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Review

The Expanding Thread of Ungulate Browsing—A Review of Forest Ecosystem Effects and Management Approaches in Europe

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Abstract: In recent decades, ungulates have expanded in number and range in Europe. This review aims to analyze the impact of ungulate browsing in different forest ecosystems and identify the main driving factors and trends. In total, 155 studies were analyzed in preparing this review, across 19 European countries. In Europe, the main browsers are represented by roe deer (*Capreolus capreolus* L.), red deer (*Cervus elaphus* L.), moose (*Alces alces* L.), chamois (*Rupicapra rupicapra* L.), and fallow deer (*Dama dama* L.). Regarding browsing severity, they frequently exceeded 50%, meaning that over half of the saplings were browsed. Ungulate density was the main driving factor of browsing severity, with areas exhibiting high browsing pressure often having more than ten individuals per square kilometer. The type of silvicultural system used played a vital role in the severity of browsing, and trends in foraging for preferred tree species were identified. Fencing was the most common non-harmful protection method used, while hunting management was the most efficient method for controlling deer numbers and browsing intensity. Large carnivores were missing in most study areas, but in the areas where they were present, they played a significant role in creating a chain reaction of ecological impacts. Considering the significant impact of ungulate browsing on forest ecosystems, there is a pressing need for more research to comprehend and effectively mitigate the effects of deer presence comprehensively.

Keywords: ungulate; browsing; regeneration; forest damage; wildlife management; forest management

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1. Introduction

The main goals of wildlife management related to population size are to increase, decrease or harvest for a continuing yield [1]. In the history of wildlife conservation, game species have experienced significant population declines until effective wildlife management techniques were introduced to keep their numbers stable [2]. The most affected group of animals was that of large predators, which disappeared partially or totally in most of Europe [3]. The decline of the Brown bear (*Ursus arctos* L.), grey wolf (*Canis lupus* L.) and Eurasian lynx (*Lynx lynx* L.) during the 18th and 19th centuries was mainly due to human expansion, environmental changes and especially direct persecution by humans [4]. Due to the expansion of human activities, settlements and agriculture, coupled with deforestation and a decline in wild ungulate populations, the pressure on large carnivores escalated as they were perceived as significant threats to both livestock and human safety [5–7]. In 21st century, the large carnivores' populations have only recovered in a few European countries (e.g., Eastern Europe, Scandinavia, and Northern Spain), while the rest still have unstable populations [8]. After the middle of the 20th century, as a result of regulated silviculture practices, modern game management, controlled hunting laws and designated hunting seasons, the population of wild ungulates, particularly in the Cervidae family, experienced an increase in numbers [9]. However, because the predator populations

have not grown in tandem with ungulate populations, the main predator–prey stabilizing factor has not occurred, resulting in uncontrolled growth of ungulates [10,11].

High densities of ungulates can be considered the result of proper wildlife management, which has both negative and positive effects on ecosystems. However, when populations exceed the carrying capacity, it can also lead to various types of damage that impact human activities, agriculture and the forestry sector. The agricultural sector is one of the most affected by a high ungulate population, causing material damage to both large- and small-scale agriculture [12–14]. As the agricultural crops offer a better alternative food source than the natural ecosystem, in some periods of the year, the ungulates are using them as both feeding and resting zones [15,16]. In some countries, such as Austria, Croatia and the Czech Republic, supplementary winter feeding of game species to prevent damages to crops is a legal obligation for hunters to prevent mortality and overwintering in areas where their presence is undesirable, which leads to an increase in ungulate numbers. In contrast, in other countries such as the Netherlands and Switzerland, the practice is prohibited [17–19].

Understanding the feeding ecology and feeding strategies of ungulates is crucial for revealing the dynamics of plant–herbivore interactions, ecosystem functioning and the preservation of biodiversity in ecosystems [20]. Plant characteristics such as traits, nutritional quality, and the spatial distribution of food resources impact herbivores' foraging choices and patch perceptions, underscoring the intricate interplay between herbivore feeding behavior and plant attributes [21]. The selective feeding behavior, preferences for browsing height, and reactions to plant defenses highlight the varied feeding strategies utilized by herbivores to maximize nutrient intake and navigate their foraging habitats [20,21]. Additionally, the horizontal structure of the vegetation plays a role in protecting the ungulates from predation threats [22].

This study focused only on the effects of browsing in forest ecosystems and on woody plants. The problems caused by ungulates to the forestry sector are numerous. Therefore, they can result in a severe depreciation in commercial forests as well as a decrease in the protection functions of a forest, by altering the forest structure and composition and by possibly removing protected species [9,23]. The ungulates can alter the growth of trees, depreciate the quality of the timber, change the forest composition, or remove certain tree species through actions, like browsing, bark stripping, fraying, trampling of saplings, and others [24,25].

Ungulate browsing refers to all forms of feeding damage other than bark stripping: removal of twigs, shoots, leaves, needles, buds, or flowers [26]. These tree parts are typically located at a height within the reach of the ungulates, making forest plantations, both natural and artificial, the most susceptible to ungulate browsing [27]. The height that can be reached by ungulate is related to the animal's size. Moose (*Alces alces* L.) affect saplings and young trees between 0.5 and 3.5 m in height [28], red deer (*Cervus elaphus* L.) can reach heights up to 2.4 m, fallow deer (*Dama dama* L.) can reach 1.7 m, and roe deer (*Capreolus capreolus* L.) usually up to 1.4 m [29]. At the same time, chamois (*Rupicapra rupicapra* L.) can consume shoots at heights less than 1.3 m but usually prefers saplings that are between 10 and 40 cm tall [30].

The main gap that is the focus of this review is represented by analyzing the impact of ungulate browsing, considering not only ecological aspects but also silvicultural practices, the applicability of hunting, and the presence and role of large carnivores. This study aims to comprehensively investigate the impact of ungulate browsing on tree species in Europe. Specifically, it seeks to identify the main browsers, the most preferred tree species, and any common browsing trends. Additionally, the study aims to analyze the effectiveness of different forestry management strategies, with a focus on hunting and on the presence of large carnivores. Overall, this research seeks to provide a systematized general overview, which can be accessible to researchers but also to forest owners and managers, aiming to inform effective forest and wildlife management practices.

2. Materials and Methods

Two databases, the Web of Science and Google Scholar, were mainly used for information retrieval. A set of keywords was used in order to identify possible articles, "ungulate", "deer", "moose", "chamois", "browsing", "effect", "impact" and "tree damage", in different combinations using Boolean operators. After conducting a preliminary search, the countries from Europe were included as an additional keyword to enhance the scope of the findings. The search was conducted with a restriction on publication year, ranging from 1900 to 2022. The search included only peer-reviewed papers written in English. The investigations concluded in April 2023. Prior to analyzing the full text, a preliminary check of inclusion was performed, utilizing the following criteria, which served as the initial sorting of the database: (1) title, (2) abstract, and (3) keywords. Following an initial screening of the complete text, additional sources were identified and incorporated as a result of examining the bibliography of the initial batch of papers.

