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Review

A Meta-Analysis of the Effects of Harvesting on the Abundance and Richness of Soil Fauna in Boreal and Temperate Forests

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Abstract: The processes of matter and energy metabolism in forest ecosystems are largely dependent on the activity of the complex of invertebrates associated with litter and soil. To quantify the effect of forest harvesting on soil fauna, we used a meta-analysis to examine a database of 720 responses to harvesting collected from 52 publications from boreal and temperate forests. Overall, forest harvesting was found to decrease the abundance of soil fauna while not affecting its richness. However, the reaction of soil fauna to forest harvesting differed significantly among the taxonomic groups, with negative, neutral, and positive effects observed. We found that the negative effect of forest harvesting on soil fauna increased with decreasing body size. In addition, the type of forest and harvesting practice played important roles in driving the responses of soil biota to forest harvesting. The abundance of *Nematoda*, *Oribatida*, and *Enchytraeidae* recovered to control values occurring approximately 10 years after harvesting. Despite the limitations of the dataset, the results obtained from our meta-analysis expand our understanding of the reaction of soil fauna to forest harvesting.

Keywords: functional traits; body size; coniferous vs. deciduous; clear-cutting vs. partial cutting

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1. Introduction

Forest ecosystems play a vital role in the biosphere by mediating fundamental nutrient and energy flow patterns [1]. Additionally, forest ecosystems are global hotspots for biodiversity, which is of critical ecological and economic importance [2]. However, a substantial portion of the global forest estate is being utilized for the production of pulp, timber, and bioenergy [3]. The intensive industrial forestry practices used to meet these demands have caused significant changes to forests globally, resulting in the simplification of managed stands and negative implications for biodiversity and ecosystem services [4]. Numerous studies on forest harvesting effects have resulted in a series of meta-analyses summarizing data on changes in various objects and soil properties in response to harvesting. For instance, harvesting has been shown to reduce soil carbon [5], significantly increase soil NO_3-N concentration, nitrification rate, and pH [6], as well as increase N_2O fluxes [7]. In Europe, common species of small mammals have been found to increase in abundance after clear-cutting [8]. Several meta-analyses have focused on richness as a surrogate for biodiversity, indicating a decrease in response to clear-cutting or no changes in the case of partial cutting [9–11].

Fauna is a critical component of soil biota and plays a pivotal role in forest ecosystems by driving the flow of matter and energy through the food web and recycling nutrients. Therefore, it is imperative to understand how forest harvesting influences soil fauna. Despite the significance of soil fauna and the plethora of studies that have evaluated the response of different groups of soil invertebrates to harvesting, there is still a dearth of review studies on this problem. Marshall [12] published a traditional review of the influence of logging on biological processes more than 20 years ago, and since then, a substantial amount of new research has been conducted. Although meta-analyses assessing changes in biodiversity resulting from forest management include soil-dwelling invertebrates, they do not consider data on the abundance and reaction of different groups of soil fauna [9–11].

To gain a more comprehensive understanding of how soil fauna responds to harvesting, a meta-analysis was conducted using a dataset generated from research conducted in boreal and temperate forests between 1981 and 2021. The following research questions were considered:

1. How do various groups of soil fauna respond to forest harvesting? Soil fauna comprises a diverse array of taxa that exhibit significant variations in biology and ecology. As a result, their response to forest harvesting can be highly heterogeneous [13]. However, existing research on this topic has primarily focused on one or two large taxa and rarely includes multiple groups [14,15]. Consequently, our comprehension of the differences in the responses of various soil fauna groups to logging and the reasons for these differences is limited.
2. Does the type of harvesting and the type of forest have a modifying effect on soil fauna response? Forest harvesting can be carried out through various practices. Clear-cutting, which is historically the most common example of even-aged silviculture practice in temperate and boreal biomes [11], may result in significant changes in environmental conditions. This includes altered light, humidity, wind speed, and other conditions which can constrain forest biota, e.g., [16]. Partial cutting or retention forestry is another practice in which some parts of the trees are left on-site to maintain organic matter inputs and nutrient cycles [17] and provide a refuge for belowground organisms [18]. The response of soil fauna to harvesting may differ depending on the practice used [9–11]. However, we still have a poor understanding of the differences in the response of individual groups of soil fauna to harvesting practices. The forest type is another important factor that can modify the impact of forest harvesting on soil fauna. Coniferous and deciduous forests, for example, are quite different from each other in terms of soil and microclimatic conditions. This is reflected in the dissimilarity of the composition and structure of soil fauna [14,19,20]. Despite this knowledge, there is still a significant gap in our understanding of the differences in the reaction of soil fauna to harvesting in different forest types.
3. What are the temporal dynamics of the forest harvesting effect on soil fauna? Harvesting leads to significant disturbance of the forest ecosystem, while also significantly activating succession processes. The high dynamics of changing conditions in such processes may determine temporal changes in the soil fauna response. However, due to the limited number of sampling periods in individual studies, we have limited knowledge of how quickly soil animals react to harvesting and what the rate of their recovery is.

