The Ground-Dwelling Ant Community and a Butterfly Inventory of a Forest Restoration Site near La Fortuna, Costa Rica

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Abstract

This study took place at the end of May 2009 during the rainy season, and it analyzes the structure and composition of ground-dwelling ant communities in a forest restoration site near La Fortuna Costa Rica as well as providing a preliminary butterfly checklist of the reforestation site. *Solenopsis geminata, Solenopsis* JTL-005, *Wasmannia auropunctata, Ectatomma ruidum,* and *Pheidole flavens* were the most abundant species and are behaviorally dominant. The species diversity and richness of the three studied habitats in order from highest to lowest was the large disturbed forest patch, the recovering pastureland, and the small disturbed forest patch. The abundance and evenness of the community is indicative of a log distribution of species richness indicating a community in the earlier stages of restoration and succession. The butterfly inventory provided 86 species. The disturbed forest patches had the greatest number of species by far, and the monocultures, as expected, had only a few of the most common species.

Introduction

Insects compose an estimated 64% of all species and they perform a disproportionate amount of functional roles including herbivory, pollination, decomposition, predation, and parasitism. For these reasons insects are integral in the functioning of any terrestrial and many aquatic ecosystems. Two particularly important indicator taxa for measuring biodiversity and restoration efforts are ants and butterflies. The shear abundance and ecological dominance of ants in nearly all terrestrial ecosystems make them the key constituents of biodiversity in many habitats, especially in tropical forests. The contribution of ants to soil health and their resilience to human disturbance make them ideal indicators of restoration success. (Holldobler and Wilson 1990) Butterflies are conspicuous members of any tropical fauna, and their appeal as well as the available literature on butterflies makes them important indicators of biodiversity (Speight et al. 2008). Both ants and butterflies effectively reflect the diversity of plants, which affect their host resources and habitat structure (Magurran 2004).

The study was aimed at measuring baseline data of ground-dwelling ant and butterfly indicator taxa to assess the progress of a forest restoration site in Costa Rica. The study examined the structure and composition of the ant community to provide a baseline assessment of the ant community as well as to provide a baseline inventory of butterflies to assist future research as well as provide general information on community structure. This data will help future research monitor restoration progress in the area.

Materials and Methods

Study Site. The study took place at Leaves and Lizards Volcano Retreat near La Fortuna, Costa Rica and Arenal Volcano from May 25-May29, 2009 and May 31, 2009 during the rainy season. The site is an approximately 11 ha tropical wet forest at about 500m elevation being restored from cattle pasture to forest. The area is in the second year of reforestation and is composed of plots of mixed disturbed forest, monocultures (mostly teak), and ornamental landscaping.

Sampling of Butterflies. Sampling of butterflies took place between 9hrs-12hrs and 14hrs-16hrs daily with occasional interruptions in sampling due to weather. There were three main sampling plots. The first was in a disturbed forest plot between bird points L and N (forest A). The second was in a smaller disturbed forest plot between bird points A and B (forest B), and the last was a teak monoculture between points C and D. Sampling was conducted using an aerial net and sightings. Species composition was recorded; however, the number of individuals per species was not determined. Butterflies were identified to species level.

Sampling of Ground-Dwelling Ants. Ground-dwelling ant sampling took place in two ways. The first was pitfall trapping using large centrifuge tubes filled a fourth with 90% ethyl acetate. Traps were laid in the ground and were spaced about 5m apart. Traps were collected after 72 hours. There were eight trap sites between bird points K and N. Only four were successfully collected; the other four were either washed out or disturbed by large animals. The second sampling method was baiting using tuna or granola and large flat, intact litter leaves as platforms. Baiting took place between bird points J and N. There were 14 bait sites about 4m apart from each other. There were 14 additional bait sites set up in the litter of a disturbed forest patch near bait site 5 and bird point L. In this intensive sampling site baits were about 2m apart. All baits were checked from 30 minutes to two hours after being set. Bait sites 1,2,8,9, and 14, and pitfall traps 1 and 2 were in recovering pastureland. Bait sites 10-13 were in a small disturbed forest patch, and bait sites 3-7, the intensive sampling bait sites, and pitfall traps 3 and 4 were in a larger disturbed forest patch. All ants were identified to species level.