As a final step, inclusion and exclusion criteria were applied to sort the selected studies. The inclusion criteria were as follows: (a) studies that focused explicitly on browsing of ungulates on tree species, (b) studies conducted in Europe as the study areas, (c) studies that measured ungulate browsing using browsing indicators (browsing proportion, browsing intensity, browsing level, browsing pressure and others), (d) studies with significant results/recommendations for developing a good workflow for future, (e) studies that measured the browsing intensity of ungulates, even if their primary objectives were broader, (f) studies that analyzed the browsing on forest ecosystems, (g) studies employing natural or field experimental approaches. On the other hand, the exclusion criteria were as follows: (A) studies focused solely on browsing on plant species other than tree species, (B) studies where the browsers were species other than ungulates (e.g., marsupials, rodents, hares or livestock), (C) studies conducted in fields other than wildlife research, forestry or other ecology science, (D) studies utilizing repetitive datasets with no significant improvements, (E) studies lacking descriptions of the ungulate species or tree species studied, (F) studies utilizing laboratory experimental approaches. By applying these inclusion and exclusion criteria, the selected studies were carefully filtered to ensure their relevance and suitability for the research on ungulate browsing. The steps followed to identify the papers included in the review are shown in Figure 1.

After filtering, 155 papers from 21 countries were relevant for full-text screening. Studies have been carried out on one, two, or more ungulate species since their range often overlaps and they tend to browse the same tree species. The earliest study included dates from 1964, while the latest dated from 2022. Most of the studies were conducted between 1999 and 2020. The main browsers and their frequency in reviewed papers are presented in Table 1, with the most commonly studied species in Europe being Roe deer (n = 95) and red deer (n = 93).

Table 1. The frequency of ungulates in the reviewed papers.

	Europe						
Species	**Roe Deer**	**Red Deer**	**Moose**	**Chamois**	**Fallow Deer**	**European Bison**	**Muntjac Deer**
N	95	93	32	19	12	4	3

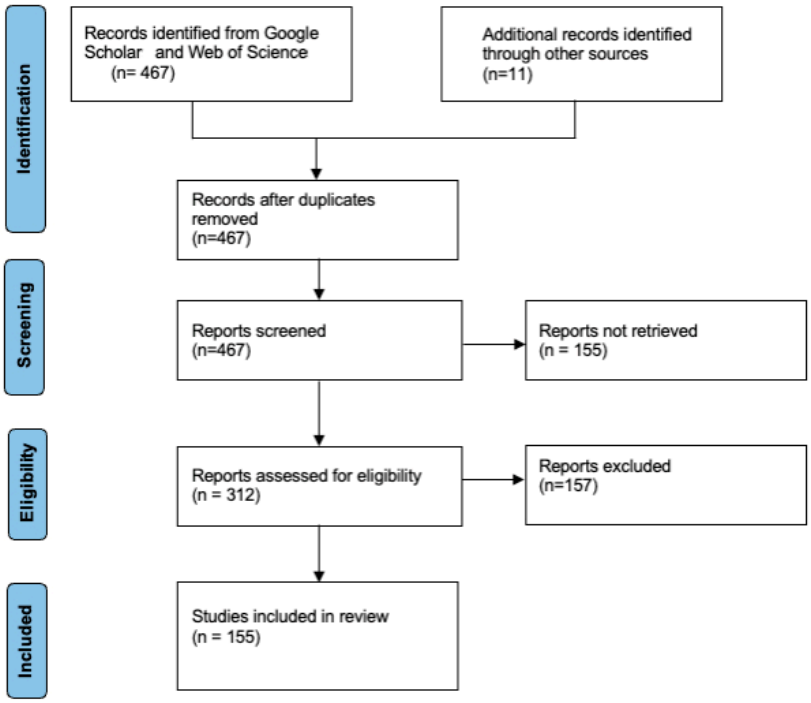

Figure 1. Study selection flow diagram. The number of works (n) identified, screened, included, and excluded was identified at each step of the process.

3. Results

In order to create a general view of the ungulate browsing magnitude from each paper, the (1) study area, (2) ungulate species, (3) browsing proportion, and (4) ungulate density were extracted and are compiled in Table 2. "Browsing proportion" is defined as the percentage of browsed saplings divided by the total number of saplings in the area. This parameter was chosen due to its widespread use in the reviewed literature as the most commonly employed metric. Both browsing proportion and ungulate density do not aim to reflect the general situation of the mentioned country; instead, they showcase the range and diversity of situations identified. The wide range of values can be attributed to the various silvicultural aspects (such as treatment, planting scheme, composition) and wildlife density. For instance, at the same ungulate density (e.g., red deer 10 ind./km^2), different browsing intensities can be observed based on sapling density (e.g., in an artificial plantation of broadleaves with a density of 3500 saplings/ha, the intensity will be significantly higher than in a natural regeneration of broadleaves from a shelterwood). On the other hand, the same regeneration area (e.g., mixed broadleaves and coniferous plantation with a planting scheme of 5000 saplings/ha) may experience varying browsing intensities depending on the ungulate species and density (e.g., 4 roe deer ind./km^2 or 13 red deer ind./km^2). Therefore, the range of the mentioned values is influenced by local situations but can also serve as a descriptor for specific regions or countries (e.g., mixed deciduous-coniferous mountainous stands with silver fir and Norway spruce).

For a better understanding of its scale, the papers were organized according to the United Nations geoscheme system for a better representation [31]. Lithuania, Norway, and Spain are not included in Table 2, as neither the browsing proportion nor the ungulate density provided useful quantitative values.

Table 2. Browsing situation as retrieved from reviewed literature.

No.	Country	Ungulate Species	Browsing Proportion (%)	Ungulate Density (ind./100 ha)	Reference
			Europe		
			Eastern Europe		
1	Czech Republic	Roe deer, red deer, Fallow deer	5–85	0.8–56	[32–40]
2	Poland	Roe deer, red deer, Chamois, Moose	12.8–58	0.5–10.4	[41–48]
		Bison	n.m. *	0.7	[41,44–46]
		Moose	n.m. *	0.31–0.5	[28]
3	Romania	Red deer, Roe deer	3–88	1.8–8.6	[25,49–56]
4	Russia	Moose	79.5–80	1–5	[57]
5	Slovakia	Roe deer, red deer	n.m. *	21	[58,59]
			Northern Europe		
6	Denmark	Roe deer	49–57	0.8–9.8	[60]
7	Finland	Roe deer	51	4–4.5	[61]
		Moose	8–75	0.4–3	[61–66]
8	Latvia	Red deer, roe deer	10–12	n.m.*	[67]
11	Sweden	Roe deer, red deer, fallow deer	5–85	1–20 (32.7)	[68–85]
		Moose	4–84	0.45–2.4	[68,69,72,76–78,86–102]
12	UK	Red deer, roe deer, fallow deer, Muntjac deer	5–81 (96)	4–60 (75)	[103–125]
			Southern Europe		
13	Italy	Roe deer, red deer, fallow deer, chamois,	7–61	4.5–25	[126–133]
14	Slovenia	Red deer, roe deer	8.2	1–12	[134,135]
16	Portugal	Red deer	10	10	[136]
			Western Europe		
17	Austria	Roe deer, red deer, chamois	5–67	3.6–25 (46)	[137–144]
18	France	Roe deer, red deer, chamois	7–100	10–15	[145–153]
19	Germany	Roe deer, red deer, fallow deer, Chamois,	5–79	5.3–20	[154–167]
20	Netherlands	Red deer, roe deer	6–85	4–14	[168,169]
21	Switzerland	Roe deer, red deer, chamois	3.3–67.5 (92.5)	10–27.5	[30,170–176]

