena et al., 2015).

Vertebrates

Fish

In fish, a variety of toxic effects have been described in different species, such as hepatotoxic, nephrotoxic, and cardiotoxic effects in *Cyprinus carpio* (Nešković et al., 1996), inhibitory effects on the activity of acetylcholinesterase in *Cnesterodon decemmaculatus* (Menéndez-Helman et al., 2012), and reproductive and behavioral changes in, respectively, *Jenynsia multidentata* and freshwater fish surubim (*Pseudoplatystoma* spp.) (Hued et al., 2012; Sinhorin et al., 2014). DNA damage induced by glyphosate upon short-term (3 days) and post-exposure (1 to 14 days) periods has been confirmed in *Anguilla anguilla* by Portuguese researchers (Marques et al., 2014).

Amphibians

Amphibians are globally declining, and environmental contamination is one of six major reasons for this problem (Collins & Storfer, 2003; Wagner & Lötters, 2013; Wagner et al., 2017). The use of pesticides, including glyphosate-based herbicides, affects freshwater systems, interfering with the reproduction and activity of most amphibians in both juvenile and adult forms. Histopathologic lesions associated with hepatic catabolism pigments and the changes in the nucleus of erythrocytes, as well as genotoxicity in peripheral blood cells, have been reported as consequences of exposure to glyphosate, such as *Leptodactylus latinasus* and *Rhinella arenarum* (Pérez-Iglesias et al., 2016; Soloneski et al., 2016). The common frog (*Rana temporaria*) and the palmate newt (*Lissotriton helveticus*) are amphibian species with, respectively, a general distribution or concentrated in the northern part of the Iberian peninsula. A behavior observational study in both species concluded that the presence of glyphosate and AMPA in concentrations below or slightly above the European Environmental Quality Standards did not affect residence time in the water for both species, which may represent a positive aspect, but can also mean that these animals do not percept or avoid contaminated waters (Wagner & Lötters, 2013). In another species, *Discoglossus pictus*, malformations increased with the concentration of Roundup ® UltraMax, and early larvae react more sensitively than embryos. Moreover, 135 mg of active ingredient per liter affected the development of the head region, leading to smaller eyes (Wagner et al., 2017). Considering the common toad *Bufo bufo*, this herbicide is moderately toxic, but lethality may be influenced by a high pH or stress induced by predation (Mikó et al., 2017).

Reptiles

In reptiles, genotoxicity has also been reported in crocodiles and lizards (Carpenter et al., 2016; López González et al., 2013). *Podarcis siculus* is a lizard distributed in southern Europe, known as field or wall lizard. It usually lives in agricultural, rural, and anthropized environments (such as city gardens), making it vulnerable to herbicides, including glyphosate. Moreover, it plays a vital role in the ecosystem and many trophic chains, since it feeds on many plant-pathogenic insects while being a prey to birds and small mammals. Studies have shown the effects of glyphosate as an endocrine-disruptive chemical in this species. In females, authors have described a dose-dependent effect of glyphosate-inducing germ cell recruitment, changes in follicular anatomy, and thecal fibrosis, leading to fewer oocytes. In males, collagen deposition and fibrosis of the testis, loss of cellular junctions, and impairment in spermatogenesis have been identified. Additionally, oxidative stress and increased glycogen, lipofuscin granules, and melanin have been detected in the liver (Chianese et al., 2023; Verderame & Scudiero, 2019). In Portugal, adult male *Podarcis bocagei* lizards exposed to a known mixture of pesticides (including glyphosate) have shown thyroid follicular lumens with more reabsorption vacuoles, as well as a larger follicular area, than the lizards from reference sites. Moreover, lizards' testes from exposed areas had more spermatogenic layers and larger seminiferous tubule diameters (Bicho et al., 2013).

Birds

Although most studies do not report the direct toxic effects of glyphosate herbicides if adequately used, population declines due to indirect changes in the wetland vegetation have been reported (Gill et al., 2018). The impact of pesticides on birds is mainly due to the depletion of food resources and/or lack of resources for nesting (Moreau et al., 2022). Densities of different species of songbirds have been described as affected by the use of glyphosate herbicides (Santillo et al., 1989). However, reproduction impairment is also described. A reduction in steroid hormones associated with exposure to glyphosate was detected in mallard ducks (*Anas platyrhynchos*), as well as alterations in the structure of the testis and epididymis (Oliveira et al., 2007). Despite the potential of birds as sentinels of this problem and their past use to monitor pesticide exposure, most bird species have never been used for glyphosate impact evaluation (Kissane & Shephard, 2017).

