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Research Article

Assessing montane grassland and butterfly biodiversity to improve management strategies in locally significant conservation areas

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Abstract

Montane grasslands must be managed effectively to conserve biodiversity since they play an important role in sustaining healthy and diversified ecosystems. A 9 km transect was used to assess plant and lepidopteran biodiversity in mountain meadows in Bilbor, Romania. Different management strategies were used in each plot. The identified plants were divided into three categories: Poaceae, Fabaceae, and other families. In the case of lepidoptera, diurnal butterfly species from three families were observed: Lycaenidae, Nymphalidae, and Pieridae. The number of plant species in the abandoned meadows was reduced, with a focus on those with low fodder value (*Nardus stricta* and *Deschampsia flexuosa*), as well as some invasive species (*Vaccinium myrtillus*). The implementation of protection and conservation measures resulted in species diversification, with an increase in the number of Poaceae (11 to 16 species) and Fabaceae (nine to fourteen species). In addition to providing more feed, the flora can benefit lepidopteran entomofauna. During the monitoring period, 29 species were identified from the three lepidopteran families. The most abundant species were *Maniola jurtina* L., *Boloria selene* Denis & Schif., *Argynnis paphia* L., *Coenonympha pamphilus* L. (Nymphalidae), *Pseudophilotes schiffermuelleri* Hemming (Lycaenidae), and *Pieris mannii* Mayer (Pieridae). Traditional mowing and grazing activities can help to maintain the structure and composition of these ecosystems, limiting biological succession to forest and sustaining floristic biodiversity.

Keywords: biodiversity; conservation; ecosystem; grassland

Introduction

Mountains with a high biodiversity are very significant at the global and European levels for the ecosystem services they provide (Păcurar and Rotar, 2014; Hussain *et al*., 2019). In recent years, there has been a continued decline in the diversity of habitats and species in mountainous areas on a European scale, prompting a reconsideration of the method of exploitation of these ecosystems (Baur *et al*., 2006; Csergő *et al*., 2013; Wezel *et al*., 2021). The reduction of semi-natural pastures is determined by recent agricultural changes,

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such as increased exploitation or abandonment. The greatest loss of biodiversity is indicated by abandoned meadows, which are in a constant state of degradation, with a decline in plant species with high feed value and an expansion in plant species with low feed value (Krause and Culmsee, 2013; Pruchniewicz, 2017). Abandoned areas see an increase in woody vegetation, while taller and more expansive plants take over, resulting in the loss of initial biodiversity (Tasser and Tappeiner, 2002; Jugovic *et al*., 2013; Pruchniewicz and Żołnierz, 2014).

There is a tendency in some mountainous areas towards the transformation of grasslands into hayfields, as a result of changes in the age and occupation structures of local rural populations. Compared to meadows, pastures have a greater diversity of species (plants and insects) (Kampmann *et al*., 2008). Traditional low-intensity agricultural practices applied to forests and mountain pastures have allowed the preservation of existing plants and wildlife, thus helping to conserve biodiversity (Pruchniewicz and Żołniers, 2014; Lessard-Therrien *et al*., 2017). By preserving useful flowers, sustainable management, developed according to certain principles, helps to achieve hay production of the highest possible quality (Lessard-Therrien *et al*., 2017; Wezel *et al*., 2021). Increasing fruit production through more intensive harvesting methods can occasionally lead to the degradation of natural habitats through a sudden decrease in biodiversity (Babai and Molnár, 2014).

There is a wide variety of plants and animals, mainly avian species, in semi-natural areas. However, to preserve these resources, management plans and funding from the government or local authorities are needed (Baur et al., 2006). The entomofauna of highland pastures and meadows includes a significant number of butterfly species. Their protection is essential because they play a crucial role in pollination for numerous plants, which helps to preserve the local flora (Koh, 2007; Ollerton *et al*., 2011). The populations of these species have declined recently on a global scale (Görn *et al*., 2014; Roy *et al*., 2015). Approximately 30% of butterfly species in Europe are thought to be in decline, and 10% are thought to be in danger of going extinct (van Swaay *et al*., 2012). Van Sway *et al*. (2013) report that between 1990 and 2011, there was a roughly 50% decline in the numerical density of diurnal butterfly populations in Europe. The situation is primarily influenced by recent climate changes, particularly global warming (Dolek *et al*., 2005; Heikkinen *et al*., 2010; Pruchniewicz and Żolnierz, 2014; Hill *et al*., 2021; Rödder *et al*., 2021), as well as the destruction and fragmentation of the natural habitat (Horak and Saforva, 2015; Steffan-Dewenter and Tscharntke, 2020; Wezel *et al*., 2021; Kajzer-Bonk and Nowicki, 2023). According to Parmesan (2003), butterflies are even a bioindicator of climate change. The natural habitat in mountainous regions is frequently degraded by human activity, which in turn reduces the richness of the flora and fauna (Baur *et al*., 2006; Horak and Safarova, 2015; Mazaloyá *et al*., 2015; Lessard-Therrien *et al*., 2015; 2017). Applying insecticides is the most dramatic intervention impacting butterfly populations (Kjaer *et al*., 2014; Pisa *et al*., 2015).

Because they are so sensitive to changes in their habitat, butterfly species are frequently used as bioindicators of particular ecosystems (Morse, 1971; Koh, 2007 2007; Rákosy and Schmitt, 2011; Jugovic *et al*., 2013; Gonzalez *et al*., 2017; Choudhary and Chishty, 2020). Furthermore, the decline in butterfly populations has an impact on the trophic chains within the ecosystem, as they serve as the trophic basis for numerous predatory species (Koh, 2007; Crowder *et al*., 2010; Jugovic *et al*., 2013; Lemelin *et al*., 2019). Lepidopteran populations benefit from the maintenance of natural habitats through appropriate management (Dollar *et al*., 2013; Buková *et al*., 2015). Because of these factors, laws in Europe and Romania set up safeguards for specific butterfly species, ensuring the preservation of their native habitats without modification (Rákosy, 2005; Schmitt and Rákosy, 2007; Dollar *et al*., 2013). The Annexes of the Habitats Directive include a list of 29 butterfly species that were removed from the Red List, together with information on their conservation status and protective measures (van Swaay *et al*., 2012). Because of this, it is crucial to understand the trophic basis of each species, particularly concerning the larval stage, as well as the plants that the adults eat (Friberg and Wiklund, 2009; Jugovic *et al*., 2013; Lanta *et al*., 2009; Clarke, 2022).

