diversity

MDPI

Article

Can Monoculture Timber Plantations Conserve More Ant Communities Than Adjacent Natural Forests?

Thembekile A. Mthimunye and Thinandavha C. Munyai *

School of Life Sciences, College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Private Bag X01, Scottsville 3209, South Africa; thembekile.advice@gmail.com
* Correspondence: munyaic2@ukzn.ac.za; Tel.: +27-33-260-6086

Abstract: Understanding where biodiversity is and how it is distributed is crucial to conserving vulnerable and dynamic ecosystems. Although natural forests support greater diversity and are vital for the conservation of organisms, recent studies have argued that monoculture plantations can be used as an alternative habitat for forest species. We investigate how ant diversity patterns and assemblage composition vary between monoculture timber plantations and adjacent natural forests using pitfall traps in the Natal Midlands of South Africa. A total of 326 ants were collected, comprising 4 subfamilies, 13 genera, and 30 species. The blue gum plantations had the highest species diversity compared to other habitats. Although two species were found exclusively in the natural forest, it had the lowest ant diversity. Generally, species assemblages between the compared plantations and the natural forests were distinct. Monoculture plantations affect ant communities, leading to a change in their distribution patterns and assemblage composition. Determining how these rapidly expanding plantations affect biodiversity at different scales is essential for preserving indigenous fauna. Although our findings proposed that blue gum plantations have the potential to conserve ant taxonomic diversity compared to pine plantations, we recommend that future studies investigate the response of ant functional diversity to monoculture timber plantations in the region.

Keywords: biodiversity; arthropods; natal midlands; pine and blue gum plantations

check for updates

Citation: Mthimunye, T.A.; Munyai, T.C. Can Monoculture Timber Plantations Conserve More Ant Communities Than Adjacent Natural Forests? *Diversity* **2022**, *14*, 430. https://doi.org/10.3390/d14060430

Academic Editor: Luc Legal

Received: 8 April 2022
Accepted: 25 May 2022
Published: 27 May 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Indigenous forests contain a large proportion of native biota and are vital for the conservation of organisms [1]. Although the forest biome is the smallest globally, it contains 65% of the global terrestrial fauna [2], leading to a high conservation value [3]. It is characterised by high species diversity due to abundant resources offering diverse niches for organisms [4]. Nonetheless, they are mostly valued based on the vertebrate taxa they support [5]. In addition to conservation value, the ecosystem services provided, which range from carbon sequestration and air purification to nutrient recycling and soil erosion prevention, are vital for environmental health. However, regardless of all these benefits, they are increasingly being fragmented or destroyed and replaced with other land uses, such as monoculture plantations, which are known to establish well in previously forested habitats.

Afforestation and, in some cases, reforestation with monoculture plantations is considered a cost-effective technique for large-scale timber production worldwide [6,7]. Apart from their economic significance, monoculture plantations can absorb atmospheric carbon and potentially rehabilitate biodiversity in previously depauperate areas, including destroyed natural forests, degraded grasslands, and non-productive agricultural land [8]. Armstrong and van Hensbergen [1] stated that pine (*Pinus*) plantations might benefit adjacent native forest species as they provide forest organisms with alternative resources and facilitate germination and maturation in plants. Brockerhoff et al. [9] supported that these intensely managed plantations have great potential for conserving native species since they improve habitat connectivity, reduce edge effects, and offer complementary forest habitats.

However, these timber trees do not occur naturally in most parts of the world. They may negatively affect biodiversity since they alter the vegetation structure and composition, resulting in homogenised habitats [10]. As the timber plantations continue to expand, the ecosystem structure and functioning of natural habitats is disrupted [10]. Kanowski, Catterall, and Wardell-Johnson [6] found that the exotic pines and blue gum (*Eucalyptus*) plantations have minimal positive effects on biodiversity compared to the other plantation types. This is more prominent when these plantations are established on rainforest landscapes since the habitat quality of native organisms is reduced [6]. Therefore, non-native plantations may have positive or negative ecological consequences, depending on the scale at which they are planted, the previous land use, and habitat structure. Understanding the biodiversity patterns in human-managed landscapes is essential for conservation, especially since anthropogenic activities increasingly replace natural vegetation. With invasive plantations taking up more land, it is necessary to investigate how different organisms are affected by these exotic forests.

Environmental disturbances such as burning, grazing, and other anthropogenic activities cause spatial heterogeneity, which either favours or hinders species diversity at the spatial or temporal scale [11,12]. Such activities play a significant role in changing the habitat openness, which alters microhabitat conditions such as temperature [13,14]. Temperature has been widely reported as one of the important factors determining ant diversity patterns and assemblage composition [15–18], particularly for its effect on foraging activity [16,19].

Insects constitute 60% of all known global terrestrial fauna, making them a dominant group [20]. Furthermore, they are useful in biodiversity modelling studies as bioindicators of environmental quality and are ecologically related to other taxa [5]. Among insects, ants are highly diverse and abundant taxa. They occupy a wide range of habitats and respond rapidly to disturbances caused by land-use changes [16]. Relatively simple sampling techniques make it possible to study biodiversity patterns at different scales.

In a previous study in South Africa, Armstrong and van Hensbergen [1] mainly focused on the effects of converting natural vegetation into monoculture timber plantations on vertebrate taxa. Others were conducted in tropical areas [6,9] and temperate regions [9]. However, limited research [21,22] has investigated diversity and distribution patterns of invertebrates, specifically in the Afrotropical areas where timber production is high and undisturbed natural forests are less common. Improving knowledge on biodiversity protection in these rapidly expanding monoculture plantations is essential, especially in South Africa, a country rich in biodiversity and endemic species. A study conducted by Munyai et al. [23] in the Natal Midlands of South Africa reported that subterranean ant species diversity was lowest in the blue gum plantation compared to adjacent grassland and natural forest.

Therefore, this study investigated ant species diversity patterns and assemblage composition between monoculture plantations and natural forests in the Natal Midlands of South Africa. In particular, we investigate (i) ant species diversity patterns and how their assemblage composition differs between three habitat types and (ii) evaluate the level of dissimilarity between the habitat types. It was hypothesised that monoculture plantations alter ant assemblages, leading to differences in ant species diversity and assemblage composition compared to adjacent natural forests.

