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Review of the ecological role of the American Bison (Bison *bison*) to identify the potential effects of its reintroduction in the ecosystems of Northern Mexico

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The reintroduction of the American bison (*Bison bison*) in Mexico has important implications for the ecosystems they will inhabit, given their critical ecological role as keystone species and ecosystem engineers. The objective of this work was to analyze the information published on the effects of the American bison to understand its potential impacts on the ecosystems of northern Mexico. Three search engines (Web of Science, Google Scholar, and ProQuest) were used to conduct a systematic review. The studies (n = 75) spanned a 29–year period (1995-2024), with the majority (66) reporting positive effects for grasslands, and only six reporting negative effects. The most frequently reported factors associated with bison activity were grazing, its sole presence without specifying intervening factors, dung, wallows, and the relationship with fire dynamics, mainly influencing grassland vegetation, mammals, birds, arthropods, and nutrient recycling. The review results suggest that reintroducing bison within their historical range in Mexico would contribute to grassland restoration if the carrying capacity is not exceeded.

Keywords: Ecological effects, ecosystem engineer, grassland restoration, keystone species, species reintroduction.

La reintroducción del bisonte americano (*Bison bison*) en México tiene implicaciones importantes para los ecosistemas que habitarán, debido a su papel ecológico crítico como especie clave e ingeniero del ecosistema. El objetivo de este trabajo fue analizar la información publicada sobre los efectos del bisonte americano para comprender sus potenciales impactos en los ecosistemas del norte de México. Se utilizaron tres motores de búsqueda (Web of Science, Google Scholar y ProQuest) para realizar una revisión sistemática. Los estudios (n = 75) cubrieron un período de 29 años (1995–2024) y la mayoría (66) reportó efectos positivos para los pastizales y solo seis efectos negativos. Los factores asociados con la actividad de los bisontes reportados con mayor frecuencia fueron el pastoreo, su presencia sin especificar factores, el estiércol, los revolcaderos y su relación con la dinámica del fuego, que influyen principalmente en la vegetación de pastizal, los mamíferos, las aves, los artrópodos y el reciclaje de nutrientes. Los resultados de la revisión sugieren que reintroducir bisontes en el área de distribución histórica en México contribuirá a restaurar los pastizales mientras no se exceda la capacidad de carga.

Palabras clave: Efectos ecológicos, especies clave, ingenieros de los ecosistemas, restauración de pastizales, reintroducción de especies

The American bison (*Bison bison*) is the largest terrestrial mammal in North America. Its historical distribution ranges from Alaska in the United States to northern Mexico, specifically in the states of Chihuahua, Coahuila, and Sonora, occasionally extending as far south as Zacatecas and Durango (List *et al.* 2007; Martin *et al.* 2022).

Although estimates of bison numbers in North America before European colonization are uncertain, the introduction of Old World diseases, like smallpox (Patterson and Runge 2002), led to the collapse of Native American populations and the subsequent abandonment of formerly managed lands, which, in turn, allowed the expansion of native vegetation (Koch *et al.* 2019; Shaw 2021). These ecological changes allowed bison numbers to reach a peak of 30–60 million individuals by the early 19th century (Seton 1927; McHugh 1979; Shaw 1995).

However, in the following decades, bison numbers decreased drastically–to fewer than 500 individuals–due to a combination of factors, including U.S. government efforts to subjugate Native Americans and to eliminate competition with cattle (Gates *et al.* 2010; Di Silvestro 2023), the immense demand for their hides (Isenberg 2000; Taylor 2011), and contributing factors such as drought (Bryson 1974). In Mexico, reports of their presence ceased in the second half of the 19th century (List *et al.* 2007), but the process that led to their demise has not been documented.

The bison was saved from extinction by timely actions to protect and reproduce the remaining individuals, to the extent that the recovery of bison in North America is considered one of the major successes in species conservation. Currently, approximately 400,000 individuals exist in conservation and commercial herds in North America, inhabiting grasslands, forests, wetlands, scrublands, tundra, induced grasslands, and pastures (USFWS 2022; Di Silvestro 2023). The bison population in Mexico is estimated to be ca. 3,000 individuals distributed across 33 private herds, nine zoos, one run by the Mexican Army, and three conservation herds (A. Esquer pers. comm.).

Bison recovery in Mexico is recent; in 2009, 23 bison were reintroduced from Wind Cave National Park in South Dakota, United States, to Rancho El Uno, located within the Janos Biosphere Reserve, Chihuahua (CONANP 2019). By August 2025, this population had grown to approximately 540 individuals, according to the manager of the herd (I. Sarellano, pers. comm.). Subsequently, from the herd of El Uno, 3 additional conservation herds have been established: 39 bison were relocated to El Carmen Reserve, within the Maderas del Carmen Flora and Fauna Protection Area, where 140 individuals were present in September 2025, according to the Conservation Director of the Reserve (A. Espinosa Treviño, pers. comm.). Forty-four individuals were relocated to El Santuario Reserve within the Cuatrociénegas Flora and Fauna Protection Area in Coahuila in November 2025. The most recent herd was established in Agua Prieta, Sonora, in March 2026 with 23 individuals from El Uno.

While bison avoided population extinction, their dramatic reduction altered the ecosystems they originally occupied, as bison are widely recognized as keystone species and ecosystem engineers. Behaviors such as wallowing (rolling on the ground in the same spots), scratching, rubbing horns against trees, foraging, browsing, and trampling affect the structure, composition, and dynamics of ecosystems by facilitating ecological processes such as seed dispersal, nutrient recycling, fire dynamics, and the maintenance of ecosystem structure (Frank and Evans 1997; Knapp *et al.* 1999; Fuhlendorf *et al.* 2008; Eyheralde 2015; Nickell *et al.* 2018). Recognizing that despite the numerical recovery of bison, its ecological role is largely absent on most of its range, conservation efforts now focus on the recovery of the functions they performed in ecosystems (Sanderson *et al.* 2008).

In Mexico, 40.1% of native grasslands have been lost, and 38.9% of the remainder are degraded (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad 2022), highlighting the urgent need for restoration. We hypothesized that, given the bison's role as a keystone and engineer species in the grasslands and shrublands of its former range, reintroducing bison could serve as a tool for grassland restoration by recovering ecological processes and increasing grassland-associated species.

Because the reintroduction of bison within their historical range in Mexico is being actively proposed and implemented, further information is needed to predict both the beneficial (positive) and potentially detrimental (negative) ecological effects on grasslands of establishing new herds. The objective of this work was to understand the ecological role of the North American bison through a systematic review of the scientific literature. This information will help to assess the potential impacts of future reintroductions in northern Mexico, support decision-making for the species' management and conservation, and identify research priorities at sites where bison herds have already been established.

Materials and methods

Systematic review. A systematic review of the ecological effects of American bison was conducted, supported by the PRISMA 2020 flow diagram (Page *et al.* 2021). Three search engines were used: Web of Science, Google Scholar, and ProQuest, in March 2024 and July 2025. The following keyword combinations were used: «bison+keystone-species», «bison+ecosystem-function», «bison+ecological-role», «bison+ecological-impact», «bison+ecosystem-impact», «bison+ecological-importance», «bison+environmental-function», «bison+environmental-impact», «bison +engineer», «bison+ecological-processes», and «bison+re-introduction».

