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Article

# Beetles Diversity in Two Urban Ecosystems in Sibiu (Romania): Dumbrava Sibiului Forest and Sub Arini Park

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**Abstract:** This study presents findings over three years of research into beetle diversity in two urban ecosystems in Sibiu, Central Romania: The Sub Arini Park (referred to after as Arini) (semi-anthropic) over 150 years old within the city, and the Dumbrava Sibiului Nature Reserve (referred to after as Dumbrava) (oak forest) over 170 years old on the city outskirts. Ground-trapping coleopteran collection in both locations (2021–2022 for Dumbrava, 2023 for Arini) was carried out in spring, summer, and autumn seasons. The study aimed to identify species and calculate ecological indices (abundance, dominance, constancy, Index of ecological significance) as input into conservation. The nature of collection technique did mean larger beetle species were collected, being the primary nature of this study. In total, 12 beetle families were identified covering 46 coleopteran species from 5,008 specimens. Section 3.1 records in table format all the beetles found. Carabid species diversity was significantly higher in Arini, due to the more varied vegetation. In Dumbrava the forest edge plays an important role in seasonal beetle migrations. The shady areas with shrub vegetation favor predatory and scavenging shrub species such as *Carabus (Procytes) coriaceus* Linnaeus, 1758 and *Phosphuga (Silpha) atrata* Linnaeus, 1758. Dominant species were: *Carabus violaceus* Linnaeus, 1758 and *Pterostichus oblongopunctatus* Fabricius, 1787 (crepuscular predators).

**Keywords:** diversity; conservation; Dumbrava Sibiului Forest; ecological indices; edaphic beetles; habitat; Romania; Sub Arini Park; Sibiu

## 1. Introduction

Forests are among the most important terrestrial biomes in the world, providing a habitat rich in biodiversity [1]. In Romania, forests cover between 0.2 and 0.3 million hectares and host more than half of the known biocenosis, playing a key role in ecological balance [2–4].

In Romania, the conservation of biodiversity is a major concern, as evidenced by the extensive studies carried out on carabids in various forest areas, contributing to a better understanding of biodiversity and their ecological role [3,5–17]. On the other hand, of the 8,000 species of coleopterans in Europe, over 6,800 are found in Romania [18], so far 122 families have been identified, grouped into 15 superfamilies. [19–23]. Insect population research in forest ecosystems is crucial to understand their dynamics and evolution over time [3,5–10].

**Our research was carried out in two different locations in Sibiu County, namely the Dumbrava Nature Reserve and the Arini semi-anthropogenic ecosystem.** Of these, the Dumbrava Nature Reserve of Sibiu is a protected area of national interest that falls into IUCN category IV. In this regard, the Natural History Museum of Sibiu keeps studies and collections of beetle species from the Dumbrava Forest. These mainly focus on species structure and distribution [24–29] to be studied as effective bioindicators of environmental quality. They comprise 386,755 species worldwide [30].

In this context, dead wood plays a fundamental role in both ecosystems investigated [3,8] to maintain species biodiversity, providing habitat for a wide range of organisms from insects and fungi to birds and mammals. This facilitates the decomposition of organic matter, allowing nutrients to be recycled into the soil [3,8,31–34]. The microhabitats hosted by dead wood are exposed to both natural and anthropogenic disturbances [10,15,35]. Sustainable forest management linked to this decomposition process of dead wood, considered a sensitive natural indicator of habitat change [36–38].

Of the species studied, species belonging to the family Carabidae are the most widespread. They play an important role as soil predators contributing to the control of other insect populations and occur in a variety of habitats throughout the year [39], making them useful as bioindicators for assessing habitat quality, so they can be used to monitor the impact of pollution and other environmental disturbances [40–42]. Numerous studies have been devoted to carabids, focusing on their systematics, distribution, trophic relationships and role in ecosystems [43–52].

This study integrates previous research on the Romanian beetle fauna, complementing existing knowledge on biodiversity at both Dumbrava and Arini. Our research also complements another recent study that identified the attack of the invasive species *Corythuca arcuata* Say, 1832 in the context of climate change affecting forest vegetation in the two ecosystems [53]. As such, this paper attempts to record and provide an important basis for future studies on beetle populations in both locations.

Also, the study of the beetles of Dumbrava and Arini aims to assess the degree of anthropogenic alteration of ecosystems and monitor the impact of human activities (grazing, logging, tourism) by analyzing the diversity and abundance of beetles. with the aim of protecting and conserving them [54]. monitoring insect populations to detect possible declines [55–57].

Investigating the abundance and biodiversity of insect and epigeic plant species is a continuing concern in ecological management. The use of classical indices of abundance is useful but has limitations in assessing numerical differences between species [58,59].

The research aimed to highlight the importance of conserving biodiversity and natural habitats. To date, there is a lack of detailed information on the influence of vegetation on edaphic beetles in the two ecosystems studied as well as the need to identify effective bioindicators for monitoring anthropogenic impacts [60–67]. In addition, the knowledge and inventory of beetles provides a clearer picture of trophic interactions and their role in nutrient cycling. This work had the following objectives:

1. Quantitative and qualitative analysis of beetle populations according to the habitat types existing in the Dumbrava nature reserve and the semi-anthropogenic Arini ecosystem (such as forest, meadows, buffer strips and scrublands) and to highlight rare, of Community interest or European protected species.

2. To assess the importance of beetles in the functioning of the ecosystems studied and to maintain their capacity to cope with anthropogenic activities such as tourism, grazing and recreation areas.

3. We used classical abundance-dominance indices as well as diversity indices to assess the population structure of Coleoptera.

4. To assess changes in the abundance structure and community composition of beetles during the growing season, with a focus on population changes in forest reserves.

5. Habitat identification is particularly important for the refuge of predatory and decaying species.

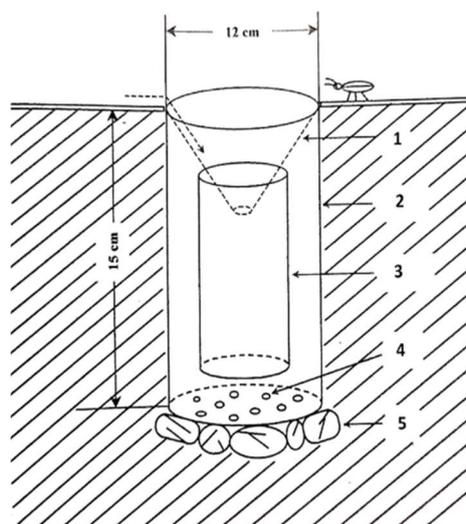
## 2. Materials and Methods

Two urban ecosystems were surveyed: the Dumbrava Forest (Section 1) and the Sub-Arini Park (section 2). As a collection method, soil traps (Figure 1, Figure 3, Figure 7) were used to collect mainly edaphic insects, large and mobile species, mainly predatory and predatory species. Less mobile taxa were occasionally collected, such as most detritivorous and xylophagous species. Those species collected incidentally require other capture methods not used in this study and are the target of future research. The traps used for both research spaces, were personally made from PET containers of two different sizes, fitted together (Figures 1, 3, 7).

### Trap components:

- **the protection vessel:** a 2- litre container with holes in the base to avoid water stagnation;
- **Collection vessel:** another container smaller than 1.5 litres, inserted into the **protection vessel**, for collecting insects.
- **Preservation solution:** a solution of water and detergent (without perfume) was used to preserve the collected insects.

Catchment size and area: diameter of the collector vessel orifice: 12 cm. Traps installation: 41 identical traps were built (24 for Dumbrava and 17 for Arini). These were buried in the ground on stones to facilitate water run-off and hidden so as not to disturb the soil fauna. A funnel made of PVC foil was installed on the mouth of each trap.



**Figure 1.** Sketch of the soil trap, 1-PVC soil trap; 2-PVC trap; 2-Protective trap; 3-Collector trap; 4- orifices for runoff of precipitation water; 5-stones to facilitate water flow.

Possible trapping area of a trap: 226.08 cm<sup>2</sup>; percentage of the circumference of the collecting circle: 29.37%. Area circumscribed by a trap: 981.25 m<sup>2</sup>.

Total catch area for the two sets of traps: 2.360,95 m<sup>2</sup>.

**The method of analysis** used was the calculation of **statistical indices**: constancy (C), dominance (D) and ecological significance (W). Below is an explanation of these categories.

**Constant (C)** was calculated for each species out of the total number of individuals in each ecosystem of Dumbrava Forest, Sub Arini Park or as the sum of species if they were reported in the two ecosystems out of the total number of species.

We analysed the insect species collected from 24 soil traps in the period 2021-2022 (Dumbrava Forest) and 17 soil traps in 2023 (Arini Park), respectively, and then classified the insects in order, families and species, considering the relationship and diversity of the flora in the area, as well as the physico-chemical properties of the soil.

We characterized the coleoptera fauna based on **ecological indices**: abundance, constancy, dominance and **synthetic index** [68–70]. This approach considered the non-uniform and random

distribution of coleopteran species in relation to their host plants, providing us with information about the structure of the entomofauna in the studied area.