* n.m.—not mentioned. Some of the studies used qualitative parameters to define the intensity of the browsing level or the ungulate density, and therefore a number or a percentage could not be clearly provided for this review.

3.1. Ungulate Browsing in Europe

Based on our established criteria, relevant studies related to ungulate browsing were found only in 21 countries out of the 50 countries in Europe. The countries with the highest number of included studies were Sweden with 35 studies, United Kingdom with 24 studies, Germany with 14 studies, France, Poland, Czech Republic and Romania each with 9 studies, Switzerland, Italy and Austria with 8 studies, and Finland with 7 studies. In contrast, the

remaining countries had a relatively low number of studies included: Russia with three studies, Slovakia, Norway, Slovenia and Netherlands with two studies, and the rest of the countries had only one study included. The number of studies included does not reflect the real situation of ungulate browsing in the specific countries; it relatively reflects the interest of researchers studying this phenomenon.

3.1.1. Ungulate Browsing in Eastern Europe

The Eastern Europe region, which includes the Czech Republic, Poland, Romania, Russia, and Slovakia, has been the subject of numerous studies on red deer, roe deer, and moose browsing (n = 31). Red deer and roe deer were identified as the primary browsers, with 26 and 19 studies including these species, respectively. The density of these species varied widely across the studies, ranging from 2.2 to 90 ind./km^2, with the highest densities observed in the Czech Republic and Slovakia. Moose were found in six studies, located in Poland and Russia, with densities up to 5 ind./km^2. The authors declared the presence of large carnivores in the study area in 14 out of the 31 studies, except Slovakia and the Czech Republic (11 studies). The ungulate density in the study areas with the presence of carnivores does not exceed 10 ind./km^2, and only in two studies did the browsing level exceed 50% [45,50]. In the Czech Republic, the browsing levels are between 5% and 85%.

A study from Northern Czech Republic found that the most frequently browsed tree species by red and roe deer are sycamore maple (*Acer pseudoplatanus* L.), black alder (*Alnus glutinosa* L.), rowan (*Sorbus aucuparia* L.), European beech (*Fagus sylvatica* L.), silver birch (*Betula pendula* Roth), sessile oak (*Quercus petraea* Matt.), and Norway spruce (Picea abies L.) [40]. In the Czech Republic, even in floodplains, where biomass production is very high, the damage caused by browsing can be barely compensated, while in artificial regenerated areas, a successful regeneration cannot be possible without fencing [32]. In unfenced areas, the ungulates significantly affect the development of silver fir, with a higher mortality and suppressed growth in height than in fenced areas [33]. During hard winters, in cases of high ungulate concentration and lack of supplementary food, the red deer feeds on all the available food, even on less preferred species like Norway spruce (up to 68% of the available saplings) [34]. Due to intense and repeated browsing by roe deer and mainly fallow deer, the sycamore maple cannot develop properly in the mixed stand, and it is overwhelmed by other species like European ash (Fraxinus excelsior L.) or field maple (*Acer campestre* L.) [36].

In Poland, Białowieża National Park represents a core area for studying the behavior and the impact of ungulates on the forest, including the effects of browsing. The area represents one of Europe's least disturbed temperate, lowland forest ecosystems [41]. This ecosystem, which has no human activities and has a stable population of large carnivores, provides evidence that areas with sufficient predator numbers experience lower browsing intensity in core areas. The observed reduction in browsing intensity is attributed to a combination of direct (lethal) and indirect (non-lethal) predator effects, the density-mediated effects of wolves on red deer being the most likely explanation [45]. In Roztocze National Park, a protected area in central-eastern Poland where natural predators are present, browsing intensity remained below significant thresholds. The only study specifically focused on moose in Poland showed that the highest preferences of moose are downy birch (*Betula pubescens* Ehrh.), silver birch (*Betula pendula* Roth), alder buckthorn (*Frangula alnus* Mill.) and rowan (*Sorbus aucuparia* L.) [28]. In Poland, natural predators have helped to keep browsing damage below critical levels. In the Tatra National Park, browsing damage was generally low, with damage on Norway spruce remaining under 5% [43].

The European bison (*Bison bonasus* L.) is a Near Threatened [177] mammal native to Europe that primarily grazes but can also browse on shrubs and trees in the forest [178,179]. In the Białowieża Primeval Forest (Poland), the European bison's tree species diet consisted of *European hornbeam* (*Carpinus betulus* L.)/Common hazel (*Coryllus avellana* L.) (33.0%), Silver birch (Betula pendula Roth.) (15.6%), willow (Salix sp). (10.6%), Scots pine (*Pinus sylvestris* L.) (9.7%) and English oak (*Quercus robur* L.) (8.3%) [44]. However, trees and

shrubs only comprise 5–33% of the European bison diet [179,180]. Compared to the other ungulate species in the Białowieża Primeval Forest, the bison is the species that has browsed the least and has the smallest browsing impact on tree species [41,45,46].

Most browsing studies in Romania have been carried out in the Northern Carpathians. The most susceptible stands of Norway spruce monocultures are those that extend beyond the spruce's naturally occurring areas [181]. The number of red deer has increased over the past six decades due to the establishment of monocultures in large areas and intensive control of wolf populations between 1961 and 1986, which led to better forage conditions and ceasing regulating effects of predators [55]. During the communist regime in Romania, there was a significant focus on timber harvesting to repay the World War II debts to the Soviet Union, which amounted to 4.3 million cubic meters [182]. The harvested areas were predominantly replanted with Norway spruce. This choice was preferred due to its ease of cultivation in nurseries, higher yield and financial value, and lower ecological demands compared to other species such as silver fir and European larch. As most of the area is represented by large spruce monocultures, the shortage of forage and game concentration in winter caused the deer to consume the Norway spruce saplings [53,54]. The reduction in wolf populations in the Northern Carpathians during the communist era increased the density of roe and red deer, which, in turn, indirectly caused high browsing pressure [56]. These past hunting management practices led to an explosion in the damage caused by deer in Norway spruce stands, which is reflected in stands aged between 21 and 80 years old and also in recently planted stands [52], as well as in the economic pressure on forest restoration [49,51]. In contrast, in other areas of Romania, where stable populations of deer and predators such as lynx, wolf, and bear are present, browsing damage is negligible compared to similar stands in Germany without a predator population. In Romania, only 3 to 6% were affected, while in Germany, the impact ranged from 17 to 39% in the same site conditions [167].