In all three search engines, scientific articles were considered; additionally, theses were included in Google Scholar and ProQuest. A total of 88,772 results were retrieved across all search engines and keyword combinations. For each search, the first 100 titles (3,300 in total) were reviewed, as relevance decreased significantly after the first 50 titles, and by the hundredth title, no further useful entries were found.

The publication selection process was carried out in four stages (Figure 1): 1) Title screening: From the initial 3,300 titles, 344 were selected based on relevance to the study objective. Screening was conducted by one author (AE). 2) Abstract screening: Abstracts of these 344 publications were reviewed by the same author, narrowing the selection to 242. 3) Duplicate removal: Duplicate entries were removed, resulting in 149 unique publications. 4) Full-text review: The remaining publications were read in full, yielding 75 publications that met all inclusion criteria and were used in the study.

Database. A database was compiled from the selected publications, including reports of ecological effects of bison, whether positive, negative, or neutral (Supplementary Data SD1). In this study, positive effects are defined as those that contribute to grassland conservation or restoration, like an increase in density or diversity of native grassland species, or the reduction of woody plants; negative effects are those that degrade grassland ecosystems; and neutral effects are those with no direct applicability to grasslands in Mexico.

For positive effects, we also recorded whether the reported outcomes were statistically significant or not, as stated by the original publications. For negative effects, we did not categorize by statistical significance because the number of negative reports (n = 6) was too small to justify this distinction.

The database included the following fields: 1) Publication information: Title, year of publication, study duration, study location, and ecosystems under study. 2) Effect outcome:

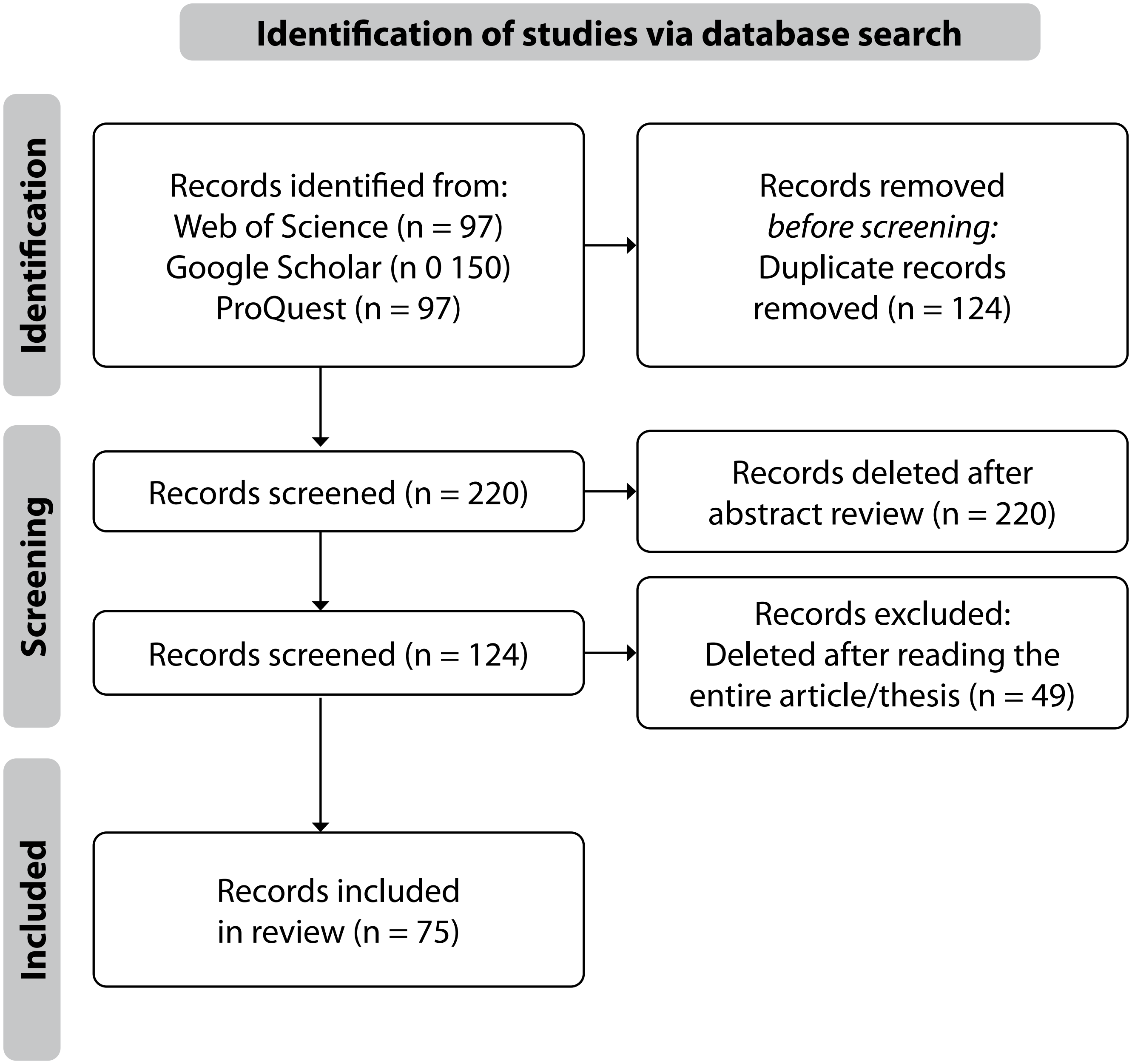

Figure 1. PRISMA 2020 flow diagram showing the different phases of the systematic review of the ecological impact of American bison.

Positive, negative, neutral. 3) Bison factor associated with the ecological effect (e.g., its sole presence without specifying the factor causing the effect; movement; trampling; grazing–whether focused solely on bison, compared to cattle, or compared to ungrazed sites; horning; browsing; dunging; urination; wallowing; carcass presence; hair; and influence on fire dynamics). 4) We grouped the associated effects with bison presence or behavior into three main categories: effects on fauna, effects on flora, and effects on the ecosystem. Within each category, specific ecological impacts were recorded and analyzed. 5) Effect on fauna: Mammals, birds, amphibians, arthropods, and microbial communities. 6) Effect on flora: Grassland vegetation, riparian vegetation, woody vegetation, and seeds. 7) Other ecosystem effects: Soil, trails, aboveground net primary productivity (ANPP), nutrient cycling, ephemeral ponds, water quality, and fungi.

Results

Systematic review. After screening 3,300 titles, 75 publications (1995–2024) met the inclusion criteria. The earliest publication was from August 1995; the number of studies on bison ecological effects has increased steadily, particularly since 2019 (Figure 2). Most publications were conducted in the United States (88%), with fewer in Canada (7%) and Mexico (2%) (Figure 3). The most frequently studied sites were Konza Prairie Biological Station (KPBS; 18 publications), Nachusa Grassland (NG; 15), Yellowstone National Park (YNP), and Tallgrass Prairie Preserve (7 each). All publications involved grasslands (tallgrass, mixed-grass, or shortgrass prairie), with some also including riparian or forested areas (Figure 4).