2. Materials and Methods

2.1. Literature Search and Inclusion Criteria

A literature search was performed to compile studies published between 1981 and 2021 focusing on the effects of forest harvesting on the abundance and richness of various groups of soil fauna—*Nematoda*, *Collembola*, *Oribatida*, *Mesostigmata*, *Enchytraeidae*, *Araneae*, and *Coleoptera* (*Carabidae* and *Staphylinidae*). The literature search was conducted via the Scopus database, using the following search words: forest and (logging or harvest * or clear-cut *) and (nematod * or collembola * or oribatid * or mesostigm * or enchytraeid * or aranea * or carabid * or staphilin *). In addition, we used elibrary.ru for searching publications in Russian. We inspected the abstracts, discarding publications clearly not relevant to our aims, and assessed the suitability of the remaining publications by scanning their methods and result sections. We discarded studies with unclear key methodological details (e.g., the sample size).

Furthermore, we screened the potential studies using a number of inclusion criteria: (1) the publications contained data on the total abundance (individual per m^2 or g of soil) and richness (species per sample) of the considered groups of soil animals. In the case of *Coleoptera,* we equated the data on the catchability (pitfall trapping method) to the abundance. Publications that assessed the impact of harvesting on species individuals, without the possibility of calculating the total abundance of the group, were not included in the dataset. (2) The dataset included studies only with the presence of control plots (mature forests). The studies comparing harvested plots only with each other were not included. (3) The dataset included studies conducted over 20 years after harvesting. However, the preliminary analysis revealed that studies of a later period are sporadic in that they can introduce a significant bias in the assessment of the logging effect.

To examine the potential effect of harvesting and forest type on soil fauna response, all data were grouped into categories. Two harvesting practices (clear-cutting and partial cutting) and three forest types (coniferous, deciduous, and mixed) were chosen. The taxonomic groups of soil animals ranged in size classes [21]: microfauna (*Nematoda*), mesofauna (*Collembola*, *Oribatida*, *Mesostigmata*, and *Enchytraeidae*), and macrofauna (*Araneae* and *Coleoptera*) and feeding type: decomposers (*Collembola*, *Oribatida*, and *Enchytraeidae*) and predators (*Mesostigmata*, *Araneae*, and *Coleoptera*). *Nematoda* were not included in more than one of the feeding groups since they include different feeding strategies [22].

A total of 51 studies met the above criteria (Table S1). Mean values of abundance or richness, sample size (n), and either standard error (SE) or standard deviation (SD) were either obtained directly from tables and texts or extracted by digitizing graphs using Plot Digitizer (URL: https://plotdigitizer.com/app (accessed on 15 January 2023).

2.2. Meta-Analysis

The logarithmic response ratio (lnRR) was used as a measurement of effect size and calculated according to Hedges et al. [23]:

$$\mathrm{LnRR} = \mathrm{Ln}(\mathrm{X_h}/\mathrm{X_c}) \tag{1}$$

where X_h is the mean abundance or richness of soil fauna on the harvesting plot and X_c is the mean abundance or richness of soil fauna on the control plot.

The mean effect sizes and 95% confidence intervals (CI) were generated by building random effect models with maximum likelihood (REML). Harvesting-induced changes in response variables were calculated as:

$$\text{Changes (\%)} = (e^{\mathrm{LnRR}} - 1 \times 100\%) \tag{2}$$

The effect size was considered significant if the 95% confidence interval did not overlap zero. Meta-regression analysis was used for assessing the effect of harvesting type (clear cutting and partial cutting) and forest type (coniferous, deciduous, and mixed) on groups of soil fauna response to harvesting. Heterogeneity among the effect sizes was evaluated using subgroup analysis based on Q-statistics. A significant value of Q_m indicates that the mean effect size differs among the modifying factors. Due to the high imbalance of the dataset, we did not test the interaction between the factors. To investigate the effect of time since harvesting on the response of soil fauna to harvesting, we fit a second-degree polynomial meta-regression model to the study as the random effect and natural log response ratios weighted by variance. As a means to evaluate possible publication bias, we constructed a funnel plot of sample size by effect size [24]. Additionally, we displayed the results of Egger's regression test (Figure S1). All analyses were performed in the R statistical environment [25], using libraries metafor for the meta-analytical diagnostics [26].

3. Results

3.1. Dataset Description

Based on the analyzed publications, a dataset was obtained including 720 observations, i.e., comparisons between treatment (forest harvesting) and control (mature forest); of these, there were 474 observations of abundance and 246 observations of the richness of soil fauna.