In European Russia, around the Moscow region, the impact of moose on forest regeneration was correlated with density: 0.2–0.3 ind./km^2 does not noticeably affect reforestation, 0.3–0.5 individuals/km^2 significantly suppress the growth of aspen (*Populus tremuloides* L.), rowan (*Sorbus aucuparia* L.), oak (*Quercus* sp.), and 0.8–1.0 ind./km^2 severely repress aspen and birch (*Betula* sp.), resulting in grassy glades on clear cuts [57]. A similar correlation was also established for roe deer in mixed pine-spruce forests of the Ural Mountains. The study found that at a density of 1.01 ind./km^2, 80% of the saplings were browsed. At a density of 0.58 ind./km^2, 58% of the trees were damaged, and at a density of 0.42 ind./km^2, 39% of the trees were affected [183]. In the eastern Ural Mountains, damage caused by roe deer in commercial forests can reach up to 100%, with Scots pine and aspen being the most targeted species [184].

In Northern Slovakia, particularly in Tatra National Park, it has been observed that rowan represents one of the most chosen tree species for browsing in post-disturbance stands, as its ecological requirements facilitate its growth in open areas and it possesses a high nutritional content in the shoots, buds and fruits [58]. In the northernmost part of Slovakia, over a period of 10 years, the exclusion of ungulates increased tree species richness and diversity by reducing the dominance of Norway spruce in terms of biomass and future composition [59].

3.1.2. Ungulate Browsing in Northern Europe

The region of Northern Europe was divided into the insular and mainland parts to highlight the different wildlife management practices and geographical differences. The insular part included the United Kingdom, where red deer is the main ungulate species causing browsing damage, observed in 16 out of 24 studies. Alongside the red deer, roe deer (present in eight studies) is also present as a secondary species that contributes to browsing, with overall damage ranging between 5% and 82%, according to the silvicultural practices, the density of planting scheme and the hunting management. In some studies,

the densities of ungulates were up to 60 ind./km^2 [108,118]. No presence of any large carnivores was declared in the studies.

The damage caused by red and roe deer species can be found in pure Sitka spruce (*Picea sitchensis* Bong.) and Scots pine (*Pinus sylvestris* L.) plantations, where the damage levels rarely exceed 50% [105,120]. In Kielder Forest, the winter browsing on Sitka spruce depends on the availability of shrubs, herbs and grasses [122]. Additionally, the two deer species were attracted to mixed plantations and natural regenerations that contain rowan (*Sorbus aucuparia* L.), Silver birch (*Betula pendula* Roth), wild cherry (*Prunus avium* L.), and oaks (Quercus sp.), where the diversity of forage is higher [103,104,109,110,118]. On the other hand, fallow deer have been documented in 5 out of the 24 studies. In the surrounding Suffolk areas, they are responsible for causing some form of browsing damage in almost (96% of cases) of all the mixed plantations of pedunculate oak (*Quercus robur* L.), chestnut (*Castanea sativa* Mill.), wild cherry (*Prunus avium* L.), and ash (Fraxinus excelsior L.) [112,113]. The muntjac deer (*Muntiacus reevesi* Ogilby) is an introduced species that, since 1975, has grown in numbers and affected mainly coppices in Eastern England through browsing [123–125].

The mainland part of Northern Europe consists of Denmark, Finland, Latvia, Lithuania, Norway, and Sweden. The primary browsers of the region are the moose and the roe deer [68]. In the current review, the moose was identified in 34 studies and roe deer in 17 studies out of the 43 conducted in the region. The red deer is found in just seven studies as a secondary species, and fallow deer in three studies. The moose densities are usually between 0.5 and 1.5 ind./km^2, with a few exceptions where the density exceeds 2.4 ind./km^2 [66,100]. The roe deer density is usually higher than 4 ind./km2 and has a maximum of 24 ind./km^2, depending on the silvicultural practices, planting scheme and hunting management [60]. The damage intensity caused by ungulate browsing was between 5 and 81%, depending on the species and location.

In Sweden, moose browsing represents the biggest hindrance to the development of forests, both for commercial (especially on Scots pine and Norway spruce stands) and for protection-purposes forests [76,77,79,81,86,90,91,101]. A possible reason for the browsing issue could be the increasing moose population over the past four decades, as also revealed by National Forest Inventories. [100,102]. A study based on data from the Swedish National Forest Inventory (1969–1972 and 1983–1987 cycles) revealed that the most common browsing species, which made up 91% of the browsing vegetation consumed by moose, were, in order: birch (*Betula* sp.), willow (Salix sp.), pine (Pinus sp.), juniper (*Juniperus* sp.), rowan (*Sorbus aucuparia* L.), and aspen (*Populus tremula* L.) [100]. The current study found that the most browsed species by moose were the Scots pine, Norway spruce, and aspen, which can be related to changes in preferences in the last four decades. In coastal Northern Sweden, the browsing occurred mainly in stands that contain both aspen and pine [88,92]. In the same area, the Scots pine represented 75% of the diet of 41 free-ranging moose [98], while in Central Sweden, 73.7% of browsing on Scots Pine was caused by moose [84]. Even though Norway spruce is a less preferred woody species for moose, they consume it when their density exceeds the ecosystem's optimum supportability [93]. It was found that the practice of fertilization only increases browsing intensity [87,89].

A study in Southern Sweden revealed that the most browsed tree species by roe deer are as follows: pedunculate oak (*Quercus robur* L.), common alder (*Alnus glutinosa* L.), European beech (*Fagus sylvatica* L.), small-leaved lime (*Tilia cordata* Mill.), wild cherry (*Prunus avium* L.), Silver birch (*Betula pendula* Roth.), Norway spruce (*Picea abies* L.) and European ash (*Fraxinus excelsior* L.) [83]. The studies included in the review primarily centered on the browsing behavior of roe deer in Norway spruce and Scots pine stands, given the significant economic implications associated with their browsing in these particular forest types. The silvicultural treatment seems not to have any influence on roe deer browsing on Norway spruce [69,72], and the stand characteristics did not influence the frequencies and pattern of browsing [76]. Plant vigor represents the parameter that controls the selectivity of red deer, with a higher attraction to the higher classes of vigor [74,75,77]. Deterrents

slightly reduce the intensity of Norway spruce and pine sapling browsing but have not shown any significant impact [70].

The only study where fallow deer is the principal species and causes browsing issues was conducted in the Koberg estate in Västergötland region, where the management type promotes high game densities for hunting purposes, and the damage caused by browsing is considered secondary damage [80].

