Sociobiology 71(2): e9698 (June, 2024) DOI: 10.13102/sociobiology.v71i2.9698

Sociobiology
An international journal on social insects

RESEARCH ARTICLE - ANTS

Diversity and Species Composition of Ants in Urban and Suburban Environments in Bejaia City (Algeria)

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Article History

Edited by
Enrico Schifani, University of Parma, Italy
Received 11 May 2023
Initial acceptance 18 June 2023
Final acceptance 28 December 2023
Publication date 09 May 2024

Keywords
Diversity, NMDS, SIMPER, Urban, Suburban, Bejaia city.

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Abstract

We conducted an ant inventory in urban and suburban spaces in Bejaia city to deal with this need for more information about ant biodiversity in the Algerian urban environment. The two methods, hand collecting, and pitfall traps, are carried out 24 days in three months (May, June, and July) of 2022. In the urban habitats, 2,653 ant individuals were collected, comprising ten species, six genera and three subfamilies. In the suburban habitats, 6,706 ant specimens were collected, comprising 19 species, 11 genera, and three subfamilies. The most abundant subfamilies in both urban and suburban habitats are Formicinae, followed by Myrmicinae and Dolichoderinae. The results showed that suburban habitats are more diversified (H'= 1.72) than urban habitats (H'= 1.25). The equitability values for suburban and urban habitats are moderate, with 0.58 and 0.54, respectively. The Jaccard similarity index value is 0.45, indicating an essential turnover of ant species between urban and suburban habitats. The ant community's composition differed between sampled sites (NMDS, Stress = 0.013). The average dissimilarity (as per SIMPER) was 90.37%. Four species (*T. simrothi*, *L.* cf. *grandis, P. cicatricosa*, and *L. myops*) contributed to 70% of the differences between sites of urban and suburban habitats.

Introduction

The dramatically increased rates of uncontrolled urbanization in various parts of the World have resulted in the loss of native species and overall threats to biodiversity (Abdel-Dayem et al., 2021). The high-speed transformation of rural to urban areas will have disastrous impacts on the environment and ecological functioning (Brooks, 2018). On the one hand, urbanization has been documented to cause shifts in the composition of arthropod communities for a variety of reasons, including pollution limiting the number of pollution-sensitive species, the urban "heat island" effect allowing certain species to live further north than their rural range, and human modification of vegetation causing changes in resource availability and succession (Toennisson, 2009). On the other hand, urbanization and manufactured habitat transformation are uneven in the landscape, and some areas in a city contain relatively well-preserved vegetation. The mosaic of transformed land and well-preserved patches provides an opportunity to observe the response of particular components of biodiversity to various levels of transformation at relatively small spatial scales (Slipinski et al., 2012). Some studies have even suggested the positive impact of human-induced changes on the fauna of urban environments through the abundant availability of specific resources or other beneficial environmental conditions. Indeed, establishing and developing specific fauna, such as invasive species, can be favored (Uno et al., 2010).

Insects are recognized as serving important roles as indicators of overall ecological health. Specifically, the diversity and presence of ants can serve as indicators of environmental quality due to their ubiquitous presence across many terrestrial

Open access journal: http://periodicos.uefs.br/index.php/sociobiology
ISSN: 0361-6525

environments and their crucial role in numerous ecosystem processes (Brooks et al., 2023). In addition, ants react differently to urbanization; some are favored by urbanization, and others are negatively affected (Garden et al., 2006). Urbanization favors ants that have pioneer or tramp behaviors, such as flexible nesting habits and omnivorous diet (Silverman, 2005), and is burdensome for specialist species, requiring adequate food or nesting resources or sensitive to the presence of aggressive ant species (Uno et al., 2010).

Previous studies on urban ant fauna have been conducted in various geographic and climatic regions. In regions with Mediterranean climate, studies have explored the composition and diversity of ant species (Espadaler & Lopez-Soria, 1991; Cherry, 2001). Additionally, research conducted in urban areas of countries with comparable climates, like Spain, has delved into the impact of urbanization (Ivanov & Keeper, 2009; Munhae et al., 2009) and the effect of park habitat characteristics on ant communities (Carpintero & Reyes-Lopez, 2014; Reyes-Lopez & Carpintero, 2014). Studies in regions with distinct climates, such as the United States (USA), have also contributed to our understanding of urban ant ecology, focusing on topics like species diversity and the influence of pollution (Sanford et al., 2009; Del Toro et al., 2010). Similarly, research in tropical climates like Brazil has highlighted the presence of native and exotic ant species in urban environments and their ecological roles (Silva et al., 2009; Rodriguez et al., 2010).

