

A Review of Forest Management Effects on Terrestrial Leaf Litter Inhabiting Arthropods

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Abstract: Leaf litter arthropods are some of the most abundant and diverse communities in forests and provide myriad ecosystem services from decomposition and mineralization to pollination and predation. They are important to forest health and management and, in turn, are affected by how we manage our forests. Various forest management techniques such as clear cutting, burning, and chemical control of invasive species all have differing effects on ground dwelling arthropods and, despite their importance, a review of the literature on these effects does not currently exist. My objective with this paper is to review the effects of different types of forest management on arthropods in leaf litter systems.

Keywords: leaf litter; forest management; arthropods

1. Introduction

Leaf litter-dwelling arthropods (Table 1) are some of the most prominent components of ecosystems in terms of both biomass and diversity [1,2]. They are critical parts of forested ecosystems [3–5] due to the wide breadth of ecosystem services they provide. Namely, litter-inhabiting arthropods act as predators [6–10], decomposers of organic matter [11,12] and serve to mineralize certain nutrients into the soil [13]. Feeding by these arthropods stimulates microorganism growth [14] and also adds fecal matter to the substrate [15]. Some arthropods that inhabit leaf litter, like termites and ants, are even considered “ecosystem engineers” due to their important effects on the ecosystem [16–18].

Table 1. Arthropods commonly encountered in forest leaf litter.

Class	Order	Family
Arachnida	Acari	Ixodidae
		Oribatida
	Araneae	Gnaphosidae
		Lycosidae
		Salticidae
		Theridiidae
Crustacea	Opiliones	
	Pseudoscorpionida	
	Amphipoda	
	Decapoda	
	Isopoda	
Chilopoda	Coleoptera	Cantharidae
Diplopoda		Carabidae
Hexapoda		Chrysomelidae
		Curculionidae



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Table 1. *Count.*

Class	Order	Family
		Elateridae
		Histerida
		Psephalidae
		Ptilodatilidae
		Scydmaenidae
		Staphylinidae
		Tenebrionidae
	Collembola	
	Dermaptera	
	Diplura	
	Diptera	Muscidae
		Simuliidae
	Orthoptera	Gryllidae
	Hemiptera	Cercopidae
		Cicadellidae
		Pentatomidae
	Hymenoptera	Formicidae
		Microhymenoptera
	Lepidoptera	Geometridae
		Noctuidae
	Thysanoptera	

Due to their phylogenetic and functional diversity, leaf litter arthropods can have significant impacts on other trophic levels as well [19]. For example, leaf litter composition has been shown to alter the alkaloid profiles of litter-dwelling ants which then impacts the chemical defenses of poison frogs which feed on these ants [20]. Leaf litter-dwelling arthropods have also been developed as bioindicators of ecosystem and soil health [5,21–24]. Some ground dwelling taxa, like beetles (Coleoptera) and spiders (Araneae), are very sensitive to habitat modifications [25,26] and forest management both directly and indirectly impacts these groups more than others.

Forest management impacts on arthropod groups also differs according to place of origin. Most studies on this subject have been done in tropical systems [27–30], however, studies from Europe [23] and North America [31,32] also exist and shed light on the different impacts of forest management in temperate forests. For instance, arthropods in tropical systems tend to decline in relation to forest harvests and altered land use—for example, urbanization—while temperate systems see increases in arthropod diversity in these situations [33]. These effects are taxa dependent, however. Acari, especially oribatid mites, respond positively to a moderate degree of urbanization while Collembola [34] and Diplopoda [35] respond negatively to all levels of urbanization. Responses may also be specific to plant species, as others have found differences in diversity and abundance of Collembola by leaf litter type, regardless of management or land-use practice [36]. High diversity in places like urban forests does not necessarily translate to high diversity in surrounding areas. Man-made barriers like roads and sidewalks form a substantial disruption to the dispersal of arthropods in these systems, so diversity in these scenarios is likely patchy and inconsistent [37].