All the analyzed groups of soil fauna in our study provided information on both abundance and richness, except for nematodes, which were represented solely by abundance data (Table S2). The majority of studies that met the above criteria were carried out in North America (44%) and Europe (48%), but several studies were conducted in Asia (Figure 1). *Coleoptera* (rove and ground beetles) and *Collembola* were the most represented groups in the dataset (Table S2). Most of the observations examined the effect of clear-cutting (459 obs.), and partial cutting was represented less frequently (261 obs.). The coniferous forest represented the most common type (508 obs.) in the dataset and there were few observations in deciduous (173 obs.) and mixed (39 obs.) forests. Egger's tests suggested that the overall LnRR for the abundance ($Z = -0.33$; $p = 0.74$) and richness ($Z = -0.08$; $p = 0.93$) was robust (Figure S1).

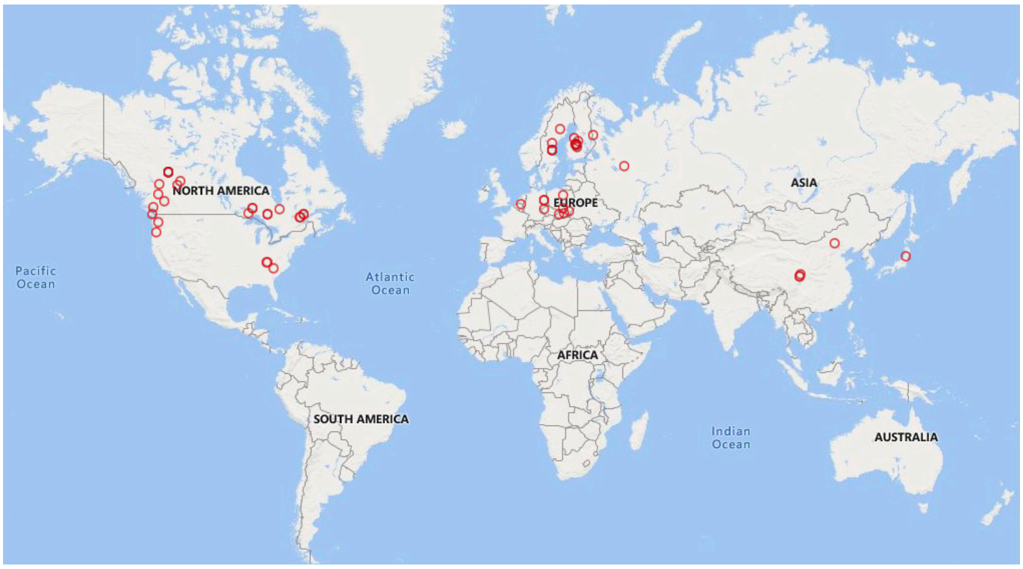

Figure 1. Map of study locations included in the meta-analysis.

3.2. The Effect of Forest Harvesting on Different Groups of Soil Fauna

In general, forest harvesting significantly decreases the abundance of soil fauna by 17% in comparison to the control (Figure 2) but does not change its richness. The effect of harvesting on abundance and richness differs among faunal groups. According to the overall effect, the number of *Nematoda* (−42%), *Collembola* (−24%), *Oribatida* (−56%), and *Mesostigmata* (−52%) is reduced and significantly differs from the control (Figure 2). On the contrary, the abundance of *Araneae* (+67%) and *Enchytraeidae* (+57%) is increased after forest harvesting. *Coleoptera* do not respond. The richness of some groups was also affected by forest harvesting. For instance, the richness of *Aranea* is enhanced (+31%), but for *Oribatida*, it is decreased (−36%). Other groups of soil fauna do not respond to harvesting.

The effect of harvesting is dependent on body size (abundance $Q_m = 22.5$; $p < 0.001$ and richness $Q_m = 7.4$; $p = 0.006$); the negative effect is increased with a decrease in the size group. Feeding type also impacts on the effects of harvesting (abundance $Q_m = 0.1$; $p = 0.892$ and richness $Q_m = 6.3$; $p = 0.012$) but only in the case of richness (Figure 3).

