Effects of Different Habitats on Ant Functional Groups: A Case Study in Lüchun County, Yunnan Province (Postprint)

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Abstract

To investigate the effects of habitat changes driven by land-use change on ant functional groups, we surveyed ant communities in seven habitat types in Lüchun County, Yunnan Province using pitfall traps and Winkler bags: natural secondary forest (N), eucalyptus forest (E), lac forest (L), rubber forest (R), lac corn agroforest (M), dry land (D), and farmland (F). A total of 37,891 ant individuals were collected, belonging to 8 subfamilies, 52 genera, and 137 species. Based on four ecological characteristics—competitive relationships, habitat requirements, behavioral dominance, and responses to environmental stress and disturbance—the 52 genera were classified into seven functional groups: Dominant Dolichoderinae (DD), Subordinate Camponotini (SC), Generalized Myrmicinae (GM), Opportunists (O), Cryptic species (C), Climate specialists (CS), and Specialist predators (SP). Species richness across functional groups was ranked as: Opportunists (10 genera, 32 species) > Climate specialists (15 genera, 29 species) > Generalized Myrmicinae (3 genera, 24 species) > Cryptic species (14 genera, 21 species) > Subordinate Camponotini (2 genera, 16 species) > Specialist predators (6 genera, 14 species) > Dominant Dolichoderinae (2 genera, 2 species). The abundance of ants in the Subordinate Camponotini, Climate specialists, and Cryptic species functional groups accounted for a higher proportion in natural secondary forests, eucalyptus forests, and lac forests, whereas the Dominant Dolichoderinae functional group accounted for a higher proportion in farmlands with high disturbance. Except for the Dominant Dolichoderinae with only 2 genera and 2 species, the species richness of most functional groups in natural secondary forests, eucalyptus forests, lac forests, and lac corn agroforests was significantly higher than that in farmland, while the species richness of the Specialist predator functional group showed little difference across habitats. The community structure of ant functional groups in eucalyptus forests and lac forests was relatively similar to that in natural secondary forests, while the community structure in rubber forests, lac corn agroforests, and dry land was similar. The degree of variation in species composition of Climate specialists, Generalized Myrmicinae, Opportunists, and Subordinate Camponotini among different habitat types was greater than that among replicate plots within the same habitat type. The ant communities of the Generalized Myrmicinae, Opportunists, and Subordinate Camponotini functional groups showed significant variation across habitats, with ant communities in eucalyptus forests, lac forests, and natural secondary forests being overall dissimilar to those in dry land and farmland. Cryptic species and Climate specialists were only relatively similar between eucalyptus forest and lac forest ant communities. The ant communities of the Specialist predator functional group showed no significant variation across habitats. Ant functional groups can indicate habitat changes, with Generalized Myrmicinae, Subordinate Camponotini, and Opportunists showing relatively good indicative effects. Essentially, this reflects differential responses of abundance of different species within functional groups and community composition changes within functional groups to disturbance and resource availability resulting from habitat changes.

Full Text

Effects of Habitat on Ant Functional Groups: A Case Study of Lüchun County, Yunnan Province, China

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Abstract

To explore the effects of habitat change driven by land use change on ant functional groups, we investigated ant communities in seven habitat types in Lüchun County, Yunnan Province using pitfall traps and Winkler bags. The habitats included secondary natural forest (N), eucalyptus plantation (E), lac insect plantation (L), rubber plantation (R), lac insect-corn agroforest (M), dryland (D), and farmland (F). A total of 37,891 individual ants were collected, belonging to 137 species, 52 genera, and 8 subfamilies of Formicidae. Based on four ecological characteristics—competitive interactions, habitat requirements, behavioral dominance, and response to environmental stress and disturbance—the 52 ant genera were divided into seven functional groups: Dominant Dolichoderinae (DD), Subordinate Camponotini (SC), Generalised Myrmicinae (GM), Opportunists (O), Cryptic Species (C), Climate Specialists (CS), and Specialist Predators (SP).

