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The assemblage of epigean ants (Formicidae) inhabiting altered patches found in a latitudinal transect of coastal matorral of semiarid Chile

Ensambles de hormigas epigeas asociadas a parches alterados encontrados en un transecto latitudinal del matorral costero del semiárido de Chile

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ABSTRACT

The aims of the study were to document taxonomically the composition of the assemblage; estimate its species richness, and describe the effect of latitudinal gradient and matorral condition on species relative abundance and species richness of assemblage. The ants were caught with interception traps (pitfall type). The study was conducted between 2008 and 2011. We recorded the presence of four endemic species and one introduced. Maximum R was estimated at six. *Solenopsis gayi* (Myrmicinae) and *Tapinoma antarticum* (Dolichoderinae) were the numerically dominant species.We observed an effect of both the latitudinal floor of matorral and the matorral condition on the relative abundance of the species, particularly in the case of endemic species. This effect did no follow neither the latitudinal gradient nor the matorral condition. The ants' responses were species specific, with influence of the study site over that provided by latitudinal gradient and matorral condition. The distribution of estimated R did not show a clear pattern in any of the two cases. We believe that our results show a complex situation derived from the interweaving of influences due both to the historical rainfall gradient and its concomitant effect on vegetation, the current state of matorral, and the severe drought recorded during the study. It is possible that under conditions of mean precipitation or above, the results are different.

Key words: SouthAmerican deserts, desertification, ecosystem rehabilitation, soil fauna, invasive species.

RESUMEN

Los propósitos del estudio fueron documentar taxonomicamente la composición del ensamble; estimar su riqueza de especies y describir el efecto del gradiente latitudinal y la condición del matorral sobre la abundancia relativa de las especies y la riqueza del ensamble. Las hormigas fueron capturadas con trampas de intercepción de caída (tipo pitfall). El estudió fue realizado entre 2008 y 2011. Registramos la presencia de cuatro especies endémicas y una introducida. El R máximo se estimó en seis. Solenopsis gayi *(Myrmicinae) y* Tapinoma antarticum *(Dolichoderinae) fueron las especies numéricamente dominantes. Observamos un efecto del piso latitudinal del matorral y de la condición de éste sobre la abundancia relativa de las especies, particularmente en el caso de las especies endémicas. Este efecto no siguió ni el gradiente latitudinal ni la condición del matorral. Estas respuestas fueron especie-específicas, con influencia del sitio de estudio. La distribución de R-estimado no mostró un patrón evidente en ninguno de los dos casos. Consideramos que nuestros resultados evidencian una situación compleja derivada del entrelazamiento de influencias debidas a la gradiente pluviométrica histórica y a su efecto concomitante sobre la vegetación, al estado actual del matorral y a la sequía severa a la que éste estuvo sujeto durante el estudio. Es posible que bajo condiciones de precipitación promedio o superior, los resultados sean diferentes.*

Palabras clave: *Desierto sudamericano, desertificación, rehabilitación de ecosistemas, introdución de especies, fauna de suelo, especies invasoras.*

Introduction

One of the most severe environmental problems affecting Chile is desertification. Presently, about 48 million hectares (~63% of mainland Chile) are being affected (Alfaro, 2006). Desertification processes in Chile are believed to intensify as a result of effects of climate change (CONAMA, 2006). Nearly 22% of Chilean affected land is located in the coastal fringe and in the hilly inland of semiarid territory (Pérez & González,

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2001). Over the last decades, in this part of the country, state agencies have intensively conducted programs based on shrub and tree-life forms to mitigate desertification (Bars, 2002). As a result, the present-day landscape is a mixture of degraded, afforested, and partially altered matorral. One of the plant species most intensively used has been *Acacia saligna* (Labill.) H. Wendl. (Fabaceae, Mimosoideae), an introduced Australian species. Despite this fact, from an ecosystem viewpoint there is a lack of knowledge regarding its effects on soil biotic elements of matorral of coastal semi-arid Chile.