The indexes used to examine community structure were ant functional groups, S (species richness), S_{Jack1} (Jackknife 1 species richness estimator), α diversity, H (Shannon's diversity index), and D (the Simpson diversity index). A rank-abundance curve was also formed. The Jackknife 1 species richness estimator (S_{Jack1}) was estimated as: $S_{Jack1}=S_{obs}+L(n-1/n)$, where S_{obc} is the observed species richness, L is the number of species occurring in one sample, and n is the number of samples. The α diversity was calculated as: $\alpha=[N(1-x)]/x$, and x is estimated from the solution of $S/N=[(1-x)(-\ln(1-x))]/x$ where S is the number of species and N is the number of individuals. The Shannon diversity index (H) was estimated as: $H=-\Sigma p_i \ln p_i$, where p_i is the proportion of workers of the ith species. The Simpson index is calculated as $D=\Sigma[(n_i(n_i-1))/(N(N-1))]$, where n_i is the number of individuals of the ith species and N is the total number of individuals sampled. The reciprocal (1/D) was used since diversity increases as the index number increases.

Results

Butterflies. There were 86 recorded species of butterflies for the three main habitats sampled. The teak area had 9 species, forest A had 65 species, and forest B had 68 species.

Ground-Dwelling Ants. The total number of ground-dwelling ants sampled at pitfall traps and bait was 642 in 44 species. The slope of the rank-abundance curve for the entire study area is indicative of a log series distribution (Figure 1). Table 2 lists the recorded species. *Solenopsis geminata, Solenopsis* JTL-005, *Wasmannia auropunctata, Ectatomma ruidum,* and *Pheidole flavens* were the most abundant species and composed 16.36, 13.55, 11.21, 10.59, and 8.26% respectively of the total ants sampled. All were found in each habitat except *S. geminata* was not found in the small disturbed forest patch, and *W. auropunctata* was not found in the recovering pastureland. *S. geminata* was the most abundant species in the pasture (27.03%), *S.* JTL-005 was the most abundant in the large forest patch (21.07%), and *W. auropunctata* was the most abundant species in the small forest patch (49%).

The species richness for the 3 habitats were 40 for the large forest patch, 13 in the recovering pasture, and 11 in the small forest patch (Table 3). Jackknife 1 speceis richness estimate values for the small forest patch and the recovering pasture were varied little from the observed value. The Jackknife 1 estimate value for the large forest patch differed greatly from the observed value, which was 65 versus 40 observed. The total observed species richness was 44 and the estimated richness was 66.

The three diversity indexes (alpha diversity, Shannon index, and reciprocal Simpson index) all showed very similar patterns of diversity over the three habitats and the total ant fauna sampled. The diversities of the small forest patch and the recovering pasture were the lowest and were very similar. The diversity of the large forest patch was the highest and was similar to the total diversity.

The functional group composition for the entire study area was, from largest percent composition to smallest, tropical climate specialists (TCS), 37%; general myrmecines (GM), 24%; cryptic specialists (C), 22%; opportunist species (O), 15%; tramp species (T), 1.4%, specialist predators (SP), 0.47%; and subordinate Campontini (SC), 0.31% (Figure 2). There were no dominant Dolichoderinae sampled.

Discussion

Ants. The abundance of *Solenopsis geminata, Solenopsis* JTL-005, *Wasmannia auropunctata, Ectatomma ruidum,* and *Pheidole flavens*, which are all behaviorally dominant species, can severely affect the species composition and abundance of other ants (Andersen 1997, Cammell et al. 1996, Cerda et al. 2009). These dominant ants can drastically reduce the foraging success of other subordinate species (Longino 2009). This was observed at bait sites where, when a dominant species began to congregate at bait, they would guard it from other species and the bait would be covered by the dominant species within an hour. *S. geminata* and *P. flavens* would have large numbers of major workers to help guard the baits, and *S. geminata* would cover the bait in soil while continuing to forage.