An alternative to expanding entomological tourism, which has emerged as a new market for the travel and tourism sector, is to protect the entomofauna in mountainous regions (Shasha *et al*., 2020; Kucher *et al*., 2023). This kind of travel gives visitors a wide-ranging viewpoint on mountain ecosystems and raises awareness of the value of protecting these delicate regions and the diversity of insects (Shedenov *et al*., 2019; Batool *et al*., 2021). Through entomological tourism, visitors can learn about the intricate relationships between various species, their life cycles, and survival techniques, as well as the crucial role that insects play in mountain ecology (Lacitignola *et al*., 2007; Lemelin *et al*., 2019). Identification of uncommon and endemic insects is made possible by this activity, which also helps with data collecting for scientific studies and biodiversity protection. However, tourism is a sector that creates jobs, revenue, and infrastructure (Shedenov *et al*., 2019; Lee and Chen, 2021; Yakymchuk *et al*., 2021). In order to balance environmental protection, the preservation of local cultural assets, and long-term economic benefits, the idea of "sustainable tourism" was developed (Malkov *et al*., 2019; Comerio and Strocci, 2019). To do this, a local management plan that guarantees the growth of ecotourism through investment programme implementation must be created (Abduganiev and Makhkamov, 2022; Ibragimov, 2022). In the current study, the biodiversity assessment of a region possessing great ecological, socioeconomic, tourism, and landscape potential was carried out to achieve this objective. Bilbor is one of the high-altitude sites in the northeastern region of Romania, being located in the middle of a large coniferous forest. This region is recognized as being one of the cleanest in Romania.

Materials and Methods

Study area

The objective of this study was to assess and evaluate the impact of local management on the faunal biodiversity of the meadows and hayfields in Bilbor commune, as well as to monitor the diurnal lepidopteran entomofauna, which is contingent upon the floristic composition of the biotope.

Bilbor commune is situated in the northern region of Harghita County, Romania, and spans an area of 38 km^2. Its coordinates are 47°04' north latitude and 25°29' east longitude (Figure 1). The elevation ranges from 900 to 1050 meters. The average annual temperature is 7-8 °C, and the climate is temperate-continental-depressive.

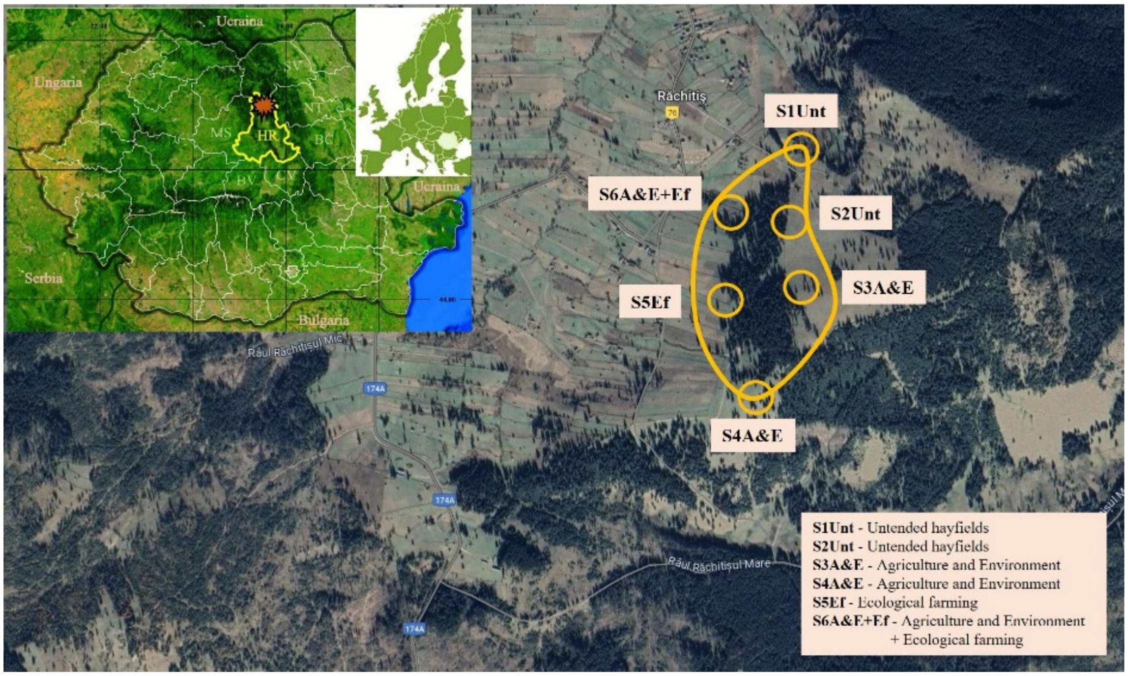

Figure 1. Study area

At altitudes exceeding 1000 metres, precipitation exceeds 1000 millimetres annually, while in valley regions, it is approximately 700 millimetres annually. A diverse array of plant and faunal communities is favoured by the zonal climatic peculiarities. Bilbor is also renowned for its abundance of mineral water springs, which are approximately 700 in number and consist of calcium, magnesium, sodium, and carbonated water. Fluorine, lithium, bromine, iodine, copper, zinc, radium, and rhodium are also present. These mineral waters possess a significant therapeutic potential as a result of their chemical composition.

The study of flora biodiversity

To examine phytocenosis, plant species are identified and percentage coverage values are calculated (Szyszko-Podgórska *et al*., 2023). The Bilbor Territorial Administrative Unit has 8,975 acres of meadows and pastures, according to the 2017 Pastoral Management. Hayfields cover 2,374.47 ha, whereas pasture covers 6,600.53 ha. Bilbor commune holds 5715.45 ha of the 8975 ha, while Monor, Lăzarea, Rusii Munți, and Şieuț own the remaining 3259.55 ha. Meadows and hayfields are administered in accordance with the pastoral development plan, and owners are required to adhere to it.

A package of measures has been prepared in accordance with the European Union's agricultural policy, which aims to encourage sustainable agricultural practices that assure biodiversity conservation, soil and water source preservation in the face of current climate change. These approaches are extremely efficient at protecting flora and fauna (Kampmann *et al*., 2008).