To determine the abundance of insect species, we used the following mathematical formula:

$$A = n/N \cdot 100 \quad (1)$$

This approach assumes that all species in an area are equal in their role in the community [71–73].

We analysed the diversity and structure of the epigean entomofauna (soil-dwelling insects) in terms of families, abundance and number of individuals in each family.

We calculated and interpreted the following **ecological indices**:

- **Abundance**: the proportion of individuals of a species in the total individuals collected.
- **Dominance**: the proportion of a species in the community (D1<1- sporadic, D2=2-4 subdominant, D3=2,1-4 dominant, D4=4,1-8 subdominant, D5=8,1-16 dominant, D6>16 eudominant).
- **Constant**: frequency of occurrence of the species in the samples (C1=0-10 very rare, C2=10,1-25 rare, C3=25,1-45 rare, C4=45,1-70 constant, C5=70,1-100 constant).
- **Index of ecological significance (Dzuba-W Index)**: W1 with values 0,1% - incidental species, W2 values between 0,1-1% - accessory species, W3 values between 1,1-5% - associated species, W4 values between 0,51-10% - complementary species, W5 values more than 10-20% - characteristic species, W6 >20 main species.

The calculation of **the ecological indices** allowed us to obtain information about the diversity of species in each ecosystem, the abundance of species in relation to the number of individuals caught, the role of species in the community of epigean entomofauna.

In Tables 3 and 5 we record the results for the constancy (c), dominance (d) and ecological significance (W) of species in each ecosystem surveyed individually and together (see also Appendix 1).

We analysed the taxonomic diversity at the level of the family Coleoptera and the species of the most numerous family Carabidae. To make the information as accessible as possible, we used tables and graphs/histograms to organize the information. We considered the richness of species (number of captures), but also the possible underestimation of the real number of individuals.

Systematic classification of the collected species was based on morphological characteristics using descriptions from Stichmann's work [68] and consultation of the BioLib database [74]. Species classification was done into families, genera and species according to the nomenclature in BioLib and food preferences according to the work [75–81]. The classification of species into endangered categories was done according to the Red List of European Coleoptera [82] and the monograph Red Book of invertebrates in Romania [83].

#### **General and specific data on the two collection stations.**

Both the Dumbrava Forest and the Sub Arini Park are in Sibiu County, Transylvania region, with geographical coordinates: 45°52'N 24°14'E / 45.87°N 24.23°E (Figure 2).



**Figure 2.** Map of Romania, of Sibiu County and of the collection area.

Below we present a table with comparative data about and from the two collection centres, then we present data about each collection centre (Table 1).

**Table 1.** Comparative tables for the 2 collection sites.

FOREST DUMBRAVA 2021-2022	SUB-ARINI PARK 2023
<b>Research place</b>	
<ul style="list-style-type: none"> <li>- located 4 km south-west of Sibiu with a maximum altitude of 606 m at Obreja Peak.</li> <li>- 993 ha.</li> <li>- about 170 years.</li> <li>- in 2000 [67] it was officially declared a <b>protected area of national interest</b> that falls into IUCN category IV.</li> </ul>	<ul style="list-style-type: none"> <li>- located in the city of Sibiu.</li> <li>- 21.65 ha.</li> <li>- about 150 years</li> <li>- founded in 1857, is the largest park in Sibiu County.</li> </ul>
<b>Monitoring area</b>	
<p>Inside the forest at an altitude of 510 m near the county road 106A, which connects Sibiu to Rășinari.</p> <p><b>This configuration delimited an area of 452.39 m<sup>2</sup> inside the forest.</b></p>	<p>The land was divided into six collection areas considering both the dendrological criteria and the topography of the site, with a length varying between 250 and 600 meters, depending on the location between the dikes.</p> <p><b>The monitoring area covered 21.65 hectares.</b></p>
<b>Collection periods</b>	

In <b>2021</b> , 16 field trips were conducted over a collection period of 156 days (between March and August).	In <b>2023</b> 25 collection trips = 184 calendar days
In <b>2022</b> , 19 field trips were carried out over a collection period of 178 days (from the beginning of April to the end of September) at the same site.	sample collection started in April and lasted until November (7 months), covering all 4 seasons.

#### Collection methods use

Soil traps were used as a collection method to collect mainly edaphic insects, large and mobile species, mainly predatory and predatory species. The traps used were hand-made from PET containers of two different sizes, fitted together (Figures 3, 7, 8). A total of 41 identical traps were constructed (24 Dumbrava and 17 Arini). These were buried in the ground on stones to facilitate water run-off and hidden so as not to disturb soil fauna. A PVC foil funnel was installed at the mouth of each protection pot. Possible trapping surface area of a trap: 226.08 cm<sup>2</sup>.

<b>A set of 12 traps</b> (labeled C <sub>1</sub> -C <sub>12</sub> ) were installed (each year) around the circumference of a circle with a radius of 12 m (Figure 3).	The land was divided into six collection areas, ranging in length from 250 to 600 meters, depending on the location between the dikes on which 17 traps were randomly distributed (Figure 7).
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#### Flora

Two phytocenological surveys were conducted at the same station for both 2021 and 2022. The surveyed plots belong vegetatively to the association <i>Quercus robur</i> - <i>Carpinetum</i> Soo et Pocs (1931) 1957 subass. <i>dacicum</i> var. with <i>Asperula odorata</i> .	It hosts a rich diversity of trees of significant scientific and aesthetic importance. The first inventories were carried out in 1965-1966 by M.I. Dollu (80 species of trees and shrubs) and C. Drăgulescu (61 tree species) [71].
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#### Method of analysis

The analysis method used was the calculation of the statistical indices Constant (C), Dominance (D) and Ecological Significance (W).

#### Results

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|--|--|
| <ul style="list-style-type: none"> <li>• 2021- 7 families (1,367 sp.)</li> <li>• 2022 -8 families (1,523 sp.)</li> </ul> | 26 species (9 families) from 2,118 samples |
| Total: 22 species (10 families) from 2,890 samples   |  |

In total, 12 beetle families were identified covering 46 coleopteran species out of 5,008 individuals. Across all three years in both ecosystems, the family Carabidae (Insecta: Coleoptera: Carabidae) has the highest abundance, dominance, constancy with 23 species identified.

#### 2.1. Dumbrava Sibiului Forest (2021-2022)

The nature reserve "Dumbrava Sibiului Park" has been officially declared a protected area of national interest, category IV IUCN. It is 4 km south-west of Sibiu city, with a maximum altitude of 606 m at Obreja Peak.

For this study a monitoring area of 2,360.95 m<sup>2</sup> was selected inside the forest at an altitude of 510 m near the county road 106A, which connects Sibiu to Rășinari. The geographical coordinates of the monitoring area are 45°47'45"N 24°9'8"E.

### 2.1.1. Approach to Sampling Vegetation Data

The objectives of the vegetation analysis at Dumbrava were to characterize the physiognomy and structure of the vegetation, to identify the edifying and characteristic floristic species and to evaluate the abundance, dominance and frequency of species. Knowledge of the physiognomy, qualitative structure (floristic composition, including edifying, characteristic species) and quantitative structure (abundance, dominance, frequency) of the phytocenoses of the surveyed stations was achieved by two phytocenological surveys at the same station. for 2021 and 2022. For each area surveyed the study of bioforms, geoelements and ecological indicators (UTR) was carried out following the preparation of synthetic phytocenological tables. The phytocenological survey was carried out in the same place where soil and entomological samples (2 floristic plots) were collected and compared with other surveys (5 floristic plots) [3]. The area of the phytocenological survey was carried out according to the square method (25 x 25 m). Braun-Blanquet method with 6 abundance steps (from + to 5) improved by Tuxen and Elenberg (ADm) was used to assess abundance-dominance.

Dominance was assessed using indices to assess the area occupied by the horizontal projection of the aboveground parts of individuals at ground level in the sample area. This cover index shows the degree of vegetation cover and station specifics Table 2.

The naming of vegetation associations was adopted according to the Code of Phytosociological Nomenclature [84]. The classification system adopted in current research at the country level is based on the work Habitats in Romania [83].

**Table 2.** Vegetation in Sibiu Dumbrava Forest.

No.	Tree species	dominance
1	<i>Quercus robur</i> L., 1753 (mature oak, over 100 years old)	7 (from 7 vegetative surveys)
2	<i>Quercus petraea</i> L., 1784	5
3	<i>Tilia</i> sp.	4
4	<i>Carpinus betulus</i> L., 1753	7
5	<i>Acer campestre</i> L., 1753	4

The analysed plots belong vegetatively to the association *Querco robori - Carpinetum* Soo et Pocs(1931) 1957 subass. *dacicum* var. with *Asperula odorata*. In the shrub layer, the main species are *Crataegus monogyna* and *Ligustrum vulgare*, also *Prunus spinosa* and *Cornus sanguinea*, species with a strong point in the associations Ord. *Prunetalia spinosae*. A wide range of floristic species grow on meadows, including buttercup (*Epilobium hirsutum*), green lettuce (*Mycelis muralis*), opatija (*Melandrium rubrum*), fall grass (*Colchicum autumnale*) and orchid species [71]. From the variety of vegetation species in the two analyzed sites, a majority of European (continental and Mediterranean) -Eur (Med, Cont) elements, followed by Eurasian, can be distinguished in terms of the spectrum of biogeographical elements. Elements (Mediterranean or Continental). The only difference between the two analysis samples is the percentage, with the first sample area being slightly more thermophilic due to the higher presence of European elements at the expense of Eurasian elements.

