LITERATURE REVIEW

Potential ecological effects of the free-roaming horses *Equus caballus* (Perissodactyla: Equidae) on wild mammals: a review of current knowledge

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**ABSTRACT.** Introduction: The horse (*Equus caballus*) is an adaptable large herbivore distributed in a wide range of terrestrial biomes that negatively affects ecosystems around the world. Most research on horse–ecosystem interactions has been focused on plants and soils, whereas horse effects on vertebrate species are poorly understood. **Objective:** We aimed to synthesize, at a global scale, the effects of free-roaming horses on wild mammals. **Methods:** We conducted a systematic literature review that included these words; "feral horses + competition", "feral horses + interactions", "feral horses + impacts", "feral horses + effects", based on the "Web of Science" internet search engine. **Results:** We located 366 articles in our search, but only 14 peer-reviewed documents described the effects of horses on local wild mammals. Most studies were published in the last decade (64%), and were located in United States (64%). Additional information showed most studies used correlational approaches while experimental approaches were used less. The effect of horses on mammal taxonomic groups varied significantly, suggesting changes on habitat structure mostly affects vertebrate species such as small rodents. Nevertheless, large ungulates exhibited interference competition derived from presence of free-roaming horses. **Conclusion:** This review identified patterns and gaps in our current knowledge about the effect of horse presence on wild mammals, and can help to readdress further research. Therefore, we recommend careful monitoring of horses and their potential effects on wildlife by using species proxies such as ungulates and rodents to determine if the presence of horses in protected areas affects conservation objectives.

**Keywords:** Wildlife, habitat, ungulates, rodents, horses, grazing.

**RESUMEN.** “Efectos ecológicos potenciales de los caballos de libre pastoreo *Equus caballus* (Perissodactyla: Equidae) en mamíferos silvestres: revisión del estado actual de conocimiento”. **Introducción:** El caballo (*Equus caballus*) es una especie adaptable ampliamente distribuida, afectando negativamente ecosistemas de todo el mundo. La mayoría de las investigaciones sobre interacciones caballos–ecosistemas se han centrado en plantas y suelos, mientras que los efectos sobre especies de vertebrados son poco conocidos. **Objetivo:** Sintetizar a escala global los efectos de los caballos de libre pastoreo en los mamíferos silvestres. **Métodos:** Realizamos una revisión sistemática de la literatura que incluía las palabras en inglés; "feral horses + competition", "Feral horses + interactions", "feral horses + impacts", "feral horses + effects", basados en el motor de búsqueda “Web of Science”. **Resultados:** Encontramos 366 artículos, de los cuales solo 14 describieron algún efecto de los caballos en los mamíferos. La mayoría de los estudios se publicaron en la última década (64%) y se ubicaron en Estados Unidos (64%). Información adicional mostró que la mayoría de los estudios usaban enfoques correlacionales, mientras que los enfoques experimentales fueron menos usados. El efecto de los caballos varió significativamente entre grupos taxonómicos, sugiriendo que los cambios en la estructura del hábitat afectan principalmente a los pequeños mamíferos como los roedores. Sin embargo, los grandes ungulados mostraron competencia de interferencia derivada de la presencia de caballos. **Conclusión:** Esta síntesis identificó patrones y vacío de información sobre el efecto de la presencia de caballos en los mamíferos silvestres y puede ayudar a orientar futuras investigaciones. Recomendamos un monitoreo cuidadoso de los caballos y sus posibles efectos en la vida silvestre mediante el uso de especies como ungulados y roedores para determinar si la presencia de caballos en áreas protegidas afecta los objetivos de conservación.

**Palabras clave:** Vida silvestre, hábitat, ungulados, roedores, caballos, pastoreo.
The horse (Equus caballus) is an adaptable herbivore distributed on several continents, inhabiting in a sort variety of terrestrial biomes, and negatively affecting ecosystems around the world (Eldridge et al., 2020). Factors such as having few predators, high survival, environmental tolerance, mobility and dispersal ability, as well as high resistance to diseases, make horses dominant over many native species (Scorolli, 2016).