On the hayfields in Bilbor, plant structure was evaluated on six plots that included hayfields and forest, each with a different management approach (Figure 1). Plots S1 and S2 are abandoned hayfields (S1Unt., where S1 stands for Site 1 and Unt. means untended). The discontinuation of the traditional usage of natural hay poses a significant threat to flora and animal variety. The decline of diurnal lepidopteran populations is caused by the extinction of species with high forage value and species utilised as a trophic source for diverse insects, as well as the invasion of other plant species, because they are sensitive indicators of habitat changes (Szanyi *et al*., 2018).

Different traditional techniques of use that contribute to habitat conservation are used on the other 4 hay plots that are declared to APIA (Agency for Payments and Intervention for Agriculture) in order to get subsidies from the budget. Plots S3 and S4 are covered by the "Agri-environment and climate" measure (S3A&E and S4A&E - Agriculture and Environment), which has been in effect since 2017. The plots with the highest biodiversity of flora are these ones. Therefore, maintaining traditional landscapes with a positive influence on biodiversity preservation is the goal of the "Agri-environment and climate" measure. On certain surfaces, chemical insecticides and fertilisers are not allowed. Manure is the only fertiliser used, and the amount of nitrogen applied should not exceed 40 kg/ha.

The method "Agri-environment + ecological agriculture" (S6A&E+Ef - Agriculture and Environment + Ecological farming) is used to plot S6 starting in 2021, while the measure "Ecological agriculture" (S5Ef - Ecological farming) is applied to plot S5 starting in 2020. These plots show an improvement in the biodiversity of the flora. Promoting environmentally friendly, sustainable farming methods is the goal of the ecological agriculture measure. To use this metric, it must meet specific eligibility requirements (Dahlström *et al*., 2013). Farmers who use this measure are required to maintain a thorough record of the activities conducted on these surfaces and to adhere to the terms of the agreement for a minimum of five years after the date of signing.

The transect that was examined covered an area of 9 km. Within this region, the biodiversity of both flora and Lepidoptera was analyzed on six specific plots, namely S1Unt, S2Unt, S3A&E, S4A&E, S5Ef, and S6A&E+Ef (Figure 1). Four samples were collected on each mapping plot, covering an area of 4x4 square meters, and the flora structure was analyzed. The identified plants were categorized into three groups: the Poaceae family, the Fabaceae family, and others. The coverage % of each species was measured in the Poaceae and Fabaceae families, which consist of plants with high fodder value. A total of 129 species belonged to other families, and their coverage was assessed at the family level. Several species, particularly those belonging to Asteraceae, Caryophyllaceae, Lamiaceae, Plantaginaceae, and Polygonaceae, serve as a food source for diurnal Lepidoptera. The adult butterflies feed on the pollen of these plants, while the larvae consume their vegetative organs.

Observing the insect population of butterflies

During the time frame of 2019-2021, diurnal Lepidoptera species were captured using an entomological net between the months of May and August, which corresponds to the final ten years. Over the course of three years, a total of 12 threadings were conducted. The obtained biological material was analysed either on-site or in the Entomology Laboratory at USAMV Cluj-Napoca. Each species was recognised by examining the physical traits and unique colour patterns of their wings. For the species that were immediately identified in the field, the specimens captured with the net were released. Information describing the bioecology and trophic underpinning of each species was gathered through extensive research of specialized literature. By understanding the trophic base, it is possible to design conservation strategies for the host plants. The management plan for the protection of lepidopteran entomofauna will be prepared by combining this knowledge with the study of local phytocenoses. When studying insect ecology, it is crucial to analyse certain ecological markers that help assess biodiversity. This analysis is important for understanding the characteristics of the observed insect population (Kok *et al*., 2020; Gajbe, 2023).

The collected Lepidoptera were used to calculate ecological indices, including abundance (A), which represents the number of individuals of a species present on the investigated surface; dominance (D), which represents the percentage of each species' participation in the total number of individuals of other species in the investigated ecosystem, indicating relative abundance; and constancy (C), which expresses the continuity of a species' appearance in the given biotope. The indicator's value directly correlates with the level of adaptation of a species to its biotope. The ecological significance index (W) is determined by the link between constancy and dominance, providing a more precise indication of a species' place within the biocenosis.

Results

Phytocoenosis monitoring

The structure of the plants detected on the phytocenosis control plots is depicted in Figure 2 by botanical families. S1Unt and S2Unt plots are situated on deserted fields. It was noted that the Poaceae and Fabaceae groups had the lowest participation rates in these. With 18% of the total species in the Poaceae participating in the first plot and 27% in the second, *Nardus stricta* is the leading plant in the family despite having a low fodder value. *Deschampsia flexuosa* was likewise found to have a high abundance of 15.3%, particularly in the first plot, and a poor fodder value (Table 1). The participation of Fabaceae family species in these plots is limited, with a maximum of 3% in the first plot (Table 2). The prominent species found in other families include *Vaccinium myrtillus* and *Vaccinium vitis-idaea* (Ericaceae), which are invasive plants found in abandoned grasslands and are known as blueberries (Table 3).

The grassland regions designated as APIA, where control plots S3A&E, S4A&E, S5Ef, and S6A&E+Ef are situated, are subject to biodiversity protection measures. Plants belonging to the Poaceae family make up the majority of the floristic composition in these plots; their percentage ranges from 46% in plot S6A&E+Ef to 52% in plot S3A&E (Table 1). *Anthoxanthum odoratum, Arrhenatherum elatius, Briza media, Cynosurus cristatum, Dactylis glomerata, Danthonia caespitosa, Danthonia decumbens, Deschampsia flexuosa, Festuca pratensis, Festuca rubra, Festuca supina, Holcus lanatus, Nardus stricta, Poa pratensis,* and *Trisetum flavescens* are some of the 16 species that have been identified from this family. *Arrhenatherum elatius, Poa pratensis, Festuca species*, and *Dactylis glomerata* have the highest fodder value among them. *Agrostis capillaris*, which accounts for 13.5% of the flora composition in plot S5Ef, is the major species among the Poaceae; in the remaining three plots, *Festuca rubra* is the predominant species, contributing between 10.5% (plot S6A&E+Ef) and 18% (S3A&E plot).