The diversity and richness of the area was likely an accurate measurement since the diversity idices used were highly similar across sites. When several indices are similar in their patterns of diversity across different sites, the ecosystem diversity is likely effectively measured (Osborn et al. 1999). The estimated species richness (66) was much higher than the actual species richness (44) suggesting the need for more exhaustive sampling; however, since the observed and estimated species accumulation curves (Figure 3) clearly began to plateau, sampling was substantial enough to give an accurate estimate of species richness and diversity. The large disturbed forest patch provided the highest diversity and species richness since it also gave the largest array of microclimates, relatively controlled climate, and the greatest number of niches for exploitation. All of these traits are most like that of a more mature forest, giving the large disturbed forest patch the expected highest diversity. An unusual result likely caused by dominant ant species is that the small forest patch had the lowest species richness, and a much lower diversity than the large forest patch and was closest to the diversity of the recovering pastureland. The small size of the forest patch increased edge effects throughout which can adversely effect the microlimatic conditions and constant temperatures found in larger more mature forest patches, and ants are particularly sensitive to these adverse results of the edge effect. It drives away many subordinate ants causing dominate species not sensitive to such conditions to take hold of the area and further drive away any intermediately dominant ants (Andersen 2000). The small forest patch samples were composed of 49% *Wasmannia auropunctata* and 25% *Pheidole flavens.* These are both dominant species that are quick to defend resources that they find, which would indicate why 74% of species sampled from baiting in this forest patch were these two species. These two species would often quickly recruit to the bait in the small forest patch due to their abundance and aggressive nature and when present at the bait they would guard it.

The low diversity of the reforestation area is largely due to the number of abundant species using most of the resources and the many rare species that had minimal available resources giving a low evenness of the ant community and is graphically represented by the rank-abundance curve (Figure 1). The rank-abundance curve represents a log series distribution, which occurs when the sample has a few common species as well as many rare species (Longino 2000). The rare species use remaining resources not appropriated by the abundant species; they fill available niches in a manner similar to niche-preemption hypothesis, which is the geometric series distribution of species abundance (May 1975). The situation of the niche-preemption hypothesis occurs when species arrive in an unsaturated environment at random time intervals and exploit the increasingly smaller proportion of remaining resources. Such areas have a low evenness but can have high species richness. To monitor the restoration process and succession rank-abundance distributions should continue to be formed to graphically represent the richness and abundance of the reforestation site. As reforestation continues the richness and evenness of the community should increase and there should be a shift in the rank-abundance curve from the low evenness of the log series distribution indicative of a habitat in the early stages of restoration to, eventually, the log normal and broken stick models which reflect a relatively uniform use of resources and a higher species richness.

Behavioral dominance on the rainforest floor in a healthy forest is poorly developed, and the absence of dominant Dolichoderinae is suspected. Dominant Dolichoderinae are highly dominant in the neotropics but only in forest canopies. The functional group composition found in most tropical wet forest floors are a large percentage of general myrmicines, tropical climate specialists, opportunists, and cryptic species; however, the response of functional group composition to disturbance level is poorly known in tropical forests (Andersen 2000). The proportions of functional groups match what is generally the expected ant composition. Attention should continue to be given to the functional group composition of ants in the study site as reforestation continues to better understand what changes in functional group composition imply about forest health and disturbance levels.

To further understand ground-dwelling ant diversity and community structure of the study area and to maximize their abilities as indicator taxa several additions should be added to future studies. The standard ground-dwelling ant sampling protocol (A.L.L. protocol) (Agosti and Alonso 2000) should be used to maximize repeatability, obtain quantifiable data that can effectively sample the entire ground-dwelling ant fauna. It implements the use of extensive pitfall trapping and mini-Winkler extracts, and is shown to obtain the greatest diversity of ants with minimal effort. This combined with baiting can provide a complete picture of the ground-dwelling ant fauna.

Butterflies.

Developing a faunal checklist of the butterfly fauna is a key part of understanding potential local endemism and unusual faunal compositions, aid in conservation efforts, and allow for more in depth future studies (DeVries 1987, Emmel and Austin 1990). The preliminary butterfly checklist (Table 1) provides baseline information to characterize the butterfly fauna of the forest restoration site.

There were a total of 86 species found. Butterfly diversity was greatest in the mixed forest patches and was very poor in the teak monoculture with only nine of the most common species found in this area. This is not surprising since monocultures have been shown to greatly reduce biodiversity and are even used to purposefully reduce biodiversity (Vandermeer and Perfecto 1997).

Butterflies were undersampled. Canopy species were rarely observed and frugivorous butterflies were only occasionally sampled since no bait traps were used. Future research should provide a greater focus to frugivorous butterfly sampling as it has a standard protocol for clear, quantifiable results and has been shown to be indicative of nectar-feeding butterfly diversity (Batra 2006).