While forest management type and regionality affects the intensity and directionality of impacts to arthropods, some general trends do exist. For example, contrary to some beliefs, plantation forestry does support leaf litter arthropod biodiversity [38,39], and arthropods are resilient to both site preparation [40] and harvesting practices [41]. However, many of these interactions are taxa dependent, with mobile species being affected differently than sessile species [42]. For example, community composition of winter-active spiders in plantation forests differed based on plantation species and whether it was native to the region [43]. My objectives with this paper are to review the effects of different types

of forest management on leaf litter arthropods and to outline gaps in knowledge with regards to ground-dwelling arthropods in forested systems.

To assess the available literature on forest management practices and their effects on leaf litter-dwelling arthropods, I used Google Scholar and ISI Web of Knowledge to search for “leaf litter”, “arthropods”, and “forest management” as well as combinations of these terms. Articles were considered acceptable if they quantified leaf litter arthropods and detailed the type of forest management used (e.g., clear-cut, slash management). Articles that investigated the impacts of arthropods on forest productivity, as well as articles evaluating soil arthropods, were not included in this review.

2. Effects of Forest Harvesting

Forest management is frequently done in such a way as to mimic natural disturbances like fire, insect outbreaks, or hurricanes [44]. Natural disturbances may occur frequently and create partial-stand clearings, resulting in a mosaic of stand types and ages. Natural disturbances may also occur as whole-stand replacing events [45]. Forest management affects microclimates of the forest floor through altering light availability, wind, temperature, and moisture, thereby indirectly affecting the arthropods that inhabit the leaf litter [46].

Harvest methods which mimic large disturbances (e.g., clear-cuts, gap cuts) create significant amounts of edge habitats which tend to have more extreme microclimates [47] and support a lower abundance of leaf litter arthropods [48]. Clear cuts also increase the temperature extremes of the forest floor and remove organic matter inputs, both of which negatively impact leaf litter arthropods [49]. Compared to unforested habitats, however, forests may have lower diversity [50] and more clustered phylogenetic relationships of leaf litter communities [32]. Single-tree selection also has significant impacts on some leaf litter dwelling arthropods and has been found to shift carabid communities towards those more associated with grassland habitats, even without substantial tree removal [51].

In addition, soil compaction from logging equipment results in a reduction in arthropod diversity [52]. In intensively managed forests like oil palm plantations, abundance and diversity of leaf litter arthropods was significantly lower compared to untouched forests [53]. Forest harvesting may also have positive effects on leaf litter arthropod communities, however. Ground-dwelling arthropods are more abundant near coarse woody debris that is left over from harvest operations [31,54]. This increase in coarse woody debris may explain observed increases in functional diversity of ants, specifically [55].

While some information is known on the impacts of forest management on leaf litter arthropods, little is known on how specific operations (e.g., single-tree selection, gap harvests) affects individual groups or their interactions. There is also little known about how arthropod communities respond to forest harvests over time or how their responses compare to that of natural disturbances.

3. Effects of Forest Restoration

Rainforest restoration presents unique forest management challenges with a variety of techniques available [56,57], and some ground-dwelling groups, like ants, have been developed as biological indicators of the progress of restoration efforts [29,30]. While restoration methods undoubtedly affect leaf litter arthropods, little has been done to examine the effects of these efforts on said communities.

In general, decomposers are less abundant in anthropogenic sites that have been cleared for pasture or other agricultural use [58,59]. However, some authors have found no differences among certain communities, such as ants, among primary forests and forests disturbed for agricultural uses [60]. Also, increased amounts of detritus leads to higher abundance of all arthropod feeding guilds in leaf litter communities, indicating that there are bottom-up limitations in rainforests [19]. These limitations have implications for methods of restoration in degraded rainforests. For example, reforestation efforts that lead to greater structural diversity of plant life likely lead to greater diversity of leaf litter as well. This diversity creates a wide range of microclimates which are beneficial to many ground-dwelling beetles [61].

Compared to other restoration methods, island plantations most closely resembled untouched forests, however, leaf litter arthropods recovered eight years post-harvest even with no restoration [27]. In contrast, methods such as brushwood transposition, wherein woody material is transported to the damaged area to create a heterogenous environment, had low leaf litter arthropod diversity [62]. In North America, second-growth forests support highly diverse populations of leaf-litter inhabiting beetles [63,64] indicating considerable resilience to forest harvesting and conservation efforts.

