forests

Article

Diversity of Beetles Captured in Pitfall Traps in the Șinca Old-Growth Forest, Brașov County, Romania: Forest Reserve versus Managed Forest

Gabriela Isaia [1,*], Ionuț-Marian Dragomir [1] and Mihai-Leonard Duduman [1,2]

1 Faculty of Silviculture and Forest Engineering, "Transilvania" University of Brașov, Sirul Beethoven 1, 500036 Brașov, Romania
2 Applied Ecology Laboratory, Forestry Faculty, "Ștefan cel Mare" University of Suceava, Universității Street 13, 720229 Suceava, Romania
* Correspondence: gabriela.isaia@unitbv.ro

Abstract: Natural forests have unique, very stable structures and host a large number of endemic species, making them of high conservation value. The Șinca Old-Growth Forest in Brasov County (Romania) is no exception, being a flagship natural forest of mixed beech and silver fir among European mountain forests. Knowledge of the diversity of beetles living in this ecosystem and of the conservation degree of the species can be obtained by comparing it with the diversity existing in a managed forest, similar in composition and structure. Thus, the present study allowed a first analysis of the terrestrial coleopteran communities captured in pitfall traps both in a forest reserve and in a managed forest. The abundance of captured beetles was about 17% higher in the forest reserve (16,393 individuals) than in the managed forest (14,008 individuals), while species richness was higher in the managed forest (44 species), where 19.1% more taxa were identified than in the forest reserve (37 species). There were significant differences between the two beetle communities indicated via a PERMANOVA test; these differences are most likely due to the presence of certain beetle species only in a certain stand type, but also due to large differences between populations of common insect species. Analyses of the Shannon, Simpson, Evenness, and Berger–Parker diversity indices showed a similar diversity between the two terrestrial beetle communities. The presence of rare species such as *Carabus variolosus* (Fabricius, 1787), *Ceruchus chrysomelinus* (Hochenwarth, 1785), and *Rhysodes sulcatus* (Fabricius, 1787) indicates the high value of this ecosystem and illustrates the importance of its conservation. A more in-depth analysis of beetle diversity in the Șinca forest may only be possible after further research based on additional beetle sampling methods capable of capturing dead wood-dependent insects in particular.

Keywords: Șinca Old-Growth Forest; beetle diversity; pitfall traps; forest reserve; managed forest

check for updates

Citation: Isaia, G.; Dragomir, I.-M.; Duduman, M.-L. Diversity of Beetles Captured in Pitfall Traps in the Șinca Old-Growth Forest, Brașov County, Romania: Forest Reserve versus Managed Forest. *Forests* **2023**, *14*, 60. https://doi.org/10.3390/f14010060

Academic Editor: Won Il Choi

Received: 6 December 2022
Revised: 22 December 2022
Accepted: 26 December 2022
Published: 28 December 2022

1. Introduction

Forests are some of the most diverse terrestrial ecosystems on Earth [1], hosting more than 50% of the world's known organisms [2]. Forest ecosystems contribute significantly to climatic and hydrological cycles [3] and store about half of all terrestrial carbon [4]. Forests currently cover about a third of Europe's land area. Of these, only 2.2% can still be characterized as natural, with low or no interventions [5]. In central and south-eastern Europe, Romania hosts relatively large areas of secular forests or forests of high naturalness, estimated at around 0.2 to 0.3 million ha [6]. In 2017, 24,000 ha of natural beech forests in Romania was included on the UNESCO World Heritage List [7], among which the Șinca Old-Growth Forest, a forest of interest for this study, stands out.

Natural (primary) forests are ecologically important as they serve as refuges for rare or endangered species, especially species sensitive to disturbance by human activities [8–10]. These forests have developed structural characteristics (large living trees, dead wood, unique structural diversity) over time [9,11–13] that are only partially found or missing in managed forests [14]. On the other hand, forests adjacent to primary forests are managed as buffer zones for forest reserves, with low-intensity intervention [15,16]. This type of low-intensity managed forest (with sanitation and conservation cuttings only) partially preserves structural components typical of natural forests, except for large dead wood (which occurs only in isolation, represented by thin branches and stumps) and trees at the limit of their biological growth capacity [17,18].

A large number of studies show that Insects in forest habitats are very sensitive to changes in forest type and structure [19]. Among them, some coleopteran species are characterized by a strong selective preference for different habitat types, having strict requirements for certain forest biocenoses, thus being present only in certain forest types [19,20]. The most common beetles living at the forest soil level are predatory and detritivorous (saprophagous, coprophagous, and necrophagous) species. Among these, ground beetles are the most sensitive to habitat changes induced by various natural [21–26] or anthropogenic disturbances [27–29], the abundance of species and the size of its population being correlated with parameters such as the amount of woody debris, the area of exposed land, and the richness of herbaceous species [25,30]. Several studies have concluded that carabids characterize the habitat, effectively reflecting biotic and abiotic conditions, and thus these species have a high potential to be used as indicators [31–37]. Dung beetles, which are frequently found at the level of the forest soil, are also considered as indicators of environmental and habitat conditions. For example, the population size of *Anoplotrupes stercorosus* (Hartmann, 1791) is closely related to habitat moisture as well as to the forest's structural characteristics, preferring areas with younger forest [38–40]. Necrophagous species belonging to the Silphidae family, depending on ephemeral sources of food, are very sensitive to changes in the forest habitat, their populations decreasing in areas with human intervention [41].

Research on the analysis of the structure and diversity of natural versus managed forests has a long tradition, at least in temperate forests in Europe [42–44]. There are also numerous studies that have analyzed the impact of anthropogenic interventions on the coleopteran diversity in forest ecosystems [45–48]. Moreover, several studies regarding the diversity of saproxylic and ground beetles in various primary forests [20,34,49,50], represented by natural ecosystems of spruce or mixtures of spruce, fir, and beech, located at the north end of the eastern Carpathians have been carried out in Romania in recent years. However, there are numerous other primary forests located along the Carpathian Mountains where the data related to beetle diversity, as well as the impact of forest management on it, are insufficient.

In this context, the present study aims to analyze the diversity of terrestrial beetles in the Șinca Old-Growth Forest (a UNESCO World Heritage site) in comparison with the diversity of terrestrial beetles in a neighboring stand affected by low-intensity management (consists only of conservation and sanitary cuts).

2. Materials and Methods

2.1. Study Area

Fieldwork was carried out in the Șinca Old-Growth Forest (45°40′ N, 25°10′ E) (Brașov County, Romania) in two neighboring mixed stands of *Fagus sylvatica* L. and *Abies alba* Mill., a stand located in the forest reserve and a managed one located in the buffer zone of the forest reserve in which conservation and sanitation cuttings were performed (Figure 1).

The Șinca Old-Growth Forest is located in the Făgăraș Mountains on the northern ridge of the southern Carpathians, at an altitude between 790 and 1400 m a.s.l., with a general northern exposure and with a slope varying between 25 and 40 g, on bedrocks characterized by sedimentary deposits and mesometamorphic crystalline schists with eutricambisol and districambisol. Vegetation is exclusively beech and mixed beech–silver fir forests [51]. The Șinca Old-Growth Forest completely overlaps the Natura 2000 site

ROSCI 0122 "Munții Făgăraș" and partially overlaps the special avifaunistic protection area ROSPA 0098 "Piemontul Făgăraș" [52].

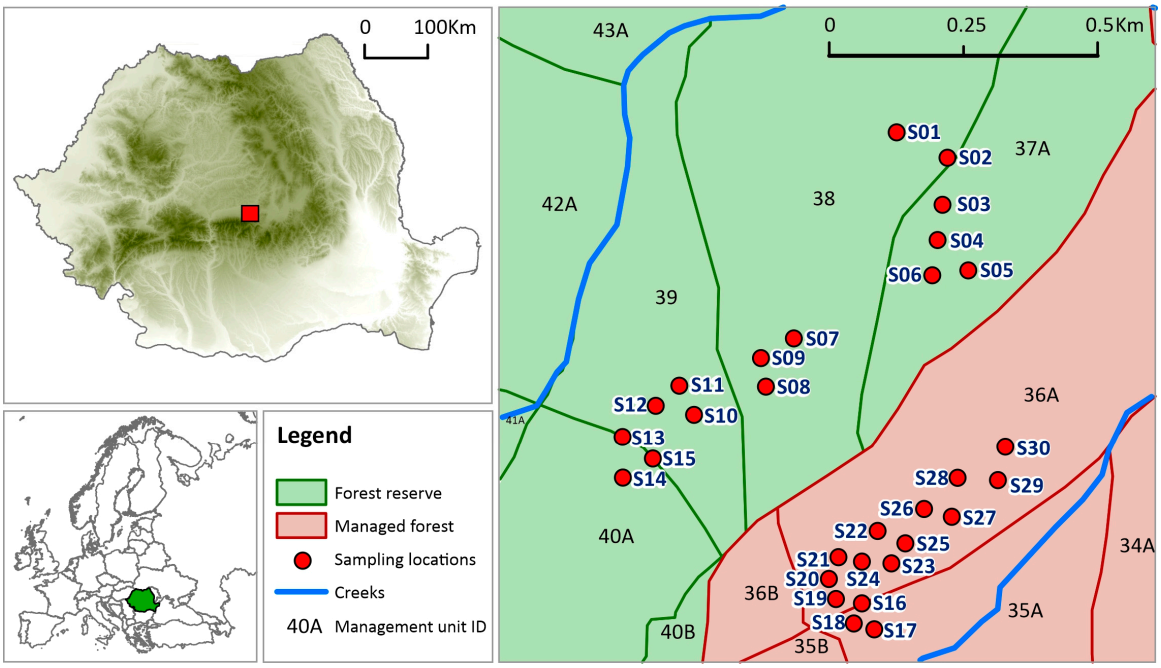

Figure 1. The map of beetle sampling locations in the Șinca Old-Growth Forest.

The characteristic climate is temperate continental, with an average annual rainfall of about 1000 mm and an average annual temperature of 4.5 °C [53].