General effects. Effects on both fauna and flora were reported. Most publications (46 of 75) reported only one type of effect, while the remaining 29 publications reported

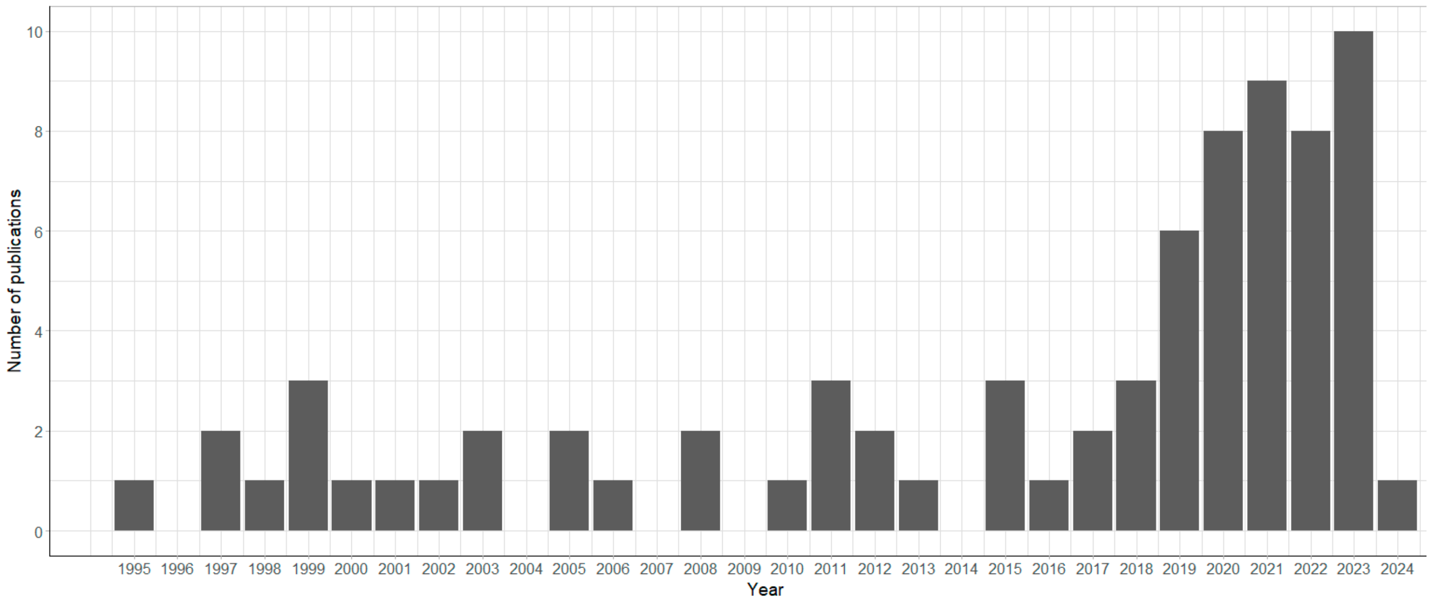

Figure 2. Number of publications per year on the ecological effects of bison from 1995 to 2024.