### 2.1.2. Trapping/Sampling and Insect Identification

Research on the species and flora of beetles in Dumbrava combined quantitative and qualitative methods. Data collection took place in the selected study area over two years, 2021-2022, considering the climatic peculiarities of each period.

To assess beetle diversity and activity, two sets of 12 traps (labelled C1-C12) were installed, one serum for each collection year (Figure 3).

Collection areas and twice-frequent collections were the same in both years. In 2021, 16 field trips were conducted over a 156-day collection period (March through August), and in 2022, 19 field trips were conducted over a 178-day collection period (early April through late September) at the same location.



**Figure 3.** Handmade traps.



Photo 1. *Stenomax aeneus* Scopoli, 1763 (original photo C. Moise)



Photo 2. *Dorcus parallelipedus* (L., 1758) (original photo C. Moise)

**Orientation and numbering:** The traps were mounted on the circumference of a circle with a radius of 12 m, centred on the coordinates (latitude 45°43'49" and longitude 24°05'30"). This configuration delimited an area of 452.39 m<sup>2</sup> within the forest. The traps were geographically oriented and numbered from 1 to 12 in a clockwise direction, starting with the trap to the north (Figure 4a, Figure 4b).



**Figure 4.** Layout of the trap: (a) (C<sub>1</sub> -C<sub>12</sub>) in 2021; (b) (C<sub>1</sub> -C<sub>12</sub>) in 2022.

**Characterization of the surrounding area:** North: Oak Forest, East: Agricultural crops (potatoes, onions) and pasture, South: Vegetable crops and meadows, West: road leading to Rășinari Commune.

## 2.2. Details About the Park Under Arini (2023)

The study provides valuable information about the ecology of Arini beetles that can be used for effective park management and biodiversity conservation.

Sub Arini Park, founded in 1857, is the largest park in Sibiu, with an area of 21.65 ha. It hosts a rich diversity of trees of significant scientific and aesthetic importance. The first inventories were

carried out in 1965-1966 by M.I Dollu and C. Drăgulescu. In 1967, the trees in the park were labelled, providing information on their scientific and popular names and region of origin [71]. Dollu identified 80 species of trees and shrubs (33 exotic and 47 native). Drăgulescu identified 61 tree species (26 exotic and 35 native) [71]. The oldest trees (specimens of alder, black poplar, linden, oaks) are over 150 years old. Approximately 95 bird species find shelter in this landscape.

### 2.2.1. Approach to Vegetation Data Sampling

E. Schneider-Binder identified and described several plant associations characteristic of the study sites [72] such as (Table 3).

**Table 3.** Plant associations characteristic of the study sites.

No.	Association	characteristic species	area
1	<i>Aegopodium-Alnetum</i> Karpati and Jurko 1961	<i>Alnus glutinosa</i> , <i>Aegopodium podagraria</i> , <i>Solanum dulcamara</i> , <i>Angelica silvestris</i> , <i>Lycopus europaeus</i> , <i>Mentha aquatica</i> , <i>Lysimachia vulgaris</i> . <i>Rudbeckia laciniata</i> is an adventive species, a rarity brought from the meadows of Avrig and has become dominant	2,3,4,5
2	<i>Agrostetum albae</i>	<i>Agrostis alba</i> , <i>Ranunculus repens</i> , <i>Carex vulpina</i> , <i>Juncus effusus</i> , <i>Trifolium repens</i>	2
3	<i>Glycerietum aquaticae</i> Nowinki 1928	form a specific appearance and <i>Carex gracilis</i> is a characteristic species	6
4	<i>Scipo-Pbramietetum</i>	classified in the association <i>Rudbeckia laciniata</i>	5,6
5	<i>Quercutum-roboris</i> <i>petraeae</i>	<i>Quercus robur</i> , <i>Quercus petraea</i> , <i>Carpinus betulus</i> , <i>Cerasus avium</i> , <i>Acer campestre</i>	6

Over the years, unfortunately, precious and rare trees such as *Abies concolor*, *Picea pungens*, *Pseudotsuga menziesii*, *Fagus sylvatica*, *F. roseo-marginata*, *Larix decidua* and others have been cut down out of carelessness and ignorance.

### 2.2.2. Trapping/Sampling and Insect Identification

Our research focused on the beetle fauna. The park was divided into 6 zones according to habitat types. The division of the plot considered both dendrological criteria and the topography of the site, ranging from 250 to 600 meters in length, depending on the location between the dikes (Figure 5).

Data collection was carried out for 7 months (April-November), covering all 3 seasons. During the 25 collection trips, totalling 184 calendar days, we identified a significant, diverse number of beetle species, which varied by habitat type. Season influences abundance and diversity.

Below is a description of the six collection areas, the vegetation present and the number of traps found in them (Table 4):

**Table 4.** Collection areas, host species and number of traps.

Collection zone	Length (m)/ Area (ha)	Tree species	Number of traps set
I	450/8	<i>Ginko biloba</i> , <i>Betula verrucosa</i> , <i>Juglans regia</i> , <i>J. nigra</i> , <i>J. nigra</i> , <i>Populus alba</i> , <i>Platanus aurifolia</i> , <i>Acer platanoides</i> , <i>Quercus robur</i> and <i>Fagus sylvatica</i> . Conifers, including native and exotic species, are well represented here, with species such as <i>Tsuga canadensis</i> , <i>Taxus baccata</i> , <i>Abies alba</i> and <i>Juniperus virginiana</i> .	8,9,17

II	600/8	<i>Populus nigra</i> , <i>Morus alba</i> , <i>Clematis vitalba</i> , <i>Cerasium avium</i> , <i>Pirus sativa</i> , <i>Crataegus monogyna</i> , <i>Platanus acerifolia</i> and <i>Acer platanoides</i>	6,7,16
III	250/10	<i>Salix alba</i> , <i>Cerasum avium</i> , <i>Prunus spinosa</i> , <i>Platanus acerifolia</i> , <i>Robinia pseudoacacia</i> and <i>Acer platanoides</i>	4,5
IV	350/7	<i>Pinus silvestris</i> and meadow vegetation	1,2,3
V	250/5	<i>Quercus robur</i> and <i>Scirpus</i> sp.	13,14,15
VI	700/14	<i>Quercus</i> sp., <i>Scirpus</i> sp. and <i>Phragmites</i> sp.	10,11,12

Trap placement and sample collection (Figure 6) consisted of 17 randomly distributed units (Figure 5, Table 5), 6 distinct sectors, use of transects and randomized sampling.

**Table 5.** The 17 traps and their location.

Trap	Location	Area description
Trap 1	between an oak root and a slope, 5 meters from an alley.	under an oak tree in a disused drainage ditch covered with dry leaves (Figure 7-t1).
Trap 2	positioned between three trees, relatively close to an alley.	area with exposed soil and rare grasses, inside the forest (Figure 7-t2).
Trap 3	in a disused drainage ditch under a footbridge.	area exposed to the sun with no tree branches above, next to an alley. Under the trap were dry leaves (Figure 7-t3).
Trap 4	between a garden fence and a path in the park.	exposed area near the driveway. In summer it was overgrown, but in September the ground was exposed
Trap 5	placed between two distant trees in a relatively exposed area	a considerable distance from paths or roads. thick grass, but not too tall
Trap 6	at the root of a willow, next to a concrete slab	shaded area away from paths. under the trap were dry leaves, twigs and exposed soil
Trap 7	positioned in the middle of the slope towards the Avrig road	the area exposed to the sun. in summer it was covered with small, dense vegetation
Trap 8	found at the root of an oak tree near a pile of fallen branches.	between a dirt road and the trinbah tachelajul. earth covered with twigs, gravel and waste, no vegetation
Trap 9	in an enclosed area under the branches of several trees.	near a fallen stump, away from driveways or roads. covered with a thick layer of dry leaves and plant debris
Trap 10	located in an open area between the park alley and the outside sidewalk	close to a bridge, surrounded by wood debris. no vegetation
Trap 11	positioned between several trees next to a dirt road.	exposed ground with dry leaves and patches covered with ivy. ivy had retreated in September
Trap 12	found among some small dandelions in a sunny area.	a long distance from roads or paths. blades of grass

Trap 13	located under several small trees, shaded by larger trees.	Enclosed area with no sun exposure. very close to a dirt road and about 5-6 feet from an alley. Dry leaves and exposed soil were under trapped
Trap 14	between the driveway and a ditch with occasional water.	area well exposed to the sun, covered with rich vegetation (20-25 cm grass)
Trap 15	under several tall trees next to the outside pavement.	shaded area covered with dry leaves and branches, no vegetation
Trap 16	in a sunny, treeless area about 7-8 meters from an alley.	rich vegetation (grasses and broad-leaved plants)
Trap 17	sunny, treeless area close to an alleyway	nearby was a rotting stump. under the trap were tall weeds covering it.



