diversity

MDPI

Article

Coverings on Pitfall Traps Influence the Abundance of Ground-Dwelling Arthropods

Juraj Litavský [1] and Pavol Prokop [1,2,*]

[1] Department of Environmental Ecology and Landscape Management, Faculty of Natural Sciences, Comenius University, Mlynská dolina B2 418, 842 15 Bratislava, Slovakia; juraj.litavsky@uniba.sk
[2] Institute of Zoology, Slovak Academy of Sciences, Dúbravská cesta 9, 845 06 Bratislava, Slovakia
* Correspondence: pavol.prokop@savba.sk

Abstract: Pitfall traps provide a cost-effective method of studying the diversity and abundance of ground-dwelling arthropods, such as beetles and spiders. Their efficiency depends on factors such as size, shape, and substances used to kill or preserve the specimens. Entomologists often employ covers on pitfall traps to prevent dilution of fixation liquids or keep the traps open. In this study, we investigated whether the presence or absence of covers, as well as their colour (black versus translucent), over pitfall traps has an impact on the species diversity and abundance of carabid beetles and harvestmen. These arthropods serve as common examples of ground-dwelling invertebrates, both in forest and meadow environments. Our findings revealed that traps with black-coloured coverings captured significantly higher numbers of beetles than translucent traps, but the uncovered traps were not significantly different from the two. The species richness tended to be highest in uncovered traps. The uncovered traps were the most efficient in capturing adult harvestmen, followed by translucent and black covers in terms of adult harvestmen abundance and diversity. In conclusion, the use of covers on pitfall traps significantly affects the estimates of arthropod abundance and should be taken into account in future research.

Keywords: arthropod abundance; carabid beetles; harvestmen

check for updates

Citation: Litavský, J.; Prokop, P. Coverings on Pitfall Traps Influence the Abundance of Ground-Dwelling Arthropods. *Diversity* **2024**, *16*, 19. https://doi.org/10.3390/d16010019

Academic Editor: Luc Legal

Received: 23 November 2023
Revised: 13 December 2023
Accepted: 23 December 2023
Published: 26 December 2023

1. Introduction

In conservation biology, the acquisition and meticulous interpretation of data by dedicated practitioners profoundly shape species management and habitat preservation strategies. Establishing standardised and cost-effective methodologies is imperative to ensure the acquisition of reliable and unbiased data that form the basis for informed conservation decisions and sustainable ecosystem management. To achieve these goals, a standardised and cost-effective methodology is needed to obtain reliable and unbiased data [1,2].

Pitfall traps, first described by Dahl [3] (1896) and Barber [4], are commonly used tools for investigating ground-dwelling arthropods in entomological and ecological research [1,5–7]. Pitfall traps are inexpensive and easy to handle, and their use alone [2] or in combination with additional trapping methods [8] provides an objective estimate of species abundance and richness [9–11], particularly for carabid beetles (Carabidae), spiders, ants, and isopods [1,12–17].

The principle functioning of a pitfall trap is very simple; since the original recommendations by Barber [4], the trap consists of a cup filled with a conservation fluid that is set with the rim of the cup level with the surface of a surrounding substrate [18]. The efficiency of pitfall traps depends on a range of variables, such as the type and concentration of conservation fluid [19–22], size [23,24], shape [25], colour [26], material [27], and presence of funnels [28] and their covers [17,28].

Covering the pitfall traps with metal or plastic plates or with wire grids may be advantageous because it protects the traps from dilution of the conservation fluid by rain, plant litter entering the trap, and the escape of certain species of arthropods [17,28,29]. Because the efficiency of pitfall traps is largely influenced by surrounding vegetation, the position of the trap, and microclimatic conditions [16,30,31], it is not surprising that research on the significance of traps covered (or uncovered) by plastic plates is not fully conclusive.

For instance, Phillipps and Cobb [32] and Buchholz and Hanning [29] did not record any differences in ground beetle abundance and species richness with respect to covering type, but their research was conducted exclusively in one habitat (burnt forest and dry grassland sites, respectively), where both dilution of the conservation fluid as well as leaves falling into uncovered traps may be very different than in forest habitats [17]. In fact, the research by Császár et al. [28] showed that the presence of a covering in the forest (but not in the meadow) had a positive influence on the trapping of large flying carabid beetles. Siewers et al. [17] similarly showed that the largest spiders and carabid beetles were recorded more frequently in covered traps, and sampling carabid beetles on tame pasture was most efficient with the use of translucent trap coverings [33]. These results suggest that the use of coverings on pitfall traps can be advantageous under certain circumstances and can positively affect the trapping of certain species. Here, we investigated whether the presence of a covering affects the species abundance and richness of carabid beetles and harvestmen, which are almost always sampled by pitfall traps [17,34–38], under the contrasting conditions of a deciduous forest and open grassland.

2. Materials and Methods

2.1. Study Site and Procedure

The research was carried out at two different sites located on the border of two geomorphological units, the Little Carpathians and the Danubian Hills in western Slovakia. The first study site (S1) represents a Carpathian oak-hornbeam forest (Figure 1) covering an area of 1.5 hectares located near the town of Modra (48°21′16.47′′ N, 17°17′21.53′′ E, 392 m a.s.l.).

Figure 1. Study site (S1) representing a Carpathian oak-hornbeam forest.

The second study site (S2) represents a meadow (Figure 2) covering an area of 1.5 hectares located near the town of Pezinok (48°19′28.33′′ N, 17°16′20.47′′ E, 243 m a.s.l.).

The sites are approximately 3.8 kilometres apart in a straight line. Ground beetles and harvestmen were captured by pitfall trapping [39], using 0.5 L plastic cups (9 cm in opening diameter) with 4% formaldehyde as a fixation fluid (approximately one-third of the volume) and a few drops of detergent to break the surface tension. At both study sites, 45 traps were installed, arranged in 3 rows of 15 traps with a minimum distance of 5 metres between neighbouring traps. Within each row, the traps were placed alternately: without cover (Figure 3), with a translucent cover (Figure 4), and with a black cover (Figure 5).

Figure 2. Study site (S2) representing a meadow.