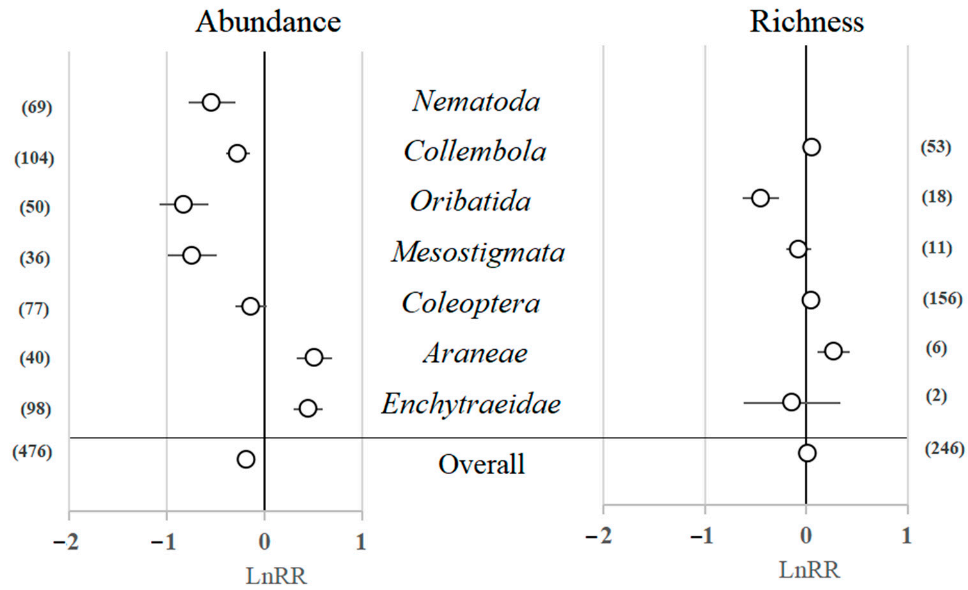

Figure 2. Effect of forest harvesting on the abundance and richness of different systematic groups of soil fauna. The mean effect size (LnRR) is significantly different from 0 if the 95% confidence interval does not overlap with it. The number of observations is given in brackets.

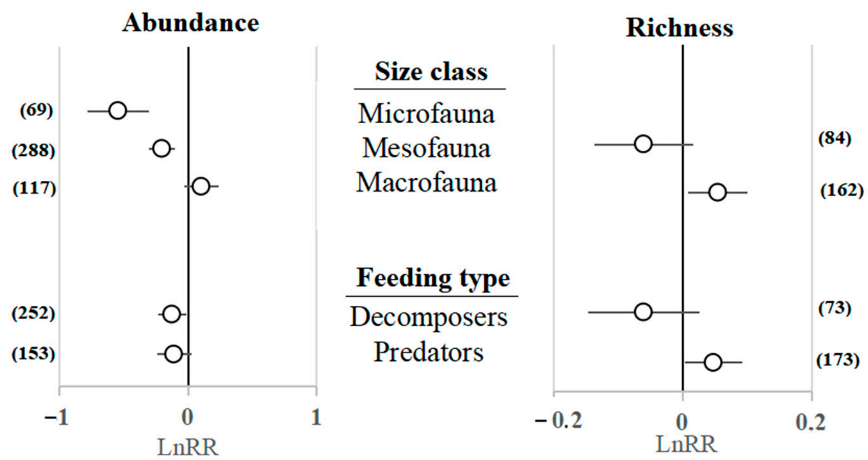

Figure 3. Effect of forest harvesting on the different size classes and feeding types of soil fauna. The mean effect size (LnRR) is significantly different from 0 if the 95% confidence interval does not overlap with it. The number of observations is given in brackets.

3.3. Type of Harvesting and Type of Forest as Modifying Factors of Soil Fauna Response

The meta-regression analysis shows that the types of harvesting and forest can modify the soil fauna responses to forest harvesting. Among the groups included in the analysis, *Collembola*, *Oribatida*, *Coleoptera,* and *Araneae* changed their response to harvesting (Table 1). The abundance of *Collembola* and *Coleoptera* was negatively affected by clear-cutting but not by partial cutting (Figure 4). The richness of these groups positively responded to clear-cutting, but in the case of *Collembola,* such an effect was not statistically significant. Partial cutting leads to an increase in *Collembola* richness but not in *Coleoptera* (Figure 4). Collembola and *Oribatida* decreased their abundance after harvesting in coniferous forests, while in deciduous and mixed forests, they did not change (Figure 5). The abundance of *Araneae* increased after harvesting in all forest types, but this effect was more pronounced in mixed forests. The richness of *Collembola* increased in deciduous forests and did not change in coniferous forests. In contrast, *Coleoptera* richness increased significantly in coniferous forests and did not react in deciduous and mixed forests.

Table 1. Modifying effect of forest and harvesting types on soil fauna responses to forest harvesting. A dash (–) signifies groups that were not analyzed due to insufficient data. The values represent *p*-values of mixed effects meta-regression for each group of soil fauna. Significant effects are in bold ($p \leq 0.05$).