**Figure 5.** Illustration of some traps used in Arini, T<sub>1</sub> (45.781310, 24.138568), T<sub>2</sub> (45.781213, 24.138834), T<sub>3</sub> (45.780928, 24.138315).

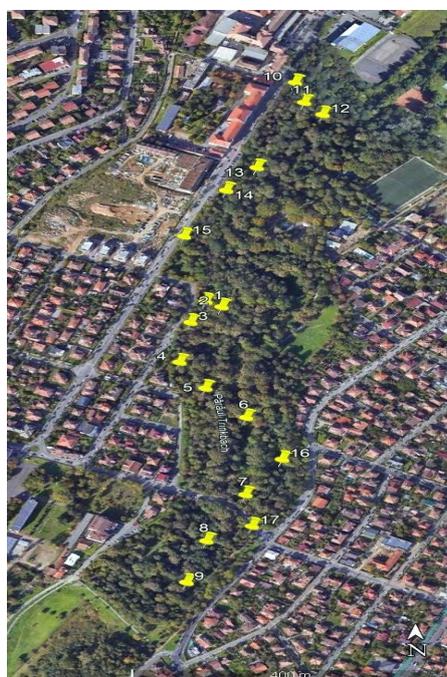


Photo 3. *Carabus (Procastes) coriaceus* L., 1758 accidental sp. (photo C. Moise)



Photo 4. *Pterostichus (Bothriopterus) oblongopunctatus* (Fabricius, 1787) accidental sp. (photo C. Moise)

**Figure 6.** Map of the collection area in Sub Arini Park and marking of the trapping sites (T<sub>1</sub> -T<sub>17</sub>).



**Figure 7.** Trap location and marking with a stake (photo Cristina Moise).

Traps were used without liquid to allow species to be released after identification. Sample collection began on April 29 through: May (6,13,20,25), June (4,10,18,24), July (2,8,16,22,29), August (5,13,20), 26), September (2,9,17,23), October (1, 14, 29), November (11).

### 3. Results

In total, throughout the three years (2021-2023) of research, from both ecosystems (Dumbrava Forest and Sub Arini Park) 5,008 specimens systematically categorized in 12 families covering 46 coleopteran species were collected. Of these, 2,890 samples were collected from the research area of the Dumbrava Forest, and 2,118 samples were collected from the Sub Arini Park.

Below we present the survey results for each individual station and then a summary of all collections over the 3 years.

#### 3.1. Entomofauna of the Dumbrava Sibiului Forest

The insects identified in the 2 years of collections (2021-2022) belong to the order Coleoptera (Insecta. Coleoptera) and are categorized into the following families Table 6:

**Table 6.** The insects identified in the 2 years of collections (2021-2022) in Dumbrava Forest.

No.	2021	%	No.	2022	%
1	Carabidae	85.89%	1	Carabidae	85.16%
2	Silphidae	4.53%	2	Tenebrionidae	3.61%
3	Scarabaeidae	3.07%	3	Geotrupidae	3.22%
4	Sphindidae	2.34%	4	Staphylinidae	2.43%
5	Elateridae	1.54%	5	Sphindidae	1.84%
6	Staphylinidae	1.83%	6	Silphidae	1.44%
7	Curculionidae	0.8%	7	Scarabaeidae	1.51%
Total: 7 families (1,367 sp.)			8	Cerambycidae	0.79%
			Total: 8 families (1,523 sp.)		

Below (Table 7) we present the families and species collected during the 2 years in the Dumbrava Forest, to which we add the ecological indices:

Table 7. Species in Dumbrava Forest (2021-2022).

No	Family	Species	Dumbrava Forest	Constancy (C)	Class (%)	Dominance (D)	Class (%)	Dzuba Ecological significance (W)	
1	I. Carabidae	<i>Carabus violaceus</i> Linnaeus, 1758	27	C <sub>2</sub>	11.57	2	D <sub>2</sub>	W <sub>5</sub>	
2		<i>Carabus (Procostes) coriaceus</i> L., 1758	34	C <sub>1</sub>	1.04	1	D <sub>2</sub>	W <sub>3</sub>	
3		<i>Carabus gigas</i> Creutzer, 1799	57	C <sub>1</sub>	1.97	1	D <sub>2</sub>	W <sub>3</sub>	
4		<i>Carabus monilis scheidleri</i> , Panzer, 1799	62	C <sub>1</sub>	2.15	1	D <sub>2</sub>	W <sub>3</sub>	
5		<i>Carabus nemoralis</i> , O. F. Müller, 1764	74	C <sub>1</sub>	2.56	1	D <sub>2</sub>	W <sub>3</sub>	
6		<i>Carabus ullrichii</i> , Germar, 1824	63	C <sub>1</sub>	2.18	1	D <sub>2</sub>	W <sub>3</sub>	
7		<i>Carabus variolosus</i> Fabricius, 1787	43	C <sub>1</sub>	1.49	1	D <sub>2</sub>	W <sub>3</sub>	
8		<i>Cychrus caraboides</i> Linnaeus, 1758	61	C <sub>1</sub>	2.11	1	D <sub>2</sub>	W <sub>3</sub>	
9		<i>Harpalus latus</i> , Linnaeus, 1758	79	C <sub>1</sub>	2.73	1	D <sub>2</sub>	W <sub>3</sub>	
10		<i>Leistus (Pogonophorus) spinibarbis</i> , Fabricius, 1775	95	C <sub>1</sub>	3.46	1	D <sub>2</sub>	W <sub>3</sub>	
11		<i>Pterostichus (Bothriopterus) oblongopunctatus</i> Fabricius, 1787	156	C <sub>1</sub>	5.40	2	D <sub>2</sub>	W <sub>4</sub>	
12		<i>Pterostichus niger</i> Schaller, 1783	941	C <sub>3</sub>	32.56	3	D <sub>3</sub>	W <sub>6</sub>	
13		<i>Pterostichus melanarius</i> , Illiger, 1798	371	C <sub>2</sub>	12.84	2	D <sub>2</sub>	W <sub>5</sub>	
14		II. Cerambycidae	<i>Rhagium sycophanta</i> Schrank, 1781	2	C <sub>1</sub>	0.07	+	D <sub>1</sub>	W <sub>1</sub>
15		<i>Morimus funereus</i> Mulsat, 1863	2	C <sub>1</sub>	0.07	+	D <sub>1</sub>	W <sub>1</sub>	
16		III. Curculionidae	<i>Pissodes pini</i> Linnaeus, 1758	49	C <sub>1</sub>	1.70	1	D <sub>2</sub>	W <sub>3</sub>

17	IV. Elateridae	<i>Ampedus sanguineus</i> Linnaeus, 1758	85	C <sub>1</sub>	2.94	1	D <sub>2</sub>	W <sub>3</sub>
18	V. Scarabaeidae	<i>Protaetia marmorata</i> Fabricius, 1792	20	C <sub>1</sub>	1.82	1	D <sub>2</sub>	W <sub>3</sub>
19	VI. Silphidae	<i>Nicrophorus vespillo</i> Linnaeus, 1758	126	C <sub>1</sub>	4.36	1	D <sub>2</sub>	W <sub>3</sub>
20		<i>Nicrophorus germanicus</i> Linnaeus, 1758	157	C <sub>1</sub>	5.43	2	D <sub>2</sub>	W <sub>4</sub>
21		<i>Oiceoptoma thoracica</i> Linnaeus, 1758	132	C <sub>1</sub>	4.57	1	D <sub>2</sub>	W <sub>3</sub>
22		<i>Necrodes littoralis</i> Linnaeus, 1758	91	C <sub>1</sub>	3.15	1	D <sub>2</sub>	W <sub>3</sub>
23	VII. Staphylini dae	<i>Ocypus (Staphylinus) olens</i> Müller, 1764	10	C <sub>1</sub>	2.20	1	D <sub>2</sub>	W <sub>3</sub>
24	VIII. Sphindidae	<i>Sphindus dubius</i> Gyllenhal, 1808	153	C <sub>1</sub>	5.29	2	D <sub>2</sub>	W <sub>4</sub>
<b>Total</b>			<b>2890</b>					

The characteristics and status of all species collected in the 2 years (2021-2022) will be presented in more detail in a common systematized table for the 2 years of collections in the Dumbrava Forest (Table 8).