Figure 3. Pitfall trap without a cover.

Figure 4. Pitfall trap with a translucent cover.

Figure 5. Pitfall trap with a black cover.

In one row, there were 5 traps without a cover, 5 with a translucent cover, and 5 with a black cover. The covers consisted of 4 mm thick plexiglass of the same size: 15 × 20 cm. Each cover was placed on one wooden lath (length: 15 cm, width: 3 cm, height: 3 cm), forming a sloping roof. The distance between the three rows (with 15 traps each) was a minimum of 15 m. These transects were placed in the centre of the monitored habitats. At study site S1, pitfall traps were exposed from 13 July 2022 to 7 August 2022 for a total of 25 days. At the same time, pitfall traps were also placed at site S2, but because this site represents a meadow on a gentle slope, 3/4 of the traps were washed out by rain. Therefore, we repeated the study at site S2 from 22 August 2022 to 16 September 2022 for a total of 25 days. The content of each trap in both study sites was collected at the end of the research (day 25). The contents of each trap were collected separately and labelled. The samples were sorted in the laboratory, and the ground beetles and harvestmen were subsequently identified using the standard determination keys of Martens [40] and Krajčovičová et al. [39] for harvestmen and Trautner and Geigenmüller [41] (1987), Hůrka [42] and Müller-Motzfeld [43] for carabid beetles. Sex and age class (juvenile or adult) were detected for each individual of the harvestmen. In terms of dispersal ability, the carabid species were divided into two groups: non-flying and flying, based on the observation of the presence or shape of the hind wings of each individual. To assess the sampling efficiency for size-related bias, adult carabid beetles were categorised based on size, distinguishing between large species (>10 mm) and small species (<10 mm). To assess the effectiveness of pitfall traps, we also considered the activity of individual carabid species, categorising them into species with nocturnal, diurnal, and mixed activity according to Hůrka [42], Müller-Motzfeld [43], and Tuf et al. [44]. The samples were fixed in 75% ethyl alcohol and deposited in the collection of the Faculty of Natural Sciences of Comenius University in Bratislava. A list of carabid species is organised according to Lorenz [45], and a list of harvestman species was drawn up following Kury et al. [46].

2.2. Statistical Analyses

A generalised linear mixed model with a Poisson distribution of data was used to examine whether the site (forest and meadow), treatment (no cover, translucent cover, and black cover), species activity (nocturnal, diurnal, or mixed), flying ability (macropterous or brachypterous wings), and size (large or small) influence the abundance and species diversity (dependent variables) of carabid beetles. Data from damaged traps were not included in the model. The ID of the pitfall trap was treated as a random effect. With respect to harvestmen, only one individual was captured in the meadow; thus, we analysed only data from the forest, and treatment was the only predictor. The interaction between variables was not significant and was removed from the models. The Fisher's exact test was applied for the comparison of the damage rates of the pitfall traps because the sample sizes were sometimes ≤ 5. All analyses were made in SPSS v. 26.3.

3. Results

3.1. Carabid Beetles' Abundance and Diversity

At study site S1, which represents a forest habitat, a total of 143 carabids belonging to 11 species were recorded (Appendix A). At this site, 40 individuals of ground beetles belonging to 7 species were captured in uncovered pitfall traps. There were 8 flying and 32 non-flying individuals recorded. In the traps with black covers on this site, 57 individuals were caught (12 flying and 45 non-flying) belonging to 7 species. In the traps with translucent covers, 46 individuals of carabids (10 flying and 36 non-flying) belonging to 10 species were recorded. A detailed description can be found in Appendix A.

At study site S2, which represents a meadow habitat, a total of 265 ground beetles belonging to 13 species were recorded. In the traps without covers at this site, 114 individuals of carabids were recorded (59 flying and 55 non-flying) belonging to a total of 10 species, while in the traps with black covers, 68 individuals (23 flying and 45 non-flying) belonging to 8 species were captured. In the traps with translucent covers, 83 individuals of ground beetles (33 flying and 50 non-flying) belonging to a total of 11 species were recorded.

A total of 29 and 41 traps in the forest and the meadow, respectively, were found to be intact and were included in statistical analyses (one trap in the forest was not included due to zero results). The total number of carabid beetles per trap ranged between 0 and 21 (mean = 5.65, 95% CI [3.61, 5.02]). The abundance in the forest and the meadow was similar, and the difference was not significant (Table 1). The effect of treatment did not reach statistical significance (Table 1), but a pairwise comparison revealed that the black cover contained significantly more beetles than the translucent traps, whereas differences between the translucent and uncovered traps were not significant (Figure 6). Beetles with mixed activity were captured significantly more frequently than nocturnal species (contrast estimate = 0.64, $p = 0.002$), and diurnal species were somewhere between these two categories (Table 2). Apterous beetles were trapped significantly more frequently than flying beetles, and the size of the species did not influence trapping rates (Tables 1 and 2).

Table 1. Results of GLMM on the abundance of carabid beetles.

	F	df1	df2	*p*
Locality	1.17	1	215	0.28
Treatment	2.88	2	215	0.058
Activity	5.11	2	215	0.007
Flying ability	5.60	1	215	0.02
Size	2.36	1	215	0.13

The species richness for each pitfall trap ranged between zero and six (mean = 2.58, 95% CI [2.27, 2.90]) and was not influenced by any of the measured variables (Table 3). However, a pairwise comparison showed that species richness was significantly higher in uncovered pitfall traps compared to traps with a black cover (Figure 7). Other differences were not significant.