In Algeria, the most studied were ants from humid and sub-humid bioclimatic stages. Cagniant (1970, 1973) and Sid-Ali et al. (2020) focused on Algerian forest ants. Barech (2014) and Dehina et al. (2009) studied ants in the Sahel of Algiers, and Aissat (2023) was interested in ants from the Algerian islands.

We conducted an ant inventory in urban and suburban spaces in Bejaia city to deal with this need for more information about ant biodiversity in the Algerian urban environment. Specifically, we studied ant communities in urban and suburban spaces to respond to the following questions: 1) How do urban and suburban habitats differ regarding ant abundance, richness, and species composition? Moreover, 2) Which ant species would be favored by the urban environment?

Material and Methods

Study area and sample sites

The study area was the city of Bejaia (36°15’N; 4°20’E), Algeria (Fig 1), which has undergone innumerable urban modifications due to human activities, including industrialization, urbanization, and agriculture. Located in the northeast of Algeria, it is characterized by a humid climate with mild winters. The maximum temperature in Bejaia averages 22 °C over the year (from 15 °C in February to 31 in August). It rains 1230 mm over the year, with a minimum of 12 mm in July and a maximum of 177 mm in January.

Sampling sites (n = 10) were defined in urban and suburban areas (Fig 1). The urban sites were: 1 (University Campus), 2 (Public Garden), 3, 4, and 5 (University Residences), of about 3 ha covered mainly grassy areas (95% of green coverage), with scattered trees and some shrubs (usually ornamental species) (5% of green coverage), suffering from high human presence (Table 1). It is crucial to emphasize that most selected sites exhibit a remarkably uniform vegetation profile. The public authorities opted to plant the same species

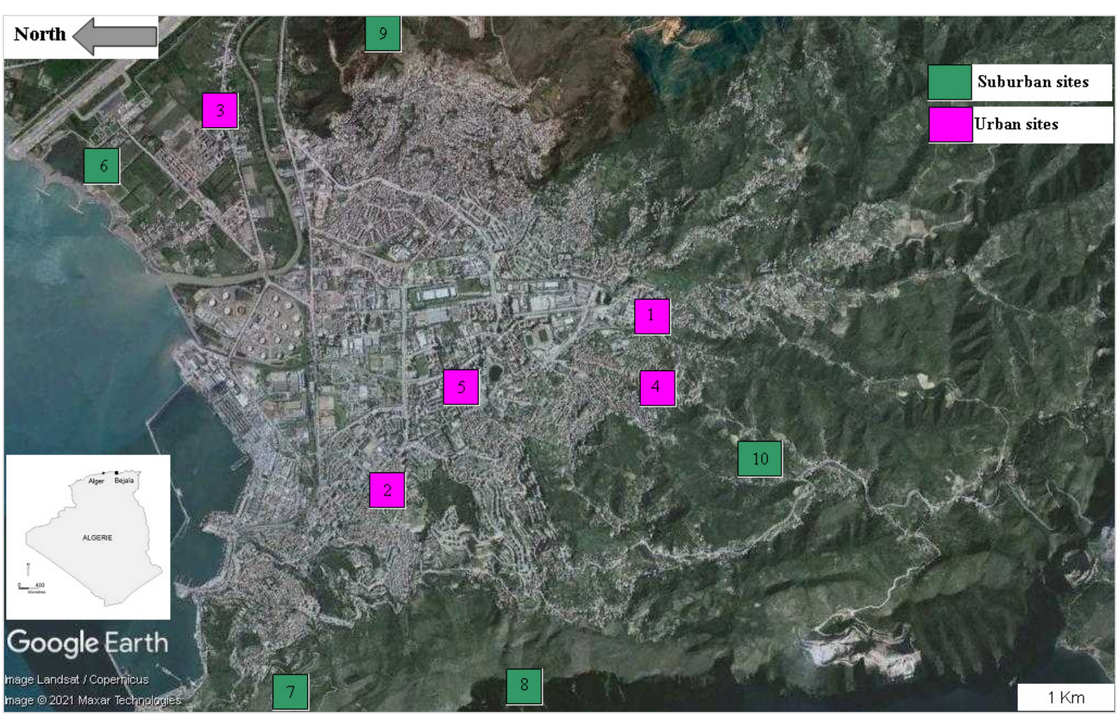

Fig 1. Study area and location of sampling sites at Bejaia city, Algeria.

of vegetation in various public areas. The suburban sites 6, 9, and 10 were wastelands, 7 (low maquis) and 8 (high maquis) of about 3 ha. These green spaces are characterized by patches of secondary growth of herbaceous (60% of green coverage), shrubby, and tree (native) vegetation (40% of green coverage), with low to reduced human presence (Sites 7 and 8 were within Gouraya National Park) (Table 1).