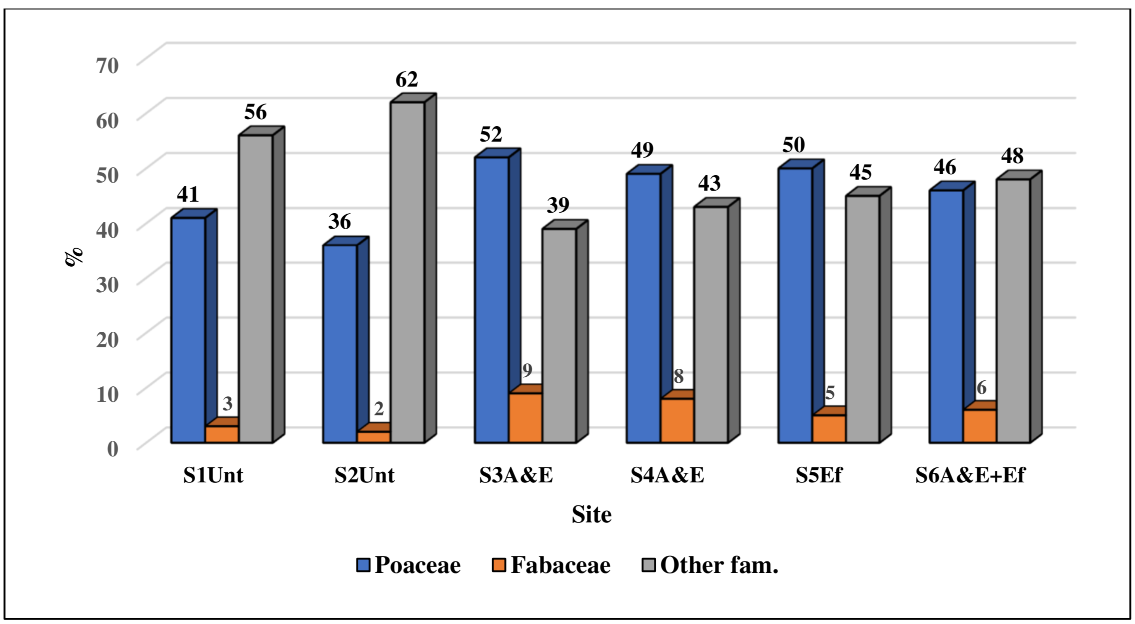

Figure 2. The percentage of participation of plant families in the phytocenosis structure

Table 1. The participation percentage of Poaceae family species in the flora structure

No.	Species	Number of species and percent of participation/Control plot					
		S1Unt	S2Unt	S3A&E	S4A&E	S5Ef	S6A&E+Ef
1	*Agrostis capillaris*	2.5	1.5	10.5	12.0	13.5	9.5
2	*Anthoxanthum odoratum*	0.5	1.0	3.5	2.5	10.0	2.0
3	*Arrhenatherum elatius*	-	-	0.5	-	-	-
4	*Briza media*	-	0.5	2.5	1.5	2.0	2.0
5	*Cynosurus cristatum*	0.4	-	2.0	1.0	1.5	1.5
6	*Dactylis glomerata*	-	-	2.0	3.5	2.5	4.5
7	*Danthonia caespitosa*	0.3	-	1.3	-	-	-
8	*Danthonia decumbens*	-	-	0.7	0.5	-	0.5
9	*Deschampsia flexuosa*	15.3	5.0	0.5	0.5	0.5	-
10	*Festuca pratensis*	-	-	1.5	1.0	2.5	3.5
11	*Festuca rubra*	2.5	0.5	18.0	16.5	11.5	10.5
12	*Festuca supina*	-	0.5	-	0.5	-	-
13	*Holcus lanatus*	-	-	1.5	1.5	0.5	1.0
14	*Nardus stricta*	18.0	27.0	0.5	0.5	-	0.5
15	*Poa pratensis*	-	-	2.5	4.0	2.5	3.0
16	*Trisetum flavescens*	1.5	-	4.5	3.5	3.0	7.5
Total %		**41**	**36**	**52**	**49**	**50**	**46**

Anthylis vulneraria, Chamaecytisus ruthenicus, Chamaecytisus supinus, Coronilla varia, Genista tinctoria, Genistella sagittalis, Lathyrus pretensis, Lotus corniculatus, Medicap lupulina, Trifolium campestre, Trifolim montanum, Trifolium pratense, Trifolium repens, and *Vicia cracca* were among the 14 species discovered within the Fabaceae family. With the use of biodiversity conservation techniques, the Fabaceae family adds 5-9% to the floristic composition of the plots (where *Trifolium pratense* is the dominating species) and 2-3% to the floristic composition of the abandoned hayfields (Table 2).

Table 2. The percentage of participation of species from the Fabaceae family in the structure of the flora

No.	Species	Number of species and percent of participation/Control plot					
		S1Unt	S2Unt	S3A&E	S4A&E	S5Ef	S6A&E+Ef
1	*Anthylis vulneraria*	-	-	0.4	0.3	0.1	0.2
2	*Chamaecytisus ruthenicus*	-	-	0.3	-	-	-
3	*Chamaecytisus supinus*	-	-	-	0.2	-	-
4	*Coronilla varia*	-	0.6	-	0.6	-	0.4
5	*Genista tictoria*	-	-	0.3	0.8	0.4	-
6	*Genistella sagittaliss*	-	-	1.5	-	0.5	0.4
7	*Lathyrus pratensis*	-	-	0.5	-	0.3	0.5
8	*Lotus corniculatus*	0.5	0.4	1.0	1.3	0.6	1.0
9	*Medicago lupulina*	-	-	0.3	0.5	0.4	0.3
10	*Trifolium campestre*	-	-	0.7	0.6	-	-
11	*Trifolium montanum*	1.0	0.5	0.5	0.6	-	0.5
12	*Trifolium pratense*	-	0.5	2.0	1.7	1.5	1.5
13	*Trifolium repens*	1.0	-	1.2	1.0	0.9	1.0
14	*Vicia cracca*	0.5	-	0.3	0.4	0.3	0.2
Total %		**3**	**2**	**9**	**8**	**5**	**6**

Other plant family species provide between 56 and 62% of the floristic composition in the plots that have been abandoned and between 39 and 48% in the plots that have biodiversity conservation measures in place (Figure 2). Numerous species in the examined area serve as trophic bases for the lepidopteran species under observation.

129 species were found in the plots under investigation, and they are categorised into 28 families in a methodical manner. The number of species and percentage of coverage for each botanical family are displayed in Table 3 for each observed plot. The Ericaceae family, with a coverage percentage between 22.5% and 26.5%, is the dominating family in plots S1Unt and S2Unt (abandoned hayfields). The Rosaceae family is in second place, with a coverage percentage between 11.1% and 19.5%. These are all invasive species. These plots have the lowest recorded biodiversity. In the S2Unt plot, 21 species were found, while in the S1Unt plot, 27 species were found. With a coverage percentage ranging from 12.5% to 14%, the Asteraceae family is the most prevalent family in plots managed conservatively.