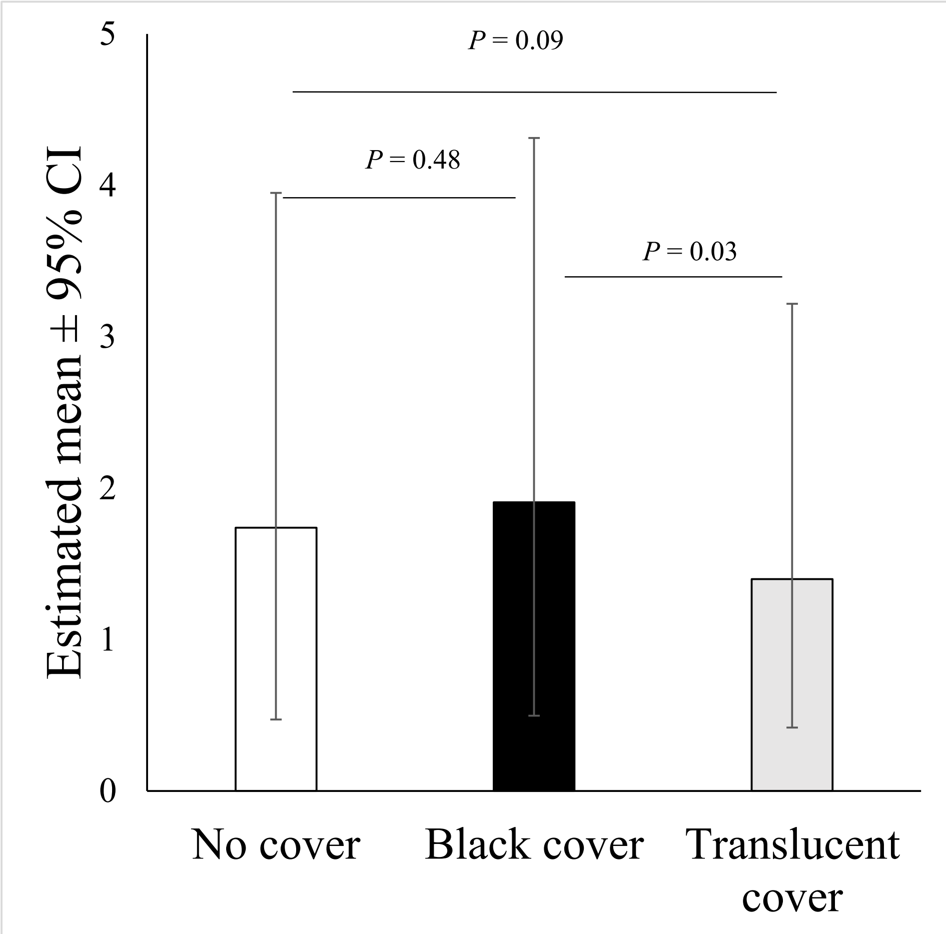

Figure 6. Differences in carabid beetles' abundance with respect to treatment. *p*-values are based on contrast estimates.

Table 2. Descriptive statistics for beetles' abundance and richness. Values are estimated means (±95% CI).

	Locality		Activity			Flying Ability		Size	
	Forest	**Meadow**	**Nocturnal**	**Diurnal**	**Mixed**	**Brachypterous**	**Macropterous**	**Small**	**Large**
Abundance	4.93 (2.37, 4.04)	6.14 (3.97, 6.12)	1.44 (0.82, 1.08)	1.0 (0.0, 0.0)	2.22 (1.73, 2.26)	2.12 (1.77, 2.39)	1.60 (0.97, 1.24)	1.54 (0.85, 2.22)	1.88 (1.33, 2.43)
Richness	2.83 (0.97, 1.66)	2.49 (1.15, 1.79)	2.70 (1.03, 1.70)	3.0 (0.0, 0.0)	2.56 (1.14, 1.83)	3.03 (0.99, 1.67)	2.33 (1.09, 1.71)	3.25 (1.77, 4.73)	2.94 (1.60, 4.28)

Table 3. Results of GLMM on the species richness of carabid beetles.

	F	df1	df2	*p*
Locality	0.001	1	64	0.98
Treatment	2.04	2	64	0.14
Activity	0.19	2	64	0.83
Flying ability	3.36	1	64	0.07
Size	0.05	1	64	0.83

3.2. Abundance and Diversity of Harvestmen

At study site S1, a total of 526 harvestmen belonging to 3 species were recorded (Appendix A). The species *Nelima sempronii* reached the highest abundance, with a total of 412 individuals, of which 409 were juveniles. In traps without a cover, 90 harvestman individuals belonging to 3 species were recorded. In the traps with black covers, 215 individuals of harvestmen belonging to 2 species were captured. The highest abundance of captured harvestman individuals was observed in traps with translucent covers, with a total of 221 individuals belonging to 3 species.

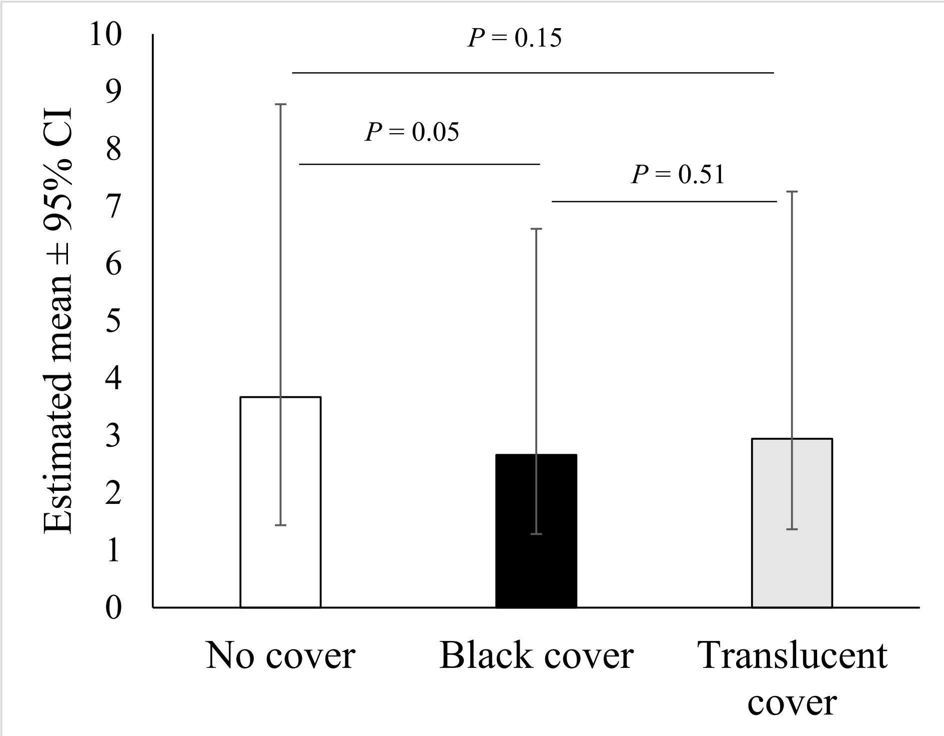

Figure 7. Differences in the carabid beetle's species diversity with respect to treatment.