Species richness across functional groups ranked as: Opportunists (10 genera, 32 species) > Climate Specialists (15 genera, 29 species) > Generalised Myrmicinae (3 genera, 24 species) > Cryptic Species (14 genera, 21 species) > Subordinate Camponotini (2 genera, 16 species) > Specialist Predators (6 genera, 14 species) > Dominant Dolichoderinae (2 genera, 2 species). Subordinate Camponotini, Climate Specialists, and Cryptic Species showed higher abundance proportions in secondary natural forests, eucalyptus plantations, and lac insect plantations, while Dominant Dolichoderinae had higher proportions in highly disturbed farmlands. Except for Dominant Dolichoderinae (only 2 genera and 2 species), most functional groups exhibited significantly higher species richness in secondary natural forests, eucalyptus plantations, lac insect plantations, and lac insect-corn agroforests compared to farmlands, whereas Specialist Predators showed little difference in species richness across habitats.

Community structures of ant functional groups in eucalyptus and lac insect plantations were similar to those in secondary natural forests, while those in rubber plantations, lac insect-corn agroforests, and drylands were also similar to each other. Climate Specialists, Generalised Myrmicinae, Opportunists, and Subordinate Camponotini showed greater variation in species composition among different habitat types than among replicate plots within the same habitat type. The ant communities of Generalised Myrmicinae, Opportunists, and Subordinate Camponotini varied significantly across habitats, with communities in eucalyptus plantations, lac insect plantations, and secondary natural forests being dissimilar to those in drylands and farmlands. Cryptic Species and Climate Specialists were only similar between eucalyptus and lac insect plantations, while Specialist Predator communities showed no significant changes across habitats. Ant functional groups can indicate habitat change, with Generalised Myrmicinae, Subordinate Camponotini, and Opportunists serving as better indicators. Essentially, these differences reflect how variations in species abundance within functional groups and community composition changes within functional groups respond differently to disturbances and resource availability caused by habitat change.

Keywords: Mountain area, Southwestern China; Ant functional group; Habitat change; Plantation; Bio-indication

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Introduction

Land use change refers to alterations in land use patterns, cover, and intensity resulting from changes in land characteristics and human activities, representing the concentrated interaction between human activities and natural ecosystems. Such changes include transforming natural landscapes into human-utilized land and modifying existing management practices on human-dominated lands, such as forest clearing and intensifying land use. China is a mountainous country, with mountainous areas accounting for two-thirds of its total land area; in southwestern China alone, mountains comprise 92.6% of the total land area. The unique topography of mountainous regions creates sensitive and fragile ecological environments, and land use intensity in southwestern China shows an increasing trend. Habitat change driven by land use change typically leads to reduced species diversity, primarily through habitat loss or destruction and changes in vegetation structure and species composition.

For animal groups, varying degrees of land disturbance alter resource availability and habitat quality, thereby affecting animal communities. Land use change transforms original landscapes, creating fragmented habitat patches, reducing habitat quality and system stability, accelerating species loss, and altering terrestrial ecosystem functions. However, traditional diversity research only focuses on measuring species diversity—providing information on species presence and abundance—while ecosystem conservation and management aim to protect ecosystem services and functions, which should be prioritized.

Ants (Hymenoptera: Formicidae) are widely distributed across terrestrial ecosystems and play important ecological roles. The concept of ant functional groups was first proposed by Greenslade based on studies in Australia' s arid regions, and later refined by Andersen according to competitive relationships, habitat requirements, behavioral dominance, and responses to environmental stress and disturbance at the genus level. Functional group classification significantly reduces system complexity, diminishes the role of individual species in ecosystems, and better indicates relationships between organisms and environmental changes, providing important bio-indication value.