Plots S3A&E (71 species) and S4A&E (62 species), where the "Agro-environment and climate" measure has been used for five years, have been shown to have the highest floristic diversity. There are 49 species identified from other botanical families on plot S5Ef, where the "Ecological agriculture" measure is applied starting in 2020, and 56 species on plot S6A&E+Ef, where the "Agri-environment + ecological agriculture" approach is employed starting in 2021.

Table 3. The percentage of participation of species from other families in the structure of the flora

No	Species	Number of species and percent of participation/Control plot											
		S1Unt		S2Unt		S3A&E		S4A&E		S5Ef		S6A&E+Ef	
		no	%	no	%	no	%	no	%	no	%	no	%
1	Apiaceae	-	-	-	-	4	2.0	3	2.0	1	1.8	1	3.0
2	Asteraceae	10	7.2	6	4.0	14	13.0	12	12.5	10	14.0	13	13.5
3	Brassicaceae	-	-	-	-	1	0.5	2	0.3	-	-	3	0.5
4	Campanulaceae	-	-	-	-	3	1.5	3	2.0	1	1.5	2	2.5
5	Caprifoliceae	1	0.5	-	-	1	1.0	2	0.6	1	1.0	1	0.8
6	Caryophyllaceae	2	2.5	-	-	4	2.0	5	2.5	3	2.4	3	1.0
7	Colchicaceae	-	-	-	-	1	0.2	1	0.1	-	-	1	0.1
8	Cyperaceae	1	1.5	1	2.5	2	0.5	2	0.4	1	0.5	1	0.3

9	Dennstaedtiaceae	-	-	-	-	1	0.1	-	-	1	0.2	-	-
10	Ericaceae	2	22.5	3	26.5	2	0.5	1	1.2	3	1.0	1	1.5
11	Euphorbiaceae	-	-	-	-	1	0.2	-	-	1	0.1	-	-
12	Equisetaceae	-	-	-	-	1	0.1	-	-	-	-	1	0.6
13	Gentianaceae	-	-	-	-	2	1.0	-	-	1	1.0	-	-
14	Hypericaceae	1	0.1	1	0.5	1	0.5	1	2.0	1	1.0	1	2.0
15	Juncaceae	1	0.5	1	1.5	1	0.3	3	0.6	1	0.5	1	0.4
16	Lamiaceae	2	4.0	3	4.5	5	3.5	4	4.9	5	4.7	5	5.2
17	Malanthiaceae	-	-	-	-	1	1.0	1	0.5	1	0.5	1	0.5
18	Orobanchaceae	1	0.1	1	0.5	2	1.0	2	2.0	2	2.0	2	2.0
19	Plantaginaceae	1	0.5	1	2.5	4	2.0	5	2.0	3	2.8	4	3.0
20	Polygonaceae	-	-	-	-	4	2.1	2	3.0	2	2.5	3	2.5
21	Polygalaceae	-	-	-	-	2	1.0	2	0.6	2	1.0	3	2.8
22	Primulaceae	-	-	-	-	2	0.2	1	0.3	-	-	-	-
23	Ranunculaceae	2	3.5	1	2.5	3	2.0	4	2.4	1	2.0	1	2.0
24	Rosaceae	1	11.1	2	19.5	3	1.2	4	2.6	5	3.1	3	1.8
25	Rubiaceae	1	1.5	1	1.5	2	0.5	2	0.5	1	0.5	1	1.0
26	Scrophulariaceae	-	-	-	-	1	0.1	-	-	1	0.2	-	-
27	Urticaceae	1	0.5	-	-	-	-	-	-	-	-	2	0.5
28	Violaceae	-	-	-	-	3	1.0	-		1	0.7	2	0.5
Total		**27**	**56**	**21**	**62**	**71**	**39**	**62**	**43**	**49**	**45**	**56**	**48**

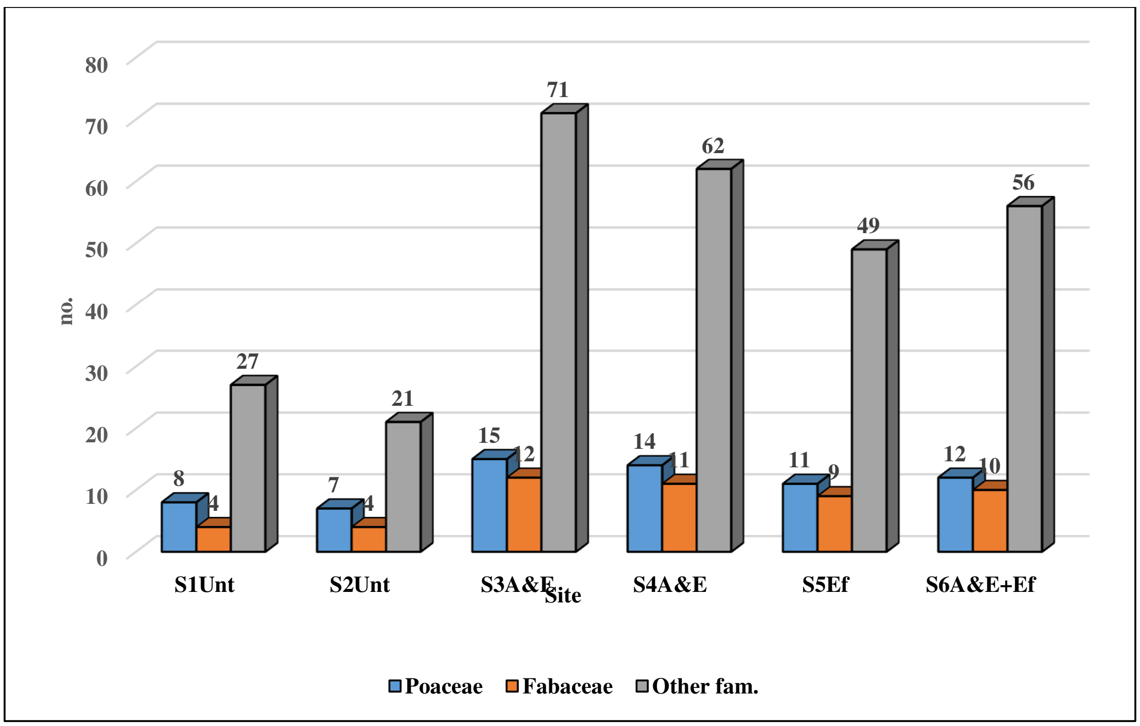

Figure 3. Number of plant species identified

Figure 3 shows the comparative situation of the number of plant species identified from the families Poaceae, Fabaceae and those from other families, in each observed plot.