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Table 1. Butterfly inventory list

	Forest A	Forest B	Teak Monoculture
Papilionidae			
Battus polydamus polydamus	x	x	x
Parides arcas mylotes	x	x	
Eurytides euryleon clusoculs	x		
Papilio anchisiades idaeus	x	x	
P. androgeus epidaurus		x	
P. cresphontes	x	x	
P. thoas		x	
Pieridae			
Aphrissa statira	x	x	
Appias drusilla	x		
Enantia licinia marion	x		
Eurema albula	x	x	
E. boisduvaliana	x	x	
E. daira	x	x	
E. mexicana		x	
E. nise	x	x	
Pheobis argante	x	x	x
P. philea philea	x	x	
P. sennae	x	x	
Nymphalidae			
Actinote leucomelas		x	
Adelpha erotia		x	
Anartia fatima	x	x	x
A. jatrophae		x	
Archaeoprepona demophon centralis	x	x	
A. demophoon gulina	x		
Caligo memnon memnon	x		
Callithomia hezia hezia	x	x	
Cissia hermes	x	x	x
C. libye		x	
Cithaerias menander	x	x	
Consul fabius cecrops	x		
Danaus gilippus thersippus	x	x	
Danaus plexippus	x	x	
Dione juno	x	x	
Doxocopa laura	x		
Dryadula phaetusa		x	
Dryas julia	x	x	
Dynamine mylitta		x	
Dynastor darius stygiamus	x		
Eresia clara		x	
Eueides aliphera	x		
Hamadryas amphinome	x		
Heliconius cydno chioneus	x	x	

H. doris		x	
H. erato petiverana	x	x	
Lycorea cleobaea atergatis	x	x	
Marpesia petreus	x	x	
Mechanitis lysimnia doryssus	x	x	
M. polymnia isthmia	x	x	
Megeuptychia antonoe		x	
Memphis arginussa eubaena	x		
M. xenocles	x	x	
Morpho amathonte	x		
M. peleides limpida	x	x	
Opsiphanes cassina		x	
Tithorea tarricina pinthias	x	x	
Riodinidae			
Charis auius		x	
C. iris	x	x	
Calephelis browni	x	x	
Metacharis victrix		x	
Nymphidium ascolia	x	x	
Sarota myrtea		x	
Thisbe irenea	x		
Lycaenidae			
Arawacus sito	x		
Atlides polybe		x	
Brangas neora		x	
Calycopis drusilla	x	x	
Cupido comyntas	x	x	
Hemiargus ceraunus	x	x	
Leptotes cassius	x	x	x
Panthiades bathildis		x	
Rekoa meton	x	x	
Hesperiidae			
Aides dysoni	x	x	
Autochoton bipunctatus	x	x	
A. longipennis		x	
A. zarex	x		
Bolla imbras	x	x	
Callimormus radiola	x	x	
Parphorus decora	x	x	
Phanus vitreus	x	x	x
Pompeius pompeius	x		
Pyrgus oileus	x	x	x
Saliana antonius	x		
Staphylus ascalaphus		x	
Urbanus dorantes	x	x	x
Urbanus proteus	x	x	
Urbanus tenna	x	x	x
total	65	68	9