Soil Fauna	Abundance		Richness	
	Harvesting Type	Forest Type	Harvesting Type	Forest Type
Nematoda	0.151	-	-	-
Collembola	**0.006**	**<0.001**	0.737	**<0.001**
Oribatida	-	**<0.001**	-	-
Mesostigmata	-	-	-	-
Coleoptera	**<0.001**	0.086	**0.038**	**0.001**
Araneae	0.244	**0.004**	-	-
Enchytraeidae	0.528	-	-	-

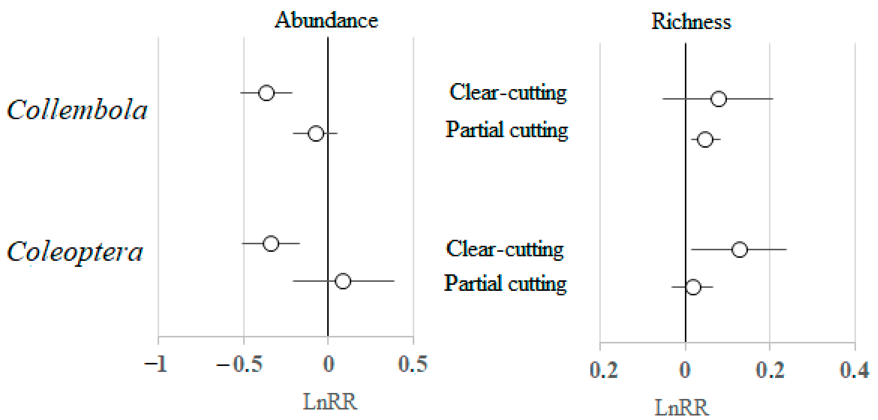

Figure 4. Modifying effect of harvesting type on the response of *Collembola* and *Coleoptera* to forest harvesting. See Table 1 for the results of the meta-regression analysis.

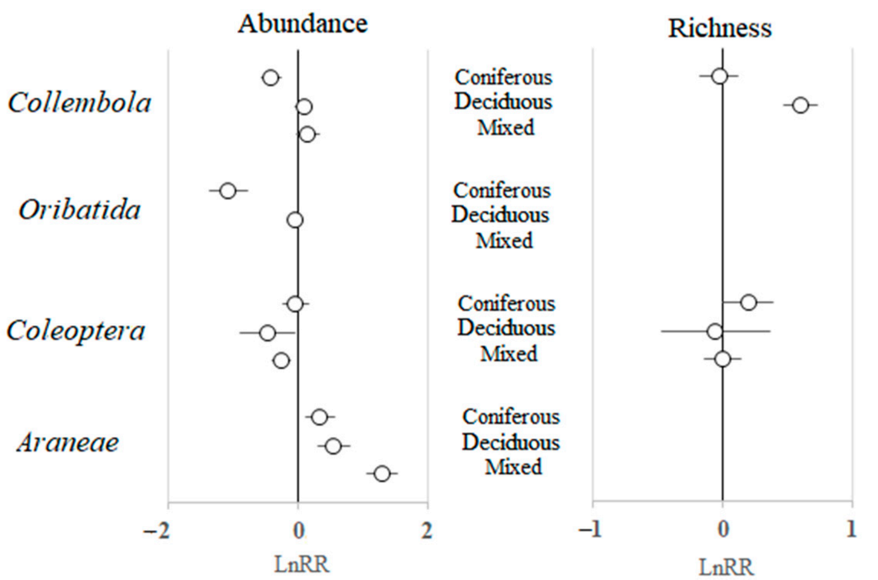

Figure 5. Modifying effect of forest type on the response of *Collembola*, *Oribatida*, *Coleoptera*, and *Araneae* to forest harvesting. See Table 1 for the results of the meta-regression analysis.

3.4. Temporal Dynamics of the Effects of Forest Harvesting on Soil Fauna

Among the groups included in the analysis, the response to harvesting of *Enchytraeidae*, *Nematoda*, and *Oribatida* changed depending on the time within a twenty-year period

(Figure 6). *Enchytraeidae* increased compared to the control plots immediately after harvesting. Abundance recovery occurred approximately 10 years after harvesting. Nematodes gradually reduced in response to logging with minimum values at five years, after which recovery was also achieved in 10 years. Oribatids sharply decreased after harvesting, and they recovered in 10 years (Figure 6). The response of soil fauna richness remained practically unchanged over time (Figure S2).