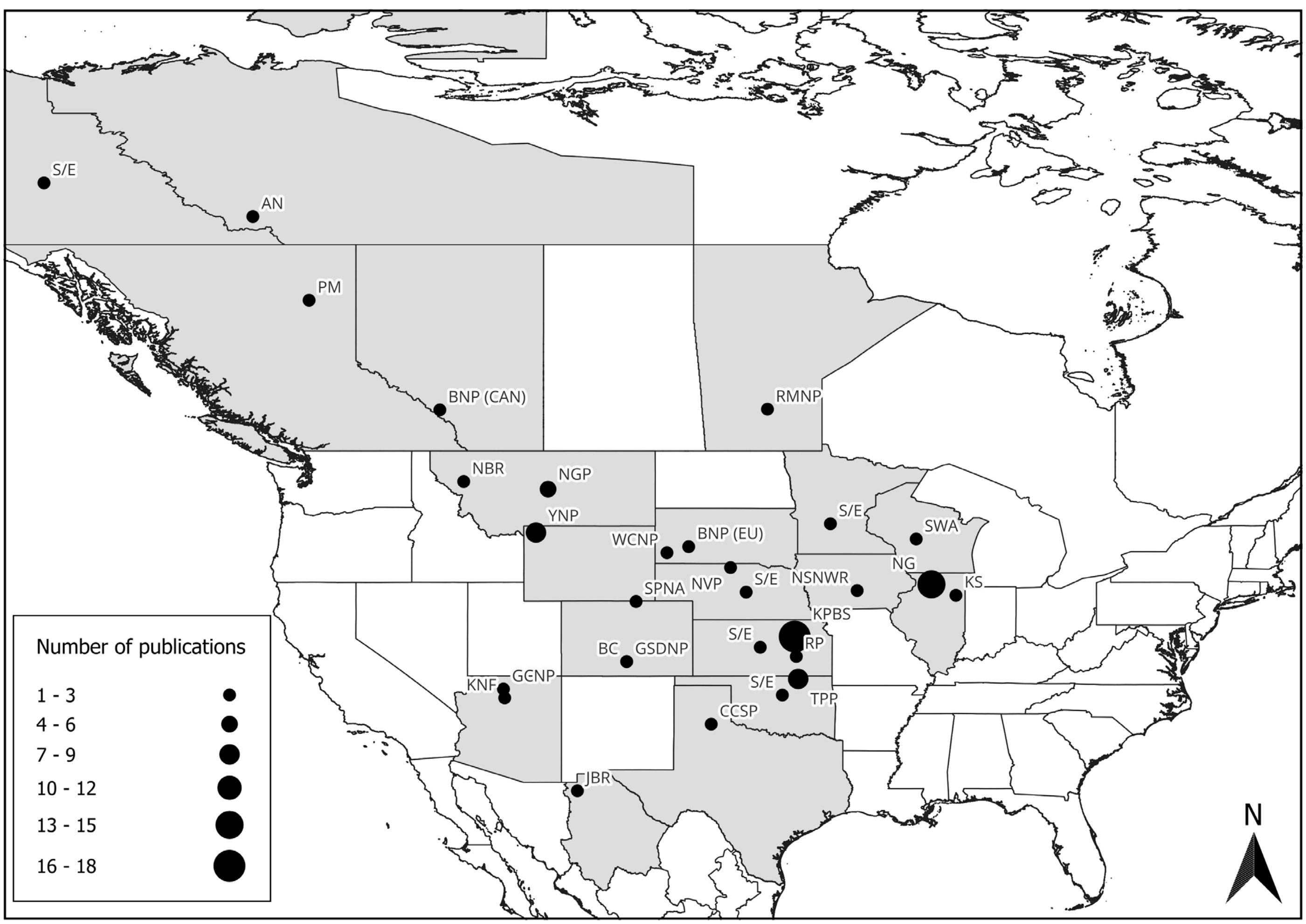

Figure 3. Sites where the publications included in the systematic review on the ecological effects of bison were conducted. The size of the circles represents the number of publications published from each site. United States site codes: Barber County (BC), Badlands National Park (BNP), Caprock Canyons State Park & Trailway (CCSP), Great Sand Dunes National Park (GSDN), Grand Canyon National Park (GCNP), Kaibab National Forest (KNF), Konza Prairie Biological Station (KPBS), Kankakee Sands (KS), National Bison Range (NBR), Nachusa Grasslands (NG), Northern Great Plains (NGP), Neal Smith National Wildlife Refuge (NSNWR), Niobrara Valley Preserve (NVP), Oklahoma State University Research Range (OSURR), Rannells Pastures (RP), Soapstone Prairie Natural Area (SPNA), Sandhill Wildlife Area (SWA), Joseph H. Williams Tallgrass Prairie Preserve (TPP), Wind Cave National Park (WCNP) and Yellowstone National Park (YNP); Canada site codes: Aishihik and Nahanni (AN), Banff National Park (BNP), Pink Mountain (PM) and Riding Mountain National Park (RMNP); Mexico site code: Janos Biosphere Reserve (JBR); Unspecified "others" site codes (S/E): Nebraska, Kansas, Oklahoma, Minnesota (United State) and Yukon (Canada).

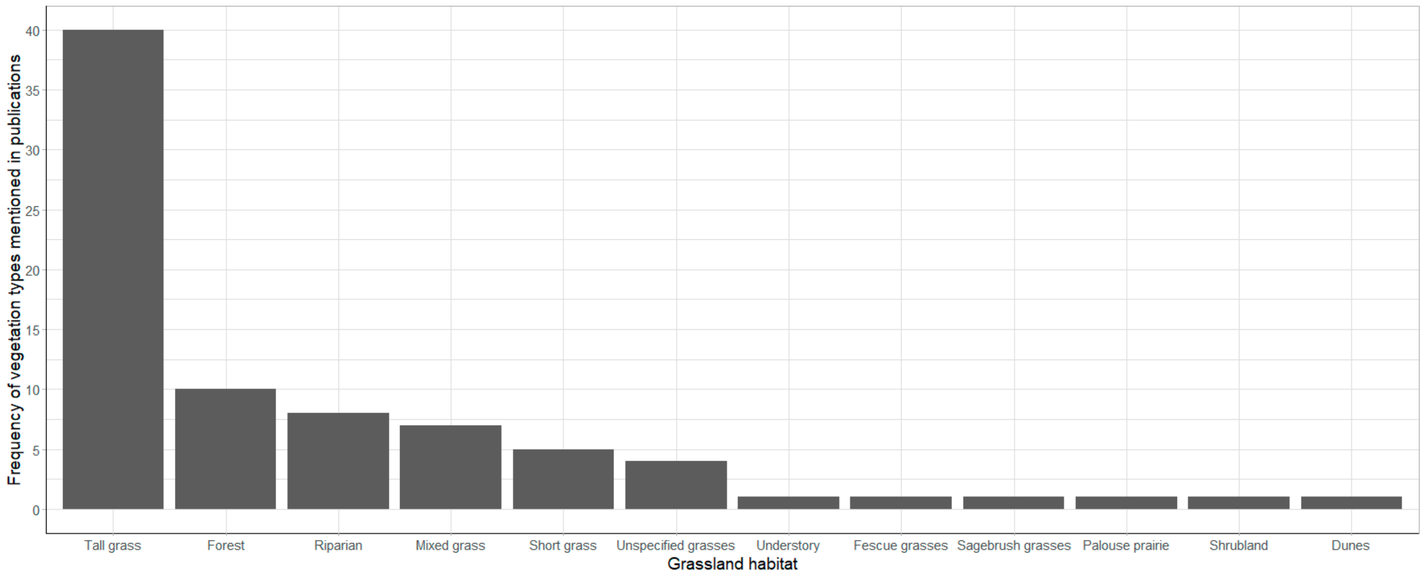

Figure 4. Number of publications per habitat type reporting ecological effects of bison.