Lepidoptera monitoring

In the period 2019-2021, the species of diurnal butterflies from three families (Lycaenidae, Nymphalidae and Pieridae) were monitored on the meadows of Bilbor commune. During the monitoring period, 17 species from the Nymphalidae family were identified, for which the flight period, the number of annual generations and the current protection status are presented (Table 6.). Among the species identified, from the point of view of the current protection status in Romania, one species is vulnerable, 7 species are potentially threatened, and 9 species are not endangered.

Table 6. Butterfly species from the Nymphalidae family

No.	Species	Conservation status	Generation/ year	Flight period
1	*Boloria selene* Denis & Schif.	vulnerable	1	May - June
2	*Aglais urticae* L.	potentially threatened	1	June - August
3	*Araschnia levana* L.	potentially threatened	2	May - June July - August
4	*Argynnis adippe* Denis & Schif.	potentially threatened	1	June - August
5	*Argynnis paphia* L.	potentially threatened	1	June - August
6	*Erebia ligea nikostrate* Fruhstorfer	potentially threatened	1	June - August
7	*Minois dryas* L.	potentially threatened	1	June - August
8	*Polygonia c-album* L.	potentially threatened	2	May June - August
9	*Argynnis aglaja* L.	safe	1	June - August
10	*Argynnis niobe* L.	safe	1	June - July
11	*Coenonympha pamphilus* L.	safe	2	May - June July - August
12	*Inachis io* L.	safe	2	May - June July - August
13	*Issoria lathonia* L.	safe	2	May - June August - August
14	*Lasiommata megera* L.	safe	2	May - June August - August
15	*Maniola jurtina* L.	safe	1	June - August
16	*Melanergia galathea* L.	safe	1	June - August
17	*Vanessa atalanta* L.	safe	2	May - June July - August

Butterflies from the Lycaenidae family are small in size, but they are highly valued for their bright colors and sometimes the metallic sheen of their wings. It is the family that has the most species, after the family Nymphalidae (Odette, 2014; Bálint *et al*., 2016). From this family, 7 species were identified, and from the point of view of the current protection status, 2 species are vulnerable, 2 species are potentially threatened, and 3 species are not endangered (Table 7).

Table 7. Butterfly species of the Lycaenidae family

No.	Species	Conservation status	Generation/ year	Flight period
1	*Lycaena dispar rutila* Werneburg	Vulnerable	2	May - June July - August
2	*Lycaena thersamon* Esper	Vulnerable	1	June - August
3	*Plebeius idas* L.	Potentially Threatened	1	June - July
4	*Pseudophilotes schiffermuelleri* Hemming	Potentially Threatened	1	May - June
5	*Aricia agestis* Denis & Schif.	Safe	1	June - August
6	*Plebeius argus* L.	Safe	1	June - August
7	*Polyommatus icarus* Rottemburg	Safe	1	June - August

In general, Pieridae species are medium-sized, with light-coloured wings (white, yellow, or orange) and dark-coloured decorations. Some species exhibit sexual dimorphism, which means that the female's ornamentation differ from the male's (Braby, 2005; Braby *et al*., 2006). Five species were identified from this family, and according to their current protection status, one is vulnerable, one is threatened, one is potentially threatened, and two are not endangered.

Table 8. Butterfly species of the Pieridae family

No.	Species	Conservation status	Generation/ year	Flight period
1	*Pieris mannii* Mayer	Vulnerable	2	May - June July - August
2	*Colias myrmidone* Esper	Threatened	2	May - June July - August
3	*Colias australis* Verity	Threatened	2	May - June July - August
4	*Artogeia napi* L.	Safe	2	May - June July - August
5	*Leptidea sinapis* L.	Safe	2	May - June July - August

For the identified lepidoptera species, the ecological indices were calculated, which are presented in table 9.

Table 9. Values of ecological indicators of lepidopteran species (2019-2021)

No.	Species	A	D		C		W	
			%	Class	%	Class	%	Class
1	*Aglais urticae* L.	52	4.41	D3	50.0	C2	2.21	W3
2	*Araschnia levana* L.	12	1.02	D1	33.3	C2	0.34	W2
3	*Argynnis adippe* Denis & Schif.	20	1.69	D2	41.7	C2	0.70	W2
4	*Argynnis aglaja* L.	24	2.03	D2	41.7	C2	0.85	W2
5	*Argynnis niobe* L.	8	0.68	D1	25.0	C1	0.17	W2
6	*Argynnis paphia* L.	109	9.24	D4	50.0	C2	4.62	W3
7	*Aricia agestis* Denis & Schif.	12	1.02	D1	33.3	C2	0.34	W2
8	*Artogeia napi* L.	21	1.78	D2	41.7	C2	0.74	W2
9	*Boloria selene* Denis & Schif.	102	8.64	D4	58.3	C3	5.04	W4

10	*Coenonympha pamphilus* L.	99	8.39	D4	66.7	C3	5.60	W4
11	*Colias australis* Verity	54	4.58	D3	50.0	C2	2.29	W3
12	*Colias myrmidone* Esper	7	0.59	D1	25.0	C1	0.15	W2
13	*Erebia ligea nikostrate* Fruhstorfer	12	1.02	D1	33.3	C2	0.34	W2
14	*Inachis io* L.	15	1.27	D2	33.3	C2	0.42	W2
15	*Issoria lathonia* L.	27	2.29	D2	41.7	C2	0.95	W2
16	*Lasiommata megera* L.	19	1.61	D2	33.3	C2	0.54	W2
17	*Leptidea sinapis* L.	41	3.47	D3	50.0	C2	1.74	W3
18	*Lycaena dispar rutila* Werneburg	29	2.46	D3	41.7	C2	1.03	W3
19	*Lycaena thersamon* Esper	7	0.59	D1	25.0	C1	0.15	W2
20	*Maniola jurtina* L.	187	15.85	D5	66.7	C3	10.57	W5
21	*Melanergia galathea* L.	10	0.85	D1	25.0	C1	0.21	W2
22	*Minois dryas* L.	42	3.56	D3	50.0	C2	1.78	W3
23	*Pieris mannii* Mayer	93	7.88	D4	66.7	C3	5.26	W4
24	*Plebeius argus* L.	43	3.64	D3	41.7	C2	1.52	W3
25	*Plebeius idas* L.	8	0.68	D1	25.0	C1	0.17	W2
26	*Polygonia c-album* L.	11	0.93	D1	25.0	C1	0.23	W2
27	*Polyommatus icarus* Rottemburg	35	2.97	D3	33.3	C2	0.99	W2
28	*Pseudophilotes schiffermuelleri* Hemming	62	5.25	D4	50.0	C2	2.63	W3
29	*Vanessa atalanta* L.	19	1.61	D2	25.0	C1	0.40	W2
Total		1180	100					