Research shows that ant functional group abundance changes significantly with stress and disturbance, effectively revealing patterns of ant community variation along biogeographical gradients and community dynamics at large scales, thereby indicating environmental change. However, these studies have not explained why ant functional groups vary along different vegetation types or environmental gradients. This study investigates ant communities across different habitat types in Yunnan' s mountainous regions, classifies ant functional groups, and compares abundance and community structure changes among functional groups to explore whether functionally grouped ants can indicate habitat change at local scales and how they respond to such changes in terms of abundance and community structure, providing a theoretical basis for using ants as indicator organisms in rapid biodiversity assessment.

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1. Materials and Methods

1.1 Sample Plot Setup and Overview

Due to the complex mountainous terrain in Yunnan Province, it is difficult to find habitats that differ in only one condition while being uniform in all others. Therefore, sample plots representing land use change were selected based on comprehensive consideration of vegetation structure, land use patterns, and natural environmental factors. The study area was located in Lüchun County, Yunnan Province, where seven habitat types were selected for ant community surveys: secondary natural forest (N), eucalyptus plantation (E), lac insect plantation (L), rubber plantation (R), lac insect-corn agroforest (M), dryland (D), and farmland (F). The selected plots had consistent slope, aspect, soil conditions, and climate. For each habitat type, two replicate plots larger than

1 ha were established, with consistent vegetation, canopy density, and litter conditions between replicates.

Secondary natural forests were dominated by tall broadleaf trees with abundant ground litter and approximately 70% canopy density. Eucalyptus plantations consisted of 6-year-old *Eucalyptus grandis* with well-developed understory shrubs and herbs, surface litter, and approximately 50% canopy density. Lac insect plantations were dominated by 6–8-year-old *Dalbergia balansae* as the primary host plant for lac insects, with a developed herbaceous layer, minor disturbances, and approximately 50% canopy density. Rubber plantations contained approximately 30-year-old *Hevea brasiliensis* with fixed tapping routes, small shrubs and herbs in inter-row spaces, approximately 75% canopy density, and high disturbance. Lac insect-corn agroforests represented a pattern of growing food crops under lac insect plantations, with lower host plant density than lac insect plantations, higher disturbance, and approximately 40% canopy density. Drylands were used for food production during the rainy season and left fallow during the dry season, with substantial disturbance. Farmland represented intensively used land where rice (*Oryza sativa*) was planted before sampling, then left fallow after harvest, with compacted soil, few herbaceous plants, ant nests in field ridges, and the highest disturbance level.

1.2 Survey Methods

In October 2012 (late rainy season) and April 2013 (dry season), ant communities in the ground, litter, and canopy layers of all habitat types were surveyed using pitfall traps and Winkler bags. For the ground layer, 15 pitfall traps (6 cm diameter, 8 cm height plastic cups) were arranged in a 5$×$3 grid with 10 m spacing in each plot. For the canopy layer, arboreal ant traps baited with a mixture of tuna and honey were fixed with thin wire on tree trunks 1.5 m above ground near each pitfall trap, yielding 15 samples per plot. For the litter layer, 1 m × 1 m quadrats located 5 m from pitfall traps were selected to collect litter and 3 cm of topsoil, which was sieved (1 cm mesh) and placed in Winkler bags for 72 hours to collect ants, with 15 samples per plot. Each ground and arboreal trap contained 50 mL of 50% ethylene glycol as trap fluid. After 48 hours, ants were collected and all specimens were stored in 75% alcohol in centrifuge tubes for laboratory identification. Ants were identified to species using relevant literature, with unidentifiable specimens treated as morphospecies.

Following Andersen' s functional group classification based on competitive relationships, habitat requirements, behavioral dominance, and responses to environmental stress and disturbance at the global genus level, we used our ant survey data and ecological information from ant literature and websites (AntWeb, AntWiki, and AntCat) to classify the 52 ant genera into seven functional groups at the genus level based on four ecological perspectives: competitive relationships, habitat requirements, behavioral dominance, and response to environmental stress and disturbance .