2. Materials and Methods

2.1. Study Area

This study was conducted at the University of KwaZulu-Natal Umgenipoort Research Facility (29°29′0.1208″ S; 29°54′0.0146″ E) situated in the KwaZulu-Natal Midlands (Figure 1) between Pietermaritzburg and the foothills of the Drakensburg mountains in the KwaZulu-Natal province of South Africa. This area experiences hot summers and cold, dry winters. The mean temperature of the site is 24.8 °C, with an average annual precipitation of 800 mm [23]. The main vegetation types in the area include the Mooi River Highland Grassland and Southern Mistbelt forest [23]. This native forest consists of tree species such

as the *Celtis Africana*, *Afrocarpus Falcatus*, *Calodendrum capense*, *Vepris lanceolate*, *Zanthoxylum davyi*, and *Podocarpus henkelii*, which are mostly deciduous and semi-deciduous [24]. However, the predominant tree species in the forest is *Podocarpus henkelii* [24].

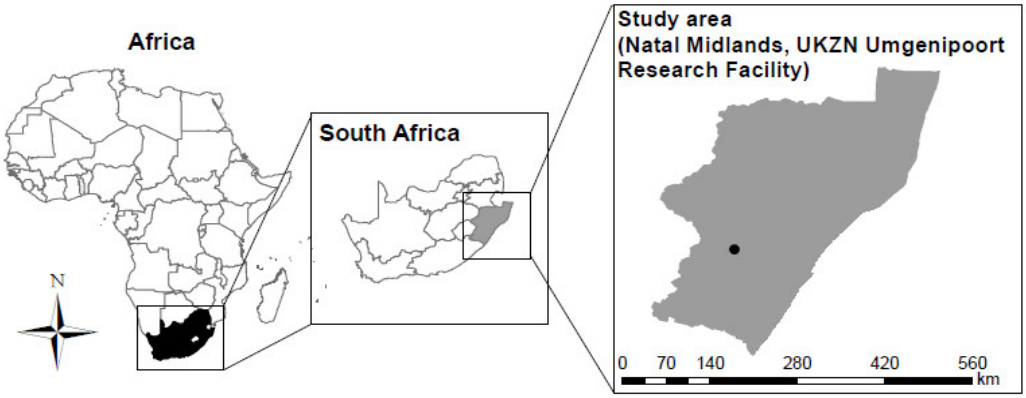

Figure 1. Location of the study area (University of KwaZulu-Natal Umgenipoort Research Facility) in the Natal Midlands of KwaZulu-Natal province in South Africa.

The Umgenipoort Research Facility and adjacent properties are further dominated by timber monoculture plantations (pine and blue gum), with perennial rivers flowing through the landscape. The three habitat types were sampled in this study: (1) Pine plantations, (2) blue gum plantations, and (3) southern Mistbelt forest, a natural habitat, which is not managed and experiences minimal to no degradation. Each habitat type was replicated seven times (Table S1; Figure S1). Although the investigated monoculture tree plantations on the site were identified at the genus level (*Pinus* and *Eucalyptus*), the dominant plantations in the Natal Midlands include *Eucalyptus grandis*, *E. nitens*, *E. smithii*, *Pinus elliotii*, and *P. patula* [25–27]. Over the years, these species have been planted in some areas in the province, including the current study area. The estimated area covered by the natural forest is 1.14 km^2, and the plantations cover a combined area of approximately 2 km^2.

2.2. Ant Sampling

Ground-dwelling ants were sampled from each of the three habitat types using standardised pitfall trapping [18,28–30]. The pitfall traps were placed on the ground with the lid removed and the mouth (62 mm in diameter) of the pitfall trap at the same level as the ground surface. For each replicate, traps were laid 10 m apart, in a 2 × 5 sampling grid, totalling 10 pitfall traps per sampling grid. Each pitfall trap was filled with 50% propylene glycol solution, which does not result in the attraction or the repulsion of ants [18]. Since propylene glycol has a slow evaporation rate, the traps were left at the study site for seven days in March 2021 to maximize the specimens captured. Seven days has been suggested as an appropriate sampling interval for this method [31,32]. For each habitat type, seven replicates were established. To prevent psuedoreplication, the replicates were separated by a distance of >300 m [18]. The collected ant samples were washed, sorted, and stored in vials containing 70% ethanol in the laboratory for identification. The specimens were identified at the genus level using Fisher and Bolton [33]. Online databases viz., AntWiki (http://www.antwiki.org/, accessed on 11 June 2021) and AntWeb (http://antweb.org/, accessed on 11 June 2021) were then used to separate ant species where possible. Specimens that could not be identified to species level were assigned to morphospecies. All voucher specimen are held at the School of Life Sciences, University of KwaZulu-Natal, in the Pietermaritzburg campus and will later be deposited at Iziko Museum of Cape Town.

2.3. Statistical Analysis

Sample coverage, which measures sample completeness in each habitat type for ant species diversity, was explored using the iNEXT online software program [34]. The number of individuals caught per sample was calculated and presented as species occurrence (Table 1). A one-way ANOVA was used to compare species richness between the habitat types. Quantitative metrics of species diversity, the Shannon–Wiener diversity index (H′), and Evenness (J′) in PAST [35] were used to investigate and compare ant diversity in the three sampled habitats. The Shannon entropies (diversity indices) of each habitat were converted to true diversities (effective numbers of species) as outlined in Jost [36]. The effective number of species represents the number of equally abundant species required to obtain the diversity value in the dataset [36,37]. The difference in ant assemblage composition across the habitats was explored through non-metric multidimensional scaling (NMDS), cluster analysis, and ANOSIM, using the Bray–Curtis similarity measure and square root transformation in Primer version 6 [38]. SIMPER was used to determine habitat dissimilarities and the main species contributing to this, utilising the S17 Bray Curtis similarity matrix and a cut-off low contribution of 90% [38].

Table 1. Observed number of species (S_{obs}), species occurrence, and sample coverage values of the habitat types sampled in Umgenipoort Research Facility. Species occurrence represents frequency of the number of individuals collected and sample coverage values depict whether the specimens collected were representative of the habitat type.