Following the processing of data on ecological indicators, the abundance (A) presented values between 7 specimens (*Colias myrmidone* Esper and *Lycaena thersamon* Esper) and 187 specimens (*Maniola jurtina* L.). The species: *Argynnis paphia* L. and *Boloria selene* Denis & Schif had an abundance of over 100 specimens. In the case of dominance (D), 9 species are subrecedents D1, which had values below 1.1%; 7 recessive species D2, which had values between 1.1-2%; 7 subdominant species D3, which had values between 2.1-5%; 5 species are dominant D4, with a value between 5.1-10%: (*Argynnis paphia* L., *Boloria selene* Denis & Schif., *Coenonympha pamphilus* L., *Pieris mannii* Mayer and *Pseudophilotes schiffermuelleri* Hemming) and a eudominant species D5, with a value of over 10% (*Maniola jurtina* L.).

In the case of the constancy index (C), the collected families fall into the following classes: 7 species are accidental C1, with the value of this indicator between 1-25%; 18 species are C2 accessories, with the indicator value between 25.1-50%; 4 species are constant C3, with the value of this indicator between 50.1-75%: (*Boloria selene* Denis & Schif., *Coenonympha pamphilus* L. and *Pieris mannii* Mayer).

The index of ecological significance (W), in its value, the collected families are distributed in the following classes: 17 species are W2 accessories, with the value of the index between 0.1-1.0%; 8 species are W3 accessories, with the index value between 1.1-5.0%; 3 species are characteristic of W4, with the value of the index between 5.1-10.0%: (*Boloria selene* Denis & Schif, *Coenonympha pamphilus* L. and *Pieris mannii* Mayer) and one species characteristic of W5, with the value of the index over 10.0% (*Maniola jurtina* L.).

Discussions

Promoting the harmonious development of grassland ecosystems is critical, since they are considered the dominating natural ecosystems in the rural environment, with the most biological variety (Han *et al*., 2021). It is well known that steep and hilly ecosystems are especially vulnerable to disturbances (Ao *et al*., 2022). To protect the biodiversity of these habitats, a management strategy for sustainable administration with minimal environmental effect is required (Munisi *et al*., 2024). This plan aims to harmonise the actions of regional institutions in charge of managing local resources in order to meet the medium and long-term goals of resource conservation and socioeconomic development. To preserve the favourable conservation status of existing species in the ecosystem (flora and fauna), their ecological requirements must be considered (Turtureanu *et al*., 2014).

The manner of utilisation of meadows has a significant impact on their floral composition. Thus, the number of plant species in the abandoned meadows is significantly reduced (plot S1Unt and S2Unt), while the number of plants with low fodder value (*Nardus stricta* and *Deschampsia flexuosa*) and other invasive species (*Vaccinium myrtillus*) has increased. Anthropogenic factors heavily influence faunal composition (Hejcman et al., 2013), and biodiversity serves as an agroecological indicator (Clergué *et al*., 2005). Excessive grazing alters the flora by consuming edible plants, allowing fewer edible species to thrive (Hartley and Mitchell, 2005; Louault et al., 2005). Therefore, broad grazing maintains plant diversification (Jewell *et al*., 2005).

By implementing the area protection and conservation measures imposed on the surfaces declared at the APIA for access to government financial funds, as well as the "Agri-environment and climate" measures, respectively "Ecological agriculture," the flora has a better chance of conservation and plant diversification, as shown in plot S3A&E - S6A&E+Ef. On these plots, there is an increase in species from the Poaceae (11 to 16 species) and Fabaceae (nine to 14 species), which are high-value fodder plants. In addition, the number of plant species from different families on these plots has increased from 49 to 71, promoting the survival of the lepidopteran entomofauna.

In addition to the benefits to biodiversity (Crowder *et al*., 2010; Choudhary and Chishty, 2020), the use of ecological agriculture measures allows for the production of ecological food products from animals fed with fodder from these surfaces (milk, cheeses, meat), thereby promoting gastronomic tourism. This can also be used to identify a place and promote agricultural and livestock products. This tourism niche is appealing to tourists in rural areas because of the unique characteristics of traditional food and an element of local development (Bessiere, 1998). Local products are generally more environmentally friendly, and their consumption is steadily expanding as a result of customers' positive attitudes (Pieniac *et al*., 2010; Aertsens *et al*., 2011; Ruiz de Maya *et al*., 2011; Baldacchino, 2015).

During the lepidopteran entomofauna monitoring period, 29 species from three families were identified. The most abundant species are *Maniola jurtina* L., *Boloria selene* Denis & Schif., *Argynnis paphia* L., *Coenonympha pamphilus* L. (Nymphalidae), *Pseudophilotes schiffermuelleri* Hemming (Lycaenidae), and *Pieris mannii* Mayer (Pieridae). It is worth noting that, while the species *Coenonympha pamphilus* L. is on the European red list (van Swaay *et al*., 2013), it is not threatened in the Bilbor area.

The species *Aglais urticae* L., *Araschnia levana* L., *Argynnis adippe* Denis & Schif., *Argynnis paphia* L., *Erebia ligea nikostrate* Fruhstorfer, *Minois dryas* L., *Polygonia c-album* L. (Nymphalidae), *Plebeius idas* L., and *Pseudophilotes schiffermuelleri* Hemming (Lycaenidae) are at risk of extinction, while the species *Boloria selene* Denis & Schif. (Nymphalidae), *Lycaena dispar rutila* Werneburg, *Lycaena thersamon* Esper (Lycaenidae), and *Pieris mannii* Mayer (Pieridae) are at risk of vulnerability (Tables 1-3). Protecting the plants that the larvae feed on is very important for the survival of this lepidopteran species, since their needs for their host plant are greater than those of the adults, which feed on the nectar of multiple plants. Four of these species, however, still have sizable populations in the Bilbor area, indicating that the area's habitats are less degraded overall, particularly in terms of the loss of these species' trophic foundation. These species are: *Boloria selene* Denis & Schif., *Pseudophilotes schiffermuelleri* Hemming, *Pieris mannii* Mayer, and *Argynnis paphia* L.