Due to their different ecological roles, arthropods are considered as one of the most important biotic components of arid ecosystems, and one of the first groups of animals to be affected by desertification (Whitford, 2001). They also meet a series of requirements that make them quite suitable for monitoring rehabilitation efforts. This is the case of Formicidae (Hoffmann, 2010). Nevertheless, knowledge on ecology of Chilean ant species is rather scanty (Torres-Contreras, 2001). We pursued the following goals in this study: (1) to taxonomically document the assemblage across a latitudinal stretch of coastal matorral and matorral condition; 2) to estimate species richness across the above mentioned factors, and 3) to describe the effect of latitudinal gradient and matorral condition on ant relative abundance (density/activity) and species richness.

Materials and Methods

The study encompassed a transect extending from Las Tacas (30°06'33" S, 71°21'29" W) to the Quereo Power Substation (31°56'08" S, 71°28'46" W) (Figure 1). The historical annual precipitation ranges from 104 mm (northern margin) to 210 mm (southern margin). Data recorded by the Meteorological Office of the Chilean Navy (unpublished), show that this gradient was not clearly expressed during the study years. Across transect, soils are sandy to loamy-sandy in texture, low to very low in organic matter, N, and P contents, but high to very high in the K-content. They correspond to stabilized dunes characterized by lack of diagnostic horizons. The transect crossed three latitudinal sections of matorral. From north to south, they were the low open shrubland (northern sector, matorral estepario costero in Spanish), the brushwood shrubland (central sector, matorral estepario boscoso), and the sclerophyllous shrubland (southern sector, matorral estepario arborescente). Details of original vegetation of the transect are provided by Luebert & Pliscoff (2006). Nowadays, as a result of dryland agriculture and cattle-raising, clear-cutting, and afforestation actions, several matorral-conditions (patch-types) can be recognized within the landscape of these sections.

Study design, specimen collection, and data analysis

For each latitudinal section of matorral (hereafter "PLV"), we selected three sites simultaneously featuring non-rehabilitated degraded land (DES-patches), degraded land afforested with *A. saligna* (ASA-patches), and land in semi natural (VSN-patches). The DES-patches lacked shrubby vegetation, though there was a poorly developed herbaceous layer formed by native and introduced species. The ASA-patches corresponded to *A. saligna* plantations ten or more years old with coverage above 40%. The VSN-patches corresponded to remnants of original matorral, altered by goat-grazing. Ants were captured using 30-pitfall interception traps installed in each of the patch types. The traps operated for three days in September/October from 2008 to 2011. To prevent oversampling, the grids were yearly moved within each site. The specimens were identified at species level following Snelling & Hunt (1975). Species richness was estimated using the Chao & Lee-1 (ACE), jackknife 1, and rarefaction (grouped, finite) estimators. The calculations were performed in the Species Diversity and Richness IV software (Seaby & Henderson, 2007).

Results

Taxonomic structure and numerical dominance of ant species

We captured 42767 ants, grouped in five species, four of them endemic. The species numerically dominant were *S. gayi* and *T. antarcticum* (Table 1). Across latitudinal sections, the largest contribution came from the middle