Habitat Types	S_{obs}	Species Occurrence	Sample Coverage
Blue gum	19	44	0.967
Natural forest	14	27	0.950
Pine	14	29	0.931

3. Results

3.1. Sample Coverage for Species Diversity and Species Occurrence

In total, 326 ant specimens were collected, with 30 species in 13 genera and four subfamilies represented (Table S2). The average sample coverage for species diversity was 0.95, indicating that the sampled ant communities represent each habitat type, even though the blue gum habitat had the highest number of observed species and species occurrence (Figure 2 and Table 1).

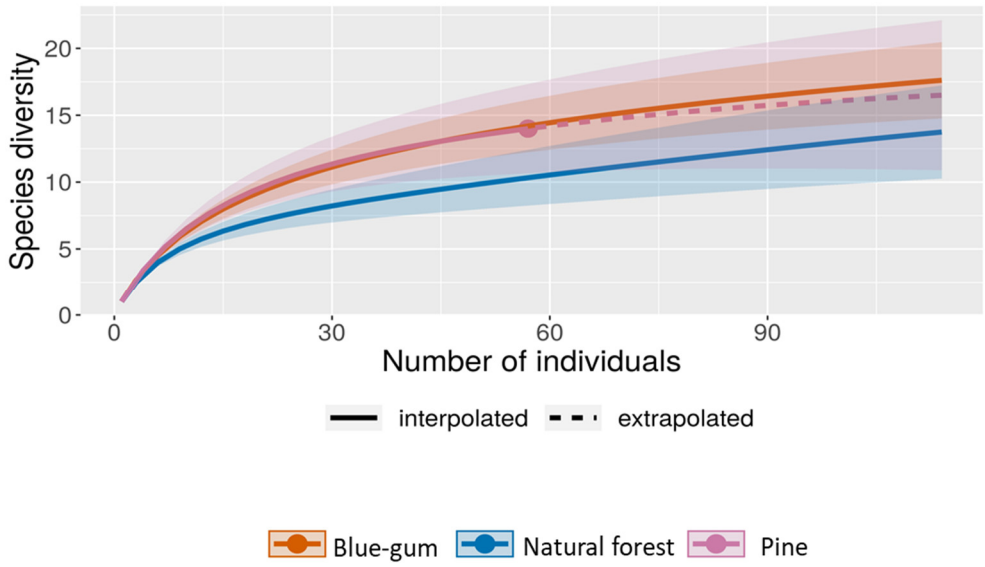

Figure 2. Sample coverage for species diversity of the sampled habitat types at Umgenipoort Research Facility.

The highly diverse subfamilies were Myrmicinae (50% total ant abundance) with 15 species in 6 genera, followed by Formicinae (27% total ant abundance), consisting of 8 species in 3 genera. The most specious genera were *Tetramorium* (7 species) and *Lepisiota* (5 species) in the Myrmicinae and Formicinae subfamilies, respectively. Five species were common to all the habitat types: *Dorylus helvolus*, *Crematogaster* UKZN_01 (*castanea* complex), *Monomorium* UKZN_10, *Solenopsis* UKZN_03, and *Tretramorium* UKZN_03 (*setigerum* gp.). The blue gum and the pine plantations had the most species in common (11 species), while 1 species (*Tetramorium* UKZN_32 (*weitzekeri* gp.)) was common to the blue gum plantation and the natural forest (Table S2). Seven species were restricted to the blue gum plantations and eight species were found explicitly in the natural forest, mainly from the genus *Hypoponera* (four species) (Table S2). *Parasyscia* UKZN_06 was also exclusively found in the natural forest, with 23 individuals collected from this habitat type (Table S2). Only three species (*Lepisiota* UKZN_02 (*capensis* gp.), *Pheidole* UKZN_07, and *Tetramorium* UKZN_10 (*simillimum* gp.)) were restricted to the pine plantations (Table S2).

3.2. Species Diversity

The highest number of species (19) was observed in the blue gum plantations (Table 1, Figure 3). However, there was no significant difference in species richness (Anova, F = 2.07, MS = 12.33, df = 2, p = 0.16) among the three habitat types (Figure 3). Variation in ant species diversity in the habitats was estimated using the Shannon–Wiener diversity index, converted into true diversities. Ant species diversity was highest in the blue gum plantations (H′ = 2.38), followed by the pine plantations (H′ = 2.31), which was also more even (J′ = 0.72) (Table 2). The natural forest had the lowest species diversity (H′ = 1.96) (Table 2).

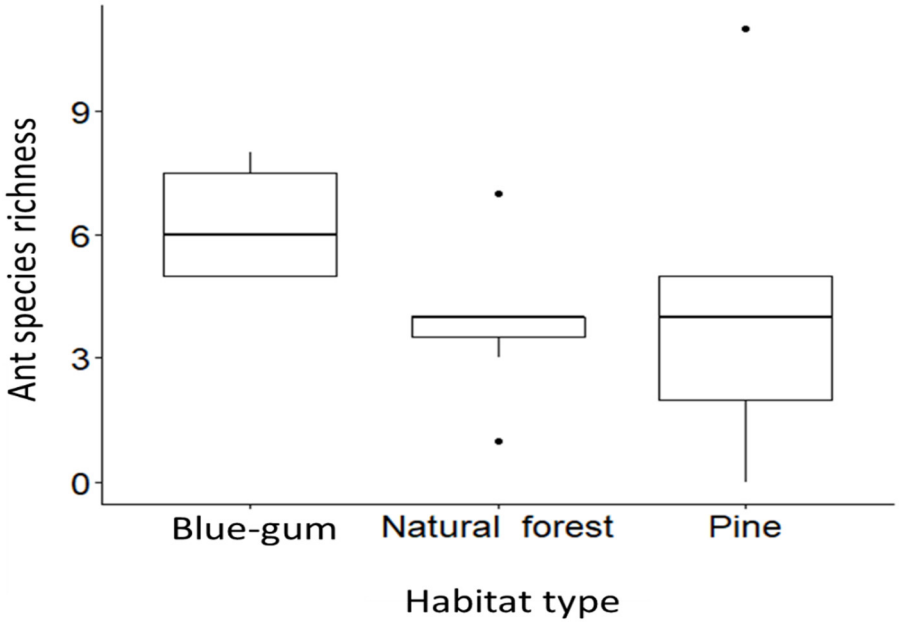

Figure 3. Boxplots representing ant species richness across the three habitat types (Blue gum, Natural forest, and Pine plantations) sampled at Umgenipoort Research Facility.