In Finland, in both natural and artificial regeneration, Scots pine was highly browsed over Norway spruce, with moose density being the only variable influencing the damage severity [62]. Moose damage is significantly greater in Southern Finland in pine stands with low sapling density, while in planting schemes of 2000–3000 stems per hectare, the damages is lower [66]. Seedling densities and the proportion of browsed seedlings vary greatly between tree species and the silvicultural treatment (thinnings, clear-cuts), the browsing intensity being correlated with tree density [63]. In Central Finland, moderate browsing by moose may be beneficial by releasing conifers from competition among tree species, especially rowan, aspen, and birch [56]. At the same time, a higher pressure represents the main threat to aspen, affecting its regeneration and population structure, with a clear gap in the middle-sized aspens.

In Denmark, Latvia, Lithuania, and Norway, less than two studies related to ungulate browsing were identified in each of the countries. The study conducted in Denmark reported that after 8 years, the natural beech (*Fagus sylvatica* L.) regeneration, under the most favorable treatment and conditions in the unfenced areas, did not exceed 130 cm due to the high density (24 ind./km^2) of roe deer [60]. In Latvia, browsing damage caused by red and roe deer accounted for 66.5% of all tree damage and 75% of the total damage to Norway spruce (*Picea abies* L.) [67], as the red deer population had exponentially increased over the past two decades [185]. The study conducted in Lithuania characterized the browsing pressure of red deer and moose during different winter conditions and found that browsing can increase up to 2.1-times during a harsher winter due to the unavailability of food [186]. In Norway, the conservation of the English yew (*Taxus baccata* L.) in natural forest reserves has been affected by roe deer [187]. In contradiction to the majority of the studies, in Central and Southern Norway, the moose was found to promote the economically important coniferous trees in commercial forests [188].

3.1.3. Ungulate Browsing in Southern Europe

The Southern Europe region, which included Italy, Slovenia, Spain and Portugal, was the focus of 12 studies. Red or roe deer were identified as the primary browsers in all nine studies, while chamois were found in three studies. The damage was mainly observed in mountainous mixed forests, which primarily were not used for timber production.

In the Graie Alps, the impact of browsing on post-disturbance forest dynamics was significant, as the regeneration was scarce, and the development conditions were harsher [126]. Browsing pressure is usually more severe on regeneration farther away from the deadwood, as the lying deadwood may provide mechanical protection to the saplings [126]. Also, in the Paneveggio-Pale di San Martino Nature Park, the percentage of adult broadleaved trees in a plot and the relative proportion of broadleaved species in mixed deciduous-coniferous stands are factors that increased the browsing activity on young trees by ungulates [127]. The high densities of red and roe deer are reducing the presence of broadleaved trees in favor of Norway spruce [135]. In the western Italian Alps [128,130] and in the North-West Dinaric Alps [134,189], the silver fir is the most preferred species by red deer, roe deer, and chamois, which causes a reduction in the percentage of fir in the future regeneration composition in favor of Norway spruce. The silver fir is overwhelmed by the spruce because the fir has a considerably lower growing rate and light regime [190]. In contrast, damage of up to 60% is focused on Norway spruce and rowan in the dominant spruce layer of the eastern Italian Alps [130]. In the coastal Mediterranean area of the Lazio coast, the roe deer exhibits a generalist feeding behavior with a preference for deciduous and evergreen woody plants (especially *Quercus suber* L. and Prunus spinosa L.), showing adaptability

to seasonal variations in food availability [134]. In Sardinia, red deer exhibited strong preferences for browsing on tree species, such as *Quercus ilex* L., *Alnus glutinosa* L. and *Salix caprea* L., highlighting the significant impact of deer browsing on vegetation composition and ecosystem dynamics [132]. In Central Italy, roe and red deer have been observed to significantly reduce the volume of the coppice system of Turkey oak (*Quercus cerris* L.) and chestnut (*Castanea sativa* Mill.) by 25% at medium and high ungulate densities [131]. In the Dinaric Alps, the non-hunting mortality of large ungulates occurs mainly due to the grey wolf and Eurasian lynx. Still, only a portion of this mortality is recorded [134].

In South-Western Spain, the only study included showed that the maritime juniper (*Juniperus macrocarpa* Sibth. & Sm.), a species with continuous growth throughout the year, has a lower relative growth rate only during the summer, when browsing by red deer significantly slows down its growth [191]. In Central Portugal, red deer browsing caused significant damage to maritime pine (*Pinus pinaster* Aiton) regeneration, but overall, the tree survival was not affected [136].

3.1.4. Ungulate Browsing in Western Europe

The Western Europe region comprises Austria, France, Germany, Netherlands, and Switzerland and includes 41 studies. Roe and red deer were the most common browsers found in the studies, being present in 39 and 35 studies, followed by chamois within 13 studies. The browsing intensities ranged from 5% to 92.5%, while the ungulate densities were between 3.6 and 46 ind./km^2. Only a few large carnivores were declared as being present in the study areas, but their number can be considered negligible, and they did not have any impact on the ungulate populations [157,158].

Browsing is a substantial concern in Austria's forestry sector, posing a significant economic challenge [13,14]. In Tyrol, the browsing leads to the disappearance of silver fir (*Abies alba* Mill.) and Scots pine (*Pinus sylvestris* L.), ultimately favoring the dominance of Norway spruce [137]. In Lower Austria, while Norway spruce has not been affected by browsing, the oaks and beech were highly preferred by roe deer, which significantly impacted the restoration efforts [141]. In the Northern Calcareous Alps, natural regeneration is highly affected by browsing in post-disturbance and marginal stands, with forest establishment being delayed significantly due to the intense browsing of red and roe deer [138]. It was found that to reduce the browsing impact, a more close-to-nature felling treatment (e.g., shelterwood, group selection) is needed. This is mainly due to the low predisposition to overall damage, as a slower transition of the forest using natural regeneration decreases the game pressure [140,192,193]. In Austria, planting is carried out using a low density of saplings per ha (e.g., 5000–6000 saplings/ha), which creates a shortage of food selection and forces the game to be less selective. At the same time, the shelterwood treatment offers a considerably higher amount of regeneration, which provides the game species enough food, the browsed saplings being counted as "compensatory mortality" [140,194].

In the Vosges Mountains in North-Eastern France, the red and roe deer intensive browsing is causing a significant loss of silver fir regeneration in favor of Norway spruce [145,153,161]. In the French Alps, in mixed uneven-aged mountain forest stands, additionally to a decrease in water availability and rising temperature, red deer, roe deer, and chamois browsing on fir and beech could jeopardize the renewal of these species in the future [152]. In North-Eastern France, the roe deer browsing on sessile oak saplings are drastically delaying the reach of the closed canopy stage [147]. Based on a 10-year study in the Grand East Region, the oak browsing index had been successfully used to estimate roe deer density [146]. Without ungulate browsing, sessile oak stumps maintain a moderate sprouting capacity up to 80 years old [150]. In the Haute-Marne administrative area, the red and roe deer population dynamics were the main driver of changes in plant and tree assemblages for over 30 years [148,149].