1.3 Data Analysis

1.3.1 Effects of Habitat Change on Ant Functional Groups We used percentage bar charts of ant abundance for different functional groups across habitat types to reveal the effects of land use change. Before analysis, ant individual counts were converted to a 6-level scoring system to prevent overrepresentation of samples near nests or foraging trails: 1 individual = 1, 2–5 = 2, 6–10 = 3, 11-20 = 4, 21-50 = 5, >50 = 6. Scored abundance data were used to calculate the proportional composition of functional groups in each plot and generate bar charts. Non-metric multidimensional scaling (NMDS) ordination was performed at the genus level after standardizing the data, with stress coefficients calculated to evaluate ordination quality (stress < 0.1 indicates good representation). Analysis of similarities (ANOSIM) was used to test the significance of community structure differences, with all analyses conducted using PRIMER v7.

1.3.2 Effects of Habitat Change on Functional Group Composition Principal coordinate analysis (PCO) was performed on transformed ant abundance data for different functional groups, with species represented by lines to illustrate relationships between species and plots. Ant community structure was compared at the 50% similarity level. PCO ordination plots were analyzed and generated using PERMANOVA+ in PRIMER v7.

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2. Results

2.1 Effects of Habitat Change on Ant Functional Group Composition and Structure

The survey collected 37,891 ant individuals belonging to 137 species, 52 genera, and 8 subfamilies, which were classified into seven functional groups . Species richness ranked as: Opportunists (10 genera, 32 species) > Climate Specialists (15 genera, 29 species) > Generalised Myrmicinae (3 genera, 24 species) > Cryptic Species (14 genera, 21 species) > Subordinate Camponotini (2 genera, 16 species) > Specialist Predators (6 genera, 14 species) > Dominant Dolichoderinae (2 genera, 2 species). Most functional groups showed higher abundance in secondary natural forests, eucalyptus plantations, and lac insect plantations, including *Hypoponera*, *Strumigenys*, *Rhoptromyrmex*, *Pseudolasius*, *Oecophylla*, and *Tetramorium*. *Monomorium* and *Camponotus* had higher abundance in lac insect plantations and lac insect-corn agroforests, while *Iridomyrmex* was more abundant in drylands and farmlands .

Species richness of ant functional groups varied across habitat types. Except for Dominant Dolichoderinae (only 2 genera and 2 species), most functional groups showed significantly higher species richness in secondary natural forests, eucalyptus plantations, lac insect plantations, and lac insect-corn agroforests compared to farmlands, while Specialist Predators showed little difference across habitats . Cryptic Species richness was highest in eucalyptus plantations; Climate Specialists were most species-rich in secondary natural forests and lac insect plantations; Generalised Myrmicinae richness was higher in secondary natural forests, eucalyptus plantations, and rubber plantations; Opportunists were most species-rich in secondary natural forests and lac insect plantations; Subordinate Camponotini richness peaked in lac insect plantations; and Specialist Predators were most diverse in secondary natural forests, though differences among habitats were small .

Habitat change differentially affected the proportional composition of ant functional groups [Figure 1: see original paper]. Generalised Myrmicinae comprised 20–50% of all ants in every plot, with higher proportions in eucalyptus plantations, rubber plantations, and drylands, lowest in farmlands, and intermediate levels in agroforests, lac insect plantations, and secondary natural forests. Climate Specialists accounted for less than 20% of ants in each plot, with relatively higher proportions in rubber plantations and agroforests, followed by secondary natural forests, lac insect plantations, and eucalyptus plantations—all significantly higher than in farmlands and drylands. Opportunists reached their highest proportion in farmlands, second-highest in secondary natural forests, and approximately 15% in remaining habitats. Subordinate Camponotini proportions were higher in agroforests and lac insect plantations, moderate in secondary natural forests, and lower in other habitats. Cryptic Species proportions were higher in lac insect plantations, eucalyptus plantations, secondary natural forests, and drylands, moderate in agroforests and rubber plantations, and absent from farmlands. Specialist Predators showed little variation across habitats except for lower proportions in farmlands. Dominant Dolichoderinae occurred only in drylands and farmlands, reaching 30% in highly disturbed farmlands.