Table 2. Mean and standard deviation of ant species richness, Shannon–Weiner diversity indices, species evenness, and true diversity, given as the effective number of species, in all the sampled habitat types at Umgenipoort Research Facility. The effective number of species represents the conversion of the Shannon–Weiner diversity index into the actual species diversity value in the community [36].

Habitat Type	Species Richness ± SD	Shannon–Wiener Diversity Index (H′)	Evenness	Effective Number of Species
Blue gum	6.29 ± 1.38	2.38	0.57	11
Natural Forest	3.86 ± 1.77	1.96	0.51	7
Pine	4.14 ± 3.58	2.31	0.72	10

3.3. Assemblage Composition

The non-metric multidimensional scaling (NMDS) plot (Figure 4) revealed that although not completely distinct, there was a variation in assemblage composition across the habitats. Most pine and blue gum plantation replicates were close together as they shared most ant species but were clearly distinguishable in assemblage composition (Table S2). The samples of the natural forests showed variation among them, yet were separable from other habitat types due to the presence of *Hypoponera* species, which was found only in this habitat type. Only *Pheidole* UKZN_07 was collected from the fourth pine replicate, resulting in an outlier in the pine plantations.

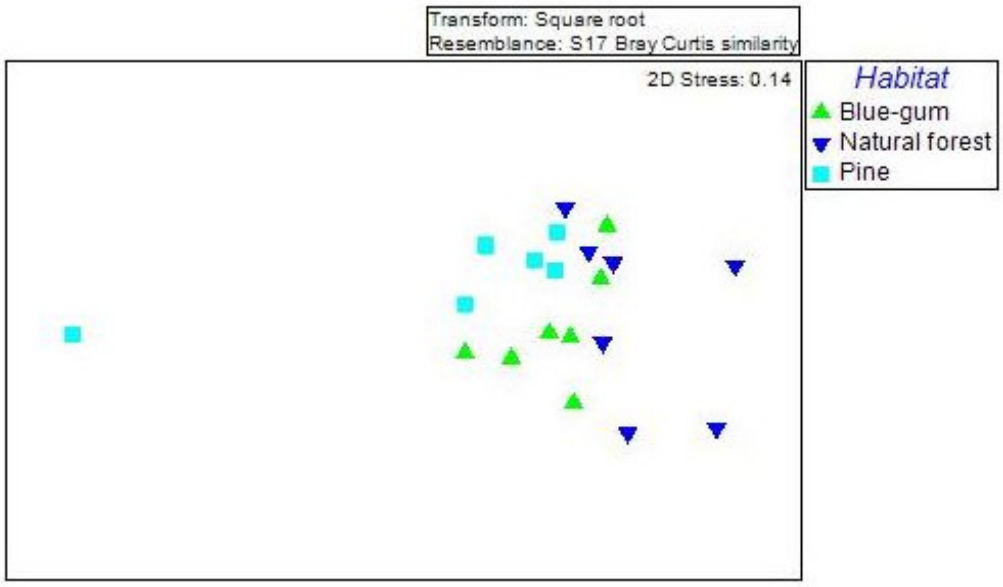

Figure 4. Non-metric multidimensional scaling (NMDS) plot showing ant assemblage composition across all the three habitat types with 20 replicates in total. The pine plantation (PN2) replicate was excluded from the NMDS analysis as it did not contain any ants. The data were square root transformed and based on the Bray–Curtis dissimilarity measurement, with a stress value of 0.14.

Relatively similar results were obtained through cluster analysis. Generally, the habitat types overlapped in assemblage composition (Figures 4 and S2). However, some samples were clustered together, showing that many species were shared between the replicates of different habitat types (Figure 4). Notably, replicates from the pine and the blue gum plantations were clustered with some replicates of the natural forest (Figure S2).

A significant difference in assemblage composition between the three habitat types was reported from a one-way ANOSIM (ANOSIM, Global R = 0.13, $p = 0.034$, no. of permutations = 999), due to the variation in assemblages between the habitat types (Table S2). A pairwise ANOSIM comparing the similarity between two habitat types simultaneously showed contrasting results. The *p*-values were greater than 0.05 for all three comparisons (Table 3), indicating that the compared habitats were identical. This was also supported by the R

statistic values (close to zero) in all the comparisons (Table 3). However, the similarity between the blue gum and the pine plantations is questionable (p = 0.06) (Table 3).

Table 3. Pairwise ANOSIM summaries comparing ant assemblages sampled across the three habitat types in Umgenipoort Research Facility. The R statistic value close to one represents dissimilarity between the habitat types, while an R statistic value close zero depicts that the habitat types were similar in assemblage composition [38]. The significance level shows the degree of similarity across the habitat types.

Groups	R Statistic	Significance Level
Blue gum, Natural forest	0.11	0.13
Blue gum, Pine	0.17	0.06
Natural forest, Pine	0.14	0.08

3.4. Percentage Similarity between the Habitats

The average similarities in assemblage composition in the sampled habitat types were 33.75%, 24.73%, and 29.74% for the blue gum, natural forest, and pine plantation, respectively (Table S3). The average dissimilarity percentage between the blue gum and the natural forest was 73.19, while the dissimilarity between the blue gum and the pine plantation was 73.02%. The natural forest and the pine plantation had the highest average dissimilarity percentage of 78.40 (Table S3). These results are similar to those reported in the NMDS plot, as the natural forest and pine plantation were more separated (Figure 4). The main species that contributed to the observed dissimilarities between the habitats are listed in Table 4. These species had a high dissimilarity/standard deviation ratio compared to other species, making them the discriminating species among the habitats (Table S3).

Table 4. SIMPER results showing the species that contributed the most to distinguishing the habitat types at Umgenipoort Research Facility (BG—Blue gum, PN—Pine, NF—Natural forest). Ratio: Dissimilarity/Standard deviation.