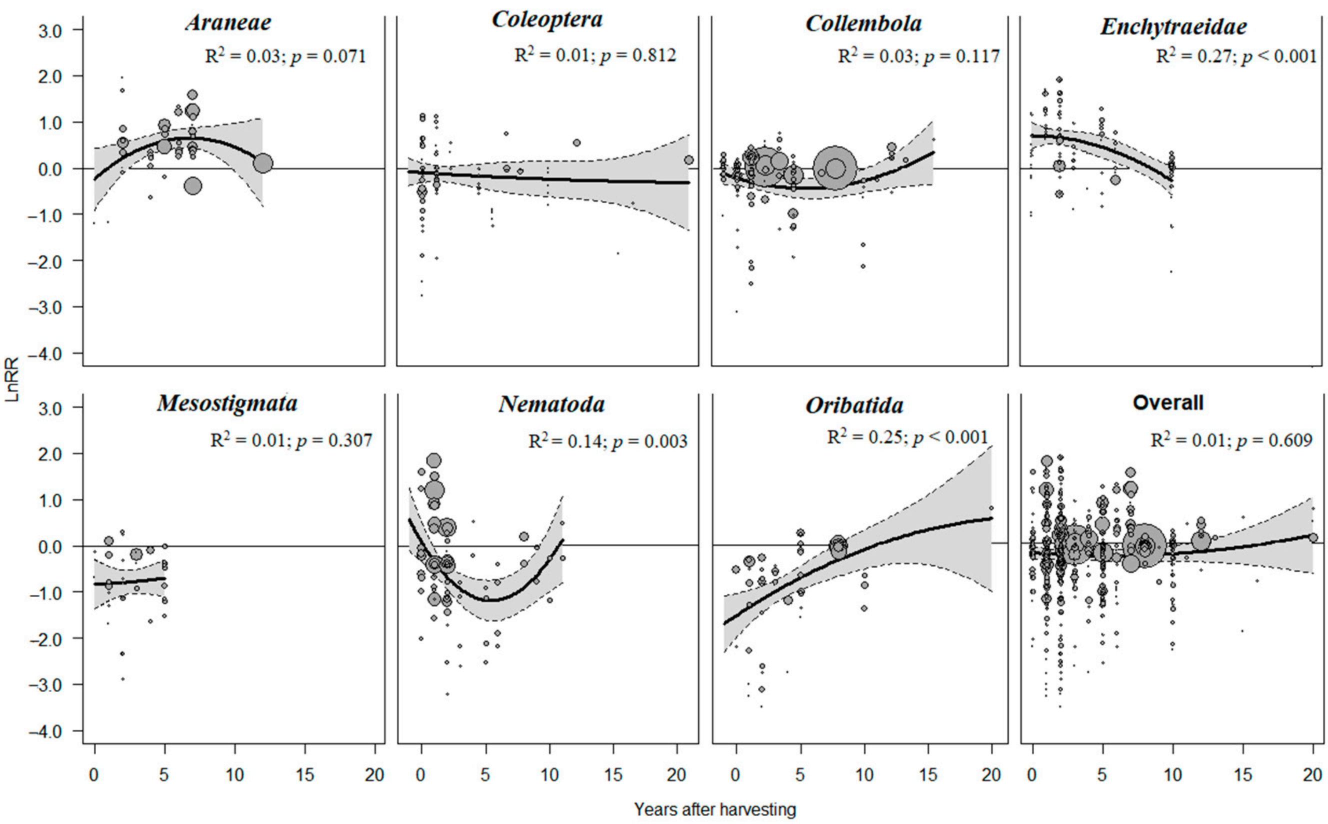

Figure 6. Temporal dynamic of the effect of forest harvesting on soil fauna abundance within a twenty-year period. The zero-line indicates the absence of the harvesting effect on soil animals.

4. Discussion

Forest harvesting is traditionally believed to have significant negative impacts on soil biota, through fragmentation of vegetation, modification of the quality and quantity of litter, alteration of root exudates, leaching of some plant nutrients, and changes in the microclimate and chemical properties of soil [12]. Confirming these negative impacts, our meta-analysis showed that, in general, harvesting leads to a reduction in the abundance of soil fauna. However, the degree of reduction is relatively small (about 20%), although individual groups such as *Oribatida* and *Mesostigmata* can decrease by more than two times (Figure 2). We did not observe a significant reduction in soil fauna richness, which suggests the possibility of resistance [27] and/or the activation of mechanisms that promote the restoration and compensation of lost taxa by colonizing species [28,29]. This finding is consistent with the results of a meta-analysis of forest management impacts on species richness, which revealed a weak effect of clear-cutting on arthropods [11]. However, the lack of changes in richness does not necessarily mean no changes in taxonomic composition. For example, closed-canopy species of *Carabidae* beetles may decrease or even disappear from clear-cut plots, while open-area-associated species rapidly colonize them [30,31]. It appears that harvesting is less destructive to soil fauna compared to forest fires, which can cause a decline in the abundance of soil macrofauna of up to 70% [32] and a reduction in richness of up to 99% [33].

4.1. Effect of Forest Harvesting on Different Groups of Soil Fauna

The conducted meta-analysis has revealed that the reaction of soil fauna to forest harvesting is not unidirectional. Differences in the biology and ecology of taxa lead to the presence of all types of reactions, including negative, neutral, and positive (Figure 2). The various reactions of soil invertebrates to disturbances may be attributed to their functional traits [34,35]. Recent works suggest that focusing on functional traits can provide greater insights into the mechanisms driving ecosystem change and recovery [36–38].