The forest reserve area selected for our study includes management units 37A, 38, 39, and 40A, totaling 98.2 ha, and the managed forest area consists of units 35A and 36A, totaling 45.4 ha. The stand in the forest reserve (Figures 1 and 2; Table 1) is predominantly of *F. sylvatica* (70%) mixed with *A. alba*, a natural, unevenly aged forest in which the age of the trees varies between 100 and 180 years, with an average consistency of 0.7 and an average volume of 574 $m^3 \times ha^{-1}$ [51] of living trees and of 134.9 $m^3 \times ha^{-1}$ [53] of dead wood. The stand in the managed forest (Figures 1 and 2; Table 1) is similar in composition and structure to those in the forest reserve, the predominant species being also *F. sylvatica* (60%) mixed with *A. alba.* Its structure is relatively unevenly aged, with trees between 130 and 180 years old, with an average consistency of 0.5 and an average volume of 382 $m^3 \times ha^{-1}$ [51] of living trees. The dead wood is present only in isolation, consisting mainly of thin branches (less than 5 cm in diameter) and stumps resulting from tree harvesting. In this stand, conservation and sanitation cuttings are carried out, removing poorly shaped, diseased, or dying trees. Conservation cutting can be applied with an intensity of up to 10% over 10 years [54].

Table 1. Forest stand characteristics (taken from the forest management plan [51]).

Stand	Management Units	Area (ha)	Altitude (m)	Expo-sition	Slope (g)	Composition (%)	Age (Years)	Canopy Cover	Mean of Volume of Living Trees ($m^3 \times ha^{-1}$)	Mean of Volume of Dead Wood ($m^3 \times ha^{-1}$)
Forest reserve	37A, 38, 39, 40A	98.2	850–1350	N	35–40	70 *Fagus sylvatica* 30 *Abies alba*	100–180	0.7	574	134.9 [53]
Managed forest	35A, 36A	45.4	950–1250	N	25–35	60 *Fagus sylvatica* 40 *Abies alba*	130–180	0.5	382	No data

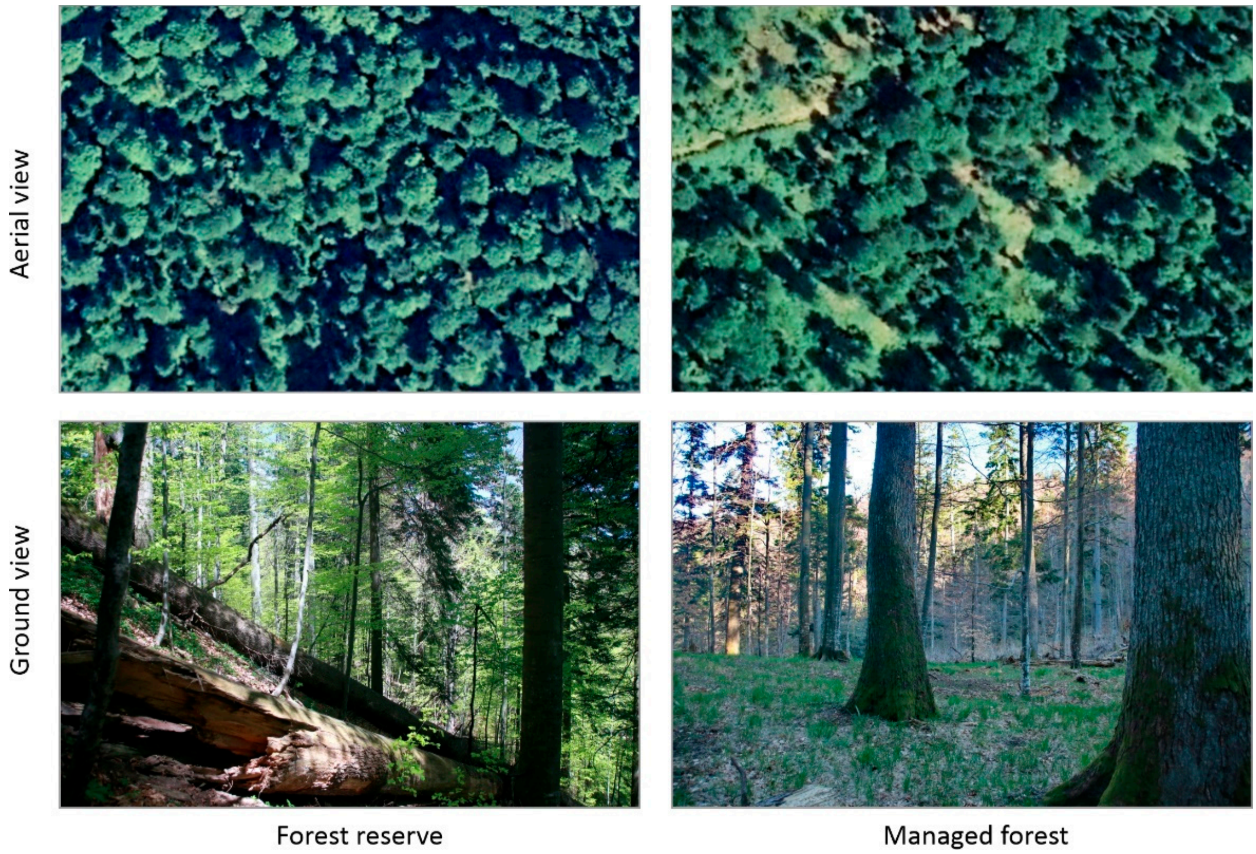

Figure 2. Aerial and ground views of forest reserve stand and managed forest stand (aerial images were taken from Google Earth).

2.2. Sampling Method and Field Design

In the 2 types of stands, 15 locations were established to collect data on the diversity of beetles that are active on the soil. The locations were chosen to have relatively similar habitat conditions for the beetles, especially in terms of the distribution of forest vegetation and dead wood. The distance between 2 locations was at least 30 m.

Three pitfall traps, consisting of 500 cm^3 polypropylene containers, were installed at each location on 4 June 2021. The pitfall traps were placed near fragments of dead wood in the case of the forest reserve and near stumps in the case of the managed forest. The insect collection vessels contained ethylene glycol (approximately 100–150 mL) to preserve catches until collection.

The entomological material was collected every two weeks, depending on the weather, between 17 June 2021 and 9 October 2021. All the traps were cleaned, and the preservative fluid was refreshed. Traps which were found destroyed or decommissioned were replaced. At the time of collection, strainers were used to pre-sort the material. The material collected from the three pitfall traps at each location was placed together in a single labeled container. The containers were subsequently stored in a freezer until laboratory analyses was performed.

2.3. Sorting and Identification of Beetles

The main activities in the laboratory were cleaning, sorting, and identifying the collected beetle species. The individuals were cleaned by placing them in a crystallizing dish filled with water and washed to eliminate any impurities left over from the collecting process. Following this, the individuals were dried using paper towels and separated by splitting the beetles from other species, such as flies, spiders, diplopods, and others. The beetles were then placed in labeled zip-lock plastic bags. Due to the typically large sample sizes, the identification procedure did not always immediately follow the sorting process; thus, the samples were re-introduced into a freezer until identification.

In the identification of species of polyspecific but also monospecific genera, external morphological characters such as the roughness of the elytra, the setulosity of the edges of the pronotum, the size and coloration of the individuals, the setulosity of the labial palps, and other characters were taken into account in the diagnosis process. The species were identified using literature both in physical and electronic form [55–58]. A Kern stereo zoom microscope type OZL-46 was used to observe the characteristics needed to identify the species. Furthermore, whenever performing procedures that required the dissection of individuals, such as with the analysis of the genital apparatus in males, a dissection kit including teasing needles, scalpels, and tweezers was used. Voucher specimens are deposited in the Forest Protection Laboratory of the Faculty of Silviculture and Forest Engineering, Brașov.

2.4. Data Analysis

All data analyses performed used the cumulative catches for each species of beetle and trap obtained as a result of successive collections from 17 June 2021 to 9 October 2021 for each of the two types of stands (forest reserve and managed forest). Therefore, the abundance and richness of beetle species captured in a stand represented the total number of individuals and species sampled in that stand.

For the analysis of species richness in the two stands, rarefaction curves were generated based on the number of individuals [59]. Estimation of species richness for trappable beetle populations was performed with the richness estimator Chao 1 [60]. All singleton species (a single individual captured per species) were included in all of the analyses performed, because the sampling method with pitfall traps minimizes the chances of capturing beetle species that do not use the sampled source (in our case, the forest ecosystem) [61]. Thus, all species of beetles captured were considered to be resident components of the assemblage of Coleoptera present at the level of the soil surface of the forest ecosystem.

The characterization of the communities of beetles captured in the pitfall traps in the two types of stands was performed using both traditional descriptors (dominance—D, constancy—C, and ecological significance—W) [62] and the PERMANOVA test [63], which allows for the evaluation of differences regarding the composition of the beetle communities in the two analyzed stands. Dominance (D) was calculated as the percentage ratio between the number of individuals of a species and the number of all beetles captured regardless of species. Depending on the D value, each species was included in one of the following categories: subrecedent species ($D \leq 1\%$), recedent species ($1\% < D \leq 2\%$), subdominant species ($2\% < D \leq 5\%$), dominant species ($5\% < D \leq 10\%$), or eudominant species ($D > 10\%$). Constancy (C) provides information related to the continuity of the presence of a species in the analyzed site. C was calculated for each individual species as a percentage ratio between the number of traps in which that species is present and the total number of traps installed in the stands. Concerning the C value, each species was placed in one of the following classes: accidental species ($1\% < C \leq 25\%$), accessory species ($25\% < C \leq 50\%$), constant species ($50\% < C \leq 75\%$), or euconstant species ($C > 75\%$). The ecological significance index W (Dzuba index) expresses the position of a species within the analyzed community according to dominance and constancy. Depending on the index's values, the species were considered accidental species ($W < 0.1\%$), accessory species ($0.1\% < D \leq 5\%$), or characteristic species ($W > 5\%$).

The application of the PERMANOVA test to analyze the significance of the differences between the beetle communities in the two sites was based on Bray–Curtis dissimilarity matrices and 999 random permutations. To avoid the effect of the most abundant species (e.g., *Anoplotrupes stercorosus*), the data were transformed using $\log10(x + 1)$ [64]. The visualization of the differences between the compositions of the two beetle communities involved the use of non-metric, multidimensional scaling (NMMS) representation [65].