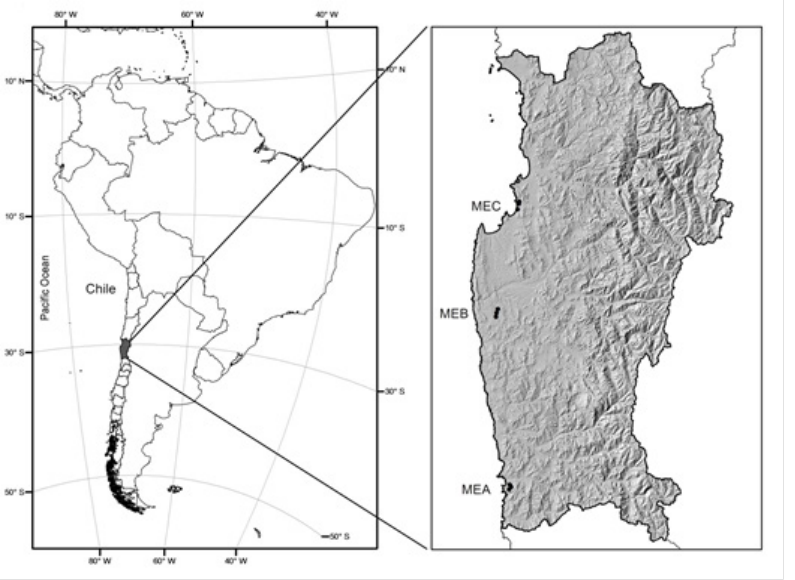

Figure 1. Geographic location of latitudinal sections of coastal shrubland studied in this work. Code for latitudinal section of shrubland (PLV): MEC: low open matorral; MEB: scrubby matorral; MEA: sclerophyllous matorral The small black dots show the study site locations. Distance between groups of sites: MEC-MEB: 80 km; MEB-MAE: 120 km. The landforms shown on the right side of the digital elevation model are the Andes Mountains.

Table 1. Taxonomic and ecological characteristics of assemblage of epigean ants recorded in a coastal stretch of semiarid of Chile. Site Las Tacas (30°06'33,2" S; 71°21'29.1" O)- site Quereo (31°56'08" S;71°28'46.3" O).

Species	Subfamily	Origin	Food habits	n	%
Camponotus morosus	Formicinae	Endemic	Omnivore	3970	9.28
Linepithema humile	Dolichoderinae	Introduced	Oportunistic	5825	13.62
Pogonomyrmex bispinosus	Myrmicinae	Endemic	Granivore	4223	9.87
Solenopsis gayi	Myrmicinae	Endemic	Granivore	17365	40.60
Tapinoma antarcticum	Dolichoderinae	Endemic	Oportunistic	11384	26.62
Total				42767	100

*Numbers as catch by pitfall-traps.

sector (MEB, Figure 1), with a total captures of ca. 59% (Table 2). Among patch-type, the highest percentage of captured specimens occurred in the *Acacia saligna*-patch (Table 3). Details of distribution of abundance across latitudinal section and matorral condition are provided by Figures 2 through 6. Out of 10 paired comparisons of relative abundance (non-parametric Spearman's rank correlation) between species, eihght showed significant correlation (Table 4).

Effect of latitudinal gradient and shrubland-condition on the relative abundance (density/activity) and taxonomic richness of the Formicidae assemblage

The preference for latitudinal section of matorral was different among species (Table 2). Across matorral-condition, three out of four species showed preference for the *Acacia saligna*-patch; *Linepithema humile*, in turn, showed

Table 2. Distribution of relative abundance of epigean ants inhabiting a latitudinal transect (30°-32° S) of coastal matorral of semiarid Chile.

	PLV							
Ant species*	MEC		MEB		MEA		TOTAL	
	n	%	n	%	n	%	n	%
CM	74	0.17	3659	8.56	237	0.55	3970	9.28
LH	2326	5.44	830	1.94	2669	6.24	5825	13.62
PB	3554	8.31	666	1.56	3	0.01	4223	9.87
SG	940	2.20	15169	35.47	1256	2.94	17365	40.61
TA	4656	10.89	4831	11.30	1897	4.44	11384	26.62
Total	11550	27.01	25155	58.82	6062	14.17	42767	100.00

*Code for species: CM: *Camponotus morosus*; LH: *Linephitema humile; PB: Pogonomyrmex spinosus; SG: Solenopsis gayi; TA: Tapinoma antarcticum.* Code for PLV, MEC, MEB, MEA: see Figure 1.

Table 3. Distribution of relative abundance (density-activity) of epigean ants across condition of matorral in a latitudinal transect (30°-32° S) of semiarid of Chile.*

	Matorral condition							
Species	DES		ASA		VSN		Total	
	n	%	n	%	n	%	n	%
CM	552	1.29	2644	6.18	774	1.81	3970	9.28
LH	2619	6.12	1350	3.16	1856	4.34	5825	13.62
PB	826	1.93	779	1.82	2618	6.12	4223	9.87
SG	5659	13.23	8862	20.72	2844	6.65	17365	40.60
TA	1998	4.67	5536	12.94	3850	9.00	11384	26.62
Total	11654	27.25	19171	44.83	11942	27.92	42767	100.00

*Code for matorral condition: DES: degraded (desertified) patch; ASA: Acacia saligna-aforested patch; VSN: patch with semi-natural vegetation; code for ant species as in Table 2.