Ants sampling

Two capture methods have been implemented, targeting epigeal ants, surface ants living under stones and in the ground, and those living in trees and crevices in rocks. The first method consists of hand collecting on different types of habitats, during which the prospected surface (5-meter radius around each pitfall trap) is traversed at random during a known time interval (2 hours). The second method is to capture mobile ants by using pitfall traps. Twenty (20) Pitfall traps were established along a 100 m linear transect, consisting of 102 ml plastic cups (12 cm height x 10 cm diameter) driven into the soil with the top of the cups flush with the ground surface, with a separated distance of 10 m between traps. Cups are filled to ¾ with an unattractive mixture of propylene glycol, which acts as a preservative by avoiding the decomposition of the harvested ants and some drops of dishwashing liquid, thus breaking the surface tension. Traps remained in sites for three days. The two methods, hand collecting and pitfall traps, were carried out on the same day, and 24 field outings were conducted over three months (May, June, and July) in 2022.

Table 1. Information about studied sites (Geographic coordinates, names of locations, plant species scientific names).

Site N°	Geographic coordinates	Locations	Plant species
01	36°75’02’’N - 5° 04’10’’E	Bejaia University campus	*Ficus elastica, Populus alba, Rosa chinensis, Aristolochia macrophylla, Lantana camara.*
02	36°75’01’’N - 5°07’18’’E	Tobal Public Garden	*Ficus elastica, Rosa chinensis, Aristolochia macrophylla, Lantana camara.*
03	36°72’95’’N - 5°06’85’’E	Iryahen University residence	*Rosa chinensis* Jacq, *Aristolochia macrophylla* Lam, *Ageratina adenophora, Myoporum tenuifolium*
04	36°75’26’’N - 5° 03’94’’E	Targa Ouzemour University residence	*Rosa chinensis, Aristolochia macrophylla, Olea europaea*
05	36°74’65’’N - 5°05’54’’E	17 Octobre 1961 University residence	*Ligustrum japonicum, Platycladus orientalis, Chamaerops humilis.*
06	36°72’60’’N - 5°07’69’’E	Sidi Ali Lebhar	*Bupleurum spinosum*, *Phragmites australis Adans, Olea europaea*
07	36°75’73’’N - 5°09’14’’E	Low maquis (National Park of Gouraya)	*Olea europaea, Erica arborea, Pinus pinaster, Fagus sylvatica, Urtica urens*
08	36°76’74’’N - 5°08’66’’E	High maquis (National Park of Gouraya)	*Quercus coccifera, Ampelodesma mauritanica, Calycotum spinosa, Cistus monspeliensis*
09	36°68’10’’N - 5°01’60’’E	Tala hamza	*Urtica urens, Olea europaea, Ficus carica*
10	36°75’99’’N - 5°04’13’’E	Ibouhatmen	*Malus sieversii, Ficus carica, Citrus limon, Olea europaea, Urtica urens*

All ants were sorted and identified to species level using the keys of Cagniant (1970, 1973, 1996, 2009), Cagniant and Espadaler (1997), taxonomic revisions of some ant genera (Seifert, 1992; Seifert, 2016; Seifert et al, 2017; Seifert et al, 2020; Schifani et al, 2022; Schifani & Alicata, 2023). Specimens of ants were deposited in the Applied Zoology and Ecophysiology Laboratory at the University of Bejaia.

Data analysis

To analyze the ant diversity, the data of the pitfall traps and hand collecting of the ten prospected sites of urban-suburban habitats are evaluated by the following indices: Total species richness index (S), relative abundance (RA%) is calculated as (RA = (ni / n)*100) where ni is the number of individuals of taxon i and n is the total number of individuals of all species. The average number of ants collected from each habitat was used to measure average richness. Moreover, the average count of all individuals for each species collected from each site was used to measure average abundance. Relative frequency of occurrence (FO %) was calculated according to Dajoz (1985): (FO = (pi / p)*100) where pi is the total number of sites containing the species taken into consideration and p is the total number of sites.