In the Bavarian Alps, the browsing preference of red and roe deer was as follows: rowan, European beech, silver fir, and Norway spruce [158]. In the same geographic area, red deer, roe deer, and chamois browsing drastically reduces the survival rate of silver

fir [155]. Additionally, ungulates influence the growth rate and species composition of natural regeneration. The total removal of browsing allows unhindered growth for all tree and plant species [132]. In North-East Germany, the height of Scots pine saplings was considerably lower when browsing occurred [154]. In Northern Germany, the browsing on beech saplings is positively influenced by the availability of birch and blueberry (*Vaccinium myrtillus* L.). In contrast, for Norway spruce, the presence of blueberry had a negative impact [156]. In Germany, proper hunting management is needed to control the high numbers of ungulates, which can easily reach up to 20 ind./km^2 (with exceptions in game units where it can reach 100 ind./km^2). A hypothesis claims that the only solution to control ungulate density in Germany and to allow successful forest regeneration can be achieved through hunting [160]. In different regions of the country, the hypothesis has been proven to be the only realistic solution to control browsing, both in protected areas (such as Bavarian Forest National Park) and in commercial forests [158,159,162,163]. The population of large predators found in Germany is scarce, and the impact on the ungulate is relatively non-existent [158,159].

In the Netherlands, in the forest heathlands [160] and other forest types [168], mainly beech and Scots pine were able to successfully regenerate, as oak, birch, and rowan were suppressed by red and roe deer.

The silver fir in the Central European Alps (Switzerland) has suffered a decline over the past two decades, being the most heavily browsed among commercially important tree species, primarily due to red deer, roe deer, and chamois [170,173,176]. However, in contrast, the lightly browsed saplings of silver fir tended to grow better than the untouched ones [175]. At higher altitudes, below the subalpine level, the Norway spruce is also affected by browsing, but the damage scale is much lower than in silver fir [30]. Between altitudes of 1600 and 2000 m, the browsing of Norway spruce significantly decreases to 3.3% [171]. In the lowlands of Northern Switzerland, the only notable browser is the roe deer, which causes damage to deciduous forest regeneration, especially in sites with lower amounts of alternative food resources [172].

3.2. Browsing Trends in Europe

As seen from the preceding sub-sections, ungulates exert a significant impact on tree regeneration, and the extent of damage is influenced by various factors such as silvicultural practices (e.g., planting schemes, composition, consistency, treatment and others.), ungulate species, wildlife or hunting management, and the presence of large carnivores. The primary trends concerning the issues caused by browsing, the underlying causes, the protective (preventing) and controlling measures implemented, as well as the presence and potential impact of large carnivores, can be observed in Table 3. The development of commercial forests poses a problem as valuable timber depreciates at harvesting age due to browsing, leading to the apical shoot being browsed and resulting in a multi-stem trunk [195,196]. Another common issue is the shift in species composition, where broadleaved tree species are more palatable than coniferous species. Additionally, it has been proven that silver fir is preferred over Norway spruce in the majority of mixed artificial regenerations [145,153,197]. The root cause of issues stemming from ungulate browsing is the high density that often surpasses accepted levels. However, in some cases, other management practices have exacerbated the situation (e.g., monocultures over large areas, introduction of exotic species, among others). Depending mainly on the severity of the phenomenon, protective (preventive) and population control measures are implemented on varying scales. The most common approach involves reducing or controlling ungulate populations through hunting [198,199], followed by fencing or the use of deterrents. Large carnivores are adequately present in only a few instances (such as Poland, Romania, Finland, Sweden, and Slovenia), while in other countries, their numbers are considered negligible, with no discernible impact on ungulate populations.

Table 3. Browsing trends in Europe.

Country	Ungulate Species	Problems	Causes	Protective Measures	Large Carnivores	Reference
Czech Republic	Red deer, Roe deer	Development of commercial forests	△	***	/	[32–40]
Poland	Red deer, Roe deer, Chamois, Moose	Development of protection forests	△	¦	+++	[41–48]
Romania	Red deer, Roe deer	Development of commercial forests	△, Monocultures on large areas	**	++	[25,50,52–56]
Russia	Moose	Unwanted changes in tree composition	△	¦	+	[57]
	Roe deer	Development of commercial forests	△	¦	+	[184,185]
Slovakia	Red deer	Favoring *Picea abies* L., Exclusion of broadleaved species	△	*	/	[58,59]
United Kingdom	Red deer, Roe deer	Risk of plantation failure	△	*	/	[104–111,114–120,122]
	Fallow deer	Risk of plantation failure	△	*	/	[112,113]
	Muntjac deer	Reduction of vegetative regeneration	△, Exotic species	*	/	[123–125]
Sweden	Moose	Development of commercial forests, Exclusion of broadleaved species	△	**	+	[68,69,72,76–78,86,88,90–99,101]
	Roe deer	Development of commercial forests, Exclusion of broadleaved species	△	***	/	[69–80]
	Fallow deer	Tree survival severely reduced	△, Hunting reserve	¦	/	[80]
Finland	Moose	Development of commercial forests	△, Low-density planting scheme	**	+	[61–66]
Denmark	Roe deer	Diminished growth in height	△	**	/	[60]
Latvia	Red deer, Roe deer	Development of commercial forests	△	*	/	[67]
Lithuania	Red deer, Moose	Development of commercial forests	Harsh winters	*	/	[187]
Norway	Roe deer	Conservation of a protected species (*Taxus baccata* L.)	△	¦	/	[188]
Italy	Red deer, Roe deer, chamois	Unwanted changes in tree composition, Reduction of broadleaved species and *Abies alba Mill.*	△	¦	/	[126–130]
Slovenia					+	[134,135]
Austria	Red deer, Roe deer, Chamois	Development of commercial forests, High financial losses	△	****	/	[137–144]
France	Red deer, Roe deer	Development of commercial forests	△	**	/	[145–153]
Germany	Red deer, Roe deer	Development of commercial forests High financial losses	△	***	/	[154–167]
Netherlands	Red deer, roe deer	Suppression of broadleaves	△	*	/	[168,169]
Switzerland	Red deer, roe deer, chamois	Unwanted changes in tree composition, Reduction of broadleaved species and *Abies alba Mill.*	△	*	/	[30,170–175]

△—high ungulate density, *—only one measure is applied, mainly hunting, **—two protective measures are applied, mainly fencing and hunting, ***, ****—a multitude of efforts are implemented, including intensive culling, ¦—no protective measure is applied, +—large carnivores are present, ++—large carnivores are present and have an impact on ungulates, +++—large carnivores are controlling the ungulate densities, /—large carnivores are not present or their number is insignificant.