Only one harvestman, *Nelima sempronii*, was recorded at study site S2, captured in a trap without a cover.

The harvestmen were analysed from 29 of the traps placed in the forest. The remaining 16 traps were omitted because they were damaged by wild boars, especially traps without covers. Because we captured both adults and juveniles, we reported separate analyses for adults and separate analyses for pooled data from all individuals (juveniles together with adults).

3.3. Adult Individuals

The total number of adult harvestmen per trap ranged from 0 to 15 (mean = 3.83, 95% CI [2.46, 5.20]). The abundance of adult harvestmen tended to be influenced by the effect of treatment ($F2{,}26 = 2.26$, $p = 0.097$); traps without a cover contained significantly more harvestmen than other traps, while there were no differences between the traps covered with black and translucent covers (Figure 8).

The total number of harvestmen species per trap ranged between zero and two (mean = 0.97, 95% CI [0.73, 1.20]). The diversity of harvestmen in the forest tended to be influenced by the effect of treatment ($F2{,}26 = 3.28$, $p = 0.054$). Traps without a cover contained significantly more species than black-covered traps, while there were no differences between the traps covered with black and translucent covers (Figure 9).

3.4. Pooled Data with Adults and Juvenile Individuals

The total number of all harvestmen per trap ranged from 5 to 38 (mean = 18.07, 95% CI [14.57, 21.57]). The total abundance of harvestmen was not significantly influenced by the effect of treatment ($F2{,}26 = 0.38$, $p = 0.69$) (Table 4). The total number of harvestmen species per trap ranged from one to three (mean = 1.86, 95% CI [1.64, 2.08]). Harvestmen diversity in the forest was not influenced by the effect of treatment ($F2{,}26 = 0.51$, $p = 0.60$) (Table 4).

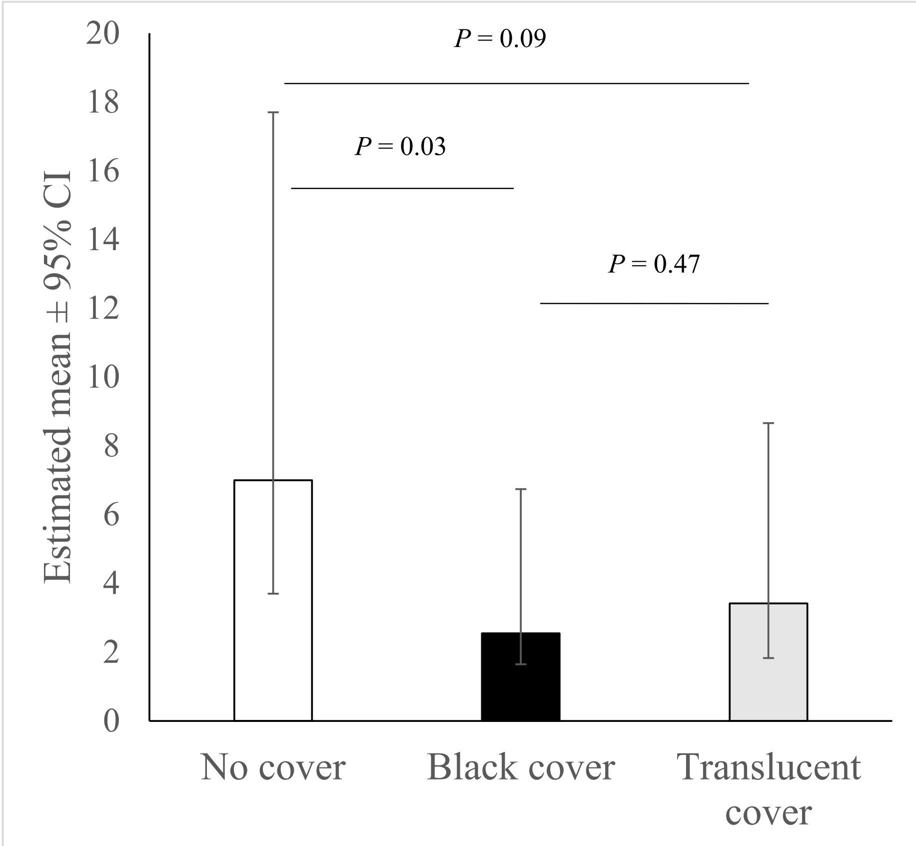

Figure 8. Differences in adult harvestmen abundance with respect to treatment.