Habitat change significantly affected ant functional group community structure, with significant differences among habitat types (ANOSIM Global $R = 0.935$, $P = 0.001$) and a stress coefficient of 0.1. Eucalyptus and lac insect plantation communities were similar to secondary natural forests (at 50% similarity), while rubber plantations, lac insect-corn agroforests, and drylands formed another similar group. Overall, farmland functional group communities were dissimilar to the other six habitat types (at 50% similarity) [Figure 2: see original paper].

2.2 Effects of Habitat Change on Species Within Functional Groups

Functional group changes reflected habitat variation, with habitat type causing greater ant community changes than variation among replicate plots within the same habitat. Specialist Predator communities showed no significant differences across all habitat types [Figure 3f: see original paper]. For Cryptic Species, differences among most habitat types were smaller than differences among replicates within the same type [Figure 3a: see original paper]. The remaining four functional groups showed greater differences among most habitat types than among replicates within habitats [FIGURE:3b, 3c, 3d, and 3e].

Habitat change had minor effects on Cryptic Species community composition [Figure 3a: see original paper]. This functional group showed similar community structure between eucalyptus and lac insect plantations, with *Recurvidris nuwa*, *Oligomyrmex altinodus*, *Plagiolepis alluaudi*, and *Hypoponera confinis* strongly associated with these habitats (Spearman correlation coefficient > 0.5). Other habitats showed mixed patterns without clear trends.

Habitat change had minor effects on Climate Specialist community composition [Figure 3b: see original paper]. No clear patterns emerged in community structure similarity across habitat types; eucalyptus plantations were dissimilar to all other types. *Rhoptromyrmex wroughtonii* and *Pseudolasius silvestrii* showed strong associations with eucalyptus plantations (Spearman correlation coefficient > 0.5).

Habitat change strongly affected Generalised Myrmicinae community composition [Figure 3c: see original paper]. This functional group showed similar community structure among eucalyptus plantations, lac insect plantations, and secondary natural forests, with *Crematogaster biroi*, *C. rogenhoferi*, *C. ferrarii*, and *Pheidole lighti* strongly associated with these habitats (Spearman correlation coefficient > 0.5). Lac insect-corn agroforests and dryland 2 also showed similarity, with *P. yeensis*, *P. spathifera*, *P. capellini*, and *Monomorium chinensis* strongly associated with these plots (Spearman correlation coefficient > 0.5). *Pheidole noda* was only strongly associated with farmland 1 (Spearman correlation coefficient > 0.5).

Habitat change strongly affected Opportunist community composition [Figure 3d: see original paper]. This functional group showed similar community structure among lac insect plantations, eucalyptus plantations, rubber plantations, and lac insect-corn agroforests, with *Tapinoma melanocephalum*, *Paratrechina flavipes*, and *Lepisiota reticulate* strongly associated with these habitats (Spearman correlation coefficient > 0.5). *Paratrechina bourbonica*, *Cardiocondyla wroughtonii*, and *C. nuda* were strongly associated with farmlands (Spearman correlation coefficient > 0.5), while *Technomyrmex antennus*, *Odontomachus circulus*, *Aphaenogaster schurri*, and *Tetramorium ciliatum* were strongly associated with secondary natural forests (Spearman correlation coefficient > 0.5).

Habitat change strongly affected Subordinate Camponotini community composition [Figure 3e: see original paper]. This functional group showed similar community structure among lac insect plantations, lac insect-corn agroforests, and secondary natural forest 2, with *Camponotus lasiselene*, *C. singularis*, *C. albosparsus*, and *Polyrhachis paracamponota* strongly associated with these habitats (Spearman correlation coefficient > 0.5). Eucalyptus plantations, lac insect-corn agroforests, and rubber plantations also showed similarity, with *C. nicobarensis*, *C. mitis*, and *P. halidayi* strongly associated with these habitats (Spearman correlation coefficient > 0.5). *Camponotus parius* was strongly associated with drylands and farmlands (Spearman correlation coefficient > 0.5).