There is a handful literature documenting the effects of feral horses on vegetation, soils, hydrology, and wildlife (Baur et al., 2017; Beever & Brussard, 2000; Beever & Herrick, 2006; Boyd et al., 2017; Cherubin et al., 2019; De Villalobos & Schwerdt, 2017; Robertson et al., 2019). Available studies have synthesized information of horse’s impact on ecosystems at regional/local scale; for example, Nimmo and Miller (2007) conducted a review of the ecological and human dimensions of horse management in Australia; Driscoll et al. (2019) synthesized the impact of wild horses in the Kosciuszko National Park, Australia; Davies and Boyd (2019) analyzed the available information of ecological effects of horse grazing on the native grasslands of North America; Scorolli (2016, 2018) compiled and analyzed information on the ecological consequences and the management of feral horses in Argentina. Recently Eldridge et al. (2020) carried out a global scale meta-analysis of potential impacts of feral horses on the structure, functionality, and composition of ecosystems. Most available information is focused on plants and soils, whereas the effects of horse presence on native wildlife vary from one study to another, focusing primarily on iconic species. For this reason, previous authors did not assess the effects of horse presence in specific taxa such mammals. Therefore, it is necessary to summarize the effect of horses on mammal species to inform and improve decision making.

Horses can affect wildlife directly by competing for resources or indirectly by altering structural components of the habitat, such as vegetation and soil (Cherubin et al., 2019; Eldridge et al., 2019; Gooch et al., 2017; Hall et al., 2016; Perry et al., 2015). Information about the effects of horse presence on the wildlife and the regions where this occurs is of great importance for the conservation of wildlife associated with horse grazing sites. We conducted a global-scale literature review to identify and summarize the effects of horse presence on wild mammals. The aim of this study was to spatially identify the available literature, determine the most common methodological approach and variables used to evaluate the effect of horse presence on wild mammals, and to classify these effects in direct or indirect.

MATERIALS AND METHODS

RESULTS

In total, 366 articles were found, but only 14 described effects of horse presence on wild mammals. We observed an increasing number of publications, where three (22%) of the 14 documents evaluated, were published between 1985 and 2000, two (14%) between 2001–2010, and nine (64%) during the last decade (2011–2020) (Appendix 1). The reviewed studies were aggregated in three countries: nine in the United States (64%), four in Australia (29%), and one in India (7%) (Fig. 1). Eight studies were focussed on ungulates (57%), seven on rodents (50%), and only one on carnivores (3%).

The 14 articles evaluated showed most studies were correlational (n = 72%), followed by the natural experiment (n = 21%) and controlled experiments (n = 7%) (Appendix 2, Table 3). Responses evaluated were highly variable between taxonomic groups. The assessed response variable most
used was abundance (n = 9), followed activity patterns (n = 6), species richness (n = 5), behavior (n = 4), habitat use (n = 3), detectability (n = 1), occupation (n = 1) and occurrence (n = 1) (Fig. 2).

Significant differences were observed between the presence of horses with regard the mammal sub-group studied ($X^2 = 12.34, p < 0.05$). The presence of horses reported direct effects on carnivores (n = 1) and ungulates (n = 8), whereas the effect on rodents reported was mostly indirect (n = 6). The only study that evaluated the effect of horse presence on carnivores determined a direct effect on daily activity patterns; at waterholes where the horses frequently visit, the records of native species was significantly lower compared to bodies of water where horses were excluded. The presence of horses was associated with soil compaction, changes in vegetation such as lower species richness, lower percentage of coverage and, lower height, and abundance of grasses and shrubs. These alterations in the structural components of the habitat caused changes in the number of refugees, abundance, activity, use of habitat, occupation, and occurrence of rodents. One study determined the direct effect of the presence of horses on the richness, abundance, and daily activity of rodents in bodies of water, these being higher in sites excluding horses. For studies analyzing the effect of horses on ungulates, water was the most limiting factor on visits, time spent at sites decreased with horse presence. Species richness and abundance showed a decrease in sites frequently visited by horses compared to sites where horses were excluded (Table 2).

Fig. 1. Global distribution of studies evaluating the impact of feral horses on populations of wild mammals.
Fig. 2. Types of variable response used to evaluate the effect of horse grazing on wild mammals.