In addition, the diversity of the two habitats, urban and suburban, was estimated using Shannon’s index (H). It was estimated as H = -Σ (pi log pi), where pi is the proportion of individuals of the i species (pi = ni/n;), and Equitability index (E), it is calculated as J = H / ln(S), the value of J varied between 0 (a single species dominates) and 1 (all species are equally abundant).

The turnover of ants between urban and suburban habitats was estimated using the Jaccard similarity index. An overall estimate was made, considering the total number of ants in each habitat. This index is based on presence-absence data. Jaccard's similarity index = Nc / (N1+N2+Nc), where Nc = number of ants common between the two habitats, N1 = total number of species present only in the urban habitat, and N2 = total number of species present only in the suburban habitat. It varies from 0 to 1, where 1 indicates that two habitats share the same ants and 0 indicates that they are completely distinct (the two habitats do not share any ants).

We used two nonparametric estimators of ant richness, 1st-order Jackknife and Chao1. Individuals and Sampled-based rarefaction curves for computing species richness were calculated using Past 3.25 (Hammer et al., 2001). Sample completeness is measured by sample coverage (C), while the coefficient of variation (CV) characterizes the degree of heterogeneity among the ant community's "discovery probabilities" (SPADE; Chao & Shen, 2015).

A t-test was used to test the means of species richness and abundance of ant communities between urban and suburban habitats. Normality and homoscedasticity of the data were confirmed prior to the analyses using the Shapiro-Wilk and Levene tests, respectively. All data were log-transformed to reduce heteroscedasticity prior to analysis. Patterns of species composition and community structure were compared between urban and suburban areas through ordination analysis (non-metric multidimensional scaling - NMDS), the Bray-Curtis similarity index was used as a distance measure (PAST; Hammer et al., 2001), and then, a PERMANOVA was performed using the same software. Due to the significant difference from this test, we performed a SIMPER analysis using a Bray-Curtis similarity index matrix to determine each ant species' contribution to the dissimilarities between urban and suburban habitats.

Results

Global ant community analysis

9,359 individual ants belonging to 20 species from 12 genera were collected across all sites (n = 10). The richest and most abundant subfamilies in both urban and suburban habitats are Formicinae, followed by Myrmicinae and Dolichoderinae (Table 2). In 10 sites, pitfall traps sampled 7,416 individuals, and hand-collecting sampled 1,943 individuals (Table 2).

On all sites, *Tapinoma simrothi*, *Lasius* cf. *grandis*, and *Pheidole cicatricosa* species were the most abundant, with 2,852 individuals (30.47%), 1,518 individuals (16.22%) and 1,502 individuals (16.05%), respectively. It is followed by two species, *Aphaenogaster testaceopilosa* and *Lasius myops*, with 962 individuals (10.28%) and 959 individuals (10.25%), respectively (Table 2).