Habitat change had minor effects on Specialist Predator community composition

[Figure 3f: see original paper]. Overall, this functional group divided into two major categories across the seven habitat types: one comprising secondary natural forests, eucalyptus plantations, lac insect plantations, and rubber plantations (with *Pachycondyla luteipes*, *Anochetus yunnanensis*, *A. subcoecus*, and *P. javana strongly associated, Spearman correlation coefficient > 0.5), and another comprising lac insect-corn agroforests, drylands, and farmlands (with* Odontoponera transversa* and *P. rufipes* strongly associated, Spearman correlation coefficient > 0.5).

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3. Discussion and Conclusion

At local scales, ant functional groups can indicate land use change, as species composition and community structure within functional groups change with environmental conditions. Our results demonstrate that ant functional groups can reveal the effects of vegetation type change on ant communities. Habitat change most strongly affected Generalised Myrmicinae, Subordinate Camponotini, and Opportunists, with clear differences in species composition and community structure across habitat types and associated species exhibiting distinct ecological characteristics, making these groups effective indicators of habitat and environmental change.

Although species composition of Cryptic Species, Climate Specialists, and Specialist Predators differed among habitats, their community structures showed no significant differences. Additionally, Subordinate Camponotini, Climate Specialists, and Cryptic Species accounted for higher abundance proportions in less disturbed plots, while Dominant Dolichoderinae appeared only in highly disturbed plots, indicating that Dominant Dolichoderinae, Cryptic Species, Specialist Predators, and Climate Specialists have relatively weaker indicator roles across different habitats.

Ant functional groups can indicate habitat change because different groups respond differently to disturbance and resource availability. Dominant Dolichoderinae are considered characteristic of open, simply structured habitats with large populations, high activity, and behavioral dominance. In this study, this group occurred only in drylands and farmlands at low abundance proportions, indicating simple habitat structure and limited resource availability in these habitats. In warm habitats lacking Dominant Dolichoderinae, Generalised Myrmicinae represent the most species-rich functional group, as observed in South African tropical savannas and most global rainforests. In this study, Generalised Myrmicinae comprised large proportions in plantations and secondary natural forests, suggesting these artificial forests possess certain forest characteristics in this subtropical monsoon region.

Opportunists are unspecialized species whose behavior is influenced by other ant groups, becoming dominant only when resource availability is low or disturbance severely affects ant reproduction and diversity. In this study, Opportunists did not show strong behavioral dominance in plantations, indicating these habitats have relatively low disturbance and can provide necessary resources for ant survival. Subordinate Camponotini have moderate competitive ability and are behaviorally submissive to dominant ant groups. Their relatively high proportions in plantations suggest these habitats have some heterogeneity and abundant resources that can provide niches for competitively weaker functional groups.

Different functional groups respond inconsistently to environmental conditions, resulting in varying bio-indication effectiveness. Generalised Myrmicinae, Subordinate Camponotini, and Opportunists responded more strongly to habitat change (in terms of species composition and community structure) than Climate Specialists, Cryptic Species, and Specialist Predators. This may be because the former three groups have weaker habitat requirements, often nest underground, and are distributed across different land use types, with their abundance changing along land use intensity gradients, providing more direct indication. The latter three groups have stricter habitat requirements, depending on specific conditions such as arboreal species, litter-dwelling species, and specialized predators; when habitats lack appropriate conditions, these functional groups are absent, resulting in weaker indication.

This study reveals the bio-indication value of ant functional groups and their responses to habitat change at local scales, demonstrating that different functional groups have varying indication effectiveness. Currently, few studies in China have applied ant functional groups at large scales, and their bio-indication value deserves further exploration in future research.

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