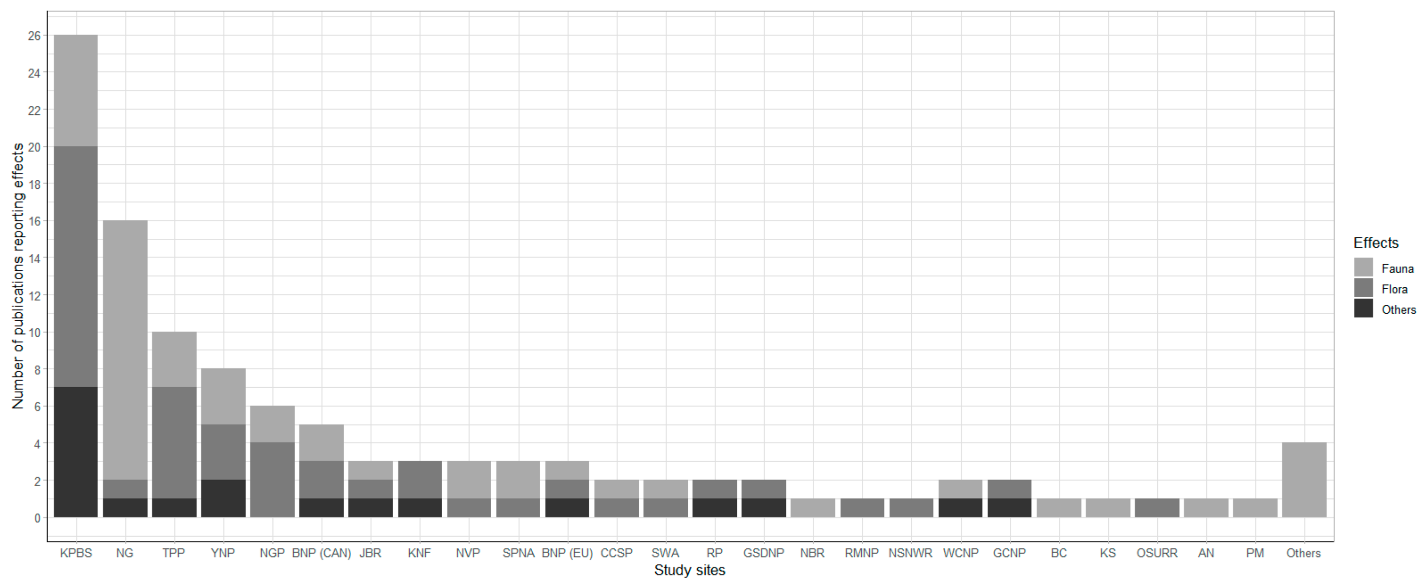

Figure 5. Number of publications of fauna (species, species group: mammals, birds, amphibians, arthropods, and microbes), flora (grassland vegetation, riparian vegetation, woody vegetation, and seeds), and others (soil, trails, ANPP, nutrient recycling, ephemeral ponds, water quality, and fungi) reporting effects generated by bison at each study site. United States site codes: Barber County (BC), Badlands National Park (BNP), Caprock Canyons State Park & Trailway (CCSP), Great Sand Dunes National Park (GSDN), Grand Canyon National Park (GCNP), Kaibab National Forest (KNF), Konza Prairie Biological Station (KPBS), Kankakee Sands (KS), National Bison Range (NBR), Nachusa Grasslands (NG), Northern Great Plains (NGP), Neal Smith National Wildlife Refuge (NSNWR), Niobrara Valley Preserve (NVP), Oklahoma State University Research Range (OSURR), Rannells Pastures (RP), Soapstone Prairie Natural Area (SPNA), Sandhill Wildlife Area (SWA), Joseph H. Williams Tallgrass Prairie Preserve (TPP), Wind Cave National Park (WCNP) and Yellowstone National Park (YNP); Canada site codes: Aishihik and Nahanni (AN), Banff National Park (BNP), Pink Mountain (PM) and Riding Mountain National Park (RMNP); Mexico site code: Janos Biosphere Reserve (JBR); Unspecified "others" site codes: Nebraska, Kansas, Oklahoma, Minnesota (United State) and Yukon (Canada).

two or more effects. Among the 26 identified study sites, 19 sites reported effects on fauna (13 positive on mammals, 11 on birds, 1 on amphibians, and 8 on arthropods; 1 negative on mammals, 2 negative on birds and arthropods; 2 neutral on mammals and arthropods), 19 on flora, and 12 on other ecosystem components (Figure 5, Supplementary Data Table S1).

The majority of publications reported positive ecological outcomes (66 out of 75), followed by negative (6) and neutral (4) outcomes (Figure 6).

Bison factors that report an ecological effect. Grazing was the most frequently reported factor linked to ecological effects (43 studies). Other common factors included bison presence (17 studies), fire dynamics (16 studies), dung deposition (10 studies), and wallowing (10 studies) (Figure 7). Fire dynamics refers to the feedback between bison grazing and fire regimes, where bison preferentially graze recently burned areas, enhancing grassland heterogeneity (Fuhlendorf *et al.* 2008). Wallowing creates shallow depressions that alter soil properties and form microhabitats (Nickell *et al.* 2018).

Effects of bison on fauna. Bison influenced five taxonomic groups: mammals (16 publications, 31 species), birds (13 publications, 101 species), amphibians (1 publication, 2 species), arthropods (12 publications, 158 species), and microbial communities (6 publications, 34 phyla).

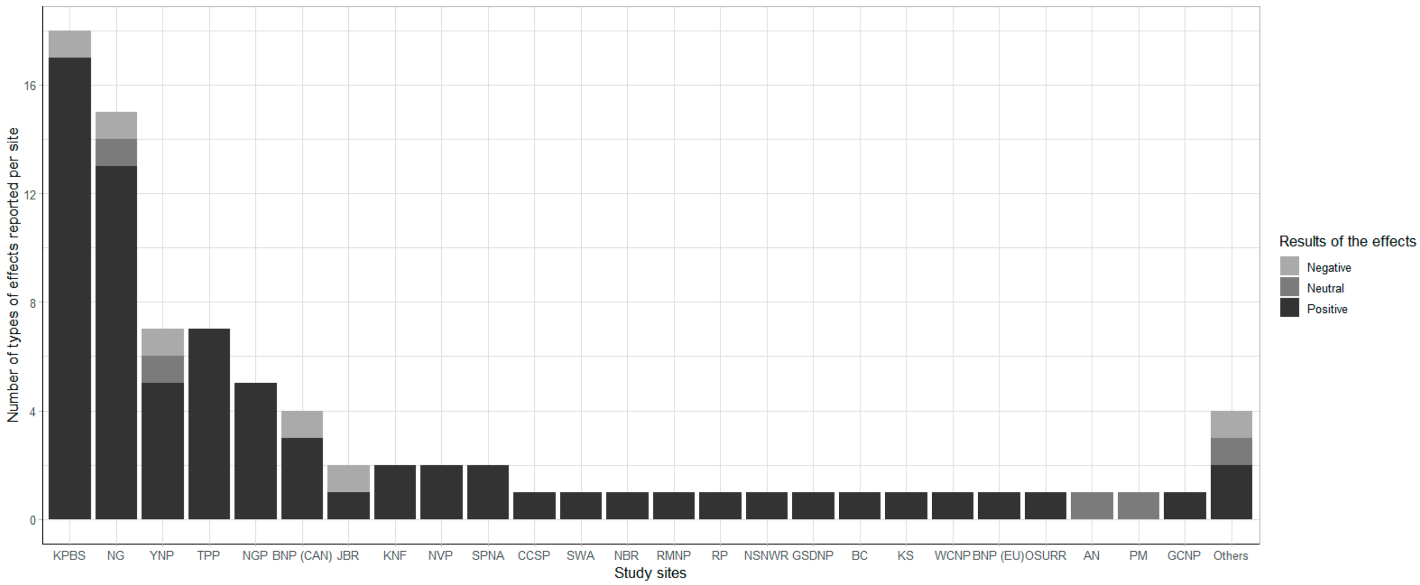

Figure 6. Number of positive (66), negative (6), and neutral (4) results in relation to temperate grassland conservation or restoration (positive, and if this result is statistically significant, not significant, negative, or neutral), on the ecological effects of bison at each study site. In this review, positive effects are defined as those that contribute to grassland conservation or restoration; negative effects are those that degrade grassland ecosystems; and neutral effects are those with no direct applicability to grasslands in Mexico. United States site codes: Barber County (BC), Badlands National Park (BNP), Caprock Canyons State Park & Trailway (CCSP), Great Sand Dunes National Park (GSDN), Grand Canyon National Park (GCNP), Kaibab National Forest (KNF), Konza Prairie Biological Station (KPBS), Kankakee Sands (KS), National Bison Range (NBR), Nachusa Grasslands (NG), Northern Great Plains (NGP), Neal Smith National Wildlife Refuge (NSNWR), Niobrara Valley Preserve (NVP), Oklahoma State University Research Range (OSURR), Rannells Pastures (RP), Soapstone Prairie Natural Area (SPNA), Sandhill Wildlife Area (SWA), Joseph H. Williams Tallgrass Prairie Preserve (TPP), Wind Cave National Park (WCNP) and Yellowstone National Park (YNP); Canada site codes: Aishihik and Nahanni (AN), Banff National Park (BNP), Pink Mountain (PM) and Riding Mountain National Park (RMNP); Mexico site code: Janos Biosphere Reserve (JBR); Unspecified "others" site codes: Nebraska, Kansas, Oklahoma, Minnesota (United State) and Yukon (Canada).