Body size is a fundamental trait that determines numerous physiological and life history parameters of an organism [39–41]. The conducted meta-analysis shows that as the size of invertebrates decreases, the negative impact of harvesting on soil fauna becomes more pronounced (Figure 3). In our opinion, one of the reasons for this dependence may be the limited dispersal ability of small-bodied soil fauna [42–44]. Small soil invertebrates have a reduced ability to actively avoid unfavorable points and/or colonize disturbed plots from adjacent undisturbed areas or refuges compared to actively moving groups of macrofauna [45–47]. For instance, oribatid mites are highly limited in their dispersal ability, even over distances of only several centimeters [48], whereas ground beetles are able to cover hundreds of meters [49].

Another fundamental trait is trophic specialization. The conducted meta-analysis did not show differences in the response of the abundance of predators and decomposers (Figure 3). However, the differences may lie at lower levels of trophic specialization (e.g., lichen feeders, fungal feeders, bacterial feeders, etc.). Unfortunately, the studies used do not allow for the extraction of such data and its inclusion in the analysis. It is worth noting that the reduction of available food resources may be one of the reasons for the decrease in the abundance of certain groups of soil fauna in clear-cut areas. The significant reduction of fungal biomass [50], and especially mycorrhizal mycelium [51,52], is likely the reason for the decrease in the number of oribatids and fungivorous nematodes in harvesting plots [12,53], which are trophically associated with this resource [54,55]. The conducted meta-analysis indicates that the richness of predatory invertebrates responds positively to harvesting. This trend is mainly due to actively moving *Coleoptera* and *Araneae*, which can increase their richness in harvesting sites through active colonization of newly formed habitats [30,31].

4.2. Types of Harvesting and Forests as Modifying Factors of Soil Fauna Response

Our synthesis provides evidence that the type of harvesting can drive soil fauna responses to logging. Partial cutting is believed to have a less pronounced negative effect on biota compared to clear-cutting [10,11] due to fewer changes in soil hydrothermal conditions [56] (Londo et al., 1999), the maintenance of microbial biomass [57], and the conservation of refugia that preserve the structure, composition, and functional characteristics of undisturbed forests [58]. However, the modifying effect of harvesting type on soil fauna strongly depends on taxonomic groups (Table 1). For nematodes, enchytraeids, and spiders, even partial harvesting has a considerable impact and causes changes in their abundance. While the abundance of springtails and beetles decreases after clear-cutting, it does not change in response to partial cutting, which is consistent with the conventional idea of the less dramatic effect of this harvesting practice. The observed increase in *Coleoptera* richness in response to clear-cutting, as opposed to partial cutting (Figure 4), essentially also reflects perturbative impact. The formation of new habitats after clear-cutting leads to the colonization of new *Coleoptera* species, which creates this effect [30,31]. Slight changes in the abundance and richness of some soil invertebrate groups in response to partial cutting suggest the benefits of this harvesting practice for the conservation of soil animal communities. However, even partial cutting can lead to disturbances and changes in soil fauna.

As demonstrated by the meta-analysis, the type of forest plays a role in modifying the impact of harvesting on soil fauna. Our analysis revealed a significantly weaker effect of harvesting on the abundance of *Collembola* and *Oribatida* in deciduous and mixed forests compared to coniferous forests (Figure 5). The negative response of soil fauna to harvesting may be due to significant changes in abiotic conditions [12]. Several studies have documented significant alterations in temperature, soil moisture, soil compaction, and the quality and thickness of forest litter resulting from harvesting coniferous forests [59–61]. Conversely, the changes in these indicators following harvesting in deciduous forests are relatively minor [14]. Evidently, the differences in soil conditions following harvesting in different forest types can explain the modifying effect of forest type on soil fauna. The restoration of deciduous forests after harvesting is characterized by extensive regeneration of trees, herbs, and grasses, in comparison to coniferous forests [14]. This rapid regeneration process may account for the varying responses of *Collembola* and *Coleoptera* richness based on the forest type (Table 1 and Figure 5). As previously mentioned, the appearance of large open spaces resulting from harvesting promotes the colonization of open-area-associated species of *Coleoptera* and an increase in their richness [30,31]. However, intensive overgrowth in deciduous forests can potentially offset this effect. In contrast, for *Collembola*, intensive overgrowth appears to contribute to the emergence of new habitats with novel conditions, leading to an increase in their diversity [62].