Mammals

Considering mammals, the studies are even more scarce. Although the acute oral toxicity of this compound for mammals is low (admissible diary intake [ADI] of 0.5 mg/kg body weight; adverse observable effect level [AOEL] of 0.1 mg/kg body weight), the effects of chronic exposure to glyphosate herbicides still require further research and discussion (European Commission, 2023a; Nova et al., 2020). Rodents have shown long-term histopathological toxic effects in several organs and systems, such as the gastrointestinal tract, the liver, the kidney, the nervous system, the pancreas, and the spleen, even when supplemented with zinc, which has antioxidant and cellular protective properties (Tizhe et al., 2014). In addition, cardiovascular effects have been reported in swine (Lee et al., 2009). Regarding the Iberian hare, 9 – 22% of the individuals hunted in glyphosate-treated areas were positive for residues of this herbicide in biological tissues. This prevalence increased to 45% in hares found dead, with maximum concentrations of 16 μg/g, and 11 μg/g, in hunted and dead hares, respectively. Authors suggested that these animals have been subjected to chronic levels of exposure to glyphosate, which may exert adverse effects, even though they are not lethal (Martinez-Haro et al., 2022). Moreover, the same authors have recently suggested that glyphosate causes significant alterations in hares' microbiota (Martínez-Haro et al., 2025).

Discussion and conclusion

In the EU, glyphosate was most recently reapproved in November 2023 for a 10-year period, valid until December 2033. This decision followed a comprehensive scientific review coordinated by the European Food Safety Authority and the European Chemicals Agency, and includes new restrictions such as the prohibition of pre-harvest use as a desiccant and mandatory measures to protect non-target organisms (European Commission, 2023b). In contrast, the US Environmental Protection Agency (EPA) continues to support the use of glyphosate, stating in 2020 that glyphosate poses no risks of concern to human health when used according to label instructions and is unlikely to be a human carcinogen or an endocrine disruptor. However, this decision was partially vacated by the U.S. Court of Appeals in 2022, which required the EPA to revisit its ecological risk assessment and comply with the Endangered Species Act (United States Environmental Protection Agency, 2025).

In 2016, some herbicides (as amitrole, isoproturon, and triasulfuron) were banned from the European Union, after having evidence of the impact they were having on non-target species as endocrine-disruptive chemicals and the risks to aquatic life (Britt Erickson, 2016). Even though glyphosate is not considered as toxic as other herbicides previously used and/or banned, its high and continuous use nowadays needs to be studied, critically evaluated and, perhaps, more regulated (Mesnage & Antoniou, 2017). A high and continuous use of glyphosate-based herbicides is considered controversial and has been continuously debated over the last few decades, with a current lack of consensus including in the European Union (European Commission, 2017).

Glyphosate is one of the most commonly used herbicides in the Iberian peninsula and some toxic effects have been described in the literature, especially in experimental animals and humans. However, most Iberian species have not been used in environmental assessments to evaluate the impact of glyphosate-based products on their health and stability. As in other geographical areas, the lack of studies is applicable to all animal taxa. As in other health concerns, the first step to regulate or mitigate a potential problem needs to be a complete evaluation of its probable consequences.

The One Health concept involves the analysis of a potential health hazard and its effects on humans, animals, and the environment. Under a One Health approach, the consequences of exposure to this and other pesticides must be integrated into a transversal risk assessment, involving a detailed analysis of the human, animal, and environmental health impacts. Only with an integrated approach would the governments and European authorities be able to provide measures to change and regulate of the use of glyphosate-based herbicides. Wildlife species can be used as bioindicators and sentinels of this issue and provide relevant information regarding the human, domestic animals, and environmental health (Kissane & Shephard, 2017).

Thus, further research, possibly involving wildlife species from different taxa and/or ecological roles, is required to have a broader understanding of the consequences of glyphosate on the Iberian populations, ecosystems, and habitats.

Authors contributions

CJB – conceptualization; writing, original draft preparation; GNM, LLG, MMH, and RA - writing, revision, and editing. All the authors agreed with the final version of the manuscript.

Ethical approval

There were no ethical considerations to declare regarding the present article.

Disclosure statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be considered potential conflicts of interest.

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Data availability statement

The data of the current study are available by reasonable request.

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