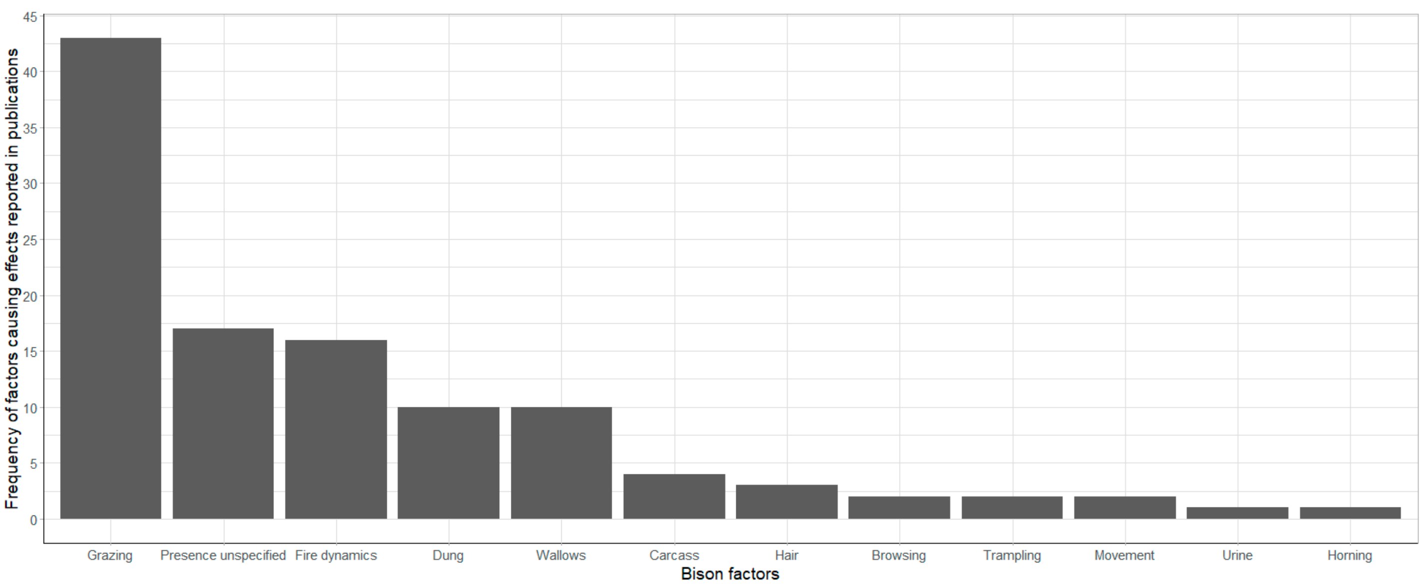

Figure 7. Frequency of factors related to bison activity, behavior, or excretions that generate ecological effects.

Most effects were positive (Table 1). Positive outcomes included increased species presence, diversity, and abundance for mammals and arthropods, and increased presence, diversity, and abundance for birds, although one publication reported a decrease in bird abundance, and contradictions exist depending on grassland type and location. Only nine of the 48 fauna publications reported non-significant results (Table 2).

Effects of bison on flora and ecosystem processes. Effects on flora were concentrated on grassland vegetation (31 studies), with fewer publications on riparian (7) and woody vegetation(5), and seeds (2) effects. Positive outcomes dominated vegetation across all vegetation types, including increased plant diversity, richness, and quality (Tables 3 and 4). Among other ecosystem components, bison influenced soil properties, trails, aboveground net primary productivity, nutrient cycling, ephemeral ponds, water quality, and fungi; effects were generally positive and frequently significant (Tables 5 and 6).

The effects on flora were grouped into four categories: Effects on flora were concentrated on grassland vegetation (31 publications), with fewer publications on riparian (7) and woody vegetation (5), and seeds (2) effects. Positive outcomes dominated across all vegetation types, including increased plant diversity, vegetation, richness, and quality (Tables 3 and 4). Among other ecosystem components,

Table 1. Number of publications per taxonomic or functional groups (n = 48) classified by effect result. The results of the effect are classified as positive (statistically significant or not significant), negative, or neutral. In this review, positive effects are defined as those that contribute to grassland conservation or restoration; negative effects are those that degrade grassland ecosystems; and neutral effects are those with no direct applicability to grasslands in Mexico.

	Group of species				
Effect result	**Mammals**	**Birds**	**Amphibians**	**Arthropods**	**Microbes**
Significant	11	7	1	7	5
No significant	2	4		3	
Total Positive	13	11	1	10	5
Negative		2		2	1
Neutral	3				
Total publications*	16	13	1	12	6

*The total number of publications per taxon is the sum of publications with positive, negative and neutral results. Positive results include both significant and non-significant results.

Table 2. Number of publications (n = 48) reporting bison-related effects at the population or community level across major taxonomic groups. Effects include promotion of species presence, changes in abundance, and shifts in richness, diversity, or community composition.

	Group of species				
Effect	**Mammals**	**Birds**	**Amphibians**	**Arthropods**	**Microbes**
Population level					
Foster presence*	8	4	1	2	4
No effect	2	4		3	
Decline		2		2	
Abundance	1	2		2	
Community level					
Richness				1	
Diversity	2	2		2	1
Composition changes					1

*"Foster presence" refers to studies that report increased occurrence or colonization of a species or group in areas influenced by bison.

Table 3. Number of publications (n = 45) reporting outcomes of bison effects on different vegetation types in relation to temperate grassland conservation or restoration. Effects are categorized as positive (statistically significant or not significant), negative, or neutral. In this review, positive effects are defined as those that contribute to grassland conservation or restoration; negative effects are those that degrade grassland ecosystems; and neutral effects are those with no direct applicability to grasslands in Mexico.

	Vegetation			
Effect result	**Grassland vegetation**	**Riparian vegetation**	**Woody vegetation**	**Seeds**
Significant	29	5	4	2
Non-significant	2	1		
Total positive	31	6	4	2
Negative		1		
Neutral			1	
Total publications*	31	7	5	2

*The total number of publications per taxon is the sum of publications with positive, negative and neutral results. Positive results include both significant and non-significant results.

bison influenced soil properties, trails, aboveground net primary productivity, nutrient cycling, ephemeral ponds, water quality, and fungi. Effects were generally positive and frequently significant (Tables 5 and 6). Fungal activity was reported in one publication (Risch *et al.* 2020).

Discussion

Table 4. Types of vegetation responses to bison reported in 45 publications from the systematic review. Effects are grouped by vegetation type: grassland, riparian, woody, and seeds. Each cell indicates the number of publications reporting the given response. Overcompensation refers to increased productivity or growth in response to herbivory. Greening refers to early green-up following grazing or disturbance.

	Vegetation			
Effect	**Grassland vegetation**	**Riparian vegetation**	**Woody vegetation**	**Seeds**
No change	2	1		
Decrease	1	2	3	
Richness	9			1
Diversity	9	4		
Increase quality	4			
Abundance	1			
Composition changes	2		1	
Dispersal				2
Growth	1			
Expansion	1			
Overcompensation	1	1		
Greening	1			

Table 5. Number of publications (n = 22) reporting ecosystem-level changes associated with bison and their relevance to temperate grassland conservation or restoration. Effects are categorized as positive (statistically significant or not significant), negative, or neutral. In this review, positive effects are defined as those that contribute to grassland conservation or restoration; negative effects are those that degrade grassland ecosystems; and neutral effects are those with no direct applicability to grasslands in Mexico. Other effects include changes in soil properties, trail formation, aboveground net primary productivity (ANPP), nutrient cycling, creation of ephemeral ponds, water quality, and fungal activity.