### TABLE 2
Effect of horse presence on wild mammals by taxonomic sub-group

| Taxonomic group | Effect of the presence of horses                                                                 | Reference |
|-----------------|--------------------------------------------------------------------------------------------------|-----------|
| Carnivores      | Change in daily activity. Less number of visits and time of use of water source.                 | Hall et al. (2016). |
| Rodents         | A decline in richness and abundance.                                                            | Beever and Brussard (2000). |
|                 | Changes in abundance.                                                                           | Beever and Brussard (2004). |
|                 | A decrease in the abundance of burrows and individuals.                                         | Ward–Fear et al. (2016). |
|                 | Less number of visits and time of use of the water sources.                                     | Hall et al. (2016). |
|                 | A decrease in the probability of occupancy.                                                      | Cherubin et al. (2019). |
|                 | A decrease in the use of habitat.                                                               | Eldridge et al. (2019). |
|                 | A decrease in occurrence and abundance.                                                          | Schulz et al. (2019). |
| Ungulates       | Subordinate during interactions with horses.                                                     | Berger (1985). |
|                 | Improved foraging performance and change in habitat use.                                       | Coates and Schemnitz (1994). |
|                 | Changes in abundance.                                                                           | Ostermann–Kelm at al. (2008). |
|                 | Subordinate during interactions with horses.                                                     | Perry et al. (2015). |
|                 | Less number of visits and time of use of water sources.                                         | Hall et al. (2016). |
|                 | Increased time in surveillance behavior and decrease in foraging time. Subordinate                | Gooch et al. (2017). |
|                 | during interactions with horses.                                                                |           |
|                 | A decrease in the frequency of use of water sources. Change in the daily activity pattern in    |           |
|                 | water sources.                                                                                  |           |
|                 | A decrease in density concerning the distance of the horses.                                    | Arandhara et al. (2020). |
During the initial search, the results showed a large number of studies, but after a detailed review, we found only a small number of articles analyzed the effects of horse presence on wild mammals. This pattern was also found by Eldridge et al. (2020), showing a lack of knowledge of the impact of horse presence on wild mammals. There seems to be a growing interest in understanding the effect of horse presence on wild mammals, but the increase in the number of publications is a general trend in many fields (Lisón et al., 2019).

Regarding the study sites, most of the research was conducted in the United States. In the early 1970s areas devoted to horse management in the United States covered 36.67 million hectares, and currently half of that still embraces horse populations in threatened ecosystems (Beever et al., 2018). Additionally, stakeholders such as ranchers, animal rights advocates, hunters, conservationists, and horse advocates are increasingly pushing decision-makers to adopt more rigorous, science-based methods and analysis to justify management actions (Beever, 2003). These factors have contributed to the high number of studies in the United State.

Our results indicated studies frequently focus on iconic species, agreeing with the results of Eldridge et al. (2020). Most studies analyzed the effects of horses on charismatic ungulates such as the pronghorn (*Antilocapra americana*) or the bighorn sheep (*Ovis canadensis*) (Coates & Schemnitz, 1994; Gooch et al., 2017; Hall et al., 2018; Ostermann-Kelm et al., 2008). Studies based on rodents also showed a trend to use charismatic species, such as the toothed rat (*Mastacomys fuscus*), a near-threatened rodent endemic to the mountainous regions of southeastern mainland Australia and Tasmania (Cherubin et al., 2019; Eldridge et al., 2019; Schulz et al., 2019). Moreover, few studies evaluated the effect of horses at community level (Beever & Brussard, 2004; Hall et al., 2016), requiring that future research tackle functional and structural changes caused by horse presence in ecosystems and biotic communities (Eldridge et al., 2020).

Most studies evaluated the effect of horses by correlating grazing factors with response variables such as abundance, activity, or behavior of wild mammals, often in combination with other environmental covariates (e.g., soil compaction, vegetation cover, water availability). Some studies used existing ranch fences to exclude horses from bodies of water or pasture areas and thus evaluate the effect of horses on mammals (Beever & Brussard, 2000, 2004; Hall et al., 2016); however, the fact that only one study was experimental suggested the difficulty of logistics to carry out experiments and manipulate populations in the wild (Mishra et al., 2004). This could explain the low number of studies devoted to evaluating the effects of horses on wildlife.

The effects of horse presence on a global scale are consistent at regional and local scales (Davies & Boyd, 2019; Eldridge et al., 2020; Nimmo & Miller, 2007). Although the effects in mammals can be varied (Eldridge et al., 2020), this review shows a pattern of effect with regard the taxonomic group. Carnivores and ungulates showed direct effects due competition with horses, whereas rodents seem to respond primarily to changes that horses cause in the structural components of the habitat. A similar pattern was observed by Schieltz and Rubenstein (2016) who conducted a review of the impacts of livestock (excluding horses) on wildlife; the study suggested changes in structure and vegetation cover were significant for small mammals, and also the interference competition as result of horse presence as the most important trigger of negative responses on ungulates. For such large mammals changes in habitat structural components showed a positive effect, hence the open spaces made by large ungulates can shape the composition of plant communities and increase spatial heterogeneity (Bakker & Olff, 2003; Eldridge et al., 2020), though, in some cases the change caused by horse presence is often negative for habitat components and wildlife.