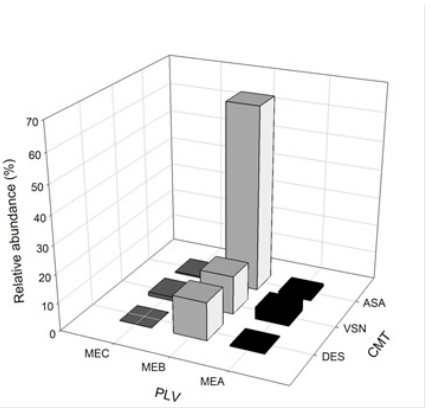

Figure 2. Distribution of relative abundance (density-activity) of Camponotus morosus across PLV and shrubland condition (CMAT). Code for PLV as in Figure 1. Code for CMT: DES: degraded (desertified) condition; VSN: semi-natural vegetation; ASA: Acacia saligna-aforested condition. Bars show percent of total captures.

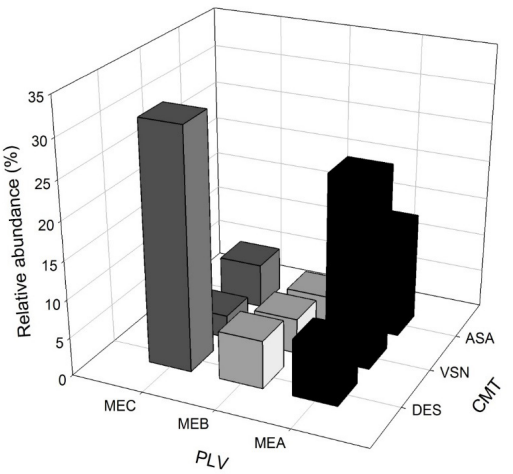

Figure 3. Distribution of relative abundance (density-activity) of *Linepithema humile* across PLV and CMAT. Codes for PLV and CMAT as Figures 1 and 2, respectively. Bars as in Figure 2.

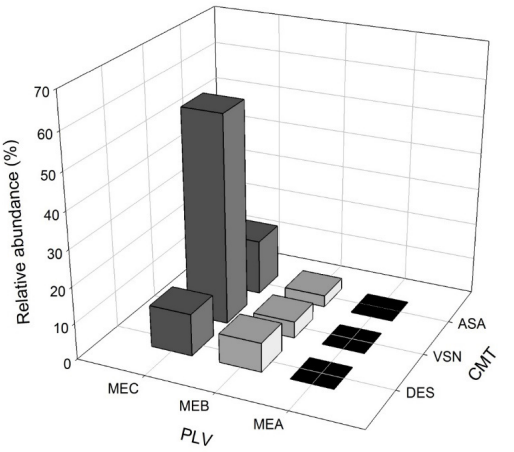

Figure 4. Distribution of relative abundance (density-activity) of *Pogonomyrmex bispinosus* across PLV and CMAT. Codes for PLV and CMAT as in Figures 1 and 2, respectively. Bars as in Figure 2.

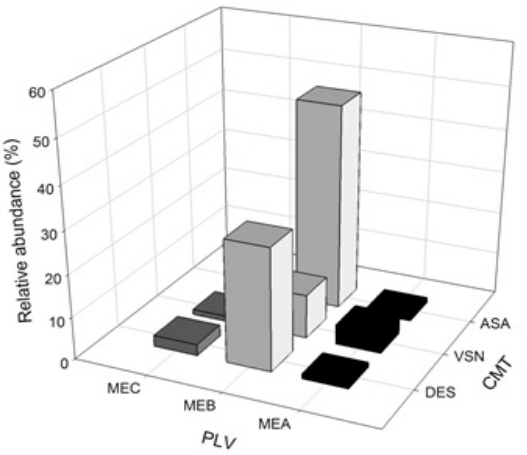

Figure 5. Distribution of relative abundance (density-activity) of *Solenopsis gayi* across PLV and CMAT. Codes for PLV and CMAT as in Figures 1 and 2, respectively. Bars as in Figure 2.