Diversity analysis in the two captured beetle communities was performed using the Shannon, Simpson, Evenness, and Berger–Parker diversity indices [61]. Analysis of the significance of the differences in the indices calculated for the two types of stands was performed using the *t*-test, after previously checking the normality (Kruskal–Wallis test) and homogeneity (Levene's test) [64].

Primary data processing, ecological index calculations, and bar graph representations were carried out in Excel (version 2021) (Microsoft Corp., Redmond, Washington, WA, USA). Testing of the significance of differences, homogeneity, and normality of distributions was performed using XLSTAT-PRO (version 2012) (Addinsoft, New York, NY, USA) plugged into Excel. The calculations related to the PERMANOVA test, the diversity indices, NMMS graphs, and boxplot were performed using PAST 4.11 (Natural History Museum, University of Oslo, Norway).

3. Results

3.1. Beetle Abundance

A total of 30,401 beetles belonging to 52 species from 12 families, order Coleoptera, were caught in the 30 pitfall traps installed in the Şinca Forest (Table S1). The most numerous family collected was Geotrupidae, which represented 75.8% of the total catches, followed by Carabidae with 20.7% and Silphidae with 3.4%. The other families were represented by only 0.1% individuals (Cerambycidae, Curculionidae, Elateridae, Leiodidae, Lucanidae, Nitidulidae, Rhysodidae, Scarabaeidae and Staphylinidae). A single species, *Anoplotrupes stercorosus* (Geotrupidae), accumulated 75.6% of the total individuals, and 6 other species, *Carabus cancellatus* Illiger, 1798, *Carabus coriaceus* Linnaeus, 1758, *Carabus linnaei* Panzer, 1810, *Carabus violaceus* Linnaeus, 1758, *Pterostichus niger* (Schaller, 1783) (Carabidae), and *Nicrophorus vespilloides* Herbst, 1784 (Silphidae), accumulated 21.8%. Also, one individual belonging to the species *Rhysodes sulcatus* (Fabricius, 1787) (Rhysodidae) and *Carabus variolosus* Fabricius, 1787 (Carabidae), which are on the EU Habitat Directive red list, were captured [66]. The species richness estimated for the insects that could be captured in pitfall traps in the case of the entire studied forest area was 86.2 ± 5.7 (Chao 1), indicating a much higher richness of beetle species compared to that found (52 species).

In the 15 pitfall traps installed in the forest reserve, 16,393 beetles belonging to 37 species from 11 families were captured (1092.9 ± 200.5 individuals per location). The family Geotrupidae was the best represented (76.7% of captured individuals), followed by Carabidae (20.4%) and Silphidae (2.8%). The other families (Cerambycidae, Curculionidae, Elateridae, Leiodidae, Lucanidae, Nitidulidae, Rhysodidae and Staphylinidae) represented 0.1% of the catch. No individuals from the family Scarabaeidae were caught. Also, a single individual of the protected species *Rhysodes sulcatus* was captured only in the forest reserve.

The 15 pitfall traps installed in the managed forest captured fewer insects than those in the forest reserve (14,008 individuals, 933.9 ± 308.0 individuals per location), but no significant differences between the means of the catches (*t*-test: $t = 1.6171$, $p = 0.1171$) were found. In this case the captured insects belonged to 44 species from 10 families (Geotrupidae, Carabidae, Cerambycidae, Curculionidae, Elateridae, Leiodidae, Lucanidae, Scarabaeidae and Staphylinidae), and no specimen from the Nitidulidae and Rhysodidae families was identified. Also, the best represented family was Geotrupidae (74.7% of captured individuals), followed by Carabidae (21.1%) and Silphidae (4.1%). Among the carabids captured only in the managed forest, the protected species *Carabus variolosus* stands out.

Twenty-five species of beetles were captured both in the forest reserve and managed forest (16 species of Carabidae, 1 species of Cerambycidae, 3 species of Curculionidae, 2 species of Geotrupidae, 1 species of Leiodidae, 4 species of Silphidae, and 2 species of Staphylinidae). The species captured only in the forest reserve were *Pterostichus jurinei* (Panzer, 1803), *Pterostichus macer* (Marsham, 1802), *Dima elateroides* Charpentier, 1825, *Dorcus parallelipipedus* (Linnaeus, 1758), *Cyllodes ater* (Herbst, 1792), *Rhysodes sulcatus*, *Lordithon lunulatus* (Linnaeus, 1761), *Platydracus chalcocephalus* (Fabricius, 1801), and *Quedius lateralis*

(Gravenhorst, 1802), and the species captured only in the managed forest were *Amara famelica* C. Zimmermann, 1832, *Carabus variolosus*, *Notiophilus biguttatus* (Fabricius, 1779), *Pterostichus foveolatus* (Duftschmid, 1812), *Pterostichus minor* (Gyllenhal, 1827), *Pterostichus pilosus* (Host, 1789), *Pterostichus transversalis* (Duftschmid, 1812), *Rhagium mordax* (De Geer, 1775), *Pissodes piceae* (Illiger, 1807), *Agriotes acuminatus* (Stephens, 1830), *Ceruchus chrysomelinus* (Hochenwarth, 1785), *Aphodius luridus* (Fabricius, 1775), *Ocypus picipennis* (Fabricius, 1793), and *Platydracus fulvipes* (Scopoli, 1763) (Table S1).

Regarding the abundance (Figure 3, Table S1) of the 37 species of beetles captured in the forest reserve, 8 species were abundant (over 100 individuals captured per species), 4 species were relatively common (catches between 11 and 100 individuals per species), and 25 species were rare (captures between 1 and 10 individuals per species), and of these, 12 species were singletons. The most abundant species in descending order were: *Anoplotrupes stercorosus*, *Carabus violaceus*, *Carabus coriaceus*, *Nicrophorus vespilloides*, *Carabus linnaei*, *Cychrus caraboides* (Linnaeus, 1758), and *Cychrus semigranosus* Palliardi, 1825. In the managed forest, of the 44 species of beetles captured, 7 species were abundant, 13 species relatively common, and 24 species rare, of which 15 species were singletons. In descending order, the most abundant species captured were *Anoplotrupes stercorosus*, *Carabus violaceus*, *Carabus coriaceus*, *Nicrophorus vespilloides*, *Carabus cancellatus*, *Carabus linnaei,* and *Carabus auronitens* Fabricius, 1792.

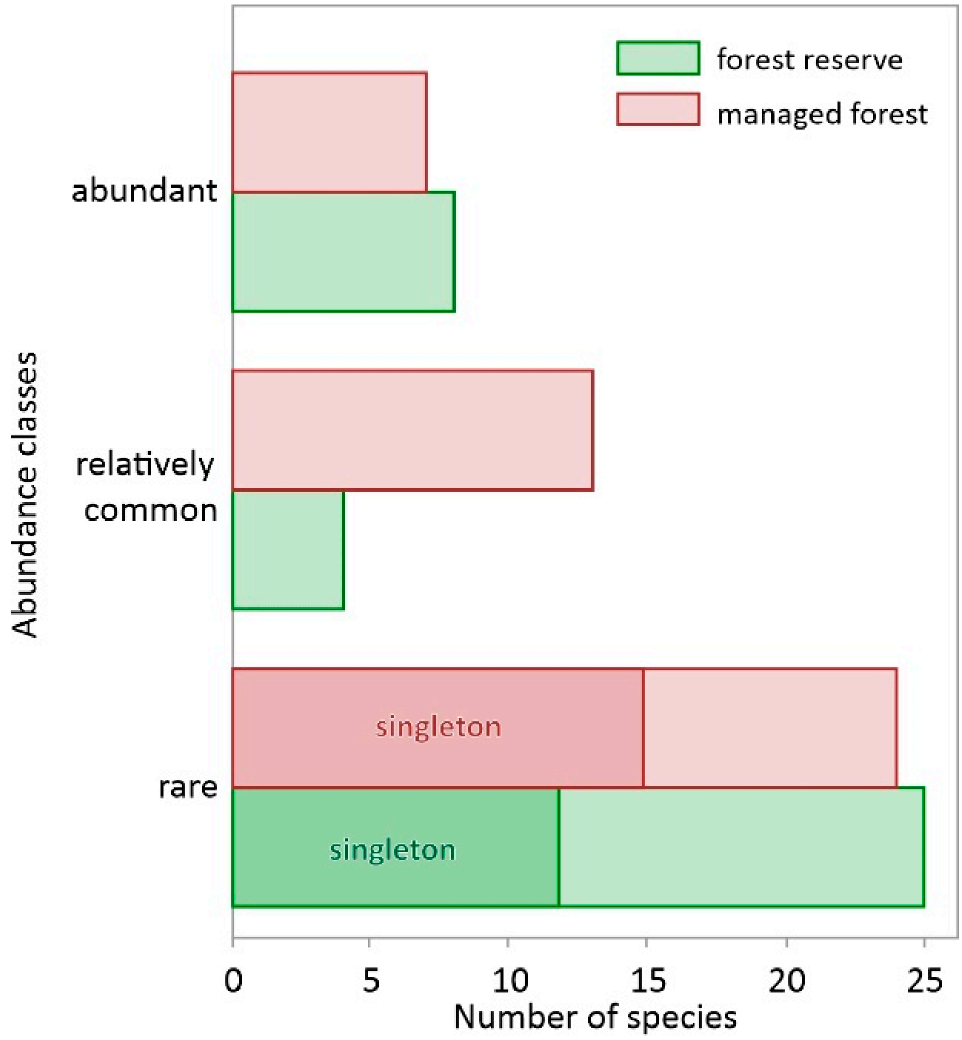

Figure 3. Distribution of the number of beetle species caught in pitfall traps by abundance classes.

The catches recorded in the two types of stands (Table S1) were similar in number of beetles for 25 species (for 14 species, the differences between means were statistically tested with the *t*-student test). However, for *Anoplotrupes stercorosus*, *Molops ovipennis* Chaudoir, 1847, and *Catops picipes* (Fabricius, 1787), significantly more individuals were captured in the forest reserve compared to the managed forest, and significantly fewer individuals were captured in the case of the species *Carabus cancellatus*, *Pterostichus oblongopunctatus* (Fabricius, 1787), and *Trypocopris vernalis* (Linnaeus, 1758).