This review also identified patterns and current knowledge gaps about the effect of horse presence on wild mammals, therefore the summary carried out in this study can help to readdress
further research by providing an organized summary of the spatial distribution information, methodological approaches, and variables used according to the different taxonomic groups. Finally, maintaining horse populations in protected areas could be contrary to conservation objectives. However, determining whether horse management within protected areas has positive or negative effects depends on ad-hoc management aims and the ecological and social implications, which may vary geographically, so it is desirable to support these management actions with empirical evidence. Owing to this, we recommend careful monitoring of horses and their potential effects on wildlife by using species proxies such as ungulates and rodents to determine whether horse presence in protected areas affects conservation objectives.

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ETHICAL, CONFLICT OF INTEREST AND FINANCIAL STATEMENTS

The authors declare that they have fully complied with all pertinent ethical and legal requirements, both during the study and in the production of the manuscript; that there are no conflicts of interest of any kind; that all financial sources are fully and clearly stated in the acknowledgments section; and that they fully agree with the final edited version of the article. A signed document has been filed in the journal archives.

The declaration of the contribution of each author to the manuscript is as follows:
B.H.M.C.: Literature review, analysis and writing the manuscript. E.C.J., V.M.G. and R.S.P. writing and review of the manuscript.

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**APPENDIX**
Appendix 1

A list of 14 articles included analyzing the effect of horses on wild mammals:

Arandhara, S., Sathishkumar, S., & Baskaran, N. (2020). Modelling the effect of covariates on the detectability and density of native blackbucks and invasive feral-horse using multiple Covariate distance sampling at point Calimere wildlife sanctuary, southern India. Mammalian Biology, 100(2), 173-186. https://doi.org/10.1007/s42991-020-00018-w.

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### Appendix 2

**ESTA TABLA NO ESTA MENCIONADA EN EL CUERPO DEL TEXTO**

#### TABLE 3

Classification of the 14 articles selected to analyze the effect of horses on wild mammals.

| Year | Country | Group | Study type | Response | Effect type | Reference               |
|------|---------|-------|------------|----------|-------------|-------------------------|
| 1985 | EE. UU  | Ungulates | Cor | B | Direct | Berger (1985). |
| 1994 | EE. UU  | Ungulates | Cor | B, HU | Direct | Coates & Schernnitz (1994). |
| 2000 | EE. UU  | Rodents | NE | R | Indirect | Beever & Brussard (2000). |
| 2004 | EE. UU  | Rodents | NE | A, R | Indirect | Beever & Brussard (2004). |
| 2008 | EE. UU  | Ungulates | CE | A, DA | Direct | Ostermann-Kelm et al. (2008). |
| 2015 | EE. UU  | Ungulates | Cor | B, DA | Direct | Perry et al. (2015). |
| 2016 | Australia | Rodents | Cor | A | Indirect | Ward-Fear et al. (2016). |
| 2016 | EE. UU  | Carnivores, Ungulates, Rodents | NE | A, DA, R | Direct | Hall et al. (2016). |
| 2017 | EE. UU  | Ungulates | Cor | B | Direct | Gooch et al. (2017). |
| 2018 | EE. UU  | Ungulates | Cor | DA, HU | Direct | Hall et al. (2018). |
| 2019 | Australia | Rodents | Cor | O | Indirect | Cherubin et al. (2019). |
| 2019 | Australia | Rodents | Cor | HU | Indirect | Eldridge et al. (2019). |
| 2019 | Australia | Rodents | Cor | A, OC | Indirect | Schulz et al. (2019). |
| 2020 | India   | Ungulates | Cor | A, D | Direct | Arandhara et al. (2020). |

Study type: CE= Controlled experiment, Cor= Correlational, NE= Natural experiment.
Response: A= Abundance, B= Behavior, D= Detectability, DA= Daily activity, HU= Habitat use, O= Occupancy, OC= Occurrence, R= Richness.