**Table 8.** Peculiarities of some species found in Dumbrava Forest in 2021-2022.

	Family	Species	Status/characteristics
1	Carabidae	<i>Carabus (Procastes) coriaceus</i> Linnaeus, 1758	Important limiting factor for their populations at the site.
		<i>Carabus (Procerus) gigas</i> Creutzer, 1799	
		<i>Carabus (Morphocarabus) scheidleri</i> Panzer, 1799	Characteristic of oak and gorgonian ecosystems, being a predatory species that feeds on larvae of <i>Lymantria</i> sp.
		<i>C. nemoralis</i> O. F. Müller, 1764	
		<i>Carabus (Hygrocarabus) variolosus</i> Fabricius, 1787	<b>Protection status</b> is given by Habitats Directive 92/43/EEC (Annex II); OUG 57/2007 (Annex 3, 4A) considered endangered in Europe - rare, protected species.
	<i>Carabus (Megodontus) violaceus</i> Linnaeus, 1758		

Included in the **IUCN European Red Lists** [63,82].

is a polyphagous species, common in deciduous forests, preferring oaks, flowering under the

2	<b>Cerambycidae</b>	<i>Rhagium (Megarhagium) sycophanta</i> Schrank, 1781	bark of fallen trees or under stumps. Adults are active from April to July [78]. Specimens were collected from traps placed in oaks and under flowering shrubs.
		<i>Morimus funereus</i> Mulsat, 1863	Present in Romanian deciduous forests [83]. Previously reported in Dumbrava Forest in 2015 [73]. Saproxyllic species, preferring beech and oak [85]. Adults emerge in spring and summer. Larvae develop in thick roots, rotting stumps, wood piles and fallen trunks [86]. Vulnerable species with protected status under Habitats Directive 92/43/EEC (Annex II); OUG 57/2007 (Annex 3, 4A) Vulnerable under criteria A1c. The Red List [87,88].
3	<b>Curculionidae</b>	<i>Pissodes pini</i> Linnaeus, 1758	Collected in 2022 as an <i>accidental species</i> in the forest.
4	<b>Geotrupidae</b>	<i>Geotrupes stercorarius</i> Scriba, 1791	Is nourished by animal excrements, especially sheep excrements, which transit through the forest towards Rășinari commune, thus helping to ensure soil fertility and organo-mineral balance.
5	<b>Elateridae</b>	<i>Ampedus sanguineus</i> Linnaeus, 1758	Common beetle species caught in small numbers.
6	<b>Silphidae</b>	<i>Oiceoptoma thoracicum</i> Linnaeus, 1758 <i>Nicrophorus germanicus</i> Linnaeus, 1758 <i>Necrodes littoralis</i> Linnaeus, 1758 <i>Nicrophorus vespillo</i> Linnaeus, 1758	These species are found in woodland habitats and feed on animal droppings [89].
7	<b>Staphylinidae</b>	<i>Ocypus (Ocypus) olens</i> Müller, 1764 <i>Staphylinus caesareus</i> Cederhjelm, 1798	Have a varied trophic diet: coprophagous, necrophagous and in some cases they also feed on dried fungi. This trophic regime emphasizes <i>the important role of these species as health biotopes of the Dumbrava Forest</i> [87,88].

As can be seen from this summary, most representatives belong to the family Carabidae (Insecta: Coleoptera) for each year. Consequently, we will analyze the representatives of this family for each year of collection in the Dumbrava Forest.

### 3.1.1. Carabidae Insect Species Identified in 2021:

11 species belonging to the family Carabidae, of which the genus *Pterostichus* was the best represented: 60.48% of the total carabid species. Dominant species: *Pterostichus niger* (Schaller, 1783) (52.13%) of which 612 specimens were caught Figure 8.

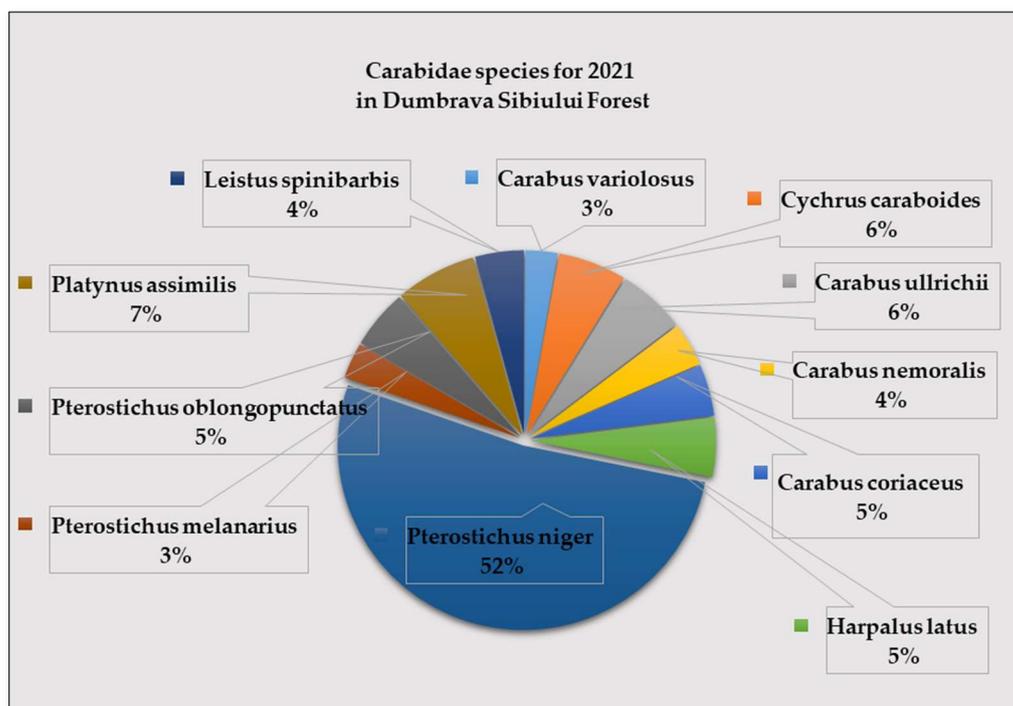


Figure 8. Percentage representation of carbide species for 2021 in Dumbrava Sibiului Forest.

Among the species captured in 2021, *Carabus (Hygrocarabus) variolosus* Fabricius, 1787 is considered a European range species. In Romania it is thought to be declining, reported in the Carpathian Mountains at low and medium altitudes up to 1700 m [5,89]. It is a zoophagous, hydrophilous species found mainly in beech and spruce forests. In Dumbrava it may be threatened in the future due to anthropogenic interference through habitat degradation and fragmentation by logging. Its **protected status** is given by the Habitats Directive 92/43/EEC (Annex II); OUG 57/2007 (Annex 3, 4A) [83,90,91]. Its presence indicates a high degree of naturalness in Dumbrava, and it is also reported in other Romanian forest ecosystems such as the Sinca Forest in Brasov County [3] (Table 5).

Following the analysis of the ecological index **Constance** (table 4): 1 **constant species**: *Pterostichus niger* Schaller, 1783, 10 **accidental species**: *Carabus (Procastes) coriaceus* Linnaeus, 1758, *C. nemoralis*, O. F. Müller, 1764, *C. variolosus* Fabricius, 1787, 1758. *C. ullrichii* Germar, 1824, *Cychrus caraboides* Linnaeus, 1758, *Harpalus latus* Linnaeus, 1758, *Leistus spinibarbis* Fabricius, 1775, *Platynus assimilis* Paykull, 1790, *Pterostichus oblongopunctatus* (Fabricius).

Regarding the **index of ecological significance** (Table 4):

- *Pterostichus niger* Schaller, 1783 was the **eudominant** species,
- The **dominant** species were: *Carabus ullrichii* Germar, 1824, *Cychrus caraboides* Linnaeus, 1758 and *Harpalus latus* Linnaeus, 1758 and
- The **subdominant species** were *Carabus variolosus* Fab-Ricius, 1787, *C. nemoralis* O. F. Müller, 1764, *C. coriaceus* Linnaeus, 1758, *Pterostichus melanarius* Illiger, 1798, *Platynus asimilis* Paykull, 1790, *Leistus spinibarbis* Fabricius, 1775 (Figure 8).

### 3.1.2. Carabidae Insect Species Identified in 2022: 9 Species of Carabidae Have Been Identified in Dumbrava Forest

Dominant genus - *Pterostichus*, 72.78% of all carabid species. Dominant species: *Pterostichus niger* Schaller, 1783 (51.27%) and *P. melanarius* Illiger, 1798 (21.51%) with a total of 944 individuals.

Constant/frequency: 1 constant species: *Pterostichus niger* Schaller, 1783, 8 incidental species: *Pterostichus melanarius* Illiger, 1798, *Carabus coriaceus* Linnaeus, 1758, *C. gigas* Creutzer, 1799, *C. nemoralis*, *C. violaceus* Linnaeus, 1758, *C. monilis scheidleri*, Panzer, 1799, *Cychnus caraboides* Linnaeus, 1758, *Harpalus latus* Linnaeus, 1758 (Figure 9).

*Carabus (Procerus) gigas* Creutzer, 1799, reported in Romania in Banat (Baile Herculane, Domogled) [92], Poștile de Fier [92], in the Macin Mountains of Dobrogea [93], Eschioi, Ioetmac [94], Poiana Lazului Gorj county, Cheile Nerei, Oravița. [44], Southern Carpathians [19,44]. The species prefers meso-hydrophilous habitats and is malacophagous, being characteristic of old beech forests. Populations are currently declining due to fragmentation and degradation by logging [83].