Table 2. List of ant species, their functional group, and proportion

Species	Number of individuals	Functional Group	Total Percent	Recovering Pastureland Percent	Small Forest Patch Percent	Larger Forest Patch Percent
Formicinae						
Brachymyrmex heeri	41	TCS	6.39	5.41	6.35	6
Camponotus excisus	1	SC	0.31		0.25	
Paratrechina JTL-001	3	O	0.48	0.68	0.25	
Paratrechina steinheili	1	O	0.16		0.25	
Myrmicinae						
Acromyrmex volcanus	1	TCS	0.16		0.25	
Adelomyrmex silvestrii	5	TCS	0.78		1.27	
Aphaenogaster phalangium	14	O	2.18		2.79	2
Atta cephalotes	2	TCS	0.31		0.51	
Cardiocondyla obscurior	9	T	1.4		2.28	
Cyphomyrmex rimosus	1	TCS	0.16	0.68		
Megalomyrmex drifti	8	TCS	1.25		1.52	
Pheidole ajax	5	GM	0.78		1.27	
Pheidole biconstricta	26	GM	4.05	2.76		25
Pheidole boruca	4	GM	0.62		1.02	1
Pheidole laticornis	18	GM	2.8	8.78	0.76	
Pheidole subarmats	3	GM	0.48	1.35	0.25	
Pheidole scalaris	5	GM	0.78		1.27	
Pheidole rugiceps	10	GM	1.56		0.76	
Pheidole flavens	53	GM	8.26	25	3.05	2
Pheidole indagastrix	12	GM	1.87		3.05	
Pheidole rogeri	5	GM	0.78		1.27	
Pheidole bilimeki	2	GM	0.31		0.51	
Pheidole cocciphaga	4	GM	0.62		1.02	
Pheidole pugnax	5	GM	0.78		1.27	
Pheidole mendicula	2	GM	0.31		0.51	
Pheidole ruida	2	GM	0.31		0.51	
Sericomyrmex amabilis	1	TCS	0.16	0.68		
Solenopsis geminata	105	TCS	16.36	27.03	15.99	
Solenopsis JTL-005	87	C	13.55	16.89	21.07	2
Solenopsis JTL-028	2	C	0.31		0.51	
Solenopsis picea	2	TCS	0.31		0.51	
Solenopsis subterranea	1	C	0.16		0.25	
Solenopsis JTL-009	30	C	4.67		7.61	
Solenopsis JTL-021	16	C	2.49		3.3	2
Solenopsis terricola	6	C	0.93			6

Trachymyrmex cornetzi	3	TCS	0.48	2.03		
Wasmannia auropunctata	72	TCS	11.21		6.35	49
Ectatomminae						
Ectatomma ruidum	68	O	10.59	3.38	10.67	2
Ectatomma tuberculatum	1	O	0.16		0.25	
Gnamptogenys alfaroi	1	TCS	0.16		0.25	
Ponerinae						
Odontomachus bauri	7	O	1.09	1.35		3
Pachycondyla harpax	1	SP	0.16		0.25	
Pachycondyla verenae	2	SP	0.31		0.51	
Pseudomyrmecinae						
Pseudomyrmex elongatus	1	TCS	0.16		0.25	
Number of ants	642			148	100	394

Table 3. Diversity and richness of ants

	Number of Individuals	Observed Species Richness	Jackknife 1 Speceies Richness Estimate	Alpha Diversity	Shannon Index	Reciprocal Simpson Index
Small Disturbed Forest Patch	100	11	12	3.156	1.576	3.27
Large Disturbed Forest Patch	394	40	65	11.124	2.646	10.13
Recovering Pastureland	148	13	15	3.433	1.966	5.67
Total	642	44	66	10.7	2.979	11.665

Figure 1. Rank-abundance curve of total ground-dwelling ants. The y axis shows the relative abundance (plotted using a $\log_{10}$ scale), and the x axis shows the species rank in order from most abundant to least abundant.