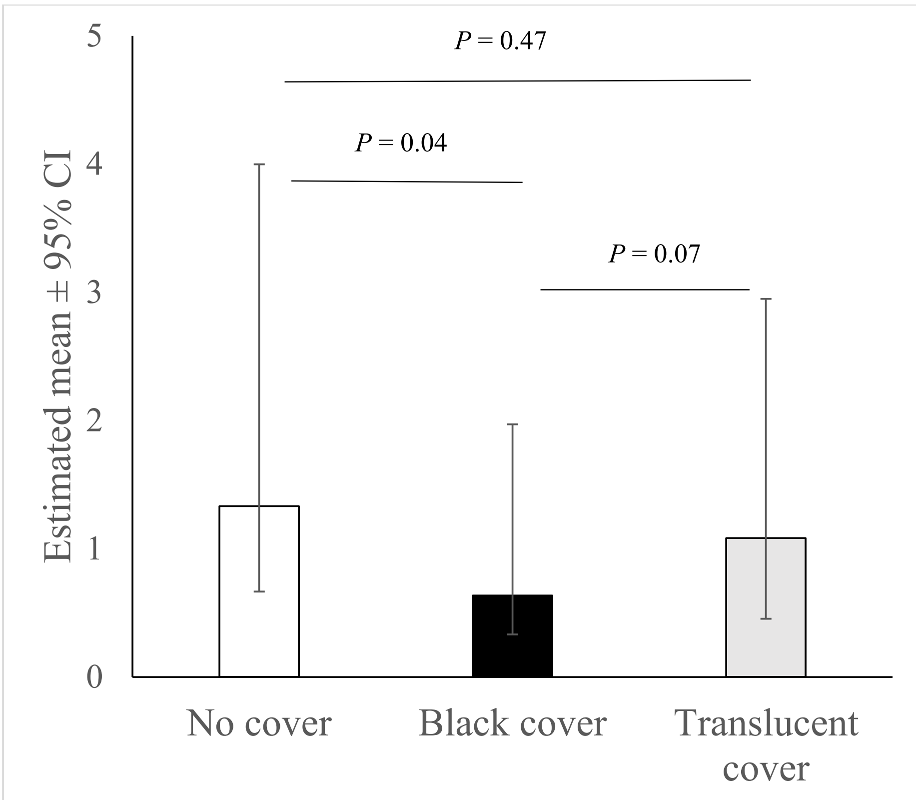

Figure 9. Differences in harvestmen species diversity with respect to treatment.

Table 4. Descriptive statistics for the effect of treatment on harvestmen abundance and diversity. Data for juveniles and adults are pooled.

			95% CI	
	Treatment	**Mean**	**Lower**	**Upper**
Abundance	No cover	15.50	12.65	18.99
	Black cover	19.55	17.10	22.34
	Translucent cover	18.00	15.75	20.57
Diversity	No cover	2.00	1.14	3.52
	Black cover	1.73	1.10	2.71
	Translucent cover	1.92	1.27	2.88

3.5. Damage Rates of Pitfall Traps

There were significant differences in pitfall trap damage rates between the forest and open meadow (Table 5). The uncovered traps in the forest were damaged significantly more frequently than the uncovered traps in the meadow. Other differences were not significant.

Table 5. Damage rates of pitfall traps with respect to locality and treatment. Numbers are sample sizes, with percentages in parentheses. The last line shows the *p*-values.

	No Cover	**Black Cover**	**Translucent Cover**
Forest	9 (60)	4 (27%)	3 (20%)
Meadow	0 (0)	3 (20%)	1 (7%)
Fisher exact test	<0.001	1.0	0.6

4. Discussion

This study evaluated the effectiveness of pitfall traps by manipulating the presence of coverings in two different visual environments (forest and meadow). Meadows typically offer open, well-lit surroundings, while woodlands present darker, more enclosed visual settings. Carabid beetle capture rates and adult harvestmen were more significantly influenced by the type of cover, while the diversity of these organisms appeared to be unaffected by the type of cover. The visual environment does not play any role in capture rates except for the rare presence of harvestmen in the meadow.

Black coverings attracted significantly more carabid beetles than translucent coverings, which contrasts with previous work by Bell et al. [33], who found that more carabid beetles were captured with the use of transparent coverings than semitransparent or opaque coverings. Other researchers showed benefits from the presence of coverings in carabid beetle trapping rates exclusively in forests [28], or this positive influence occurred exclusively in large, flying beetles [17]. As a result, Brown and Matthews [1] recommend the use of translucent coverings as an unbiased alternative compared to other colours/transparencies.

Our research showed not only that translucent coverings are less effective in terms of carabid beetles' abundance but also that beetles' flying ability and activity, but not their size, influence capture rates. Brachypterous species and species with mixed activity were trapped more frequently than nocturnal and diurnal species. With respect to the latter, any interpretations must be given with extreme caution due to their limited sample sizes. With respect to the former, our observation underscores the inherent attraction of carabid beetles to dark refuges, such as those found underground or beneath stones [29,47], elucidating their inclination towards the black-covered traps. This explanation helps to resolve the remaining two variables: Brachypterous species could spend more of their time on the ground than macropterous species, investing more time and energy in flying [48]. Species with mixed activity could have more opportunities to search for shelters during the day when black coverings can serve as "ecological traps." Interestingly, Császár et al. [28] showed that macropterous carabid beetles were more attracted to covered traps than brachypterous species. In contrast to our study, Császár et al. [28] did not investigate the flying abilities of captured individuals but rather labelled species as brachypterous or apterous. There are, however, also interindividual differences within species that are precisely examined in our current study. The efficiency of pitfall traps is not dependent solely on beetles' density but also on their movement activity [32,47], which can be influenced by flying ability. Therefore, we consider our results to be more accurate and ecologically valid.

Black covers, on the other hand, have never been efficient for trapping adult harvestmen. Harvestmen were most frequently caught in open traps lacking any cover. However, traps without covers tended to attract a generally larger number of harvestmen species, although not significantly more than translucent covers. Unlike juveniles, adult harvestmen may spend a significant proportion of their time searching for mates in vegetation [49]. Therefore, the sexual activity of adults may explain differences in capture rates between juveniles and adults.

Our results suggest that uncovered pitfall traps seem to be more efficient in terms of ground-dwelling arthropods than covered traps because they were similarly successful in capturing carabid beetles compared to black-covered traps and tended to be most efficient in terms of species richness of carabid beetles. Similarly, uncovered traps were more successful in estimating the abundance and diversity. However, uncovered traps in the forest were significantly more vulnerable to damage, probably by wild boar. Wild boars typically exhibit a preference for forested areas over open habitats [50,51]. Perhaps a lack of cover is responsible for more intense evaporation rates, which attracts wild boars who use their sense of smell when searching for food [52]. Alternatively, uncovered traps were more frequently, but not intentionally, trampled by wild boars, and covers served as protection against trampling. It seems that the use of covers has benefits in addition to their protection against dilution, the accumulation of debris, and the escape of certain species of arthropods [17,28,29].

The probability of the capture of an individual in the population in pitfall traps could be influenced by habitat structure, the movement behaviour of animals, and various microclimatic effects [1,5,53]. The efficiency of pitfall traps examined in two contrasting habitats in our study suggests that uncovered traps are most efficient at capturing adult harvestmen in terms of their abundance and diversity. Similar trends, albeit less significant, were observed for carabid beetles. Given that pitfall traps are routinely used in many areas of ecological research, most researchers do not use any covers (or at least do not report their use [5], and it would be easiest to recommend not using any coverings to standardise this method across researchers. On the other hand, uncovered traps showed very high damage rates. Therefore, frequent inspections of the pitfalls and the avoidance of days with heavy rainfall would be the best options.