It is of paramount importance to keep in mind that not all arthropod species are affected in the same ways by these restoration efforts. For example, common species appear to be unaffected while rarer species are more effected by both deforestation and reforestation [65]. Considering the amazing biodiversity of arthropods in rainforests, the effects on rare species are highly concerning. There are significant gaps in knowledge regarding what those rare species are, how they interact with more common species, and how these transition periods of reforestation affect them.

4. Invasive Species Control

Control of forest pests often involves intense management including sanitation harvests and chemical control. In general, control of invasive species negatively impacts leaf litter arthropod communities, although in different ways. As previously mentioned, sanitation harvests, which are often clear cuts, negatively impact leaf litter dwelling arthropod communities through an increase in forest floor temperatures and a reduction in organic matter inputs [49]. Chemical control also impacts arthropods on the forest floor. For example, diflubenzuron, a commonly used chemical control of the invasive gypsy moth, caused reductions in mites, thrips, centipedes and spiders [3,66].

A lack of invasive species control also impacts ground dwelling arthropods in the leaf litter. For example, increased ash wood on the ground from emerald ash borer (EAB) infestation causes increases in leaf litter arthropods [67]. Tree-killing invasive insects, like EAB, may also result in changes to leaf litter-dwelling arthropod communities by temporarily increasing the litterfall input, which is then followed by significant light gaps in the canopy [68]. Invasive plants may represent an initial pulse of novel resources for leaf litter arthropods, thereby showing some benefit early on. However, following decomposition, there is an overall negative effect of invasive plants on leaf litter arthropods [69].

There are several significant gaps in knowledge with regards to invasive species control and leaf litter arthropods. The current literature mainly covers the effects of chemicals or impacts of the invasive species itself on leaf litter arthropod groups. However, there is little known about how leaf litter affects the resiliency of forests to invasive pests or how invasive plants affect these communities.

5. Effects of Fire

Compared to logging operations, fire has a much bigger impact on leaf litter arthropods [70]. Fire has been used for thousands of years by indigenous peoples around the world in agricultural, forest, and wildlife management [71–74]. Decades of fire suppression has led to an increase in fuel load and significant changes to the landscape, such as loss of dominant fire-dependent species, and there have been recent efforts to get fire back on the ground and reincorporated as an essential part of forest management [75]. Fire has complex effects on leaf litter arthropods through the creation of more structurally diverse habitats [76,77] and through changes to the forest floor microclimate [78]. Fire increases temperature and changes soil pH, as well as fluctuations in soil moisture [79]. The exposure to extreme temperatures, increased light, and reduced moisture frequently result in habitat loss [80], especially for those fire-intolerant species that are prone to inhabiting mid- and late-successional forests [81,82]. Changes to plant communities through fire can also modify soil moisture, invariably affecting ground-dwelling arthropods [83].

Fire, like harvesting operations and invasive species control, impacts different taxa in different ways [84–86]. For example, species richness of beetles increased following fire in

the Sierra Nevada mountain range, but the intensity and directionality of impacts were taxon specific with no general patterns [87]. Some general patterns have emerged, however, from the literature. There is typically a significant, immediate reduction in arthropod abundance following fire [28,88,89]. These communities, however, appear to be resilient to fire [86,90–95] and abundance and diversity of leaf litter arthropods actually increases following burning [96,97].

Leaf litter arthropods also have complicated relationships with fungi [98] and fire has been shown to reduce total fungal biomass in forests [99]. Arthropod feeding on senescent hyphal structures of fungi stimulates fungal growth [97], and the presence of leaf litter decomposing arthropods is significantly related to mycorrhizal growth in some tree species like red maple [14].

While it is known that fire has significant effects on leaf litter dwelling arthropods, there is a significant gap in knowledge as to how various arthropod characteristics affect their interactions with fire. How different environmental and landscape characteristics affect leaf litter following a burn and what this means for associated arthropod communities remains unexplored.

6. Conclusions

While we have determined some general trends of effects of forest management on leaf litter arthropods, there is still much to uncover. Arthropods are most definitely affected by forest management activities, but appear to be resilient to these human activities. However, it is unknown how specific types of management affect specific taxa, and this is important from the standpoint of monitoring overall forest health. More work is necessary to understand how various types of forest management affect specific groups like beetles, spiders, ants, and other bioindicators.

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