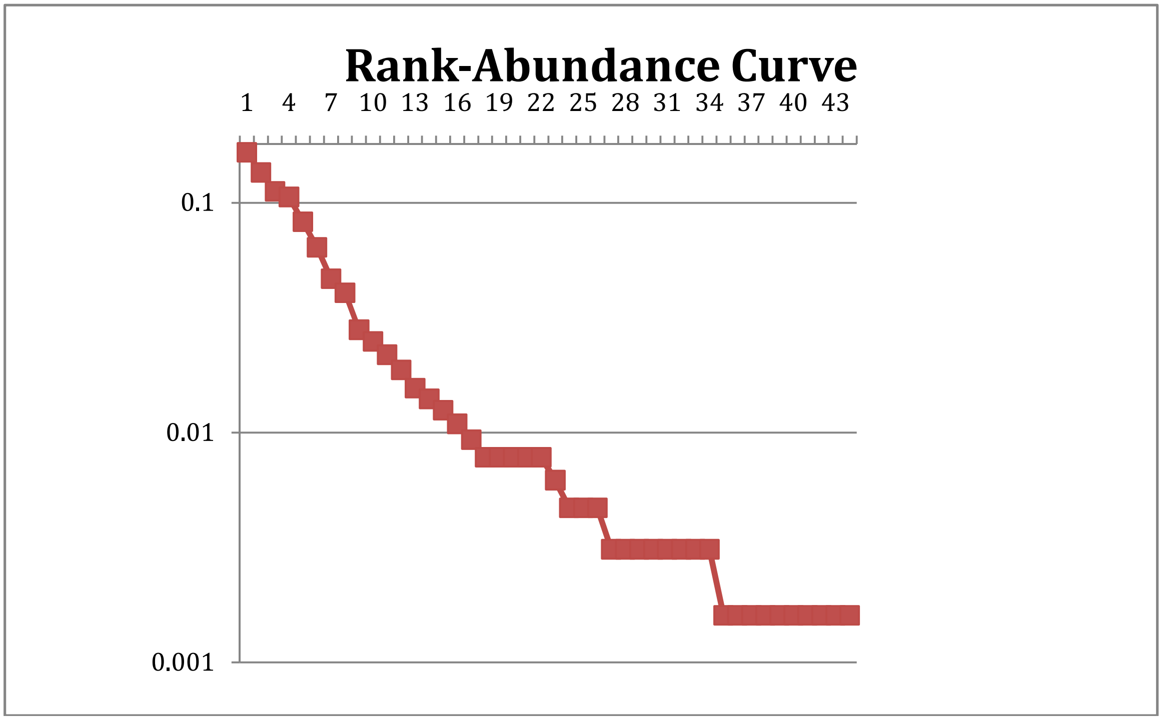

Figure 2. The functional group composition of total ground-dwelling ants.

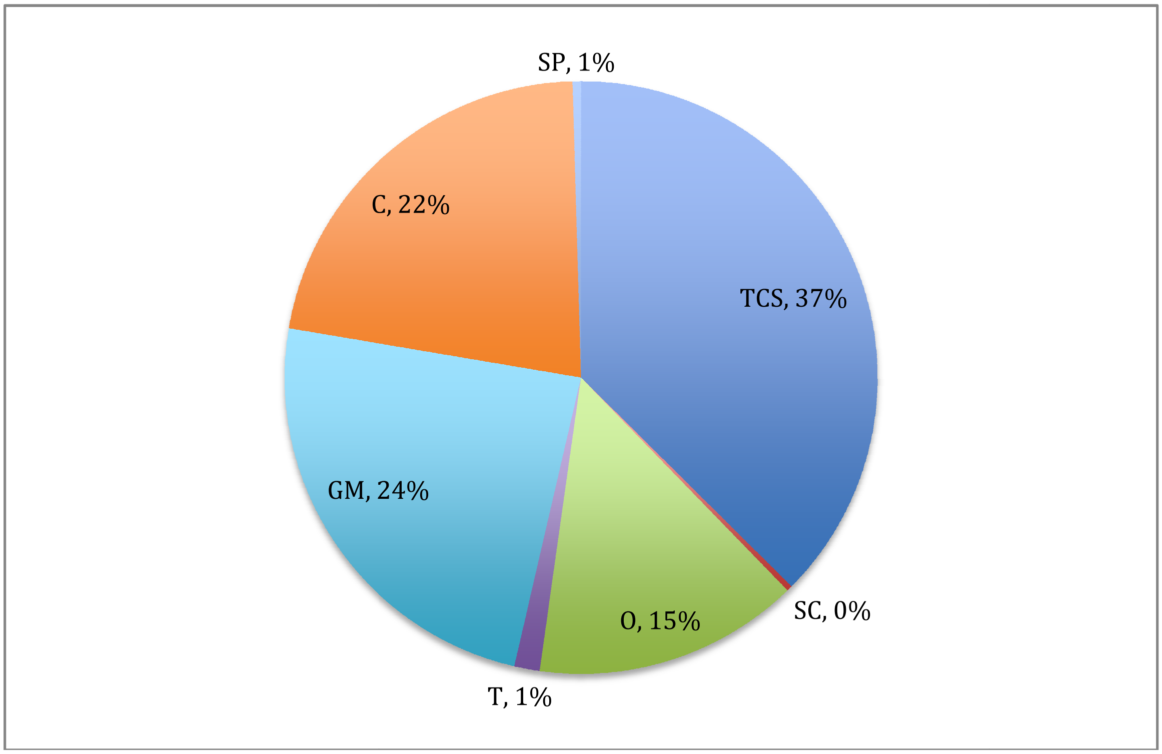

Figure 3. Species accumulation and richness curve of total ground-dwelling ants. The y axis is the number of species the x axis shows the number of samples.