Regarding the number of recorded individuals of harvestmen at study site S2, representing a meadow, where only one individual of *Nelima sempronii* was recorded, such a case is not unusual. During the research of opiliofauna at a similar meadow located 11 km straight-line distance from our research site (S2), Litavský et al. [54] captured only one individual of the harvestman—*Opilio saxatilis* (Koch, 1839). The mentioned authors conducted research on epigeic macrofauna at monthly intervals from 19 February 2021 to 2 June 2022 using the same method as we did, except that the number of pitfall traps was 5. During the same study, Litavský et al. [54] recorded up to 259 individuals of harvestmen belonging to 6 species in a pasture grazed by cows, which was located 600 m from the investigated meadow. From this fact, it may be inferred that the abundance and species richness of harvestmen inhabiting meadows in the given area are very poor, even though the method used for researching epigeic arthropods was suitable.

5. Conclusions

Pitfall traps remain a widely employed method to sample ground-dwelling arthropods, yet concerns about biases and interpretational issues persist. Standardisation in their usage remains a notable point stressed by various authors, with around 70% of published works lacking crucial specifics on trap coverings, colours, or materials [1,5], impeding definitive generalisations. We recommend the use of uncovered traps to capture ground-dwelling invertebrates. Uncovered traps appear to be the most efficient way to capture adult harvestmen. Carabids and harvestmen, being diverse indicators of environmental change, reinforce the standardisation of these methods in assessing ecosystem alterations.

Author Contributions: Conceptualization, J.L. and P.P.; methodology, J.L. and P.P.; formal analysis, J.L. and P.P.; investigation, J.L. and P.P.; writing—original draft preparation, J.L. and P.P.; writing—review and editing, J.L. and P.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic VEGA No. 1/0007/21 and No. 1/0255/23.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Data associated with this paper will be available at http://thrips.katalogdruhov.sk/publications/prokop, accessed on 22 December 2023.

Acknowledgments: Three anonymous reviewers made helpful comments on an earlier draft.

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

Appendix A

Table A1. Total number of individuals of ground beetles and harvestmen caught by the pitfall traps with the three types of covers: no cover, black cover, and translucent cover.

Study Sites				**S1**			**S2**	
Type of covering			No cover	Black cover	Trans. cover	No cover	Black cover	Trans. cover
Taxon								
Carabidae Latreille, 1802	Sp. act.	Size						
Abax parallelepipedus (Piller and Mitterpacher, 1783)	mix	L	1N	2N	2N			
Amara equestris (Duftschmid, 1812)	noc	S				10F	6F	4F
Bradycellus csikii Laczo, 1912	noc	S					1F	
Calathus erratus (C.R. Sahlberg, 1827)	noc	L				1F	1F	2F
Calathus fuscipes (Goeze, 1777)	mix	L	2F		2F; 2N	12F; 54N	10F; 44N	8F; 48N
Calathus melanocephalus (Linnaeus, 1758)	noc	S				1N	1N	1N
Calosoma sycophanta (Linnaeus, 1758)	noc	L			1F			
Carabus convexus Fabricius, 1775	noc	L	17N	15N	14N			
Carabus nemoralis O.F. Müller, 1764	noc	L	2N	2N	3N			
Carabus ulrichii Germar, 1823	mix	L	11N	26N	13N			
Harpalus atratus Latreille, 1804	noc	L	1N		2N	13F	3F	7F
Harpalus griseus (Panzer, 1796)	noc	L				1F		2F
Harpalus rufipes (DeGeer, 1774)	noc	L	6F	10F	5F	10F		2F
Microlestes minutulus (Goeze, 1777)	noc	S						1F
Nebria brevicollis (Fabricius, 1792)	noc	L						1F
Notiophilus rufipes Curtis, 1829	diur	S		1F	1F			
Ophonus azureus (Fabricius, 1775)	noc	S				2F		
Ophonus puncticeps Stephens, 1828	mix	S				2F	1F	4F
Poecilus cupreus (Linnaeus, 1758)	diur	L			1F			
Trechus quadristriatus (Schrank, 1781)	noc	S		1F		8F	1F	2F; 1N
∑ individuals			40	57	46	114	68	83
Opiliones Sundevall, 1833								
Lacinius horridus (Panzer, 1794)			40♀; 1j	28♀; 2j	37♀; 3j			
Nelima sempronii Szalay, 1951			1♀; 47j	185j	2♀; 177j	1♀		
Zachaeus crista (Brullé, 1832)			1♂		2♀			
∑ individuals			90	215	221	1	0	0

Explanations: S1—study site representing a forest; S2—study site representing a meadow; F—flying; N—non-flying; J—juveniles; Sp. act.—species activity of carabids; noc—nocturnal; diur—diurnal; mix—mixed.