Individual-based rarefaction curves suggest that managed forests are likely to have greater species richness than forest reserves, although the curves are not asymptote (they do not tend to merge towards the end with a horizontal line) for either of the two stands (Figure 4). This hypothesis is also supported by the values calculated for the Chao 1 estimator for species richness, 56.5 $\pm$ 4.4 for the forest reserve and 70.3 $\pm$ 6.5 for the managed forest, thus indicating the need to continue sampling efforts for beetles that can be captured in pitfall traps.

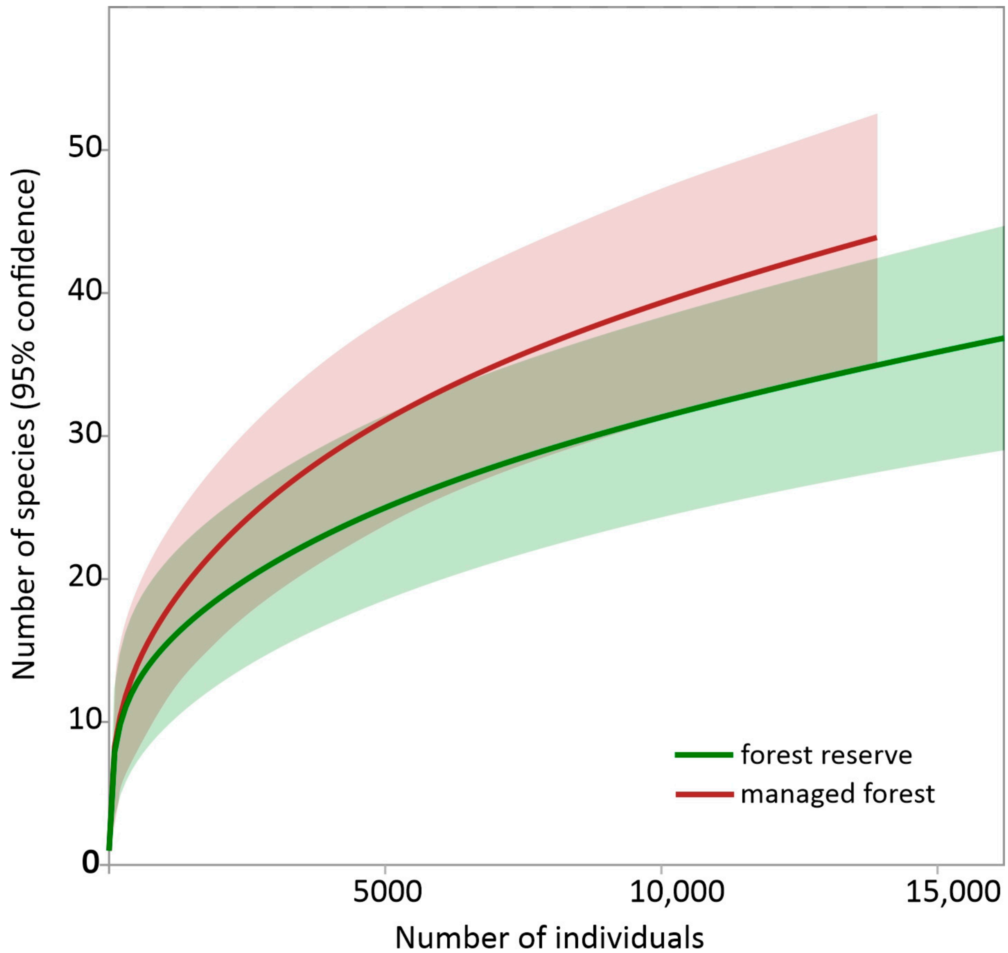

Figure 4. Individual-based rarefaction curves for species sampled in pitfall traps in each stand type.

3.2. Beetle Dominance and Constancy

Anoplotrupes stercorosus was the eudominant species in the captures from the pitfall traps in the two types of stands. Two *Carabus* species (*C. violaceus* and *C. coriaceus*) stood out as dominant species in both forests. Two beetle species were identified as subdominant species for each forest: *Nicrophorus vespilloides* was subdominant in both stands, *Carabus cancellatus* was subdominant in the managed forest, and *Carabus linnaei* was subdominant in the forest reserve. Regarding the recedent species, *Pterostichus niger* was identified in the forest reserve and *Carabus linnaei* in the managed forest. Subrecedent species represented the majority of species captured in the two types of stands, with 31 species in the forest reserve and 38 species in the managed forest, of which 22 species were common (Figure 5, Table S2).

Regarding the constancy of the beetles captured (Figure 6, Table S2), it was found that there were 9 euconstant species (7 species of Carabidae, 1 species of Geotrupidae, and 1 species of Silphidae), 3 constant species (Carabidae), 1 accessory species (Carabidae), and 24 accidental species in the forest reserve. In the catches from the managed forest, 8 euconstant species (6 species of Carabidae, 1 species of Geotrupidae, and 1 species of Silfidae), 2 constant species (one species each of Carabidae and Geotrupidae), 9 accessory species (5 Carabidae, 1 Cerambycidae, 3 Silphidae), and 25 accidental species were identified.

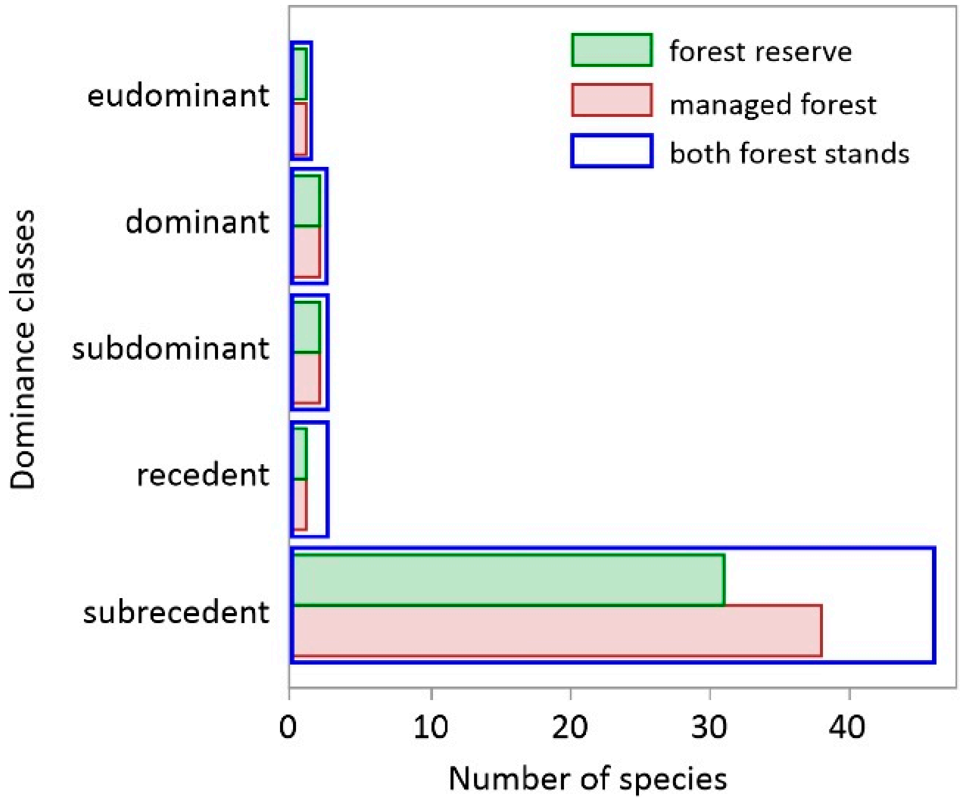

Figure 5. Distribution of the number of beetle species caught in pitfall traps by dominance classes.

Among the 29 common species identified in the two stands, 17 species fell into similar constancy classes (7 euconstant species, 1 accessory species, and 9 accidental species). However, there were common species that were assigned to different constancy classes. *Carabus auronites* and *Cychrus semigranosus* were euconstant species in the forest reserve, and in the managed forest they were accessory, respectively constant species. *Carabus cancellatus*, *Licinus hoffmannseggii,* and *Molops ovipennis* were constant species in the forest reserve, while in the managed forest they were euconstant, accessory, and accidental species, respectively (Table S2).

The ecological significance of beetles captured in pitfall traps was assessed using the Dzuba index (W) (ecological significance index) (Table S2). Thus, in the forest reserve *Anoplotrupes stercorosus* was the only species classified as a characteristic species, 9 were accessory species (8 species of Carabidae and one species of Silphidae), and 28 were accidental species. On the other hand, 3 characteristic species (*Anoplotrupes stercorosus*, *Carabus coriaceus*, and *Carabus violaceus*) and 8 accessory species (6 species of Carabidae, one species of Geotrupidae, and one species of Silphidae) were found in the managed forest.