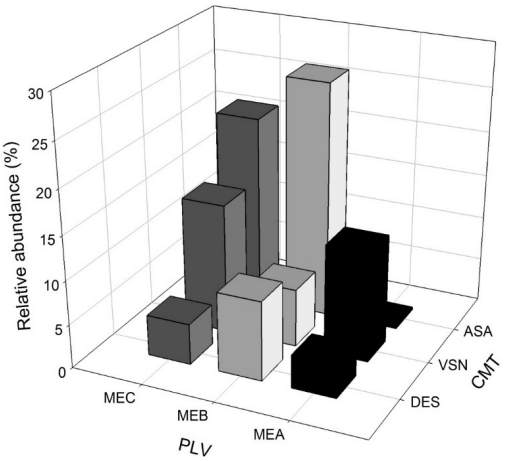

Figure 6. Distribution of relative abundance (density-activity) of *Tapinoma antarcticum* across PLV and CMAT. Codes for PLV and CMAT as in Figures 1 and 2, respectively. Bars as in Figure 2.

Table 4. Coefficients of correlation (non-parametric Spearman's ϱ) of relative abundance between pairs of ant-species inhabiting a coastal transect (30°-32° S) of semiarid Chile.

Species *	ϱ	Prob < p
SG/TA	0.248	< 0.01**
PB/TA	0.432	< 0.01**
PB/SG	0.147	0.128
LH/TA	-0.222	0.021*
LH/SG	0.309	< 0.01**
LH/PB	-0.287	< 0.01**
CM/TA	0.283	< 0.01**
CM/SG	0.727	< 0.01**
CM/PB	0.091	0.331
CM/LH	0.215	0.025*

*Species code: as in Table 2.

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preference for the degraded-patch (Table 3). The highest number of species was recorded in the three patch-types of matorral in the middle-section of transect (Table 5).

Discussion

Taxonomic structure of the Formicidae assemblage

For the study area, the endemic species recorded as well as the introduced one are in correspondence as previously documented (Snelling & Hunt, 1975). Biological and field ecology information about the recorded species are rather scanty in Chile (Torres-Contreras, 2001). Functionally, *S. gayi* and *P. bispinosus* are considered granivorous (Vásquez *et al.,* 1995) and *C. morosus* has been reported to feed on dead insects, vertebrate faeces, and plant-detritus (Grez *et al.,* 1986). Compared to the aforementioned species, *T. antarcticum* is much lesser known (Torres-Contreras, 2001). In southwestern North America, whereas *Tapinoma* species show opportunistic behavior, *Linepithema humile* behaves in an opportunistic way, dominating over native species (Andersen, 1997). Until now, in Chile, the economic importance, the invasive capacity and the aggressive behavior of this species, have attracted most of the interest of researchers (Torres-Contreras, 2001, Torres-Contreras *et al.,* 2014). International literature holds that habitat fragmentation, exotic vegetation, urbanization, deforestation and high rainfall, specially if takes place during summer, facilitate penetration of *L. humile;* in turn, high temperatures and low humidity prevent ti. MacMahon *et al.* (2000) point out that *L. humile* displaces native species via competitive interference. We have no Chilean information exploring this topic. Out of the four paired correlations between relative abundances involving *L. humile*, two showed positive correlation (*S. gayi* and *C. morosus*) and two showed negative correlation (*T. antarcticum* and *P. bispinosus*). In this work, *L. humile* occupies

Table 5. Estimation of taxonomic richness of assemblage of epigean ants inhabiting a transect (30°-32° S) of coastal matorral of semiarid Chile.

	Latitudinal section of matorral								
	MEC			MEB			MEA		
	shrubland condition			shrubland condition			shrubland condition		
Estimator	SDE	VSN	ASA	SDE	VSN	ASA	SDE	VSN	ASA
Chao & Lee 1 (ACE)	4	4	5	5	5	5	4	5	4
Jackknife 1st order*	4.9 (0.9)	4 (0)	5 (0)	5 (0)	5 (0)	5 (0)	4 (0)	5.9 (0.9)	5.8 (1.8)
Pooled rarefaction**	4 (0.01)	4 (0)	5(0)	5 (0)	5 (0)	5 (0)	4 (0)	5 (0)	4 (0)
N° observed ant species	4	4	5	5	5	5	4	5	4

In parenthesis: * standard deviation; ** standard error; code for latitudinal section of matorral as in Figure 1; code for matorral condition as in Table 3.

the third place in terms of numerical dominance, superseding the endemic species *C. morosus* and *P. bispinosus*. This fact may reflect the overall degradation condition of the studied transect and that invasion by *L. humile* is an active process in the area.