Habitat Type Combinations	Species	Diss/SD Ratio
BG & NF	*Hypoponera* UKZN_03	0.77
	Lepisiota UKZN_08 (*crinita* gp.)	0.77
BG & PN	*Tetramorium* UKZN_03 (*setigerum* gp.)	0.99
	Monomorium UKZN_10	0.97
NF & PN	*Solenopsis* UKZN_03	0.98
	Monomorium UKZN_10	0.91

4. Discussion

Monoculture plantations are often characterized by poor biological diversity and limited resource availability. Nonetheless, this should not be generalised to all organisms. The current study investigated the effects of monoculture plantations on ant communities, specifically comparing ant diversity and assemblage composition in the natural forests, pine, and blue gum plantations. It further determined how distinct these habitat types were in assemblage composition if the difference existed.

4.1. Ant Species Diversity

The current study results are comparable to those reported in previous studies. For example, a similar study by Ratsirarson et al. [39], conducted in Cape Peninsula National Park, South Africa, collected a relatively similar number of leaf litter invertebrate species (19 and 17) as in this study (19 and 14) from the blue gum and pine plantations, respectively. However, compared to the latter study, more species were collected from the natural forests (22). It was suggested that the forest type and latitude were possibly responsible for such trends in the compared study [39], since the site was located in a region characterised by a Mediterranean climate.

The current study reported higher number of species in blue gum plantations as compared to the other habitat types (Figure 3, Table 2), even though the difference was insignificant. These results were similar to those obtained from Samways, Caldwell, and Osborn [21]. The latter study observed that although invertebrate species richness and diversity in exotic vegetation was low compared to native vegetation types, the blue gum plantations had the highest invertebrate diversity among the sampled exotic plantations [21]. Some studies have argued that adjacent vegetation with a similar structure as forests can support more forest species [40,41] since these sites gain species from the surrounding natural forests, which act as source areas [3]. This could have been the case in this study, as many species were common between habitat types (Table S2). Corresponding to the findings of this current study, Murray et al. [42] found that pine plantations had the lowest species richness in order Hymenoptera, Blattodea, and Acari. It was suggested that the seasonal response of arthropods to resource availability and moisture in the plantations should also be considered [42]. Similarly, Corley et al. [43] observed a reduction in ant species richness and the abundance of dense plantations.

In contrast to this study's findings, natural grasslands supported high ant, spider, and orthopteran species richness compared to the surrounding pine plantations, as reported in a study conducted in the Natal Midlands, South Africa [44]. Notably, the open habitat of the grasslands enhances ant activity due to increased exposure to the sun, favouring this thermophilic taxon. Ant species richness was reported to be higher in primary forests of the Amazon, with a unique assemblage composition compared to secondary forests [3]. However, the former study was conducted at a large scale, in a continuum of indigenous forests, consisting of more ant species that are less tolerant to disturbance. This was further supported Achury and Suarez [5], as they reported high ant species richness in densely forested plantation areas compared to more disturbed sites in central Colombia. The type of land use activity and the level of disturbance might have contributed to similar conclusions from these past observations. In addition, most of these were conducted along the equatorial regions, with the largest land biomass made up of ants [3] and which experience high temperatures and speciation rates.

4.2. Ant Species Assemblages

It was argued that that abundant leaf litter reduces ground temperature, favouring the survival of generalist arthropod groups [10]. Although drivers of assemblage composition were not investigated in the current study, such an observation is consistent with low diversity in the pine plantations, a habitat characterised by deep, dense leaf litter in our study. Species sampled in the pine plantation of the current study were mainly generalist group (*Crematogaster*, *Solenopsis*, and *Tetramorium*) and are tolerant to a wide range of environmental conditions [12]. Correspondingly, Riedel et al. [45] found that generalists dominated plantations established on areas that were formerly pastures areas. Ant assemblages have a better chance of thriving in timber plantations since open habitats favour the establishment of understory vegetation to increase niches [46,47]. The current study's findings support this speculation since the pine plantations had distinct ant assemblages compared with the natural forest.

Although ant assemblages varied among the habitat types, some samples of the natural forests were clearly separated from one another and overlapped with the other habitat types (Figure 4). This is explained by microhabitat heterogeneity within each of the three habitats, which accounts for the observed slight similarity of ant species assemblages, with some species having a broad range of environmental tolerance. Although timber plantations generally have low plant species richness, they may offer a complex habitat structure to ground-dwelling invertebrates. Budiaman et al. [48] postulated that clear cutting of timber plantations reduces favourable microhabitat conditions for ground-dwelling ants, causing a decrease in ant species communities and altered assemblages. Burghouts et al. [49] noted that horizontal habitat complexity affects ground-foraging invertebrate activity. This may be facilitated by salvage logging. Georgiev et al. [50] found

that salvage logging enhances biodiversity, particularly invertebrate species associated with open habitat structures. Salvage logging was not notably observed in the sampled study site; nonetheless, the presence of dead or decaying wood within the blue gum plantation stands may have diversified ant nests and forage grounds [50,51].

Non-native plantations have an effect on invertebrates communities at the species level [21]. Particularly, woody plant invaders have a greater influence on arthropods than herbaceous plants species [52]. In this study, four *Hypoponera* species dominated the natural forests. These ants nest and forage in leaf litter, soil, decaying wood, and shaded microhabitats with adequate moisture and are generally predators [53]. This could explain their absence in plantations associated with dry soil and open habitats. In addition, species belonging to genus *Parasyscia* were only found in the natural forest (Table S2). These cryptobiotic species are leaf litter specialists, mostly nesting below rocks and decomposing logs [54], which offer protection against extreme soil temperatures experienced in open habitats [17]. Since ants use pheromones to communicate, dense vegetation may prevent chemical detection among populations and efficient foraging [55]. However, the close spatial proximity between the habitat types and the historical vegetation type, which were mainly grasslands and forests in this particular site, could explain why many species were shared between the habitats.

Vegetation height and density have an impact on epigeic insects since this alters ground surface temperature [56]. Although not measured in the current study, temperature differences associated with habitat openness could explain assemblage variations between the plantations and the natural forest. Andersen [13] proposed that ant species have different preferences in the amount of habitat openness they can tolerate. Warm temperatures favour ant survival by promoting forage abundance [57], foraging time [16], and ant productivity [58]. Controversially, temperature may be a limiting factor in ant species richness since it causes physiological stress in shade-adapted species, such as forest specialists [16,58]. It is essential to note that the morphology of the plants, rather than their status as indigenous or non-native, is more vital in affecting ground-dwelling invertebrates.