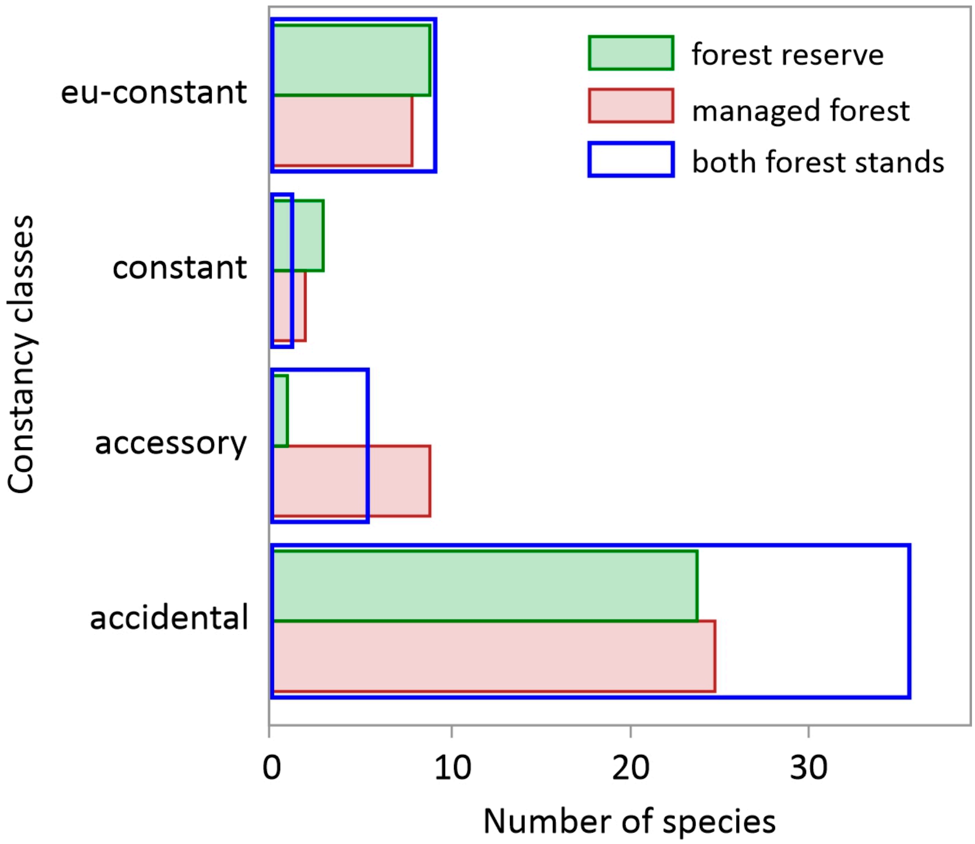

Figure 6. Distribution of the number of beetle species caught in pitfall traps by constancy classes.

3.3. PERMANOVA Analysis of the Differences between the Two Beetle Communities

Permutational multivariate analysis of variance indicated the existence of significant differences regarding the composition of the captured insects between the beetle communities collected in pitfall traps from the forest reserve and the managed forest (F = 8.063, $p < 0.01$) (Figure 7a). Regarding the populations of beetles from the Geotrupidae family (F = 4.193, $p = 0.04$) (Figure 7b) and from the Carabidae family (F = 5.025, $p < 0.01$) (Figure 7c), significant differences were registered between the forest reserve and managed forest. However, no significant influence of stand type was found on the populations of Silphidae beetles (F = 0.838, $p = 0.44$) (Figure 7d).

A significant influence of the type of stand was found on beetle communities grouped according to food preferences, at least in the case of predatory beetles (PERMANOVA: F = 5.01, $p < 0.01$, Figure 7e) and detritivorous species (PERMANOVA: F = 3.51, $p < 0.01$, Figure 7f). There were no differences in herbivorous insect and xylophagous beetle communities between the forest reserve and the managed forest. Mycetophagous insects (*Cyllodes ater* and *Rhysodes sulcatus*) were caught only in the forest reserve.

3.4. Beetle Community Diversity

The diversity of coleopteran communities captured using pitfall traps in the two stand types was measured using the Shannon, Simpson, Evenness, and Berger–Parker indices. In the case of the first three indices, the average values are higher for the managed forest as compared to the forest reserve (Figure 8), but without significant differences between them. In the case of the Berger–Parker index, the average values are similar for the two stand types.

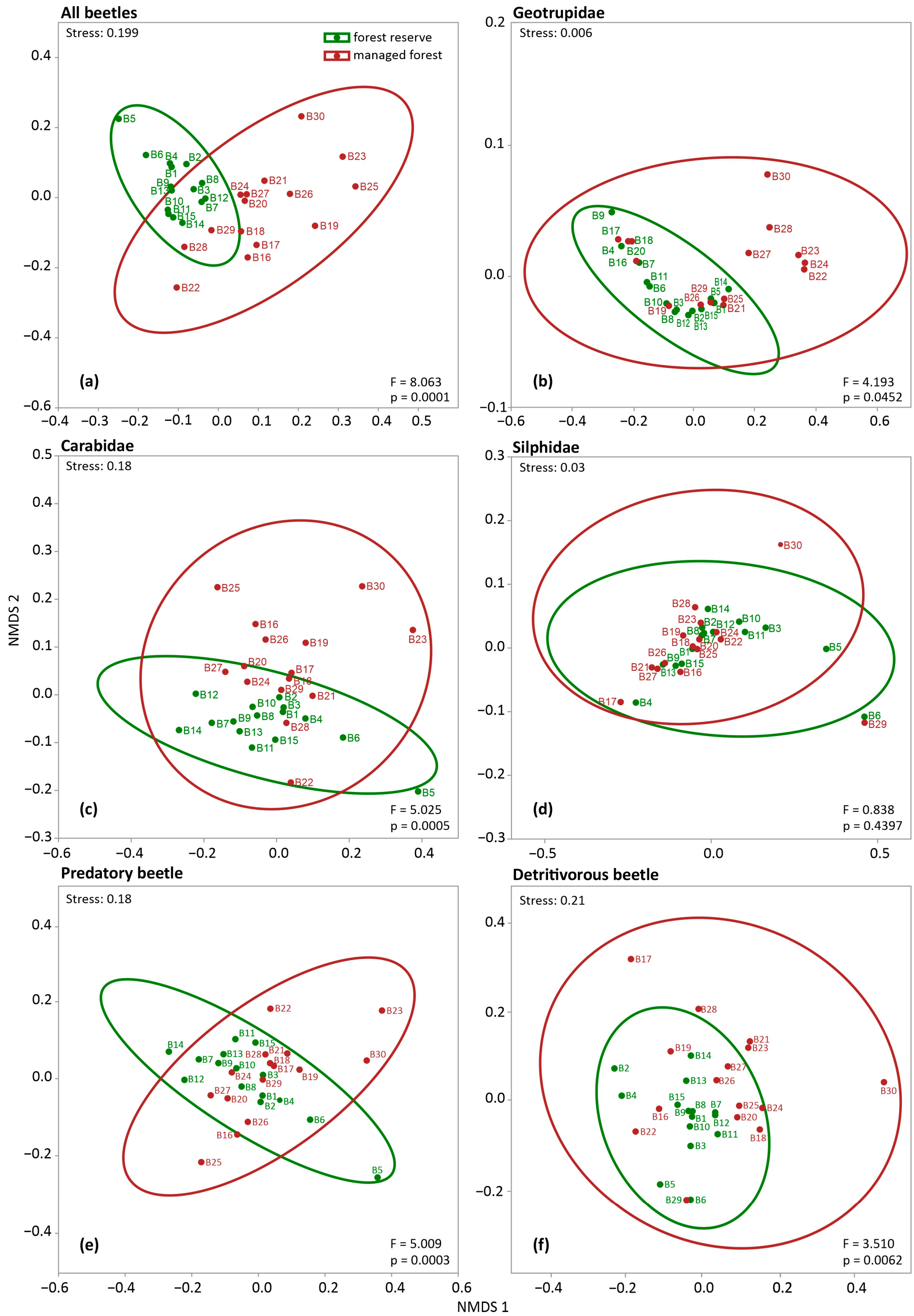

Figure 7. Non-metric, multidimensional scaling (NMDS) of Bray–Curtis distances of sampled beetle communities according to stand type (forest reserve and managed forest) and all beetles captured (**a**), Geotrupidae beetles (**b**), Carabidae beetles (**c**), Silphidae beetles (**d**), and two trophic guilds, the predatory (**e**) and the detritivorous group (**f**). Pairwise PERMANOVA with 999 permutations (using pseudo-F ratios) was used for all comparisons.

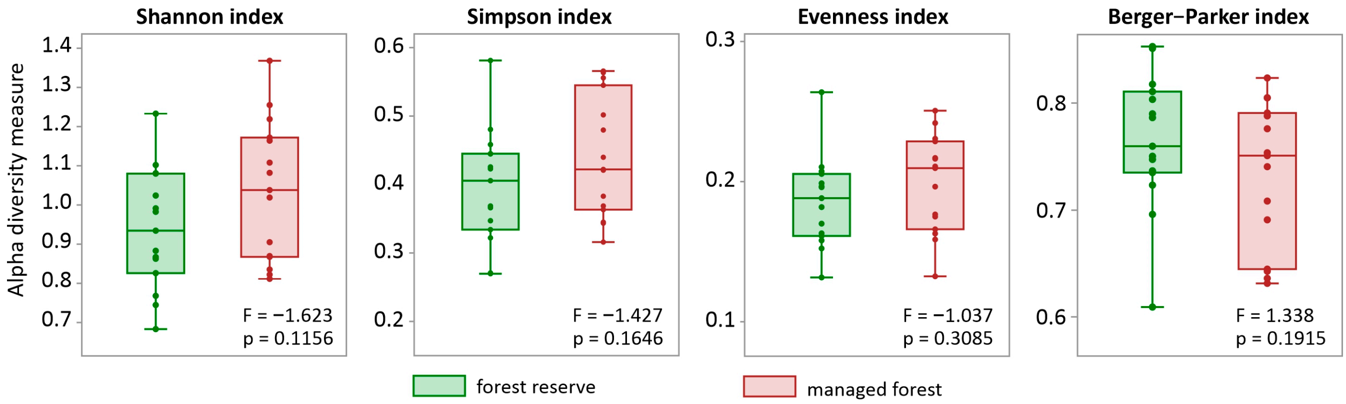

Figure 8. Comparison of captured Coleoptera community diversities between forest reserve and managed forest. Diversity was measured using the Shannon index, Simpson index, Evenness index, and Berger–Parker index. The top and bottom boundaries of each box indicate the 75th and 25th quartile values, respectively. The lines within each box represent the median values. The differences between alpha diversity indices were tested with a *t*-test.

4. Discussion

Numerous studies show that forest management is an important factor influencing forest diversity [67], including beetle diversity [45,48]. The present study confirms this, at least regarding the beetles living on the ground in the Șinca Forest. The abundance of the average catches in the forest reserve was about 17% higher than in the managed forest, while species richness was higher in the managed forest, where 19.1% more species were caught. Significant differences between the beetle communities in the two stands were also noticeable (Figure 6a). Human intervention in forests through tree removal most often leads to a decrease in the abundance and richness of arthropod species, especially xylobiont species [68,69], but it seems that changes in landscape characteristics affect the abundance and richness of the beetles living on the ground less than xylobiont ones [70] (in our case, low-intensity interventions led to lower stand consistency and a lack of dead wood in the managed forest).