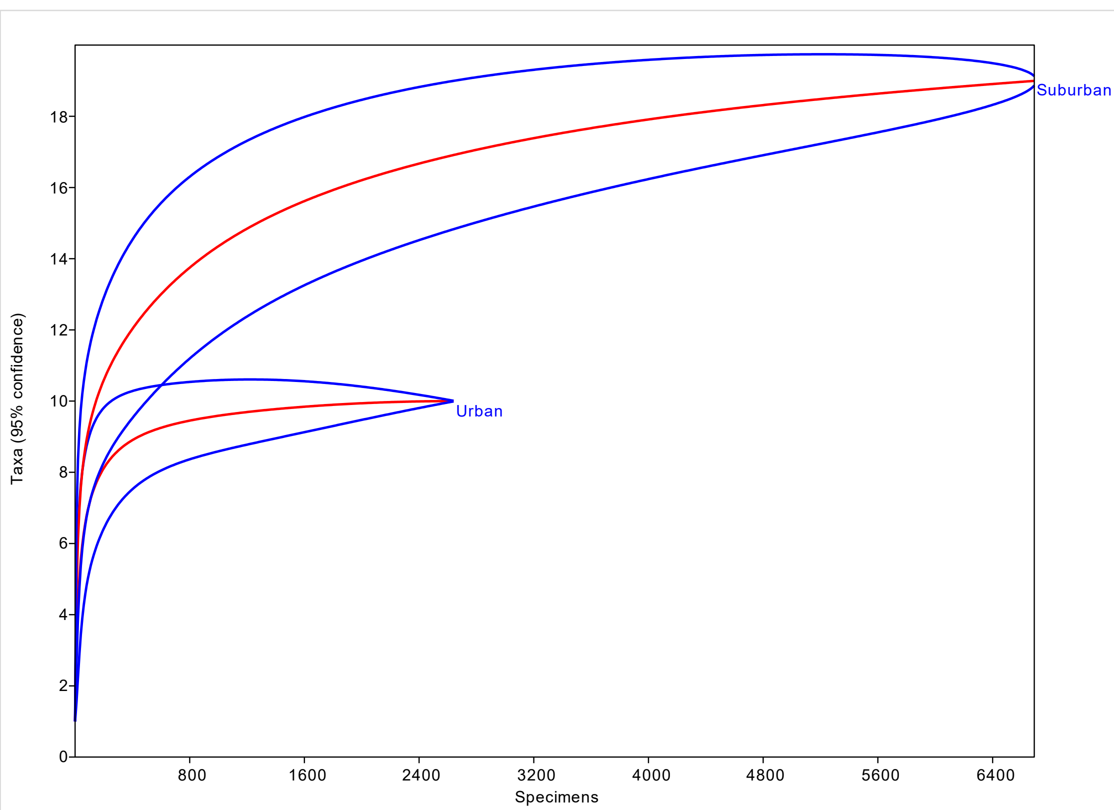

Fig 2. Rarefaction curves calculated using abundance in the pitfall traps and hand collecting of urban and suburban sites (Red lines are the observed values and Blue lines are 95% confidence intervals).

Table 2. Ants abundance of urban and suburban sites (PT: Pitfall traps; HC: Hand collecting).

	Species	Urban sites					Collecting methods		Suburban sites					Collecting methods	
		1	2	3	4	5	PT	HC	6	7	8	9	10	PT	HC
Myrmicinae	*Aphaenogaster testaceopilosa* (Lucas, 1849)	40	0	0	0	0	23	17	0	668	75	0	179	804	118
	Aphaenogaster cf. *crocea*	0	0	0	0	0	0	0	0	4	0	0	7	10	1
	Aphaenogaster depilis Santschi, 1911	0	0	0	0	0	0	0	0	1	0	0	0	1	0
	Aphaenogaster dulcineae Emery, 1924	0	0	0	0	0	0	0	0	0	0	0	23	22	1
	Tetramorium biskrense Forel, 1904	0	0	0	0	0	0	0	0	5	5	0	0	8	2
	Crematogaster scutellaris (Olivier, 1792)	117	0	0	0	0	64	53	0	227	20	21	0	188	80
Formicinae	*Cataglyphis bicolor* (Fabricius, 1973)	15	0	0	0	0	12	3	298	0	0	35	2	297	38
	Cataglyphis diehli (Forel, 1902)	0	0	0	0	0	0	0	2	0	0	1	1	4	0
	Camponotus atlantis Forel, 1890	2	0	0	0	0	2	0	0	0	1	0	0	1	0
	Camponotus lateralis (Olivier, 1792)	0	0	0	0	0	0	0	0	0	4	0	0	4	0
	Camponotus spissinodis (Forel, 1909)	8	0	0	0	0	6	2	0	0	3	0	0	3	0
	Lasius myops Forel, 1894	458	77	0	424	0	908	51	0	0	0	0	0	0	0
	Lasius cf. *grandis* (Forel, 1909)	0	173	524	375	220	995	297	0	0	226	0	0	204	22
	Lasius lasioides (Emery, 1869)	0	0	0	0	0	0	0	0	0	76	0	0	69	7
	*Messor barbarus (*Linnaeus, 1767)	0	24	0	0	0	12	12	2	0	0	0	80	69	13
	Messor bernardi Cagniant, 1967	0	95	0	0	0	88	7	1	8	2	0	0	9	2
	Monomorium salomonis (Linnaeus, 1758)	0	0	0	0	0	0	0	0	474	0	0	0	308	166
	Pheidole cicatricosa Stitz, 1917	0	0	0	0	0	0	0	0	1313	189	0	0	1258	244
Dolichoderinae	*Tapinoma simrothi* Krausse, 1911	61	40	0	0	0	93	8	167	0	0	1704	880	1954	797
	Bothriomyrmex decapitans Santschi, 1911	0	0	0	0	0	0	0	2	0	0	0	0	0	2
	Total of individuals	701	409	524	799	220	2203	450	472	2700	601	1761	1172	5213	1493