Responses of species richness and relative abundance to latitudinal gradient

Two Chilean myrmecofauna-hotspots have been recognized: the area extending from 30° to 37° S (10 species) and the area extending from 37° to 45 S (eight species) (Snelling & Hunt, 1975). More recent work has increases richness for tract 30-37° S (Sáiz & Carvajal, 1990; Solervicens *et al.,* 1991; Solervicens & Estrada, 2002). Since the segment covered by our study is an ecotonal band located between the Atacamenian zone (18-30 S), almost devoid of ant species, and central Chile (30-37° S), the section so far richer, the decrease in species richness found in our study is an expected result. We observed a latitudinal effect on distribution of ant abundance. This effect was species-specific. This kind of response seems to be common within Formicidae (Sáiz & Carvajal, 1990). We recognize three situations, two of them related to the endemic species and one related to the introduced one. The first case is *P. bispinosus*, whose relative abundance decreases in the southward direction. The second case involves *C. morosus, S. gayi* and *T. antarcticum*, which tend to prefer the middle segment of the study-transect. The third case involves *L. humile,* which showed no preference whatsoever, as expected for an invasive species. We have no a clear answer for the observed latitudinal effect. The list of possible determining factors is extensive in published literature. Among the principal ones are those related to altitude and aridity gradients, soil type heterogeneity, landscape characteristics, and seasonal variation in rainfall and temperature (MacMahon *et al.,* 2000; Dunn *et al.,* 2007; Crist, 2009). Our study-transect did not show major differences in physiographic features, soil characteristics, and annual air temperatures; however, it shows a historical rainfall gradient that is reflected from north to south in the main characteristics of seminatural matorral (open low matorral to sclerophyllous matorral) (Luebert & Pliscoff, 2006). Nevertheless, as a result of intense agropastoral activities practiced in the area since early post-colonial time, this matorral is altered in different degrees of intensity (Rolando, 2003). Given that human pressure has not been the same across the study-transect, we advance the idea that these human induced conditions are one of the main responsible for the observed effect of latitude, reinforcing a site effect over a gradient effect.

Formicidae responses to shrubland alteration

Most research examining the effects of disturbances on the epigean fauna is based on pseudo-experimental designs. We followed this approach and are well aware of its limitations. In fact, these designs use as treatment variables the field's prevailing conditions, usually a result of landscape management. The data obtained from these studies in many cases contains a large amount of "noise". This noise is the result not only of lack of control the researcher has over treatment variables, but also it is due to the natural variability of these systems, especially in studies covering wide areas. Probably, this noise is one of the reasons of the inconsistent results obtained in studies about the responses of ants to habitat alterations conducted in desert sites (Whitford *et al.,* 1999; Nash *et al.,* 2000, 2004; Bestelmeyer, 2005; Hoffmann, 2010). We are well aware we were exposed to this kind of noise. When designing the work, we hypothesized that the seminatural patches would show higher relative abundance and richness, following the rainfall gradient and/or matorral semipristinity. Our study did not provided fully evidence in this direction, but agrees well with the site effect hypothesis. Given that the knowledge on the biology of Chilean ants species is quite poor (Torres-Contreras, 2001), a deeper interpretation of our results was not feasible, evidencing the need to improve the knowledge of the natural history of the mirmecofauna, common elements in many arid regions, among them northern Chile.

Conclusions

We recorded the presence of five, possibly six, ant species. This richness is lower than that reported from central Chile and other arid regions. Four recorded species were native. There was no evidence on the effect of latitudinal gradient

or matorral condition. Ants' responses were found to be site and species-specific. We interpret these results as the combined effects of local natural features (e.g., climate pattern, landscape physiography, vegetation, and soil), interplaying with derived from human actions.

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