Regarding abundance, most of the beetles belonged to the family Geotrupidae. Of these, *Anoplotrupes stercorosus* was by far the eudominant species, accounting for about three quarters of the total number of beetles, with significantly more individuals caught in the forest reserve (+15.1%) than in the managed forest. Similar studies have reported significant catches of this species in pitfall traps installed in a pine forest in southern Poland (about 47–49% of the total individuals caught) [24], or in the forests of the Maramureș Mountains [34]. The large number of individuals captured was not accidental; this dung beetle species is the most common among the Geotrupidae living in forest ecosystems in Central Europe. Its abundance is related to the richness of specific food sources (animal excrement, fruiting bodies of some fungi, decaying litter, etc.) but also to the humidity of the substrate, with beetles avoiding wet areas [39]. The Șinca Forest is characterized by high diversity and richness of mammals [53], which provide continuous food sources for this insect. The greater number of *A. stercorosus* caught in the forest reserve is likely due to higher food supplies.

The Carabidae family was the second representative in abundance; it was also distinguished by a significant variation of insect communities in the two stands (Figure 6c). This most likely happened due to the local diversity of microhabitats in the sampling locations, an aspect also discussed in similar studies [37,71]. Among the carabids, *Carabus cancellatus* stood out, for which about 20 times more individuals were captured in the managed forest than in the forest reserve. This species is characteristic of open habitats [33], a condition that is more frequent in the managed forest, which has a lower consistency and more significant layer of grassy vegetation on the ground than the forest reserve (Figure 2). On the other hand, *Pterostichus niger* was more common in the forest reserve, this species preferring forest habitats with more hygrophilic soils [72]. However, there were species of carabids for which only one specimen was caught. Most of them are not characteristic of forest habitats (e.g., *Pterostichus macer* prefers swampy areas, and *Amara famelica* prefers habitats with warm soil [73]). In the managed forest, the capture of an individual of *Carabus variolosus*, a rare, protected, wetland-loving species, is worth noting; it is considered an indicator of naturalness [74].

The Silphidae communities captured in the two stands were similar, being represented by *Nicrophorus* species, of which *N. vespilloides* was the most abundant. They are specific to forest habitats, have a necrophagous diet, and are dependent on animal carcasses [75].

In both stand types, the beetle communities captured in pitfall traps were composed of either low numbers or singleton individuals belonging to species common to mixed conifer–beech forests, which are trophically dependent on decaying wood in these ecosystems. Of these, *Prionus coriarius* (Linnaeus, 1758) and *Rhagium mordax* (Cerambycidae), *Hylobius abietis* (Linnaeus, 1758) and *Pissodes piceae* (Curculionidae), and *Dorcus parallelipipedus* (Lucanidae) are xylophagous species which develop between bark and wood or in the wood of weakened or dead trees as well as in tree stumps [55,76–78]. We noticed the xylophagous species *Ceruchus chrysomelinus* (Lucanidae), caught only in the managed forest, is now considered a relict species, endangered in the mountain forests of Central Europe [79]. Also noteworthy was the presence of two mycetophagous beetle species, *Cyllodes ater* (Nitidulidae) and *Rhysodes sulcatus* (Rhysodidae), in the forest reserve catches, which are closely related to fungi that develop on dead wood [80,81], *Rhysodes sulcatus* being a relict, endangered species. Other common beetle species were also caught: *Agriotes acuminatus*, *Dima elateroides* (Elateridae), *Catops picipes* (Leiodidae), *Aphodius luridus* (Scarabaeidae), or predatory species of Staphylinidae.

The characterization of the two beetle communities using indices of abundance, dominance, constancy, and ecological significance allowed classification of species by different positions of importance within the samples captured from pitfall traps. Few species were described as abundant, dominant, euconstant, or characteristic, whereas most species were classified as rare, subrecedent, or accidental. However, this species characterization has certain limitations, as it is expected that the sampling method used (pitfall traps) does not comprise the true richness and population size of terrestrial beetle species [82], and classifications based on the used indices are only indicative [83].

The assessment of the diversity of the beetle communities under study using the Shannon, Simpson, Evenness, and Berger–Parker indices showed that the two communities have similar diversity, most likely affected by the eudominant species *Anoplotrupes stercorosus*. The calculated Shannon values (Figures 3 and 4) was lower than the theoretical maximum value indicating high diversity (Shannon index = 5) [84]. Also, the values of the Simpson and Evenness indices were much lower than the maximum value of 1 (typical of high diversity). These indices take into account the abundance, dominance, or evenness of the present species and are therefore particularly sensitive to highly abundant species [85].

This study has a number of limitations. The sampling level used may not accurately point out the differences in terrestrial insect diversity between the two stand types. Thus, the presented results can be viewed as an initial assessment of the differences between the two beetle communities captured in pitfall traps in the forest reserve and the managed forest. Probably a dataset including information collected using other sampling methods (flight traps, etc.) would provide a wealth of information, especially on xylobiont species, as has been found in other studies [26,69,86,87].

5. Conclusions

The present study provides a first insight into the diversity of terrestrial beetles in the Șinca Forest by comparing beetle communities captured in pitfall traps in two stands: the forest reserve and the managed forest. Among the captured insects, relict species (endangered in European forests) that indicate a high degree of naturalness of the ecosystems were identified: *Carabus variolosus*, *Ceruchus chrysomelinus,* and *Rhysodes sulcatus*. The PERMANOVA test indicated significant differences between the beetle communities captured in the two types of stands, most likely due to the capture of a large number of singleton species found in only one of the two communities, but also due to the large differences in abundances for some beetle species. The Shannon, Simpson, Evenness, and Berger–Parker tests failed to show significant differences in the diversity of the two beetle communities.

Further research using other sampling methods capable of capturing other insect groups, especially xylobionts, is needed to better emphasize the differences in beetle diversity in the forest reserve compared to the managed forest.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/f14010060/s1, Table S1: Coleoptera species collected in pitfall traps from Șinca Forest: abundance, mean of catches per location and species, and significance of differences between means of catches in forest reserve and managed forest stands; Table S2: Coleoptera species collected in pitfall traps from Șinca Forest: constancy (C); dominance (D); and ecological significance index (W), and feeding preference: H—herbivory; X—xylophagous; P—predatory; D—detritivorous; M—mycetophagous.

Author Contributions: Conceptualization, G.I. and M.-L.D.; methodology, G.I. and M.-L.D.; field investigation, G.I. and I.-M.D.; insect identification, I.-M.D.; data curation, G.I. and M.-L.D.; writing—original draft preparation, G.I. and M.-L.D.; writing—review and editing, G.I. and M.-L.D.; visualization, M.-L.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by a grant of the Romanian Ministry of Education and Research, CNCS-UEFISCDI, project number PN-III-P4-ID-PCE-2020-2696, within PNCDI III. The APC was funded by the Transilvania University of Brașov.

Data Availability Statement: On reasonable request, derived data supporting the findings of this study are available from the corresponding authors.

Acknowledgments: The authors thank the two anonymous reviewers for their valuable and constructive recommendations, which contributed to the improvement of the paper. We are grateful to all students from the Faculty of Silviculture and Forest Engineering Brașov for their voluntary help in collecting the field data, with a special mention to Alexandru Patrașcu for his involvement in both field and laboratory activities. The authors would like to thank Ion Cătălin Petrițan for his moral and material support in the study. We thank Sorin Urdea, manager of the forest district, for permission to perform our study in the Șinca Old-Growth Forest.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Lindenmayer, D.B.; Franklin, J.F.; Fischer, J. General management principles and a checklist of strategies to guide forest biodiversity conservation. *Biol. Conserv.* **2006**, *131*, 433–445. [CrossRef]
2. Davies, S.J.; Abiem, I.; Abu Salim, K.; Aguilar, S.; Allen, D.; Alonso, A.; Anderson-Teixeira, K.; Andrade, A.; Arellano, G.; Ashton, P.S.; et al. ForestGEO: Understanding forest diversity and dynamics through a global observatory network. *Biol. Conserv.* **2021**, *253*, 108907. [CrossRef]
3. Immerzeel, W.W.; Lutz, A.F.; Andrade, M.; Bahl, A.; Biemans, H.; Bolch, T.; Hyde, S.; Brumby, S.; Davies, B.J.; Elmore, A.C.; et al. Importance and vulnerability of the world's water towers. *Nature* **2020**, *577*, 364–369. [CrossRef] [PubMed]
4. Keenan, T.F.; Williams, C.A. The Terrestrial Carbon Sink. *Annu. Rev. Env. Resour.* **2018**, *43*, 219–243. [CrossRef]
5. Europe, F. State of Europe's forests 2020. Ministerial Conference on the Protection of Forests in Europe, Bratislava, Slovakia. Available online: https://foresteurope.org/state-of-europes-forests/ (accessed on 6 November 2022).
6. Luick, R.; Reif, A.; Schneider, E.; Grossmann, M.; Fodor, E. Pădurile virgine în inima Europei. Importanța, situația curentă și viitorul pădurilor virgine ale României. *Bucov. For.* **2021**, *21*, 105–126. [CrossRef]
7. Biriș, I.-A.; Teodosiu, M.; Turcu, D.-O.; Merce, O.; Lorenț, A.; Apostol, J.; Marcu, C. 24000 ha of primary beech forests, the Romanian proposal in UNESCO World Heritage. *Bucov. For.* **2016**, *16*, 107–116.
8. Peterken, G.F. *Natural Woodland: Ecology and Conservation in Northern Temperate Regions*; Cambridge University Press: Cambridge, UK, 1996; p. 522.
9. Paillet, Y.; Pernot, C.; Boulanger, V.; Debaive, N.; Fuhr, M.; Gilg, O.; Gosselin, F. Quantifying the recovery of old-growth attributes in forest reserves: A first reference for France. *For. Ecol. Manag.* **2015**, *346*, 51–64. [CrossRef]