3.3. Frequency of Tree Species in the Literature Reviewed

In the context of this review, only the studies that included tree species of silvicultural interest were considered, both in terms of timber production and in terms of their protective and biodiversity aspects. The frequency of tree species included in studies, either as an individual species or as a part of a composition scheme, is presented in Figure 2. The frequency of these tree species in studies does not necessarily reflect the preferences of ungulates but rather their silvicultural importance, mainly determined by their value at harvesting age, the share in the planting scheme and their production in nurseries.

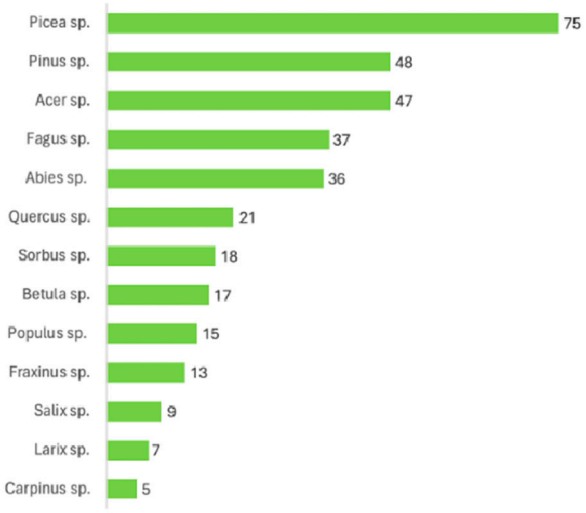

Figure 2. Frequency of tree species analyzed in the reviewed studies.

Despite Norway spruce being one of the species with low palatability, it is one of the most common species in Europe, which has been extended beyond its natural range [181,190] and is indirectly the subject of many browsing studies (n = 75), whether as a species affected or favored. Pine species, known for their ecological plasticity, have been included in numerous composition schemes at the European level. In this case, pine (n = 48) has higher palatability than spruce but, in some instances, it is favored over deciduous species. Species from the Aceraceae family (n = 47) exhibit both high ecological plasticity and silvicultural interest [190], but they are highly palatable and are often the first species browsed, one of the most important silvicultural species in the mountainous region is the silver fir (n = 36), which is frequently overwhelmed by ungulates to the detriment of Norway spruce [145,189,197]. Species from the genera Quercus, Sorbus, Betula, Populus, Fraxinus, and Salix are considered the most consumed by ungulates, leading to their suppression and reduced growth, potentially being overtaken by species that have not been browsed [28,40,44,108,200].

4. Discussion

The repercussions of ungulate browsing are diverse and far-reaching in natural ecosystems, encompassing hindrance to tree regeneration, alteration of forest composition through selective feeding, reduction in overall biodiversity, economic losses stemming from the reconstruction of plantations, degradation of soil quality and increased erosion, and disruption of the natural regeneration process, affecting the long-term resilience of ecosystems.

The high densities of ungulate species are the primary factor contributing to the adverse impact of ungulate browsing on forest ecosystems, with ungulate populations significantly increasing in numbers and expanding their geographical range in Europe [9,13,201–205], resulting in substantial economic and ecological consequences in forestry [13,14,206]. Browsing damage has intensified in the past few decades, as the number of studies on the topic has grown since 1999. According to the results of this review, the populations of roe deer, red deer and moose, as native species, have significantly increased in number and range, and

their density can be used as an indicator of their browsing. These ungulates extended their range and started occupying new ecosystems as they adapted to their requirements.

The other species mentioned in this review can be considered of secondary interest in various ways, such as having a lower browsing impact, overlapping ranges with the main species, occupying specific regions only (e.g., Chamois, European bison), or being introduced species (e.g., Muntjac deer in the UK). The chamois was found mainly in mountainous and alpine areas of Poland, Austria, France, Germany, Switzerland, Slovenia, and Italy and was reported as a secondary species with the roe and red deer, with no study focused only on the sole impact of the chamois [30,43,48,127,128,130,134,137–140,152,155,162,170,173–175]. In most cases, fallow deer were reported as secondary browsers, except in Sweden and the UK, where they are managed as a main game species, resulting in higher densities than those found in other studies [80,112,113]. The Muntjac deer from the UK is an introduced species that has overbred in the absence of natural predators, significantly damaging tree regeneration [104,111,123–125]. All research on the European bison has been conducted in the Białowieża Primeval Forest in Poland, and conservation efforts are focused on increasing their population, as the browsing is seen as a natural phenomenon [41,44–46].

As shown in this review, the ungulate preferences focus, when available, on broadleaves over coniferous due to their high forage quality, taste and palatability, digestibility, and other phenological factors [17,30,78,99,107,108,150,207,208]. One of the most favored broadleaved species in Europe is the rowan (*Sorbus aucuparia* L.), but this tree species acts more like an attractant for the deer in freshly cut forests, as it does not have any commercial importance [74,126]. This category of commercial species, which are designated for future crop trees all of the oak species (*Quercus* sp.), are highly consumed predominantly [40,57,141,147,150,168,209–211]. Higher-latitude birch is affected mainly by moose browsing, as it is a highly prolific species and it is often used in the plantation schemes in Scandinavia [57,64,86,100,102,212]. A general trend for browsing preference can be seen in the case of the *Abies* genera, which have seen a drastic reduction in number and height in mixed plantations, both natural and artificial. In Central, Southern Europe and the Czech Republic, the silver fir (*Abies alba* Mill.) has seen a decline in recent decades, which is related to the browsing damage, and its presence in future composition is replaced by other less palatable species such as the Norway spruce (*Picea abies* L.) [23,136,144,152,164,167,213]. Studies conducted in Northern Europe and Eastern Europe have shown that pines are preferred over spruces within the coniferous group. Mainly in Sweden, Scotland, and Finland, where the Scots pine is a principal species in composition schemes, it is highly preferred over the Norway spruce due to its chemical composition and nutritional properties [62,64,73,84–86,89,95,99,101]. Even if the Norway spruce does not represent an important forage species in mixed natural regenerations, due to the practice of large-scale monocultures, the ungulates adapted and consumed the spruce over acceptable limits [25,49,52–55].

The silvicultural systems identified in this review play a vital role on the damage levels and can be divided as follows: clear-cuts where all the crop trees are harvested at once, on the whole area, repeated treatments such as shelterwood, continuous cover system with selection cuttings and coppice systems. The silvicultural system type is designated for artificial and natural regeneration, which, together with the planting scheme and the regeneration composition, acts as variables that influence the browsing phenomena. The forest predisposition to browsing damage strictly correlates to the silvicultural system and regeneration method. The clear-cut system has the highest susceptibility to browsing due to the creation of a suitable habitat for most ungulates. The browsing impact is particularly high because of the limited availability of artificial regeneration (planting density), leading to a shortage of food resources [70,169]. The shelterwood and selection systems have been proven to be less affected by browsing, as these treatments offer a considerably higher amount of natural regeneration, which satisfies the food requirements of ungulates, and the browsed saplings can be counted as "compensatory mortality" [23,67,130]. Silvicultural aspects, such as planting schemes, sapling density, composition, forest treatments, and

tending operations, play a crucial role in shaping ecosystems and influencing browsing behavior. Factors like release cutting and respacing periodicity, thinning intensity and type, as well as disturbances, can impact the availability of plants, shrubs, and young trees for browsers.