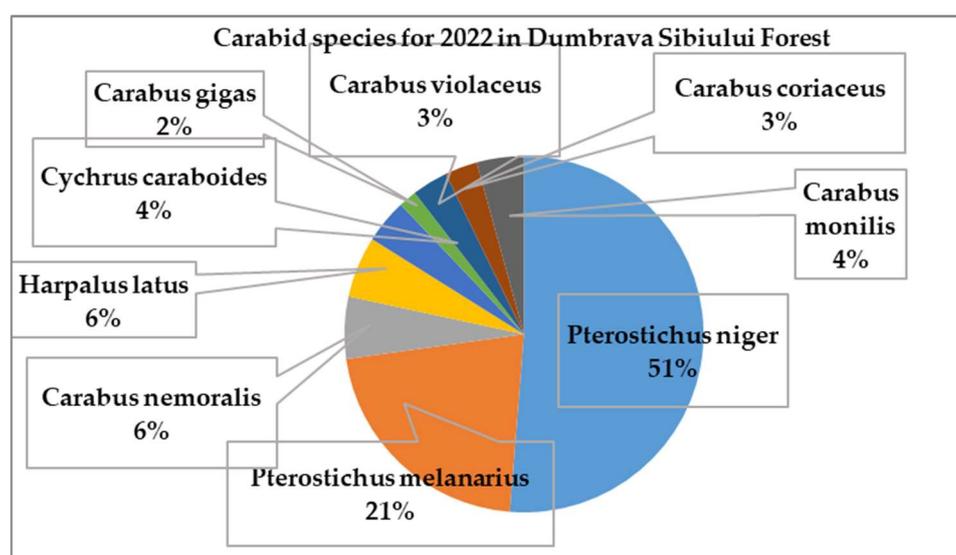


Figure 9. Percentage representation of carabid species for 2022 in Dumbrava Sibiului Forest.

Significant differences in species dynamics occurred over the years.

**In 2021 we reported 12 species of carabid:** *Carabus variolosus* Fabricius, 1787, *Cychnus caraboides* Linnaeus, 1758, *Carabus ullrichii* Germar, 1824, *Platynus assimilis* Paykull, 1790, *Leistus (Pogonophorus) spinibarbis*, Fabricius, which were not found in 2022.

**In 2022 we reported 3 species of carabids:** *Carabus gigas* Creutzer, 1799, *Carabus violaceus* Linnaeus, 1758, *Carabus monilis scheidleri*, Panzer, 1799 also collected in 2021.

Of the 13 (Table 4) carabid species reported in both years, six were consistently collected during both survey seasons: *Carabus nemoralis* O. F. Müller, 1764, *Carabus (Procerus) coriaceus* Linnaeus, 1758, *Harpalus latus* Linnaeus, 1758, *Pterostichus niger* Schaller, *Pterostichus melanarius* Illiger, 1798, *Pterostichus oblongopunctatus* Fabricius, 1787.

**The number of carabid species identified decreased in 2022 compared to 2021.** The genus *Pterostichus* was dominant. *Pterostichus niger* Schaller, 1783, a polyphagous opportunistic (predominantly predatory) species inhabiting edaphic (soil and foliage) habitats in deforested and reforested areas, preferring forest habitats with wetter soils [3,95], accounted for more than 50% of the total captured. Species.

### 3.2. Coleoptera Found in the Sub Arini Park in 2023

A total of 8/9 families, out of 26 beetle species, were identified in an area of 21.65 hectares from 2,118 samples: Carabidae (50%), Coccinellidae (15.38%), Staphylinidae (11.53%), Lucanidae (7.69%),



1		<i>Bembidion illigeri</i> Latreille, 1802	43	C <sub>1</sub>	2.03	1	D <sub>2</sub>	W <sub>3</sub>	
2		<i>Bradycellus ruficollis</i> Stephens, 1828	50	C <sub>1</sub>	2.36	1	D <sub>2</sub>	W <sub>3</sub>	
3	<b>I. Carabidae</b>	<i>Carabus violaceus</i> Linnaeus, 1758	551	C <sub>2</sub>	11.57	2	D <sub>2</sub>	W <sub>5</sub>	
4		<i>Carabus (Procastes) coriaceus</i> L., 1758	18	C <sub>1</sub>	1.04	1	D <sub>2</sub>	W <sub>3</sub>	
5		<i>Harpalus aeneus</i> Fabricius, 1775	58	C <sub>1</sub>	2.74	1	D <sub>2</sub>	W <sub>3</sub>	
6		<i>Harpalus rubripes</i> Dufischmid, 1812	46	C <sub>1</sub>	2.17	1	D <sub>2</sub>	W <sub>3</sub>	
7		<i>Harpalus rufipes</i> Degeer, 1774	65	C <sub>1</sub>	3.07	1	D <sub>2</sub>	W <sub>3</sub>	
8		<i>Lebia chlorocephala</i> Hoffkan, 1803	47	C <sub>1</sub>	2.22	1	D <sub>2</sub>	W <sub>3</sub>	
9		<i>Leistus ferrugineus</i> Linnaeus, 1758	73	C <sub>1</sub>	3.45	1	D <sub>2</sub>	W <sub>3</sub>	
10		<i>Nebria picicornis</i> Fabricius, 1775, 1801	69	C <sub>1</sub>	3.26	1	D <sub>2</sub>	W <sub>3</sub>	
11		<i>Platynus assimilis</i> , Paykull, 1790	77	C <sub>1</sub>	3.64	1	D <sub>2</sub>	W <sub>3</sub>	
12		<i>Pterostichus madidus</i> Fabricius, 1775	48	C <sub>1</sub>	2.27	1	D <sub>2</sub>	W <sub>3</sub>	
13		<b>II. Cerambycidae</b>	<i>Cerambyx pig</i> Linnaeus, 1758	2	C <sub>1</sub>	0.09	+	D <sub>1</sub>	W <sub>1</sub>
14		<b>III. Coccinellidae</b>	<i>Coccinella septempunctata</i> L., 1758	94	C <sub>1</sub>	4.44	1	D <sub>2</sub>	W <sub>3</sub>
15	<i>Harmonia axyridis</i> Pallas, 1773		82	C <sub>1</sub>	3.87	1	D <sub>2</sub>	W <sub>3</sub>	
16		<i>Stethorus punctillum</i> Weise, 1891	32	C <sub>1</sub>	1.51	1	D <sub>2</sub>	W <sub>3</sub>	
17		<i>Dorcus parallelipedus</i> L., 1758	3	C <sub>1</sub>	0.14	+	D <sub>1</sub>	W <sub>1</sub>	
18	<b>VI. Lucanidae</b>	<i>Lucanus cervus</i> Linnaeus, 1758	2	C <sub>1</sub>	0.09	+	D <sub>1</sub>	W <sub>1</sub>	
19	<b>V. Scarabaeidae</b>	<i>Protaetia marmorata</i> Fabricius, 1792	71	C <sub>1</sub>	1.82	1	D <sub>2</sub>	W <sub>3</sub>	
20	<b>VI. Geotrupidae</b>	<i>Geotrupes stercorosus</i> Scriba, 1791	71	C <sub>1</sub>	3.35	1	D <sub>2</sub>	W <sub>3</sub>	
21	<b>VII. Silphidae</b>	<i>Phosphuga (Silpha) atrata</i> L., 1758	90	C <sub>1</sub>	4.25	1	D <sub>2</sub>	W <sub>3</sub>	
22	<b>VIII. Staphylinidae</b>	<i>Staphylinus caesareus</i> Cederh., 1798	133	C <sub>1</sub>	6.28	2	D <sub>2</sub>	W <sub>4</sub>	
23		<i>Ocyopus (Staphylinus) olens</i> M., 1764	100	C <sub>1</sub>	2.20	1	D <sub>2</sub>	W <sub>3</sub>	

24		<i>Xantholins linearis</i> Olivier, 1795	119	C <sub>1</sub>	5.62	2	D <sub>2</sub>	W <sub>4</sub>
25	<b>XI.Tenebrioni dae</b>	<i>Stenomax aeneus</i> Scopoli, 1763	174	C <sub>1</sub>	8.22	2	D <sub>2</sub>	W <sub>4</sub>
<b>Total</b>			<b>2118</b>					

**Table 10.** Characteristics of some species found in Sub Arini Park (2023).

No.	Family	Species	Status / Comments
1	Coccinellidae	<i>Coccinella septempunctata</i> Linnaeus, 1758 <i>Harmonia axyridis</i> Pallas, 1773 <i>Stethorus punctillum</i> Weise, 1891.	The presence of these zoophagous species is related to the food source represented by aphids found on <i>Sambucus nigra</i> shrubs inside the Sub Arini Park and other low plants or trees.
2	Cerambycidae	<i>Cerambyx pig</i> Linnaeus, 1758	<b>species protected under the Habitats Directive 92/43/EEC</b> present in natural, semi-natural forests and in urban parks with old oaks, it develops in 3-5 years on <i>Quercus</i> sp. species from dead wood of living trees. As conservation measures for this species, it is recommended to secure in time and space the habitat of the species, which is represented by old oaks [8].
3	Lucanidae	<i>Lucanus cervus</i> Linnaeus, 1758 <i>Dorcus parallelipedus</i> Linnaeus, 1758	<b>species protected under Council of Europe Directive 92/43/EEC [95–98].</b> The presence of oak trees in Arini creates a favorable habitat. For this reason, it was accidentally observed in the park, but has also been reported in other habitats in Romania [99]
4	Scarabaeidae	<i>Protaetia marmorata</i> Fabricius, 1792	<b>very rare species, protected in Europe [82].</b>
5	Carabidae	<i>Carabus violaceus</i> Linnaeus, 1758	<b>the dominant predatory species</b> in shaded areas with shrubby vegetation from April to November. Present in all collection areas, with 1181 specimens (58.18% of the total), it was found in all traps near alleyways where food sources were also found, with most specimens being caught. during the period when the snail population was increasing. They overwinter as larvae which were identified as of October 1, 2023.