Sampling effort

The rarefaction curves based on individuals and samples (Fig 2, Fig 3, and Fig 4) indicate that the sampling effort was enough to sample the species from urban and suburban sites. In addition to the curves, very high C values (100%) exhibit a good representation of the ants in the samples and a very low probability of discovering new ants if additional sampling effort is still deployed. The CV values for each of the two habitats show a substantial heterogeneity in the probabilities of finding ant species in the samples (Table 3).

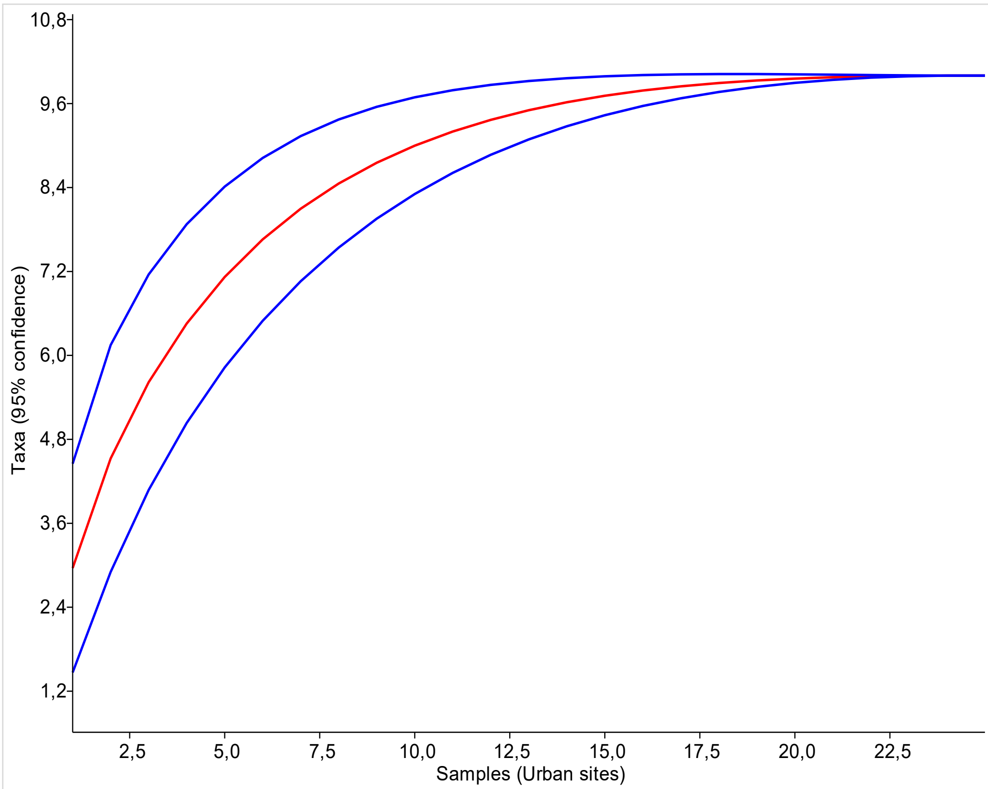

Fig 3. Rarefaction curves calculated using the number of ant samples of urban sites (Red lines are the observed values and Blue lines are 95% confidence intervals).