	Other effects						
Effect result	**Soil**	**Trails**	**ANPP**	**Nutrient recycling**	**Ephemeral ponds**	**Water quality**	**Fungi**
Positive	4	2	3	8	1	2	1
Significant	3	2	3	7	1		1
Non-significant	1			1		2	

ANPP = Aboveground Net Primary Productivity.

Table 6. Number of publications (n = 22) reporting specific types of ecosystem dynamic changes caused by bison. Effects are organized by ecosystem component. Other effects include changes in soil conditions, trail formation, aboveground net primary productivity (ANPP), nutrient recycling, ephemeral ponds, water quality, and fungal activity.

	Other effects						
Specific effect	**Soil**	**Trails**	**ANPP**	**Nutrient recycling**	**Ephemeral ponds**	**Water quality**	**Fungi**
No alteration	1			1		2	
Increase*				4			1
Productivity	3		2	4			
Compensation**			2				
Formation of trails		1			1		

ANPP = Aboveground Net Primary Productivity

* "General increases" refer to unspecified improvements in ecosystem function as reported by the study authors.

** Compensation refers to overcompensation or increased productivity following disturbance (e.g. grazing).

Systematic review. The marked increase in the number of publications since 2019 (Figure 2) is a likely result of two parallel situations: the long-term follow-up of reintroduced herds (e.g., at Konza Prairie and Nachusa Grassland), and the urgency to address both, the recovery of species and ecological functions, as well and overall grassland conservation and restoration in the current climate change and biodiversity loss scenarios (e.g., General Assembly 2022; Banff National Park 2023; U.S. Department of the Interior 2023). Current bison reintroductions have likely fostered this research trend, leading to a more profound understanding of the species' keystone and ecosystem-engineering effects. This temporal pattern is consistent with the findings that grazing, fire dynamics, and wallowing, factors that require long-term follow-up to detect, were among the most frequently reported mechanisms (Figure 7). If monitoring in less-studied systems like the Chihuahuan Desert continues, novel effects are likely to be revealed.

Synthesis of bison effects on vegetation, associated species, and ecosystem dynamics. Grazing effects. Grazing was not only the most frequently examined factor in our review but also the most consistently linked to positive ecological outcomes. The underlying ecological process emerging from the publications is that by reducing the biomass of dominant grasses, bison increases light available to other plants and reduces competition, which in turn facilitates the establishment of subordinate forbs and grasses (Steuter *et al.* 1995; Towne *et al.* 2005; Elson and Hartnett 2017).

This mechanism explains the recurrent reports of increases in plant species richness, vegetation heterogeneity, and forb diversity across tallgrass and mixed-grass prairies (Fuhlendorf *et al.* 2008; Wilkins *et al.* 2019; McMillan *et al.* 2018; Ling *et al.* 2023). This effect is amplified by bison's highly mobile grazing behavior, which prevents the localized overgrazing characteristic of domestic cattle. From a restoration perspective, this implies that bison reintroduction can actively reverse the dominance of competitive grasses, a common occurrence on degraded, ungrazed, or cattle-grazed grasslands, without requiring mechanical or chemical intervention (Wilkins *et al.* 2019; Ratajczak *et al.* 2025).

The positive effects of bison grazing extend beyond grasslands to riparian zones, where bison activities increase vegetation heterogeneity and native species richness, shifting riparian plant communities (Reimondo 2012; Wilkins *et al.* 2019; Sze *et al.* 2023), but instead of reducing light limitation, bison likely influence plant communities through trampling, selective browsing, and soil disturbance, which create gaps for colonization by native species. This context-dependent difference underscores the importance of considering habitat-specific responses when predicting reintroduction outcomes.

The interaction between bison and fire represents an important mechanism for maintaining grassland openness and heterogeneity. Bison preferentially graze recently burned areas, a behavior that creates a positive feedback loop where grazing reduces fuel, which in turn influences fire frequency and intensity (Fuhlendorf *et al.* 2008; Blackburn *et al.* 2020). This synergy generates a shifting mosaic of vegetation patches that supports greater plant and arthropod diversity than either grazing or fire alone (Joern 2005; Ling *et al.* 2019). In the context of Mexican grasslands, where fire suppression has been widespread, reintroducing bison without also restoring fire regimes may limit the full expression of their ecological effects.

Grazing-induced vegetation changes cascade upward to fauna in six publications. The increased herbaceous cover and spatial heterogeneity created by bison support greater bird diversity (Boyce *et al.* 2022), likely by providing a diversity of nesting and foraging microhabitats. However, the effects on fossorial mammals such as gophers appear more indirect and context-dependent (Steuter *et al.* 1995). This variability suggests that faunal responses may be mediated by local soil conditions, plant community composition, and the presence of other interacting species. For Mexican reintroduction sites, predicting faunal responses will require baseline data on existing grassland bird and small mammal communities.

Dung and nutrient cycling. Bison dung goes beyond being a waste product; it operates at multi-torphic levels. Its high water content enhances soil moisture, while its organic matter fuels microbial activity, increasing both microbial biomass and diversity (Chantos 2017; Hawkins and Zeglin 2022). This microbial enrichment, in turn, accelerates decomposition and nutrient mineralization, creating hot spots of fertility in otherwise nutrient-limited grasslands. The effects cascade upward: dung beetle communities respond rapidly to bison reintroduction, and their burrowing and feeding activities further enhance soil aeration, water infiltration, and nutrient movement into deeper soil layers (Nicholas *et al.* 2019; Hosler *et al.* 2020). From a restoration perspective, this implies that bison reintroduction can prime soil food webs and nutrient cycling in degraded grasslands, processes that are slow to recover under passive restoration alone.

Wallowing and soil disturbance. Wallowing transforms the physical environment at fine spatial scales, with large ecological consequences. Wallows exhibit higher soil moisture, temperature, nutrient availability, and bulk density than adjacent grasslands (McMillan 1999). These altered conditions persist even in abandoned wallows, where water retention creates ephemeral ponds that support amphibian breeding (Gerlanc and Kaufman 2003) and generate unique arthropod assemblages, including Lepidoptera that are scarce in the surrounding matrix (Hess et al. 2014; Nickell *et al.* 2018). Wallows, therefore, are natural disturbance patches that increase overall landscape heterogeneity. For Mexican reintroduction sites, which experience pronounced dry seasons and limited surface water, wallows may become critical refugia for moisture-dependent invertebrates and amphibians.

Other ecological effects. Several less-studied bison behaviors collectively contribute to a functional portfolio that reinforces grassland resilience: Seed dispersal (epizoochory): Bison transport seeds embedded in their fur, particularly around the head and neck, dispersing native grasses and forbs across the landscape (Rosas 2003; Eyheralde 2015). This mechanism is especially valuable in fragmented grasslands where natural dispersal vectors may be scarce.