References

1. Brown, G.R.; Matthews, I.M. A review of extensive variation in the design of pitfall traps and a proposal for a standard pitfall trap design for monitoring ground-active arthropod biodiversity. *Ecol. Evol.* **2016**, *6*, 3953–3964. [CrossRef]
2. Bertoia, A.; Murray, T.; Robertson, B.C.; Monks, J.M. Pitfall trapping outperforms other methods for surveying ground-dwelling large-bodied alpine invertebrates. *J. Insect Conserv.* **2023**, *27*, 679–692. [CrossRef]
3. Dahl, F. Vergleichende Untersuchungen über die Lebensweise wirbelloser Aasfresser. *Sitz. Ber. Akad. Wiss. Berlin.* **1896**, 17–30.
4. Barber, H.S. Traps for cave-inhabiting insects. *J. Elisha Mitchell Sci. Soc.* **1931**, *46*, 259–266.
5. Hohbein, R.R.; Conway, C.J. Pitfall traps: A review of methods for estimating arthropod abundance. *Wildl. Soc. Bull.* **2018**, *42*, 597–606. [CrossRef]
6. Privet, K.; Vedel, V.; Fortunel, C.; Orivel, J.; Martinez, Q.; Cerdan, A.; Baraloto, C.; Pétillon, J. Relative efficiency of pitfall trapping vs. nocturnal hand collecting in assessing soil-dwelling spider diversity along a structural gradient of neotropical habitats. *Diversity* **2020**, *12*, 81. [CrossRef]
7. Southwood, T.R.E.; Henderson, P.A. *Ecological Methods*; Blackwell Science: Oxford, UK, 2000; 575p.
8. Kim, D.; Cho, Y.B.; Kim, J.L.; Jeong Hong, E.; Kim, C.; Cha, J.Y.; Han, Y.G. Analysis of capture efficiency of pitfall traps for the National Ecosystem Survey of Korea. *J. Asia-Pac. Biodivers.* **2021**, *14*, 333–340. [CrossRef]
9. Topping, C.J.; Sunderland, K.D. Limitations to the use of pitfall traps in ecological studies exemplified by a study of spiders in a field of winter wheat. *J. Appl. Ecol.* **1992**, *29*, 485–491. [CrossRef]
10. New, T.R. *Invertebrate Surveys for Conservation*; Oxford University Press: Oxford, UK, 1998; 204p.
11. Santos, S.A.P.; Cabanas, J.E.; Pereira, J.A. Abundance and diversity of soil arthropods in olive grove ecosystem (Portugal), effect of pitfall trap type. *Eur. J. Soil Biol.* **2007**, *43*, 77–83. [CrossRef]
12. Uetz, G.W.; Unzicker, J.D. Pitfall trapping in ecological studies of wandering spiders. *J. Arachnol.* **1975**, *3*, 101–111.
13. Adis, J. Problems of interpreting arthropod sampling with pitfall traps. *Zool. Anz. Jena* **1979**, *202*, 177–184.
14. Cardoso, P. Standardization and optimization of arthropod inventories—The case of Iberian spiders. *Biodivers. Conserv.* **2009**, *18*, 3949–3962. [CrossRef]
15. Curtis, D.J. Pitfalls in spider community studies (Arachnida, Araneae). *J. Arachnol.* **1980**, *8*, 271–280.
16. Ericson, D. The interpretation of pitfall catches of *Pterostichus cupreus* and *Pt. melanarius* (Coloeoptera, Carabidae) in cereal fields. *Pedobiologia* **1979**, *19*, 320–328. [CrossRef]
17. Siewers, J.; Schirmel, J.; Buchholz, S. The efficiency of pitfall traps as a method of sampling epigeal arthropods in litter rich forest habitats. *Eur. J. Entomol.* **2014**, *111*, 69–74. [CrossRef]
18. Balogh, J. *Lebensgemeinschaften der Landtiere*; Akademie Verlag: Berlin, Germany, 1958; 560p.
19. Aristophanous, M. Does your preservative preserve? A comparison of the efficacy of some pitfall trap solutions in preserving the internal reproductive organs of dung beetles. *ZooKeys* **2010**, *34*, 1–16. [CrossRef]
20. Pekár, S. Differential effects of formaldehyde concentration and detergent on the catching efficiency of surface active arthropods by pitfall traps. *Pedobiologia* **2002**, *46*, 539–547. [CrossRef]
21. Schmidt, M.H.; Clough, Y.; Schutz, W.; Westphalen, A.; Tscharntke, T. Capture efficiency and preservation attributes of different fluids in pitfall traps. *J. Arachnol.* **2006**, *34*, 159–162. [CrossRef]
22. Jud, P.; Schmidt-Entling, M.H. Fluid type, dilution, and bitter agent influence spider preservation in pitfall traps. *Entomol. Exp. Appl.* **2008**, *129*, 356–359. [CrossRef]
23. Brennan, K.E.; Majer, J.D.; Reygaert, N. Determination of an optimal pitfall trap size for sampling spiders in a Western Australian Jarrah forest. *J. Insect Conserv.* **1999**, *3*, 297–307. [CrossRef]
24. Stašiov, S.; Čiliak, M.; Wiezik, M.; Svitok, M.; Wieziková, A.; Diviaková, A. Pitfall trap design affects the capture efficiency of harvestmen (Opiliones) and millipedes (Diplopoda). *Ecol. Evol.* **2021**, *11*, 9864–9875. [CrossRef]
25. Luff, M.L. Some features influencing the efficiency of pitfall traps. *Oecologia* **1975**, *19*, 345–357. [CrossRef]
26. Buchholz, S.; Jess, A.M.; Hertenstein, F.; Schirmel, J. Effect of the colour of pitfall traps on their capture efficiency of carabid beetles (Coleoptera: Carabidae), spiders (Araneae) and other arthropods. *Eur. J. Entomol.* **2010**, *107*, 277–280. [CrossRef]
27. Waage, B.E. Trapping efficiency of carabid beetles in glass and plastic pitfall traps containing different solutions. *Fauna Nor. Ser. B* **1985**, *32*, 33–36.
28. Császár, P.; Torma, A.; Gallé-Szpisjak, N.; Tölgyesi, C.; Gallé, R. Efficiency of pitfall traps with funnels and/or roofs in capturing ground-dwelling arthropods. *Eur. J. Entomol.* **2018**, *115*, 15–24. [CrossRef]
29. Buchholz, S.; Hannig, K. Do covers influence the capture efficiency of pitfall traps? *Eur. J. Entomol.* **2009**, *106*, 667–671. [CrossRef]
30. Greenslade, P.J.M. Pitfall trapping as a method for studying populations of Carabidae (Coleoptera). *J. Anim. Ecol.* **1964**, *33*, 301–310. [CrossRef]
31. Ward, D.F.; New, T.R.; Yen, A.L. Effects of pitfall trap spacing on the abundance, richness and composition of invertebrate catches. *J. Insect Conserv.* **2001**, *5*, 47–53. [CrossRef]
32. Phillips, I.D.; Cobb, T.P. Effects of habitat structure and lid transparency on pitfall catches. *Environ. Entomol.* **2005**, *34*, 875–882. [CrossRef]
33. Bell, A.J.; Phillips, I.D.; Floate, K.D.; Hoemsen, B.M.; Phillips, C.E. Effects of pitfall trap lid transparency and habitat structure on the catches of *Carabid beetles* (Coleoptera: Carabidae) in tame pasture. *Environ. Entomol.* **2014**, *43*, 139–145. [CrossRef]