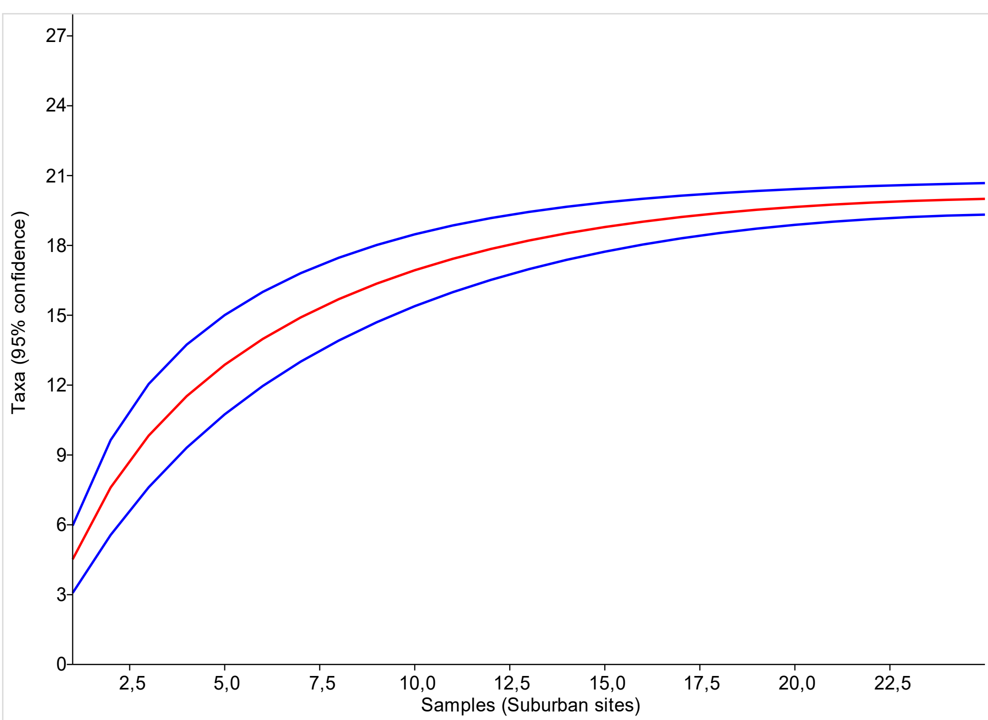

Fig 4. Rarefaction curves calculated using the number of ant samples of suburban sites (Red lines are the observed values and Blue lines are 95% confidence intervals).

Table 3. SIMPER analysis of ants' contributions to dissimilarities between urban and suburban communities.

Taxon	Av. dissim	Contrib. %	Cumulative %	Urban sites	Suburban sites
Tapinoma simrothi	28.66	31.61	31.61	20.2	550
Lasius cf. *grandis*	14.7	16.21	47.82	258	45.2
Pheidole cicatricosa	11.62	12.82	60.64	0	300
Lasius myops	10.87	11.99	72.64	192	0
Aphaenogaster testaceopilosa	7.607	8.392	81.03	8	184
Cataglyphis bicolor	6.57	7.247	88.28	3	67
Monomorium salomonis	2,947	3,25	91.53	0	94.8
Crematogaster scutellaris	2,832	3,124	94.65	23,4	53.6
Messor bernardi	1.407	1.552	96.2	19	2.2
Lasius lasioides	1,392	1.536	97.74	0	15.2
Messor barbarus	1.196	1.32	99.06	4.8	16.4
Aphaenogaster dulcineae	0.2743	0.3026	99.36	0	4.6
Camponotus spissinodis	0.1279	0.1411	99.5	1.6	0.6
Tetramorium biskrense	0.1227	0.1353	99.64	0	2
Aphaenogaster cf. *crocea*	0.1084	0.1195	99.76	0	2.2
Camponotus lateralis	0.07327	0.08082	99.84	0	0.8
Cataglyphis diehli	0.06252	0.06896	99.91	0	0.8
Bothriomyrmex decapitans	0.04179	0.0461	99.95	0	0.4
Camponotus atlantis	0.03501	0.03862	99.99	0.4	0.2
Aphaenogaster depilis	0.006216	0.006857	100	0	0.2

Ant community analysis per habitat

A total of 2,653 individual ants were collected in the urban habitats, comprising ten species and six genera. In the suburban habitats, 6,706 ant specimens belonging to 19 species and 11 genera were collected. The average ant species richness was higher in the suburban habitats (6.8 ± 0.82 SE) than in the urban habitats (3.2 ± 0.44 SE) (t-test: $p < 0.001$: Fig 5). The average ant abundance was significantly higher in suburban habitats (67.06 ± 25.60 SE) than in urban habitats (26.53 ± 9.38 SE; t-test: $p < 0.001$: Fig 6).