10. Sabatini, F.M.; Burrascano, S.; Keeton, W.S.; Levers, C.; Lindner, M.; Pötzschner, F.; Verkerk, P.J.; Bauhus, J.; Buchwald, E.; Chaskovsky, O.; et al. Where are Europe's last primary forests? *Divers. Distrib.* **2018**, *24*, 1426–1439. [CrossRef]
11. Burrascano, S.; Keeton, W.S.; Sabatini, F.M.; Blasi, C. Commonality and variability in the structural attributes of moist temperate old-growth forests: A global review. *For. Ecol. Manag.* **2013**, *291*, 458–479. [CrossRef]
12. Duduman, G.; Barnoaiea, I.; Avăcăriței, D.; Barbu, C.-O.; Coșofreț, V.-C.; Dănilă, I.-C.; Duduman, M.-L.; Măciucă, A.; Drăgoi, M. Aboveground Biomass of Living Trees Depends on Topographic Conditions and Tree Diversity in Temperate Montane Forests from the Slătioara-Rarău Area (Romania). *Forests* **2021**, *12*, 1507. [CrossRef]
13. Vandekerkhove, K.; De Keersmaeker, L.; Menke, N.; Meyer, P.; Verschelde, P. When nature takes over from man: Dead wood accumulation in previously managed oak and beech woodlands in North-western and Central Europe. *For. Ecol. Manag.* **2009**, *258*, 425–435. [CrossRef]
14. Duduman, G. A forest management planning tool to create highly diverse uneven-aged stands. *For. Int. J. For. Res.* **2011**, *84*, 301–314. [CrossRef]
15. Burrascano, S.; Chytrý, M.; Kuemmerle, T.; Giarrizzo, E.; Luyssaert, S.; Sabatini, F.M.; Blasi, C. Current European policies are unlikely to jointly foster carbon sequestration and protect biodiversity. *Biol. Conserv.* **2016**, *201*, 370–376. [CrossRef]
16. Navarro, L.M.; Pereira, H.M. Rewilding Abandoned Landscapes in Europe. *Ecosystems* **2012**, *15*, 900–912. [CrossRef]
17. Duduman, G.; Drăgoi, M. *Forest management Planning—Spatial-Temporal Organization*; Editura Universității "Ștefan cel Mare" Suceava: Suceava, Romania, 2019; p. X+209.
18. Jonsson, B.G.; Siitonen, J. Dead wood and sustainable forest management. In *Biodiversity in Dead Wood*; Jonsson, B.G., Stokland, J.N., Siitonen, J., Eds.; Ecology, Biodiversity and Conservation; Cambridge University Press: Cambridge, UK, 2012; pp. 302–337.
19. Li, W.-B.; Liu, N.-Y.; Wu, Y.-H.; Zhang, Y.-C.; Xu, Q.; Chu, J.; Wang, S.-Y.; Fang, J. Community composition and diversity of ground beetles (Coleoptera: Carabidae) in Yaoluoping National Nature Reserve. *J. Insect Sci.* **2017**, *17*, 114. [CrossRef]
20. Olenici, N.; Fodor, E. The diversity of saproxylic beetles' from the Natural Reserve Voievodeasa forest, North-Eastern Romania. *Ann. For. Res.* **2021**, *64*, 31–60. [CrossRef]
21. Holliday, N. Species responses of carabid beetles (Coleoptera: Carabidae) during post-fire regeneration of boreal forest. *Can. Entomol.* **1991**, *123*, 1369–1389. [CrossRef]
22. Wikars, L.-O. Clear-cutting before burning prevents establishment of the fire-adapted *Agonum quadripunctatum* (Coleoptera: Carabidae). In Proceedings of the Annales Zoologici Fennici, Helsinki, Finland, 8 December 1995; pp. 375–384.
23. Saint-Germain, M.; Larrivée, M.; Drapeau, P.; Fahrig, L.; Buddle, C.M. Short-term response of ground beetles (Coleoptera: Carabidae) to fire and logging in a spruce-dominated boreal landscape. *For. Ecol. Manag.* **2005**, *212*, 118–126. [CrossRef]
24. Błońska, E.; Bednarz, B.; Kacprzyk, M.; Piaszczyk, W.; Lasota, J. Effect of scots pine forest management on soil properties and carabid beetle occurrence under post-fire environmental conditions-a case study from Central Europe. *For. Ecosyst.* **2020**, *7*, 1–12. [CrossRef]
25. Cobb, T.; Langor, D.; Spence, J. Biodiversity and multiple disturbances: Boreal forest ground beetle (Coleoptera: Carabidae) responses to wildfire, harvesting, and herbicide. *Can. J. For. Res.* **2007**, *37*, 1310–1323. [CrossRef]
26. Tello, F.; González, M.E.; Micó, E.; Valdivia, N.; Torres, F.; Lara, A.; García-López, A. Short-Interval, Severe Wildfires Alter Saproxylic Beetle Diversity in Andean Araucaria Forests in Northwest Chilean Patagonia. *Forests* **2022**, *13*, 441. [CrossRef]
27. Niemelä, J.; Langor, D.; Spence, J.R. Effects of clear-cut harvesting on boreal ground-beetle assemblages (Coleoptera: Carabidae) in western Canada. *Conserv. Biol.* **1993**, *7*, 551–561. [CrossRef]
28. Work, T.T.; Shorthouse, D.P.; Spence, J.R.; Volney, W.J.A.; Langor, D. Stand composition and structure of the boreal mixedwood and epigaeic arthropods of the Ecosystem Management Emulating Natural Disturbance (EMEND) landbase in northwestern Alberta. *Can. J. For. Res.* **2004**, *34*, 417–430. [CrossRef]
29. Allen, C.D.; Macalady, A.K.; Chenchouni, H.; Bachelet, D.; McDowell, N.; Vennetier, M.; Kitzberger, T.; Rigling, A.; Breshears, D.D.; Hogg, E.H.; et al. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *For. Ecol. Manag.* **2010**, *259*, 660–684. [CrossRef]
30. Pearce, J.L.; Venier, L.A.; McKee, J.; Pedlar, J.; McKenney, D. Influence of habitat and microhabitat on carabid (Coleoptera: Carabidae) assemblages in four stand types. *Can. Entomol.* **2003**, *135*, 337–357. [CrossRef]
31. Koivula, M.J. Useful model organisms, indicators, or both? Ground beetles (Coleoptera, Carabidae) reflecting environmental conditions. *Zookeys* **2011**, *100*, 287–317. [CrossRef]
32. Spence, J.R.; Niemelä, J.K. Sampling carabid assemblages with pitfall traps: The madness and the method. *Can. Entomol.* **1994**, *126*, 881–894. [CrossRef]
33. Jad'ud'ová, J.; Kanianska, R.; Kizeková, M.; Makovníková, J. Evaluation of Habitat Provision On the Basis of Carabidae Diversity in Slovak Permanent Grasslands. *IOP Conf. Ser. Earth Environ. Sci.* **2016**, *44*, 052031. [CrossRef]
34. Nitu, E. Species diversity of the beetle fauna, a sensitive parameter for ecological monitoring. Maramures Mountains Nature Park (Romania). *Transylv. Rev. Syst. Ecol. Res.* **2008**, *5*, 143–154.
35. Rainio, J.; Niemelä, J. Ground beetles (Coleoptera: Carabidae) as bioindicators. *Biodivers. Conserv.* **2003**, *12*, 487–506. [CrossRef]
36. Kotze, D.J.; O'Hara, R.B. Species decline—But why? Explanations of carabid beetle (Coleoptera, Carabidae) declines in Europe. *Oecologia* **2003**, *135*, 138–148. [CrossRef]
37. Avgın, S.S.; Luff, M.L. Ground beetles (Coleoptera: Carabidae) as bioindicators of human impact. *Munis Entomol. Zool.* **2010**, *5*, 209–215.