			<b>Predatory species codominant</b> with <i>Carabus violaceus</i> Linnaeus, 1758 in the summer season, common in forest habitats, present in all sectors and traps, with 656 individuals (32.32%).
6	Carabidae	<i>Pterostichus oblongopunctatus</i> Fabricius, 1787	
7	Carabidae	<i>Pterostichus niger</i> Schaller, 1783	<b>predatory species</b> present in Zones II, III and IV with 141 individuals (6.95%), feeding on oligochaetes, molluscs and insect larvae.
8	<b>Tenebrioninae</b>	<i>Stenomax aeneus</i> Scopoli, 1763	The species is a large primary decomposer that feeds on bird and mammal carcasses, helping to maintain the organic-mineral balance of the forest floor.

#### 4. Discussion

Among those mentioned above, there is also an important decomposer species: *Phosphuga (Silpha) atrata* Linnaeus, 1758 (Insecta; Coleoptera; Staphylinidae), a scavenger, present in the park from June to September, decomposes the carcasses of birds and mammals, contributing to the organo-mineral balance of the soil. *Phosphuga (Silpha) atrata* Linnaeus, 1758, has been found in zones II, III and V, especially inside the park, among trees such as *Populus nigra*, *Morus alba*, *Clematis vitalba*, *Cerasium avium*, *Pirus sativa*, *Crataegus monogyna*, *Platanus acerifolia* and *Acer platanoides*. These species were caught using traps placed near *Salix alba*, *Cerasum avium*, *Prunus spinosa*, *Platanus acerifolia*, *Quercus robur* and *Scirpus* sp.

The degraded grasslands within the park had low diversity, accounting for only 2.1% of the total sampled, while the shrub-covered valleys running through the park had both a higher number of species and higher occupancy, contributing 13.5% of the total individuals sampled.

The areas of the park populated by *Robinia pseudoacacia* and *Acer platanoides*, as well as the bare areas with southern exposure, showed the lowest entomofaunal diversity. Thus, the opportunistic species *Pterostichus oblongopunctatus* Fabricius, 1787 was reported in the wooded area.

The Arini Forest habitat (*Quercutum-roboris petraeae* association) provides a stable microclimate and diverse food resources for beetles, with species diversity naturally varying with the season, which correlates with the thermodynamic state. In summer, the biodiversity of the forest ecosystem exceeds in spring, while coleopterological diversity increases in fall in the forest habitat, but the total number of species decreases. The fall season had the highest species diversity when beetles are most active. An increased concentration of species numbers was observed in areas with tree vegetation. Predatory species were the most phenologically abundant compared to other categories such as coprophages and phytophages. Seasonal dynamics of the main trophic categories show a slight imbalance caused by the dominance of the opportunistic predatory species *Pterostichus oblongopunctatus* Fabricius, 1787. This species is known to invade forest ecosystems whose dynamics have been recently disturbed by logging or reforestation or anthropogenic intervention [3].

Beetle density varied with trap location, as well as climatic conditions and trap season. The discrepancy in the distribution of different beetle species is influenced by the variation in habitat environment and becomes more evident towards the end of the trapping period, from October onwards, when the beetles are preparing for the hibernation diapause.

##### 4.1. Summary of All Species Collected at Both Locations

A total of 5,008 specimens systematically categorized into 12 families covering 46 coleopteran species were collected over all three years in both ecosystems (Table 7, Annex 1). Of these, 2,890 specimens were collected from the research area of Pădurea Dumbrava (22 species belonging to 10 families) and 2,118 specimens were collected from the sub-Arini Park (26 species included in 9

families). Table 7/Appendix, below, presents the systematic list of coleopteran species collected in the two ecosystems, Dumbrava Sibiului Forest and Sub Arini Park in the period 2021-2023.

Across all three years in both ecosystems, the family Carabidae (Insecta: Carabidae) has the highest abundance, dominance, constancy with 23 species identified (Figure 12).



**Figure 12.** The graphic representation of the number of species and their classification in the families belonging to the Coleoptera order.

In terms of ecological significance (Table 11), the results obtained were as follows: W1-10.87% incidental species, W3-65.22% associated species, W4-13.04% complementary species, W5-6.52% characteristic species, W6-4.35% main species.

**Table 11.** Coleoptera species collected from the two ecosystems in the years 2021-2023.

N o	Family	Species	Dumbrava Forest (2021- 2022)	Sub Arini Park (2023)	Constancy (C)	Clas s (%)	Dominanc e (D)	Clas s (%)	Dzuba Ecological significanc e (W)
1		<i>Bembidion illigeri</i> Latreille, 1802	-	43	C <sub>1</sub>	2.03	1	D <sub>2</sub>	W <sub>3</sub>
2		<i>Bradycellus ruficollis</i> Stephens, 1828	-	50	C <sub>1</sub>	2.36	1	D <sub>2</sub>	W <sub>3</sub>
3		<i>Carabus violaceus</i> Linnaeus, 1758	27	551	C <sub>2</sub>	11.57	2	D <sub>2</sub>	W <sub>5</sub>
4		<i>Carabus (Procastes) coriaceus</i> Linnaeus, 1758	34	18	C <sub>1</sub>	1.04	1	D <sub>2</sub>	W <sub>3</sub>
5	I.	<i>Carabus gigas</i> Creutzer, 1799	57	-	C <sub>1</sub>	1.97	1	D <sub>2</sub>	W <sub>3</sub>

6	<b>Carabidae</b>	<i>Carabus monilis</i> <i>scheidleri</i> , Panzer, 1799	62	-	C <sub>1</sub>	2.15	1	D <sub>2</sub>	W <sub>3</sub>
7		<i>Carabus</i> <i>nemoralis</i> , O. F. Müller, 1764	74	-	C <sub>1</sub>	2.56	1	D <sub>2</sub>	W <sub>3</sub>
8		<i>Carabus</i> <i>ullrichii</i> , Germar, 1824	63	-	C <sub>1</sub>	2.18	1	D <sub>2</sub>	W <sub>3</sub>
9		<i>Carabus</i> <i>variolosus</i> Fabricius, 1787	43	-	C <sub>1</sub>	1.49	1	D <sub>2</sub>	W <sub>3</sub>
10		<i>Cychrus</i> <i>caraboides</i> Linnaeus, 1758	61	-	C <sub>1</sub>	2.11	1	D <sub>2</sub>	W <sub>3</sub>
11		<i>Harpalus</i> <i>aeneus</i> Fabricius, 1775	-	58	C <sub>1</sub>	2.74	1	D <sub>2</sub>	W <sub>3</sub>
12		<i>Harpalus latus</i> , Linnaeus, 1758	79	-	C <sub>1</sub>	2.73	1	D <sub>2</sub>	W <sub>3</sub>
13		<i>Harpalus</i> <i>rubripes</i> Dufischmid, 1812	-	46	C <sub>1</sub>	2.17	1	D <sub>2</sub>	W <sub>3</sub>
14		<i>Harpalus</i> <i>rufipes</i> Degeer, 1774	-	65	C <sub>1</sub>	3.07	1	D <sub>2</sub>	W <sub>3</sub>
15		<i>Lebia</i> <i>chlorocephala</i> Hoffkan, 1803	-	47	C <sub>1</sub>	2.22	1	D <sub>2</sub>	W <sub>3</sub>
16		<i>Leistus</i> <i>ferrugineus</i> Linnaeus, 1758	-	73	C <sub>1</sub>	3.45	1	D <sub>2</sub>	W <sub>3</sub>
17		<i>Leistus</i> ( <i>Pogonophorus</i> ) <i>spinibarbis</i> , Fabr., 1775	95	-	C <sub>1</sub>	3.46	1	D <sub>2</sub>	W <sub>3</sub>
18		<i>Nebria</i> <i>picicornis</i> Fabricius, 1775, 1801	-	69	C <sub>1</sub>	3.26	1	D <sub>2</sub>	W <sub>3</sub>