4.3. Temporal Dynamics of the Effects of Forest Harvesting on Soil Fauna

An important question regarding the impact of logging on soil animals is how long it takes for soil animal communities to re-establish after disturbances. The collected dataset partially allowed us to answer this question in terms of the restoration of the abundance of individual groups of soil fauna. It is well-known that soil fauna dynamics after forest harvesting are animal group dependent [63]. Our findings indicate that the population recovery of *Nematoda*, *Enchytraeidae*, and *Oribatida*, which were studied mostly in coniferous forests (Table S1), takes place around the end of the first decade following forest harvesting (Figure 6). This timeframe is consistent with the intensive development of deciduous trees at harvesting plots [64,65]. The development of these young secondary "forests" may ameliorate the unfavorable conditions that are experienced after harvesting. Another reason may be related to the dynamics of ectomycorrhizal biomass. It is noted that the peak of ectomycorrhizal mycelium during boreal forest succession falls on a period of 10–20 years [66]. Apparently, such an increase in mycorrhizal biomass, after its dramatic reduction as a result of harvesting [66], may be the reason for the restoration of the abundance of nematodes and oribatids, which are closely related to ectomycorrhizal mycelium in their diet [54,55]. At the same time recent literature data indicate that soil microarthropods mainly feed on saprotrophic fungi, while ectomycorrhizal fungi are consumed by only a few species [67]. Despite the relatively large datasets on the abundance of *Collembola* and *Coleoptera*, no temporal dependence of the effect size over twenty years was found. The period of observation for *Mesostigmata* and *Araneae* after harvesting turned out to be very short, about five years, which does not allow us to fully assess the dynamics of their response to harvesting. Therefore, we cannot assert that the reactions of the soil fauna will be the same during further succession within 20 years after harvesting. Due to the dynamic nature of ecosystems and the various scenarios of succession, we cannot claim that the soil fauna will react to harvesting in the same way beyond the initial 20-year period.

4.4. Data Set Limitations

Regrettably, the dataset used in this study did not include a sufficient number of research results regarding the impact of harvesting on soil fauna. In numerous studies, it was not feasible to obtain the required information, such as the sample size, mean, or deviation from the mean, to conduct a meta-analysis. Moreover, we encountered difficulty in determining the sampling methodology, as the studies' design descriptions were often limited. Our dataset was unbalanced concerning harvesting and forest types within taxonomic groups, which impeded our ability to assess the interaction effects of these modifying factors on soil fauna responses. In certain cases, the assessing effect of modifying factors was not accessible due to insufficient data. The groups of soil fauna could include ecologically diverse taxa, which could lead to different reactions within these groups to logging. Unfortunately, the studies used for the meta-analysis did not provide high-resolution taxonomic data (family or genera). Therefore, we were unable to characterize the intra-group variability of the response of fauna to forest harvesting and its causes.

5. Conclusions

Our meta-analysis of studies on soil fauna confirms the traditional notion that harvesting has a negative impact on forest ecosystems. The observed changes in the abundance and richness of soil fauna can have significant implications for the character and intensity of important ecosystem processes where soil-dwelling invertebrates play a pivotal role. Furthermore, our study provides new insights into the modifying factors and temporal dynamics of soil fauna response. Our meta-analysis enabled a comparison of the response to the harvesting of a wide range of groups of soil fauna, demonstrating considerable differences between taxa. We found that oribatids were the most sensitive to harvesting, with their abundance and richness being almost halved following felling. In contrast, *Araneae* showed an increase in their abundance and richness. The response of other groups of animals occupied intermediate positions. One possible explanation for the differing responses may be attributed to body size, as we found that the negative effect of forest harvesting on soil fauna increased with decreasing body size. Our findings also suggest that partial cutting may have less dramatic effects on soil fauna than clear-cutting, which confirms the potential of this forestry practice to reduce disturbances in forest ecosystems. Additionally, our study revealed that harvesting in deciduous forests may have a less pronounced impact on soil fauna than in coniferous forests. The temporal analysis showed that the restoration of the abundance of individual groups of soil fauna can occur by the end of the first decade after harvesting. Despite the relatively large dataset, we identified a lack of data on the reaction of individual groups of soil fauna to harvesting, depending on the types of practice and forest. Therefore, our meta-analysis findings expand our understanding of the response of soil fauna to harvesting and indicate a need for further research into additional aspects of this impact.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/f14050923/s1. Table S1. Data Sources [13–15,31,46,53,59,68–111]; Table S2. Structure of the dataset; Figure S1: Funnel plots of the relationship between the sample size and effect size for the abundance and richness of soil fauna; Figure S2: Temporal dynamics of the effect of forest harvesting on the soil fauna richness within a twenty-year period.

Author Contributions: Conceptualization, A.K. and E.P.; methodology, A.K. and E.P.; software, A.K.; formal analysis, A.K.; resources, A.K., E.P., A.T., A.D., and T.K.; data curation, A.K., E.P., A.T., A.D., and T.K.; writing—original draft preparation, A.K.; writing—review and editing, A.K., E.P., A.T., A.D., and T.K. All authors have read and agreed to the published version of the manuscript.

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