5. Conclusions

The findings of the current study showed no significant difference in species richness between the plantations and the natural forest, even though the blue gum plantations had the highest number of species and diversity. There was a variation in assemblage composition across the habitat types. Therefore, the effects of monoculture plantations on species should not be generalised for all taxa. Our study therefore supports that some of these monoculture plantations (for example, blue gum plantations) have the potential to conserve taxonomic ant diversity. Given that ants play a vital role in ecosystem functioning, the conservation of ants in plantations could reduce the tension between plantation production and biodiversity conservation in natural ecosystems. However, for a robust conclusion on this, future studies should consider investigating the variation in ant functional diversity with these habitat types.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/d14060430/s1, Figure S1: Landscape of the Umgenipoort Research Facility with the three habitat types (Natural forests (NF), Blue-gum (BG) and Pine plantations (PN), with their replicates, and the sampling design showing each habitat replicated seven times. The replicates are >300 m apart, sampled in a 2 × 5 sampling grid with sampling points located 10 m apart, Figure S2: Dendrogram showing similarities (based on the Bray Curtis similarity abundance data) in ant communities between the sampled habitat types (Blue-gum, Natural forests and Pine) and their replicates in Umgenipoort Research Facility, Table S1: The average canopy cover and the geographical coordinates (latitude and longitude) of each replicate in the three habitat types (Blue-gum, Natural forest and Pine) sampled in Umgenipoort Research Facility, Table S2: Ant subfamilies and species, with their abundance and richness in each habitat types (Blue-gum (BG); Pine (PN) and Natural forest (NF)) sampled in Umgenipoort Research Facility, in the Natal Midlands of Kwa-Zulu Natal, Table S3: SIMPER analysis results showing the species contributing mostly to the observed differences in

assemblage composition in each habitat type sampled in Umgenipoort Research Facility, using the Bray Curtis similarity matrix and a cut off low contributions of 90%. (Av.Abund—Average abundance, Av.Sim—Average similarity, Sim/SD—Similarity/Standard deviation, Contrib%—Contribution%, Cum%—Cumulative%), Table S4: SIMPER analysis results showing the species resulting in the dissimilarities in assemblage composition within the habitat types sampled in Umgenipoort Research Facility, using the Bray Curtis similarity and a cut off low contributions of 90%. (Av.Abund—Average abundance, Av.Sim—Average similarity, Diss/SD—Dissimilarity/Standard deviation, Contrib%—Contribution%, Cum%—Cumulative%).

Author Contributions: T.C.M. designed and conceptualized the study; T.A.M. and T.C.M. collected the data; T.A.M. analysed the data and led writing, under supervision by T.C.M. and T.C.M. was responsible for funding acquisition. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Oppenheimer Generations Research and Conservation and the National Research Foundation, Grant number 114416 to TC Munyai.

Institutional Review Board Statement: Permission to sample ants in the study site was approved by Oppenheimer Generations Research and Conservation.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data used in the current study are available in Table S2.

Acknowledgments: We would like to convey our appreciation to the Umgenipoort Research Facility owners for granting access to the study area, in particular Thulani Mnguni and his staff. We are more than grateful to Nkululeko Mbanjwa, Luyanda Hlamaphi, Lindiwe Khoza and, in particular, Nokubonga Thabethe, who helped us both in the lab and the field.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Armstrong, A.J.; Van Hensbergen, H.J. Impacts of Afforestation with Pines on Assemblages of Native Biota in South Africa. *S. Afr. For. J.* **1996**, *175*, 35–42. [CrossRef]
2. Lovett, J. Our forests our future. Report of the World Commission on forests and sustainable development. *Environ. Dev. Econ.* **2001**, *6*, 151–153.
3. Solar, R.R.D.C.; Barlow, J.; Andersen, A.N.; Schoereder, J.H.; Berenguer, E.; Ferreira, J.N.; Gardner, T.A. Biodiversity consequences of land-use change and forest disturbance in the Amazon: A multi-scale assessment using ant communities. *Biol. Conserv.* **2016**, *197*, 98–107. [CrossRef]
4. Klunk, C.L.; Giehl, E.L.H.; Lopes, B.C.; Marcineiro, F.R.; Rosumek, F.B. Simple does not mean poor: Grasslands and forests harbor similar ant species richness and distinct composition in highlands of southern Brazil. *Biota Neotrop.* **2018**, *18*, e20170507. [CrossRef]
5. Achury, R.; Suarez, A.V. Richness and Composition of Ground-dwelling Ants in Tropical Rainforest and Surrounding Landscapes in the Colombian Inter-Andean Valley. *Neotropical Èntomol.* **2018**, *47*, 731–741. [CrossRef]
6. Kanowski, J.; Catterall, C.P.; Wardell-Johnson, G.W. Consequences of broadscale timber plantations for biodiversity in cleared rainforest landscapes of tropical and subtropical Australia. *For. Ecol. Manag.* **2005**, *208*, 359–372. [CrossRef]
7. Stephens, S.S.; Wagner, M.R. Forest plantations and biodiversity: A fresh perspective. *J. For.* **2007**, *105*, 307–313.
8. Lamb, D. Large-scale Ecological Restoration of Degraded Tropical Forest Lands: The Potential Role of Timber Plantations. *Restor. Ecol.* **1998**, *6*, 271–279. [CrossRef]
9. Brockerhoff, E.G.; Jactel, H.; Parrotta, J.A.; Quine, C.P.; Sayer, J. Plantation forests and biodiversity: Oxymoron or opportunity? *Biodivers. Conserv.* **2008**, *17*, 925–951. [CrossRef]
10. Magura, T.; Tóthmérész, B.; Elek, Z. Impacts of Leaf-litter Addition on Carabids in a Conifer Plantation. *Biodivers. Conserv.* **2005**, *14*, 475–491. [CrossRef]
11. Bernadou, A.; Céréghino, R.; Barcet, H.; Combe, M.; Espadaler, X.; Fourcassié, V. Physical and land-cover variables influence ant functional groups and species diversity along elevational gradients. *Landsc. Ecol.* **2013**, *28*, 1387–1400. [CrossRef]
12. García-Martínez, M.A.; Martínez-Tlapa, D.L.; Pérez-Toledo, G.R.; Quiroz-Robledo, L.N.; Castaño-Meneses, G.; Laborde, J.; Valenzuela-González, J.E. Taxonomic, Species and Functional Group Diversity of Ants in a Tropical Anthropogenic Landscape. *Trop. Conserv. Sci.* **2015**, *8*, 1017–1032. [CrossRef]
13. Andersen, A.N. Responses of ant communities to disturbance: Five principles for understanding the disturbance dynamics of a globally dominant faunal group. *J. Anim. Ecol.* **2019**, *88*, 350–362. [CrossRef] [PubMed]