38. Lobo, J.M. Estimation of dung beetle biomass (Coleoptera: Scarabaeoidea). *Eur. J. Entomol.* **1993**, *90*, 235–238.
39. Byk, A.; Semkiw, P. Habitat preferences of the forest dung beetle *Anoplotrupes stercorosus* (Scriba, 1791)(Coleoptera: Geotrupidae) in the Białowieża Forest. *Acta Sci. Pol. Silvarum Colendarum Ratio Et Ind. Lignaria* **2010**, *9*, 17–28.
40. Mittal, I.; Bhati, R. Food preference of some dung beetles (Coleoptera: Scarabaeidae). *J. Entomol. Res.* **1998**, *22*, 107–115.
41. Creighton, J.C.; Bastarache, R.; Lomolino, M.V.; Belk, M.C. Effect of forest removal on the abundance of the endangered American burying beetle, *Nicrophorus americanus* (Coleoptera: Silphidae). *J. Insect Conserv.* **2009**, *13*, 37–43. [CrossRef]
42. Rubner, K.; Rubner, H.; Rittershofer, F. Grundlagen des naturnahen Waldbaus in Europa. *Forstwiss. Cent.* **1968**, *87*, 8–36. [CrossRef]
43. Keeton, W.S.; Chernyavskyy, M.; Gratzer, G.; Main-Knorn, M.; Shpylchak, M.; Bihun, Y. Structural characteristics and aboveground biomass of old-growth spruce–fir stands in the eastern Carpathian mountains, Ukraine. *Plant Biosyst. Int. J. Deal. All Asp. Plant Biol.* **2010**, *144*, 148–159. [CrossRef]
44. European Economic Area. *Developing a Forest Naturalness Indicator for Europe. Concept and Methodology for a High Nature Value (HNV) Forest Indicator. EEA Technical Report No 13/2014*; Publications Office of the European Union: Luxembourg, 2014; p. 64.
45. Chowdhury, S.; Jennions, M.D.; Zalucki, M.P.; Maron, M.; Watson, J.E.M.; Fuller, R.A. Protected areas and the future of insect conservation. *Trends Ecol. Evol.* **2022**, *38*, 85–95. [CrossRef]
46. Canelles, Q.; Aquilué, N.; James, P.M.A.; Lawler, J.; Brotons, L. Global review on interactions between insect pests and other forest disturbances. *Landsc. Ecol.* **2021**, *36*, 945–972. [CrossRef]
47. Jouveau, S.; Toïgo, M.; Giffard, B.; Castagneyrol, B.; van Halder, I.; Vétillard, F.; Jactel, H. Carabid activity-density increases with forest vegetation diversity at different spatial scales. *Insect Conserv. Divers.* **2020**, *13*, 36–46. [CrossRef]
48. Oettel, J.; Lapin, K. Linking forest management and biodiversity indicators to strengthen sustainable forest management in Europe. *Ecol. Indic.* **2021**, *122*, 107275. [CrossRef]
49. Nițu, E.; Olenici, N.; Popa, I.; Nae, A.; Biriș, I.-A. Soil and saproxylic species (Coleoptera, Collembola, Araneae) in primeval forests from the northern part of South-Easthern Carpathians. *Ann. For. Res.* **2010**, *52*, 27–54.
50. Nitzu, E.; Olenici, N. The first study on the beetle fauna in the Giumalau spruce primeval forest (Eastern Carpathians, Romania), mainly based on a quantitative analysis of terrestrial and saproxylic species. In *Buse J., Saproxylic Beetles–Their Role and Diversity in European Woodland and Tree Habitats, Proceedings of the 5th Symposium and Workshop on the Conservation of Saproxylic Beetles, Leuphana University of Lüneburg, Germany, 14–16 June 2008*; Pensoft: Sofia, Bulgaria, 2009; pp. 27–48.
51. Sima, G.; Gherman, S.; Banu, C. *Forest Management Plan of the Public and Private Property Forest Fund of the Șinca Commune, Brașov County*; S.C. Omni S.R.L.: Timișoara, Romania, 2015; p. 546.
52. Guțu, O.; Urdea, S.; Gotea, C.; Lorenț, A.; Struțeanu, M.; Matei, S. Șinca Old Gowth Forest. 2015, 2. Available online: https://padurivirgine.ro/wp-content/uploads/2021/06/pliant-Codrii-Seculari-de-la-Sinca-ME_GO-revizuit.pdf (accessed on 3 November 2022).
53. Petritan, I.C.; Commarmot, B.; Hobi, M.L.; Petritan, A.M.; Bigler, C.; Abrudan, I.V.; Rigling, A. Structural patterns of beech and silver fir suggest stability and resilience of the virgin forest Sinca in the Southern Carpathians, Romania. *For. Ecol. Manag.* **2015**, *356*, 184–195. [CrossRef]
54. M.M.A.P. Technical rules on the choice and application of treatments and the Guide to good practice on the choice and application of treatments. *Monitorul Oficial al României* **2022**, *190(994bis)*, 10–70.
55. Bense, U. *Longhorn Beetles: Illustrated Key to the Cerambycidae an Vesperidae of Europe*; Margraf Verlag: Weikersheim, Germany, 1995; p. 512.
56. Lohse, G.A.; Freude, H.; Harde, K.W.; Klausnitzer, B. *Die Käfer Mitteleuropas. 12: Supplementbd. 1: Mit Katalogteil*; Spektrum Akad; Verlag: Krefeld, Germany, 1989; p. 346.
57. Löbl, I.; Smetana, A. *Catalogue of Palaearctic Coleoptera*; Apollo Books: Stenstrup, Denmark, 2003; Volume 6.
58. Trautner, J.; Geigenmüller, K. *Tiger Beetles, Ground Beetles. Illustrated Key to the Cicindelidae and Carabidae of Europe*; Triops Verlag: Nördlingen, Germany, 1987; p. 488.
59. Chao, A.; Gotelli, N.J.; Hsieh, T.C.; Sander, E.L.; Ma, K.H.; Colwell, R.K.; Ellison, A.M. Rarefaction and extrapolation with Hill numbers: A framework for sampling and estimation in species diversity studies. *Ecol. Monogr.* **2014**, *84*, 45–67. [CrossRef]
60. Colwell, R.K.; Coddington, J.A. Estimating terrestrial biodiversity through extrapolation. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **1994**, *345*, 101–118. [CrossRef]
61. Magurran, A.E. *Measuring Biological Diversity*; Wiley: Hoboken, NJ, USA, 2004; p. 256.
62. Engelmann, H.D. Zur Dominanzklassifizierung von Bodenarthropoden. *Pedobiologia* **1978**, *18*, 378–380.
63. Anderson, M.J. Permutational Multivariate Analysis of Variance (PERMANOVA). Wiley StatsRef: Statistics Reference Online. pp. 1–15. Available online: https://onlinelibrary.wiley.com/doi/full/10.1002/9781118445112.stat07841 (accessed on 2 November 2022).
64. Zar, J.H. *Biostatistical Analysis*, 5th ed.; Pearson Prentice Hall: Upper Saddle River, NJ, USA, 2010.
65. Taguchi, Y.H.; Oono, Y. Relational patterns of gene expression via non-metric multidimensional scaling analysis. *Bioinformatics* **2005**, *21*, 730–740. [CrossRef]
66. Commission, E.; Environment, D.-G.f.; Sundseth, K. *The EU Birds and Habitats Directives: For Nature and People in Europe*; Publications Office: Luxembourg, Belgium, 2018.
67. Schulze, E.D. Effects of forest management on biodiversity in temperate deciduous forests: An overview based on Central European beech forests. *J. Nat. Conserv.* **2018**, *43*, 213–226. [CrossRef]

68. Kazerani, F.; Farashiani, M.E.; Sagheb-Talebi, K.; Thorn, S. Forest management alters alpha-, beta-, and gamma diversity of saproxylic flies (Brachycera) in the Hyrcanian forests, Iran. *For. Ecol. Manag.* **2021**, *496*, 119444. [CrossRef]
69. McGeoch, M.A.; Schroeder, M.; Ekbom, B.; Larsson, S. Saproxylic beetle diversity in a managed boreal forest: Importance of stand characteristics and forestry conservation measures. *Divers. Distrib.* **2007**, *13*, 418–429. [CrossRef]
70. Janssen, P.; Fortin, D.; Hébert, C. Beetle diversity in a matrix of old-growth boreal forest: Influence of habitat heterogeneity at multiple scales. *Ecography* **2009**, *32*, 423–432. [CrossRef]
71. Rischen, T.; Frenzel, T.; Fischer, K. Biodiversity in agricultural landscapes: Different non-crop habitats increase diversity of ground-dwelling beetles (Coleoptera) but support different communities. *Biodivers. Conserv.* **2021**, *30*, 3965–3981. [CrossRef]
72. Brygadyrenko, V. Evaluation of ecological niches of abundant species of Poecilus and Pterostichus (Coleoptera: Carabidae) in forests of steppe zone of Ukraine. *Entomol. Fenn.* **2016**, *27*, 81–100. [CrossRef]
73. Secretariat, G. GBIF Backbone Taxonomy. Checklist Dataset. Available online: https://www.gbif.org/dataset (accessed on 3 December 2022).
74. Matern, A.; Drees, C.; Kleinwächter, M.; Assmann, T. Habitat modelling for the conservation of the rare ground beetle species *Carabus variolosus* (Coleoptera, Carabidae) in the riparian zones of headwaters. *Biol. Conserv.* **2007**, *136*, 618–627. [CrossRef]
75. Esh, M.; Oxbrough, A. Macrohabitat associations and phenology of carrion beetles (Coleoptera: Silphidae, Leiodidae: Cholevinae). *J. Insect Conserv.* **2021**, *25*, 123–136. [CrossRef]
76. Leather, S.R.; Day, K.R.; Salisbury, A.N. The biology and ecology of the large pine weevil, *Hylobius abietis* (Coleoptera: Curculionidae): A problem of dispersal? *Bull. Entomol. Res.* **1999**, *89*, 3–16. [CrossRef]
77. Starzyk, J. Bionomics, ecology and economic importance of the fir weevil, *Pissodes piceae* (III.)(Col., Curculionidae) in mountain forests. *J. Appl. Entomol.* **1996**, *120*, 65–75. [CrossRef]
78. Hendriks, P. Life cycle length of the lesser stag beetle (Coleoptera: Lucanidae: Dorcus parallelipipedus). *Entomol. Ber.* **2019**, *79*, 208–216.
79. Kašák, J.; Mazalová, M.; Šipoš, J.; Foit, J.; Hučín, M.; Kuras, T. Habitat preferences of Ceruchus chrysomelinus, an endangered relict beetle of the natural Central European montane forests. *Insect Conserv. Divers.* **2019**, *12*, 206–215. [CrossRef]
80. Yakovlev, E.; Hokkanen, T. Cyllodes ater (Coleoptera, Nitidulidae) found again in Finland. *Entomol. Fenn.* **1994**, *5*, 203–204. [CrossRef]
81. Bekchiev, R.; Crevecoeur, L.; Gielen, K.; Bosmans, B.; Smets, K.; Kostova, R. One Hundred Years of Solitude: Rediscovery of the Rare and Protected Beetle *Rhysodes sulcatus* (Fabricius, 1787)(Coleoptera: Rhysodidae) in Bulgaria. *Acta Zool. Bulg.* **2020**, *72*, 381–384.
82. Coddington, J.A.; Agnarsson, I.; Miller, J.A.; Kuntner, M.; Hormiga, G. Undersampling bias: The null hypothesis for singleton species in tropical arthropod surveys. *J. Anim. Ecol.* **2009**, *78*, 573–584. [CrossRef] [PubMed]
83. Wong, M.K.L.; Guénard, B.; Lewis, O.T. Trait-based ecology of terrestrial arthropods. *Biol. Rev.* **2019**, *94*, 999–1022. [CrossRef]
84. Washington, H.G. Diversity, biotic and similarity indices: A review with special relevance to aquatic ecosystems. *Water Res.* **1984**, *18*, 653–694. [CrossRef]
85. Tóthmérész, B. Comparison of different methods for diversity ordering. *J. Veg. Sci.* **1995**, *6*, 283–290. [CrossRef]
86. Byriel, D.B.; Ro-Poulsen, H.; Kepfer-Rojas, S.; Hansen, A.K.; Hansen, R.R.; Justesen, M.J.; Kristensen, E.; Møller, C.B.; Schmidt, I.K. Contrasting responses of multiple insect taxa to common heathland management regimes and old-growth successional stages. *Biodivers. Conserv.* **2022**, *31*. [CrossRef]
87. Larcenaire, C.; Wang, F.; Holásková, I.; Turcotte, R.; Gutensohn, M.; Park, Y.-L. Effects of Forest Management on the Insect Assemblage of Black Cherry (*Prunus serotina*) in the Allegheny National Forest. *Plants* **2022**, *11*, 2596. [CrossRef]