34. Litavský, J.; Majzlan, O.; Stašiov, S.; Svitok, M.; Fedor, P. The associations between ground beetle (Coleoptera: Carabidae) communities and environmental condition in floodplain forests in the Pannonian Basin. *Eur. J. Entomol.* **2021**, *118*, 14–23. [CrossRef]
35. Litavský, J.; Stašiov, S.; Svitok, M.; Michalková, E.; Majzlan, O.; Žarnovičan, H.; Fedor, P. Epigean communities of harvestmen (Opiliones) in Pannonian Basin floodplain forests: An interaction with environmental parameters. *Biologia* **2018**, *73*, 753–763. [CrossRef]
36. Ruchin, A.; Alekseev, S.; Khapugin, A.; Esin, M. Fauna and Species Diversity of Ground Beetles (Coleoptera, Carabidae) in Meadows. *Entomol. Appl. Sci. Lett.* **2021**, *8*, 28–39. [CrossRef]
37. Ivanič Porhajašová, J.; Babošová, M. Impact of arable farming management on the biodiversity of Carabidae (Coleoptera). *Saudi J. Biol. Sci.* **2022**, *29*, 103371. [CrossRef]
38. Gajdoš, P.; Majzlan, O.; David, S.; Purgat, P.; Litavský, J. Assemblages of ground-living spiders (Araneae) and harvestmen (Opiliones) of the recultivated old chemical waste dump in Vrakuňa (Bratislava, Slovakia). *Biologia* **2023**, *78*, 149–162. [CrossRef]
39. Krajčovičová, K.; Šestáková, A.; Christophoryová, J.; Litavský, J.; Purkart, A.; Fenďa, P. *Základy Arachnologického Výskumu*; Univerzita Komenského v Bratislave: Bratislava, Slovakia, 2022; 168p.
40. Martens, J. Spinnentiere, Arachnida: Weberknechte, Opiliones. In *Die Tierwelt Deutschlands*; VEB Gustav Fischer Verlag: Jena, Germany, 1978; Volume 64, 464p.
41. Trautner, J.; Geigenmüller, K. *Tiger Beetles, Ground Beetles: Illustrated Key to the Cicindelidae and Carabidae of Europe*; Josef Margraf: Aichtal, Germany, 1987; 487p.
42. Hůrka, K. *Carabidae of the Czech and Slovak Republics*; Kabourek: Zlín, Czech Republic, 1996; 565p. (In Czech and English)
43. Müller-Motzfeld, G. Adephaga 1. Carabidae (Laufkäfer). In *Die Käfer Mitteleuropas*, 2nd ed.; Freude, H., Harde, K.W., Lohse, G.A., Klausnitzer, B., Eds.; Spektrum: Berlin/Heidelberg, Germany, 2004; pp. 1–521.
44. Tuf, I.H.; Dedek, P.; Veselý, M. Does the diurnal activity pattern of carabid beetles depend on season, ground temperature and habitat? *Arch. Biol. Sci.* **2012**, *64*, 721–732. [CrossRef]
45. Lorenz, W. Carabcat database. In *Catalogue of Life Checklist (v.03 (08/2021) 2021*; Bánki, O., Roskov, Y., Döring, M., Ower, G., Hernández Robles, D.R., Plata Corredor, C.A., Stjernegaard Jeppesen, T., Örn, A., Vandepitte, L., et al., Eds. Available online: https://www.catalogueoflife.org/data/dataset/1146 (accessed on 1 November 2023).
46. Kury, A.B.; Mendes, A.C.; Cardoso, L.; Kury, M.S.; Granado, A.A.; Giribet, G.; Cruz-López, J.A.; Longhorn, S.J.; Medrano, M.A.; de Oliveira, A.B.R.; et al. Catalogue of Life Checklist (Version 2023-09-06) 2023. Available online: https://www.catalogueoflife.org/data/dataset/2256 (accessed on 1 November 2023).
47. Jopp, F.; Reuter, H. Dispersal of carabid beetles—Emergence of distribution patterns. *Ecol. Model.* **2005**, *186*, 389–405. [CrossRef]
48. Venn, S. To fly or not to fly: Factors influencing the flight capacity of carabid beetles (Coleoptera: Carabidae). *Eur. J. Entomol.* **2016**, *113*, 587–600. [CrossRef]
49. Machado, G.; Burns, M. Reproductive biology of harvestmen (Arachnida: Opiliones): A review of a rapidly evolving research field. *Curr. Zool.* **2023**, 1–21. [CrossRef]
50. Kim, Y.; Cho, S.; Choung, Y. Habitat preference of wild boar (*Sus scrofa*) for feeding in cool-temperate forests. *J. Ecol. Environ.* **2019**, *43*, 30. [CrossRef]
51. Meriggi, A.; Sacchi, O. Habitat requirements of wild boars in the northern Apennines (N Italy): A multi-level approach. *Ital. J. Zool.* **2001**, *68*, 47–55. [CrossRef]
52. Mayer, J.J. Wild pig behavior. In *Wild Pigs Biology, Damage, Control, Techniques, and Management*; Savannah River National Laboratory: Aiken, SC, USA, 2009; pp. 77–104.
53. Melbourne, B.A. Bias in the effect of habitat structure on pitfall traps: An experimental evaluation. *Aust. J. Ecol.* **1999**, *24*, 228–239. [CrossRef]
54. Litavský, J.; Žarnovičan, H.; Majzlan, O. Vplyv manažmentových opatrení na spoločenstvá koscov (Opiliones) vo výskumnej stanici Šúr a jej okolí. In *20. Arachnologická Konferencia: Zborník Abstraktov*, 1st ed.; Slovenská Arachnologická Spoločnosť: Bratislava, Slovakia, 2022; p. 20.