14. Andersen, A.N.; Penman, T.D.; Debas, N.; Houadria, M. Ant community responses to experimental fire and logging in a eucalypt forest of south-eastern Australia. *For. Ecol. Manag.* **2009**, *258*, 188–197. [CrossRef]
15. Bestelmeyer, B.T. The trade-off between thermal tolerance and behavioural dominance in a subtropical South American ant community. *J. Anim. Ecol.* **2008**, *69*, 998–1009. [CrossRef]
16. Sanders, N.J.; Lessard, J.-P.; Fitzpatrick, M.C.; Dunn, R.R. Temperature, but not productivity or geometry, predicts elevational diversity gradients in ants across spatial grains. *Glob. Ecol. Biogeogr.* **2007**, *16*, 640–649. [CrossRef]
17. Dean, W.R.J.; Turner, J.S. Ants nesting under stones in the semi-arid Karoo, South Africa: Predator avoidance or temperature benefits? *J. Arid Environ.* **1991**, *21*, 59–69. [CrossRef]
18. Munyai, T.C.; Foord, S.H. Ants on a mountain: Spatial, environmental and habitat associations along an altitudinal transect in a centre of endemism. *J. Insect Conserv.* **2012**, *16*, 677–695. [CrossRef]
19. Tizón, R.; Wulff, J.P.; Peláez, D.V. The effect of increase in the temperature on the foraging of Acromyrmex lobicornis (Hymenoptera: Formicidae). *Zoöl. Stud.* **2014**, *53*, 40. [CrossRef]
20. Colwell, R.K.; Coddington, J.A. Estimating terrestrial biodiversity through extrapolation. *Philos. Trans. R. Soc. B Biol. Sci.* **1994**, *345*, 101–118. [CrossRef]
21. Samways, M.J.; Caldwell, P.M.; Osborn, R. Ground-living invertebrate assemblages in native, planted and invasive vegetation in South Africa. *Agric. Ecosyst. Environ.* **1996**, *59*, 19–32. [CrossRef]
22. Robson, T.C.; Baker, A.C.; Murray, B.R. Differences in leaf-litter invertebrate assemblages between radiata pine plantations and neighbouring native eucalypt woodland. *Austral Ecol.* **2009**, *34*, 368–376. [CrossRef]
23. Munyai, T.C.; Khoza, L.R.; Foord, S.H. Hidden just beneath our feet: Subterranean ants of the KwaZulu-Natal midlands. *Afr. J. Ecol.* **2021**, *59*, 554–560. [CrossRef]
24. Mucina, L.; Rutherford, M. *The Vegetation of South Africa, Lesotho and Swaziland*; Strelitzia: Pretoria, South Africa, 2006; Volume 19.
25. Bulcock, H.; Jewitt, G. Field data collection and analysis of canopy and litter interception in commercial forest plantations in the KwaZulu-Natal Midlands, South Africa. *Hydrol. Earth Syst. Sci.* **2012**, *16*, 3717–3728. [CrossRef]
26. Mitchell, R.; Coutinho, T.; Steenkamp, E.; Herbert, M.; Wingfield, M. Future outlook forPinus patulain South Africa in the presence of the pitch canker fungus (Fusarium circinatum). *South. For. J. For. Sci.* **2012**, *74*, 203–210. [CrossRef]
27. Peerbhay, K.Y.; Mutanga, O.; Ismail, R. Investigating the Capability of Few Strategically Placed Worldview-2 Multispectral Bands to Discriminate Forest Species in KwaZulu-Natal, South Africa. *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.* **2014**, *7*, 307–316. [CrossRef]
28. Munyai, T.C.; Foord, S.H. An inventory of epigeal ants of the western Soutpansberg Mountain Range, South Africa. *Koedoe* **2015**, *57*, 1244. [CrossRef]
29. Botes, A.; McGeoch, M.A.; Robertson, H.G.; Van Niekerk, A.; Davids, H.P.; Chown, S.L. Ants, altitude and change in the northern Cape Floristic Region. *J. Biogeogr.* **2006**, *33*, 71–90. [CrossRef]
30. Parr, C.L.; Robertson, H.G.; Biggs, H.C.; Chown, S.L. Response of African savanna ants to long-term fire regimes. *J. Appl. Ecol.* **2004**, *41*, 630–642. [CrossRef]
31. Hohbein, R.R.; Conway, C.J. Pitfall traps: A review of methods for estimating arthropod abundance. *Wildl. Soc. Bull.* **2018**, *42*, 597–606. [CrossRef]
32. Sheikh, A.H.; Ganaie, G.A.; Thomas, M.; Bhandari, R.; Rather, Y.A. Ant pitfall trap sampling: An overview. *J. Entomol. Res.* **2018**, *42*, 421–436. [CrossRef]
33. Fisher, B.L.; Bolton, B. *Ants of Africa and Madagascar: A Guide to the Genera*; University of California Press: Oakland, CA, USA, 2016.
34. Chao, A.; Ma, K.H.; Hsieh, T.C. iNEXT (iNterpolation and EXTrapolation) Online: Software for Interpolation and Extrapolation of Species Diversity. Available online: http://chao.stat.nthu.edu.tw/wordpress/software (accessed on 19 June 2021).
35. Hammer, Ø.; Harper, D.A.T.; Ryan, P.D. Past: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontol. Electron.* **2001**, *4*, 9.
36. Jost, L. Entropy and diversity. *Oikos* **2006**, *113*, 363–375. [CrossRef]
37. Beck, J.; Schwanghart, W. Comparing measures of species diversity from incomplete inventories: An update. *Methods Ecol. Evol.* **2010**, *1*, 38–44. [CrossRef]
38. Clarke, K.R.; Gorley, R.N. *PRIMER v6: User Manual/Tutorial (Plymouth Routines in Multivariate Ecological Research)*; PRIMER-E: Plymouth, UK, 2006.
39. Ratsirarson, H.; Robertson, H.G.; Picker, M.D.; van Noort, S. Indigenous forests versus exotic eucalypt and pine plantations: A comparison of leaf-litter invertebrate communities. *Afr. Entomol.* **2002**, *10*, 93–99.
40. Ricketts, T.H. The Matrix Matters: Effective Isolation in Fragmented Landscapes. *Am. Nat.* **2001**, *158*, 87–99. [CrossRef]
41. Yekwayo, I.; Pryke, J.S.; Roets, F.; Samways, M.J. Surrounding vegetation matters for arthropods of small, natural patches of indigenous forest. *Insect Conserv. Divers.* **2016**, *9*, 224–235. [CrossRef]
42. Murray, B.R.; Baker, A.C.; Robson, T.C. Impacts of the Replacement of Native Woodland with Exotic Pine Plantations on Leaf-Litter Invertebrate Assemblages: A Test of a Novel Framework. *Int. J. Ecol.* **2009**, *2009*, 490395. [CrossRef]
43. Corley, J.C.; DiMarco, R.D.; Fischbein, D.; Lantschner, M.V.; Martínez, A.S.; Masciocchi, M.; Mattiacci, A.; Paritsis, J.; Villacide, J.M. A synthesis on the impact of non-native conifer plantations on ant and beetle diversity in north-western Patagonia. *South. For. J. For. Sci.* **2018**, *80*, 285–291. [CrossRef]