Browsing and horning: By rubbing against and breaking woody plants, bison suppress shrub encroachment, a major driver of grassland loss in the Chihuahuan Desert (Coppedge and Shaw 1997; Fredrickson *et al.* 2006; Painter *et al.* 2022). Trampling: Hoof action incorporates organic matter into soil, breaks biological crusts, and creates microsites for seed germination (Reimondo 2012). Urine deposition: Nitrogen-rich urine creates localized nutrient pulses that enhance forage quality (Frank and Evans 1997). Carrion provisioning: Bison carcasses support scavengers (e.g., coyotes, ravens, golden eagles) and drive localized nutrient pulses that alter soil microbial communities (Risch *et al.* 2020; Obermueller *et al.* 2021).

Trail formation: Bison trails may facilitate access to forage for other ungulates, potentially promoting species coexistence (Whyte *et al.* 2024).

Collectively, these behaviors confirm bison as ecosystem engineers. For restoration planning in Mexico, this means that even moderate-sized herds can deliver a suite of complementary ecological functions provided they have sufficient space to move and express these behaviors.

Effects of concern. Although the literature predominantly reports positive effects, two concerns deserve management attention. First, disease transmission (e.g., Rickettsia, EHDV) and overgrazing are not inherent properties of bison but rather emerge under high population densities or constrained movement (Kauffman *et al.* 2022). This distinction is critical: it implies that with appropriate population monitoring and proactive management (e.g., translocations, sustainable harvest), these risks can be mitigated without compromising the species' ecological benefits. Second, the lack of evidence for other potential concerns (e.g., stream degradation, competition with native herbivores) in our review does not confirm their absence; it highlights the need to monitor the effects on Mexican reintroduction sites.

Limitations influencing research. Our review identified several methodological constraints that may limit the generalization of the findings and can help define future research. Many publications were conducted within a relatively short time since reintroduction; therefore, ecological responses may require many years to decades before effects become evident (Blackburn 2018; Blackburn *et al.* 2020). This temporal constraint suggests that long-term monitoring should be included within reintroduction programs, or at least to reassess the impacts at longer intervals (ca. 10 years; Nickell et al. 2018; Nolasco *et al.* 2022).

Differences in the methods across publications reported that small founder populations may not generate detectable ecological effects (Fahnestock *et al.* 2002; Keery 2009). This is particularly relevant for the Mexican context, where most herds are smaller than the 400–1000 individuals suggested by Sanderson *et al.* (2008) as necessary to interact with 10–50% of the landscape. Future research should compare ecological outcomes across herds of different sizes and densities, ideally under similar environmental conditions.

Methodological variability across publications, including differences in environmental conditions and variables measured, makes cross-site comparisons challenging. Standardizing basic monitoring protocols across reintroduction sites would greatly enhance the cumulative value of future research. This variability is methodological but also geographical, with 88% of studies concentrated in U.S. tallgrass prairies, leaving a significant knowledge gap for semi-arid and desert grasslands like those of the Chihuahuan Desert. This reinforces the urgency of establishing and monitoring bison reintroduction sites in northern Mexico, not only for conservation but also to generate region-specific ecological data.

Potential effects of bison reintroduction in Mexico. The mechanisms documented in more humid grasslands like the tallgrass prairies -grazing heterogeneity, wallow microhabitats, dung-driven nutrient pulses- are likely to operate in the Chihuahuan Desert, but their magnitude will be constrained by lower primary productivity and reduced and less predictable precipitation. Therefore, we predict that: (1) positive effects on plant diversity will be more pronounced in wetter years or along streams; (2) wallows may serve as critical ephemeral wetlands for amphibians, invertebrates, and mesic flora; and (3) overgrazing risk is higher in these drier environments, requiring lower stocking densities and more frequent population assessments. These predictions are testable and should guide monitoring protocols at existing and future reintroduction sites within their historical Mexican range (CONANP 2019). These efforts should be accompanied by comprehensive impact assessments, adaptive management strategies and rigorous scientific monitoring.

Bison could also serve as disease reservoirs, potentially affecting livestock and native fauna. Health screening before translocation and ongoing surveillance of both reintroduced bison and surrounding domestic animals are essential to prevent zoonotic outbreaks (Pfannenstiel and Ruder 2015; Beristain-Ruiz *et al.* 2021).

Despite these concerns, the potential ecological benefits are substantial. Decades of livestock overgrazing and land-use change have driven desertification and shrub encroachment (Fredrickson *et al.* 2006; Ceballos *et al.* 2010; Archer *et al.* 2022) across northern Mexico. Bison, when present in sufficient numbers or combined with prescribed fire or mechanical shrub control, could help reverse this trend through selectively grazing, rubbing on woody vegetation, trampling, and native seed dispersal. However, these outcomes are contingent on adequate rainfall to support grass recovery. Bison-induced vegetation heterogeneity, including patch creation in both grasslands and riparian zones, may enhance plant and animal diversity (Towne *et al.* 2005; Boyce *et al.* 2022).

Socially, bison reintroduction could catalyze engaging local communities. In Mexico, most grasslands are owned by ejidos, communities, or private individuals. Establishing new conservation herds requires that landowners receive tangible benefits from ecotourism, sustainable harvest, carbon credits, or payment for ecosystem services, without which restoration efforts are unlikely to succeed.

Bison-induced vegetation heterogeneity may benefit keystone species such as prairie dogs (*Cynomys ludovicianus* and *C. mexicanus*), which depend on open grasslands (Ceballos *et al.* 1999; Miller *et al.* 2000). Furthermore, since bison coexisted with wolves historically, they have developed effective predation defense; thus, replacing cattle with bison in wolf reintroduction areas may reduce livestock predation and human-predator conflict, contributing to the recovery of the Mexican wolf (*Canis lupus baileyi*).

Bison reintroduction in northern Mexico goes beyond a species recovery project; it is a multifaceted restoration strategy with the potential to reverse grassland degradation, support endangered fauna, and engage local communities. Realizing this potential will require adaptive, science-based management that explicitly addresses the drier climate, disease risks, and socioeconomic realities of the Chihuahuan Desert.

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Declaration of Artificial Intelligence use

AI-assisted language editing (DeepSeek) was used solely to improve spelling, grammar, readability, and reference formatting. AI was not used to generate scientific content, interpret results, analyze data, identify references, or develop conclusions. All scientific content was developed, verified, and approved by the authors, who take full responsibility for the manuscript.

Author Contributions

Alejandra Espinosa and Rurik List conceptualized the study, designed the methodology, wrote the original draft, and reviewed and revised the manuscript following peer review. A. Espinosa conducted the literature review, curated the data, performed the formal analyses, and prepared the figures and tables.

Supplementary data

SD1. Database of published literature on the potential ecological effects of bison (*Bison bison*) reintroduction in ecosystems of northern Mexico. The database includes publication metadata, effect outcomes (classified as positive, negative, or neutral), and the specific bison factor associated with each effect. Ecological effects resulting from bison presence or behavior are categorized into three main domains: fauna, flora, and ecosystem processes. This supplementary data can be accessed at: https://doi.org/10.13140/RG.2.2.22691.41768

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