According to Freese *et al*. (2005) and van Swaay *et al*. (2013), there is a threat of extinction for the species *Colias myrmidone* Esper in Europe. Currently, only Slovakia, Romania, and Poland have reported on it. It is included in Habitats Directive II as a result. The species is only known to exist in the Bilbor depression and close to Gheorgheni, and even then, its number is quite little, putting it in danger of going extinct in Romania as well. The only plants that the larvae eat are those in the *Chamaecytisus* genus, particularly *Chamaecytisus ratisbonensis and* Chamaecytisus ruthenicus *(*Fabaceae*), which have been found in the area under* investigation. Furthermore, leguminous plants are the larval food of the endangered species *Colias australis* Verity, whose host species in the Bilbor area is *Coronilla varia*. The plants that these two species' larvae eat are restricted to plots where flora biodiversity conservation management is practiced.

The application of herbicides can have an impact on the population of *Aglais urticae* L. and *Araschnia levana* L., two possibly vulnerable species whose larvae feed on weeds like *Urtica* and *Cardus* plants. *Cardus acanthoides* and *Cardus nutans* (Asteraceae), as well as *Urtica dioica* and *Urtica urens* (Urticaceae), were found in the region, particularly on the deserted meadows and on the plots that were only partially disclosed to APIA.

Plants in the genus *Viola* serve as the primary trophic foundation for larvae of *Argynnis adippe* Denis & Schif. and *Argynnis paphia* L., as well as other species within the Nymphalidae family (Benjamin *et al*., 2021). *Viola canina, V. declinata, V. hirta, V. odorata, V. palustris, V. riviniana*, and *V. tricolour* were found on plots S3–S6. Because *Viola* species are susceptible to animal trampling, it is crucial for these plants to have traditional grazing and for the herd to be associated with each pasture's creditworthiness. These plants suffer greatly from overgrazing, particularly from sheep and goats (Benjamin *et al*., 2021).

Although the larvae of *Lycaena rutila* Werneburg (a protected species under Berne Convention, annexe II) and *Lycaena thersamon* Esper (a vulnerable species under Lycaenidae) are polyphagous, their primary food source is the Caryophyllaceae family of plants. *Cerastium holosteoides, Lychnis floos-cucule, Rumex acetosa, R. acetosella, R. alpinus, R. aquaticus, R. crispus*, and *R. hydrolapathum* were among the members of this family found in the area. This family of plants prefers acidic soils; calcareous amendments alter the soil's natural acidity, which modifies the makeup of the native flora (Boch *et al*., 2021; Guderjan *et al*., 2023). The trophic base of the larvae at the susceptible species *Boloria selene* Denis & Schif. (Nymphalidae) is plants in the genus Viola, while the larvae of *Pieris mannii* Mayer (Pieridae) feed on plants in the Brassicaceae family, particularly those in the *Sinapis* genus. The mowing season will occur after the identified diurnal butterflies' flowering phase, as their adults feed on the nectar of a rich complex of herbaceous plants (Wezel *et al*., 2021). It would be best to mow in the Bilbor region after July 1st. Their self-seeding can also be guaranteed by using this strategy. The entomofauna of butterflies and beetles is positively impacted by both mowing in stages that preserve unmown strips and mowing in conjunction with grazing (Mazalová *et al*., 2015). According to Valkó *et al*. (2012) and Görn *et al*. (2014), there are species of *Lycaena dispar rutila* Werneburg, *Lycaena thersamon* Esper, *Araschnia levana* L., *Argynnis aglaja* L., *Argynnis paphia* L., *Boloria selene* Denis & Schif., *Erebia ligea nikostrate* Fruhstorfer, and *Maniola jurtina* L.; however, other Lycaenidae prefer moist habitats.

Conclusion

The Bilbor area's richness of flora and fauna depends on adhering to certain regulations that must be put into place as part of a management plan to guarantee the preservation of this ecosystem's current features. An improvement in the floristic composition, particularly of plants with high fodder value, was reported on the meadows where the "Agri-environment and climate" and "Ecological agriculture" measures from the European Union's agricultural policy for habitat protection and conservation were applied. Additionally, the maintenance of plants used as a trophic base for diurnal lepidoptera was noted. 29 species from the families Lycaenidae (7 species), Nymphalidae (17 species), and Pieridae (5 species) were identified from the group of these lepidoptera, which are bioindicators of climate change and habitat degradation. From the perspective of the ecological significance index (W), the species *Maniola jurtina* L., with an index value exceeding 10% (W5), and the species *Boloria selene* Denis & Schif, *Coenonympha pamphilus* L., and *Pieris mannii* Mayer are characteristic species, with a value of this index between 5.1 and 10% (W4). The fact that the monitored species that have a vulnerable conservation status or are potentially threatened at the national and European levels are substantially represented in the Bilbor area confirms the reasonably strong conservation status of the zonal biodiversity. The population is well represented in this area for the potentially threatened species *Pseudophilotes schiffermuelleri* Hemming, *Argynnis paphia* L., and *Coenonympha pamphilus* L., as well as the vulnerable species *Boloria selene* Denis & Schiffermüller. Only in the Bilbor region does *Colias myrmidone* Esper, which is critically endangered and seeing a drop in population throughout Europe, exist. There are reports of a very tiny population of *Lycaena dispar rutile* Werneburg, *Lycaena thersamon* Esper, and *Colias australis* Verity—all of which are considered vulnerable species in the nation—in the Bilbor area.

Authors' Contributions

Conceptualization, I.D.H., T.F. and I.O.; methodology, I.D.H. and I.O.; software, A.M.T. and I.B.H.; validation, I.D.H., I.B.H., T.F. and I.O.; formal analysis, A.M.T. and I.O.; investigation, I.D.H. and I.O.; writing— original draft preparation, I.D.H. and I.O.; writing—review and editing, I.D.H., A.M.T. and I.O.; visualization, I.O., A.M.T. and I.B.H.; supervision, I.O.; project administration, I.D.H.; funding acquisition, I.D.H. All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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