44. Eckert, M.; Gaigher, R.; Pryke, J.S.; Samways, M.J. Rapid recovery of soil arthropod assemblages after exotic plantation tree removal from hydromorphic soils in a grassland-timber production mosaic. *Restor. Ecol.* **2019**, *27*, 1357–1368. [CrossRef]
45. Riedel, J.; Dorn, S.; Brand, G.; Barrios, H.; Mody, K. Effects of ants on arthropod assemblages of a native timber tree in a tropical reforestation plantation. *J. Appl. Entomol.* **2012**, *137*, 418–428. [CrossRef]
46. Corley, J.; Sackmann, P.; Rusch, V.; Bettinelli, J.; Paritsis, J. Effects of pine silviculture on the ant assemblages (Hymenoptera: Formicidae) of the Patagonian steppe. *For. Ecol. Manag.* **2006**, *222*, 162–166. [CrossRef]
47. Stephens, S.S.; Bosu, P.P.; Wager, M.R. Effect of overstory tree species diversity and composition on ground foraging ants (Hymenoptera: Formicidae) in timber plantations in Ghana. *Int. J. Biodivers. Sci. Ecosyst. Serv. Manag.* **2016**, *12*, 96–107. [CrossRef]
48. Budiaman, A.; Haneda, N.F.; Nugraha, A.I.; Haikal, F. Impacts of Clear Cutting on Diversity of Ground Ants (Hymenoptera: Formicidae) in Pine Plantation Forest in Sukabumi Forest Management Unit, West Java. *J. Manaj. Hutan Trop.* **2021**, *27*, 42–49. [CrossRef]
49. Burghouts, T.; Ernsting, G.; Korthals, G.; De Vries, T.; Vries, T.D. Litterfall, leaf litter decomposition and litter invertebrates in primary and selectively logged dipterocarp forest in Sabah, Malaysia. *Philos. Trans. R. Soc. B Biol. Sci.* **1992**, *335*, 407–416. [CrossRef]
50. Georgiev, K.B.; Beudert, B.; Bässler, C.; Feldhaar, H.; Heibl, C.; Karasch, P.; Müller, J.; Perlík, M.; Weiss, I.; Thorn, S. Forest disturbance and salvage logging have neutral long-term effects on drinking water quality but alter biodiversity. *For. Ecol. Manag.* **2021**, *495*, 119354. [CrossRef]
51. Grodsky, S.M.; Campbell, J.W.; Fritts, S.R.; Wigley, T.B.; Moorman, C.E. Variable responses of non-native and native ants to coarse woody debris removal following forest bioenergy harvests. *For. Ecol. Manag.* **2018**, *427*, 414–422. [CrossRef]
52. Van Hengstum, T.; Hooftman, D.A.P.; Oostermeijer, J.G.B.; Van Tienderen, P.H. Impact of plant invasions on local arthropod communities: A meta-analysis. *J. Ecol.* **2014**, *102*, 4–11. [CrossRef]
53. Foitzik, S.; Heinze, J.; Oberstadt, B.; Herbers, J.M. Mate guarding and alternative reproductive tactics in the ant Hypoponera opacior. *Anim. Behav.* **2002**, *63*, 597–604. [CrossRef]
54. Borowiec, M.L. Generic revision of the ant subfamily Dorylinae (Hymenoptera, Formicidae). *ZooKeys* **2016**, *608*, 1–280. [CrossRef]
55. Ramos, C.S.; Bellocq, M.I.; Paris, C.I.; Filloy, J. Environmental drivers of ant species richness and composition across the Argentine Pampas grassland. *Austral Ecol.* **2018**, *43*, 424–434. [CrossRef]
56. Samways, M.J. Land Forms and Winter Habitat Refugia in the Conservation of Montane Grasshoppers in Southern Africa. *Conserv. Biol.* **1990**, *4*, 375–382. [CrossRef]
57. Stuble, K.L.; Pelini, S.L.; Diamond, S.E.; Fowler, D.A.; Dunn, R.R.; Sanders, N.J. Foraging by forest ants under experimental climatic warming: A test at two sites. *Ecol. Evol.* **2013**, *3*, 482–491. [CrossRef] [PubMed]
58. Kaspari, M.; O'Donnell, S.; Kercher, J.R. Energy, Density, and Constraints to Species Richness: Ant Assemblages along a Productivity Gradient. *Am. Nat.* **2000**, *155*, 280–293. [CrossRef] [PubMed]