In addition to the negative effects of ungulate browsing, this phenomenon also has some positive effects on the forest ecosystem, even though most of the literature focuses only on the negative impact. Browsing itself, as a natural phenomenon, does not significantly affect the ecosystem; rather, the altered high densities of ungulates create problems. Selective browsing on competitive dominant plants enhances the diversity of both seedling survival and growth [213]. Under normal densities of ungulates, plant communities can increase in cover and richness, as normal levels of browsing create favorable scenarios for plant growth [214]. Ungulates have an important role in maintaining plant diversity in forest ecosystems in the absence of episodic artificial or natural disturbances (fire or mechanical tending) [215].

A general overview of preventing and controlling browsing methods was split into two categories: techniques that promote non-harmful/banishment of ungulates and procedures that promote the extraction of ungulates. The first category represents short-term solutions that prevent young trees from being affected by ungulates until they reach a particular stage of development or height [216]. The most commonly used method was fencing, which was typically installed across the entire target area and by using electric fences or different types of steel wire [33,73,96,124,179]. Other methods, such as tree guards, repellents, and natural obstacles (such as repellents, slash, mounds, stumps barriers, and others), have proven to be even shorter-term solutions with highly fluctuating results [69,217–221]. While these short-term prevention measures can be effective, they do not fully solve the problem and move it to another area. Additionally, these measures create additional economic pressure on forest owners and managers and do not provide any immediate financial revenue.

The other category of measures, which promotes the extraction of ungulates, is represented by hunting and natural predator–prey interactions. Hunting is practiced in all of the countries mentioned in this study, but, in only a few countries, such as Austria, Germany, France, Sweden, and the UK [14,163,167], hunting management plans focus on a reduction in ungulate numbers for browsing-related issues. The intervention of the hunter is needed as the ungulates breed uncontrollably and prevent the regeneration from reaching the canopy stage, inflicting higher financial pressure on forest owners. Compared to the non-harmful methods for preventing and controlling the browsing, hunting generates revenues through selling licenses, trade of meat and trophies and other revenues gained through hunting [221,222]. In some areas of Germany, the overabundance of ungulates has reached such a high rate that hunting is seen as the only viable solution [159,160,163,164]. A controlled culling has to be adopted in regions where browsing has gotten out of control. Also, alternative measures such as fertility control have to be taken into account as future measures [223].

Out of the 153 studies included in the review, only 15 declared the presence of predators in the study area. Out of the 15 studies, only 6 of them showed a stable population of predators that can impact the numbers of ungulates, while the other 4 had a deficient number of predators in their study area [97,157,158]. In Poland, Romania, Russia, and Slovenia, the presence of large predators such as the grey wolf, European lynx and brown bear has been shown to impact the ungulate population and behavior. Areas with higher predator densities have lowered the browsing intensity, and the ungulate density has been balanced with the ecosystem carrying capacity [41–43,45,46,56,57]. A study comparing the browsing impact on similar forest stands and ungulate density in Germany and Romania showed that the presence of stable populations of large carnivores reduces browsing intensity (to less than 5%) [167]. The reintroduction of natural predator–prey interactions can have a beneficial effect not only on the browsing issue but also on the overall balance of the ecosystem [10,45,188,224–227]. Studies have provided evidence that the ungulates actively avoid areas where predators and hunting activities are prevalent, preferring loca-

tions with lower risks to their safety [228,229]. In areas with high densities of predators, the feeding and resting behavior of ungulates changes, as they tend to be more cautious and avoid high-predation-risk areas (e.g., large clear-cuts with no refuge) [230–232]. This suggests that the reduction in browsing damage may not only be due to the predation of ungulates themselves but also by the changes in behavior caused by the presence of carnivores. As the natural reoccupation of large carnivores of their former habitats can be a slow process, relocation procedures from countries with high densities of carnivores have to be carried out to countries with low populations [233]. For this purpose, relocation action will be challenging, as well as the education of local communities and changes in their perception [234].

In this branch of wildlife studies, it is crucial to acknowledge several limitations that affect a uniform analysis of the impact of ungulates. The lack of clear standardization in data collection methods affects the ability to compare different studies, even within the same country. This review found both quantitative and qualitative parameters used to assess browsing intensity, which can lead to an improper assessment of the severity of the phenomenon and create unfair comparisons between study areas. The density of ungulates is an important parameter as it explains the primary cause of browsing. In certain instances, the forest ecosystem has been altered in recent decades due to the high densities of ungulates. It is, therefore, logical to establish thresholds for acceptable ungulate densities based on different forest scenarios [235]. This approach can help in managing ungulate populations effectively and maintaining a balanced ecosystem. It is important to acknowledge that browsing by ungulates not only changes the forest ecosystem but also influences the behavior and ecology of the ungulates themselves. The interaction between ungulates and their forest habitat is dynamic, with both sides adapting to each other's presence and characteristics [23]. Understanding how ungulate behavior is influenced by the forest ecosystem is essential for effective management and conservation strategies. In some cases, counting and determining the number of ungulates can be challenging due to habitat diversity, sensitivity to disturbance, the risk of overcounting, and other factors. As shown in Table 1, some of the data were not clearly mentioned, and qualitative terms such as "high" or "severe" were often used to describe the browsing intensity or ungulate density.

Regarding future research directions for studying ungulate browsing, it is essential to standardize the measurement units used in studies to enable proper comparison and assessment. Additionally, study areas should extend to regions where browsing phenomena are not causing significant damage to identify the variables that keep damage under control. Future studies should focus on analyzing browsing in different geographic regions with varying carnivore densities, hunting management, and forest management practices. By doing so, a better understanding of the impact of ungulate browsing on the environment can be gained, and an effective management strategy can be developed to mitigate its effects.

5. Conclusions

This research confirms that ungulate browsing represents a critical issue to the development of young forests in Europe, as their numbers have reached alarming numbers in the past few decades. The results provided valuable insights on local and regional aspects of the dynamics of ungulate herbivory in vastly different ecosystems. The results revealed that the overpopulation of ungulate represents the main cause of the damage, followed by silvicultural systems, lack of natural predators and hunting management. High levels of browsing can explain why some palatable species decrease in density while promoting the growth of other unpalatable tree species. Effective forest management practices, including proper hunting management and predator presence, are essential for controlling ungulate populations and promoting successful forest regeneration. This review highlights that the ungulates expanded in numbers and range in past decades, and ungulate browsing is a real issue.

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