19		<i>Platynus assimilis</i> , Paykull, 1790	-	77	C <sub>1</sub>	3.64	1	D <sub>2</sub>	W <sub>3</sub>
20		<i>Pterostichus (B.) oblongopunctatus</i> Fabr, 1787	156	-	C <sub>1</sub>	5.40	2	D <sub>2</sub>	W <sub>4</sub>
21		<i>Pterostichus niger</i> Schaller, 1783	941	-	C <sub>3</sub>	32.56	3	D <sub>3</sub>	W <sub>6</sub>
22		<i>Pterostichus madidus</i> Fabricius, 1775	-	48	C <sub>1</sub>	2.27	1	D <sub>2</sub>	W <sub>3</sub>
23		<i>Pterostichus melanarius</i> , Illiger, 1798	371	-	C <sub>2</sub>	12.84	2	D <sub>2</sub>	W <sub>5</sub>
24	II. <b>Cerambycida</b>	<i>Cerambyx pig</i> Linnaeus, 1758	-	2	C <sub>1</sub>	0.09	+	D <sub>1</sub>	W <sub>1</sub>
25	e	<i>Rhagium sycophanta</i> Schrank, 1781	2	-	C <sub>1</sub>	0.07	+	D <sub>1</sub>	W <sub>1</sub>
26		<i>Morimus funereus</i> Mulsat, 1863	2	-	C <sub>1</sub>	0.07	+	D <sub>1</sub>	W <sub>1</sub>
27	III. <b>Coccinellidae</b>	<i>Coccinella septempunctata</i> Linnaeus, 1758	-	94	C <sub>1</sub>	4.44	1	D <sub>2</sub>	W <sub>3</sub>
28		<i>Harmonia axyridis</i> Pallas, 1773	-	82	C <sub>1</sub>	3.87	1	D <sub>2</sub>	W <sub>3</sub>
30		<i>Stethorus punctillum</i> Weise, 1891	-	32	C <sub>1</sub>	1.51	1	D <sub>2</sub>	W <sub>3</sub>
31	IV. <b>Curculionida</b>	<i>Pissodes pini</i> Linnaeus, 1758	49	-	C <sub>1</sub>	1.70	1	D <sub>2</sub>	W <sub>3</sub>
32	V. <b>Elateridae</b>	<i>Ampedus sanguineus</i> Linnaeus, 1758	85	-	C <sub>1</sub>	2.94	1	D <sub>2</sub>	W <sub>3</sub>
33	VI. <b>Lucanidae</b>	<i>Dorcus parallelipedus</i> Linnaeus, 1758	-	3	C <sub>1</sub>	0.14	+	D <sub>1</sub>	W <sub>1</sub>

34		<i>Lucanus cervus</i> Linnaeus, 1758	-	2	C <sub>1</sub>	0.09	+	D <sub>1</sub>	W <sub>1</sub>
35	<b>VII.</b> <b>Scarabaeidae</b>	<i>Protaetia marmorata</i> Fabricius, 1792	20	71	C <sub>1</sub>	1.82	1	D <sub>2</sub>	W <sub>3</sub>
	<b>VIII.</b> <b>Geotrupidae</b>	<i>Geotrupes stercorosus</i> Scriba, 1791	-	71	C <sub>1</sub>	3.35	1	D <sub>2</sub>	W <sub>3</sub>
37	<b>IX. Silphidae</b>	<i>Phosphuga (Silpha) atrata</i> Linnaeus, 1758	-	90	C <sub>1</sub>	4.25	1	D <sub>2</sub>	W <sub>3</sub>
38		<i>Nicrophorus vespillo</i> Linnaeus, 1758	126	-	C <sub>1</sub>	4.36	1	D <sub>2</sub>	W <sub>3</sub>
39		<i>Nicrophorus germanicus</i> Linnaeus, 1758	157	-	C <sub>1</sub>	5.43	2	D <sub>2</sub>	W <sub>4</sub>
40		<i>Oiceoptoma thoracica</i> Linnaeus, 1758	132	-	C <sub>1</sub>	4.57	1	D <sub>2</sub>	W <sub>3</sub>
41		<i>Necrodes littoralis</i> Linnaeus, 1758	91	-	C <sub>1</sub>	3.15	1	D <sub>2</sub>	W <sub>3</sub>
42	<b>X.</b> <b>Staphylinida</b> <b>e</b>	<i>Staphylinus caesareus</i> Cederhjelm, 1798	-	133	C <sub>1</sub>	6.28	2	D <sub>2</sub>	W <sub>4</sub>
43		<i>Ocypus (Staphylinus) olens</i> Müller, 1764	10	100	C <sub>1</sub>	2.20	1	D <sub>2</sub>	W <sub>3</sub>
44		<i>Xantholins linearis</i> Olivier, 1795	-	119	C <sub>1</sub>	5.62	2	D <sub>2</sub>	W <sub>4</sub>
45	<b>XI.</b> <b>Sphindidae</b>	<i>Sphindus dubius</i> Gyllenhal, 1808	153	-	C <sub>1</sub>	5.29	2	D <sub>2</sub>	W <sub>4</sub>
46	<b>XII.</b> <b>Tenebrionida</b> <b>e</b>	<i>Stenomax aeneus</i> Scopoli, 1763	-	174	C <sub>1</sub>	8.22	2	D <sub>2</sub>	W <sub>4</sub>
<b>Total</b>			<b>2890</b>	<b>2118</b>					

#### 4.2. Weather Impact on Insect Populations.

The increasingly warmer winters of the last three years have increased the likelihood of survival of the beetle populations in Dumbrava (Table 12).

**Table 12.** Sibiu Meteorological Station.

↓	minimum temperature	January	↑	minimum temperature	January
2021	-3,4 °C		2022	-4,52 °C	
	maximum temperature	June		maximum temperature	June
	25,08 °C			26,81 °C	
	average temperature	9,85 °C		average temperature	11,60 °C

Depending on temperature, entomofauna resumed their activity in spring 2022 in late April as temperatures began to rise. In the winter of 2022, soil insects did not experience many days of low temperatures; the mild winter reduced freeze-thaw periods, which did not affect their winter survival.

We found that diapause ended in mid-winter, but the beetles remained dormant until temperatures became favourable. Even though mortality was higher among some species, when climatic conditions became favourable, the number of individuals in some populations began to increase, thus explaining the abundance of *Carabus violaceus* Linnaeus, 1758 and *Perosticus niger* Schaller, 1783.

Precipitation is an important ecological factor and influenced the flora and entomofauna of Dumbrava. The amount of precipitation was quite low during the three years of the study, the wettest periods were recorded in late April, May and early June.

The atmospheric humidity in the study ecosystem depended on the air temperature, the movement of air currents in the forest and the degree of vegetation cover in the area where the traps were set, as well as the atmospheric pressure on the days and months of trapping. The combination of these ecological factors determined the distribution of insects, and the number of individuals collected in each trap over the three years.

Our study emphasizes the diversity, weight, distribution and importance of coleopteran populations expressed by the number and abundance of Carabidae species which, due to the collection methods, represent 79.81% of the total insects captured.

Our research has shown that the dominant plant, shrub and tree species directly influence the diversity and abundance of beetle populations collected during the three years of study. The number of carabid species collected in Arini is higher because these species are hyperparasitic, thus ensuring a limitation of pest populations in the park, and the vegetation is more diverse compared to the vegetation of Dumbrava forest.

Forest management is an important factor influencing the biodiversity of forest ecosystems, as shown by numerous studies [100–104], including the diversity of insect species and especially beetles [30,105]. The research confirms this hypothesis regarding edaphic entomofauna, the diversity of plants studied in both locations.

Human intervention in forest ecosystems by removing trees most often leads to decreases in the abundance and species richness of arthropods, especially beetles [106–108], but changes in landscape characteristics appear to affect the abundance of epigeal insects less than other insect categories. [109–112]. The dynamics of beetle species identified from the 2021-2023 data centralization is due to transformations in the forest perimeter and the park through anthropization, creation of recreational areas, pollution due to human activity, etc.

This beetle study is a valuable approach that provides important information about the ecological status of these two ecosystems. The continuation of the study and the implementation of

measures to protect natural habitats are essential to maintain biodiversity and ecological balance [113].

The information obtained can form the basis for future studies on the structure of entomofauna and flora and possible measures to protect endangered species.

## 5. Conclusions

In the two ecosystems studied, Coleoptera have adapted to fill a few niches. In general, these insects, are predatory, omnivorous, even phytophagous and are considered natural pest control agents in agroecosystems with the Carabids important ecological bioindicators of soil and soil productivity. They play a significant role in disturbing forest biocenosis. The biomass of carabids is closely related to the biomass of macrofauna responsible for leaf decomposition.

In total during the 3 years of research and entomofauna analysis across both locations, captured by soil traps, in the two forest ecosystems, the 11 families included 46 coleopteran species with 5.008 identified specimens belonging to the following trophic categories:

- ✓ first-order consumers (phytophagous species, feeding on fresh plant matter),
- ✓ second-order consumers (predatory species with molluscs, worms, and insects as their trophic base), and
- ✓ decomposers (detritivores species, feeding on plant detritus, coprophagous species, feeding on animal dung, scavenging species, feeding on corpses).

Apart from the dominant species *Pterostichus niger* Schaller, 1783 from Dumbrava and *Carabus violaceus* Linnaeus, 1758 from Arini, most of the carabid species are dominant, occupying a percentage between 1.5-85% of the total species caught, they are large predatory species that feed on molluscs, but also on insect larvae.

The beetle diversity demonstrates their importance within both locations and the forest functions in relation to the flora, weather conditions, soil and ecosystem functions, an essential factor for the adaptation of the studied areas to climatic changes.

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