In urban habitats, *Lasius* cf. *grandis* and *Lasius myops* species were the most abundant, with 1,292 individuals (48.7%) and 959 individuals (36.1%), respectively. It is

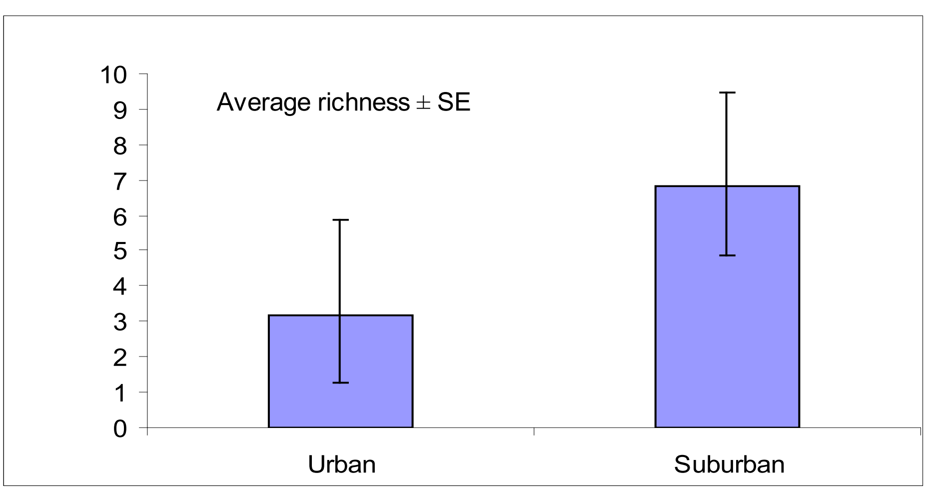

Fig 5. The average richness of urban and suburban ants (SE: Standard errors).

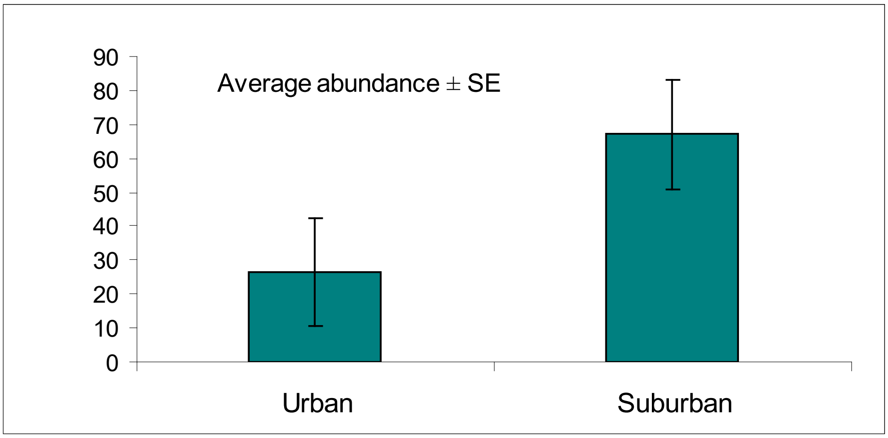

Fig 6. The average abundance of urban and suburban ants (SE: Standard errors).

followed by two species, *Crematogaster scutellaris* and *Tapinoma simrothi* with 117 individuals (4.41%) and 101 individuals (3.82%), respectively (Fig 7). Regarding the relative frequency of occurrences, *L.* cf. *grandis* and *L. myops* were also the most common, occurring at 4 of 5 sites of urban habitats. *Aphaenogaster* cf. *crocea*, *Cataglyphis bicolor*, *Camponotus atlantis*, *Camponotus spissinodis*, *Messor barbarus*, *Messor bernardi* and *T. simrothi* were each found at only a single site (Fig 7).

On suburban habitats, *T. simrothi* was the most abundant, with 2,751 individuals (41.10%), followed by *Pheidole cicatricosa* with 1,502 individuals (22.42%), *Aphaenogaster testaceopilosa* with 922 individuals (13.7%), *Monomorium salomonis* with 474 individuals (7.13%), and *C. bicolor* with 355 individuals (5.04%). All other 14 species collected had an abundance of < 300 individuals. Of the 19 species, six species were found at 3 of 5 sites, namely, *T. simrothi, P. cicatricosa, Crematogaster scutellaris, C. bicolor, A. testaceopilosa, Cataglyphis diehli, M. bernardi.* While eight species each were found only on one single site, namely, *M. salomonis, L.* cf. *grandis*, *L. lasioides Aphaenogaster foreli*, *Aphaenogaster depilis*, *C. atlantis*, *Camponotus lateralis*, and *C. spissinodis* (Fig 8).

The results showed that suburban habitats are more diversified (H' = 1.72) than urban habitats (H' = 1.25). The equitability values for suburban and urban habitats are moderate, with 0.58 and 0.54, respectively. The values indicate that some ant species were more abundant than others in both habitats (Table 3).

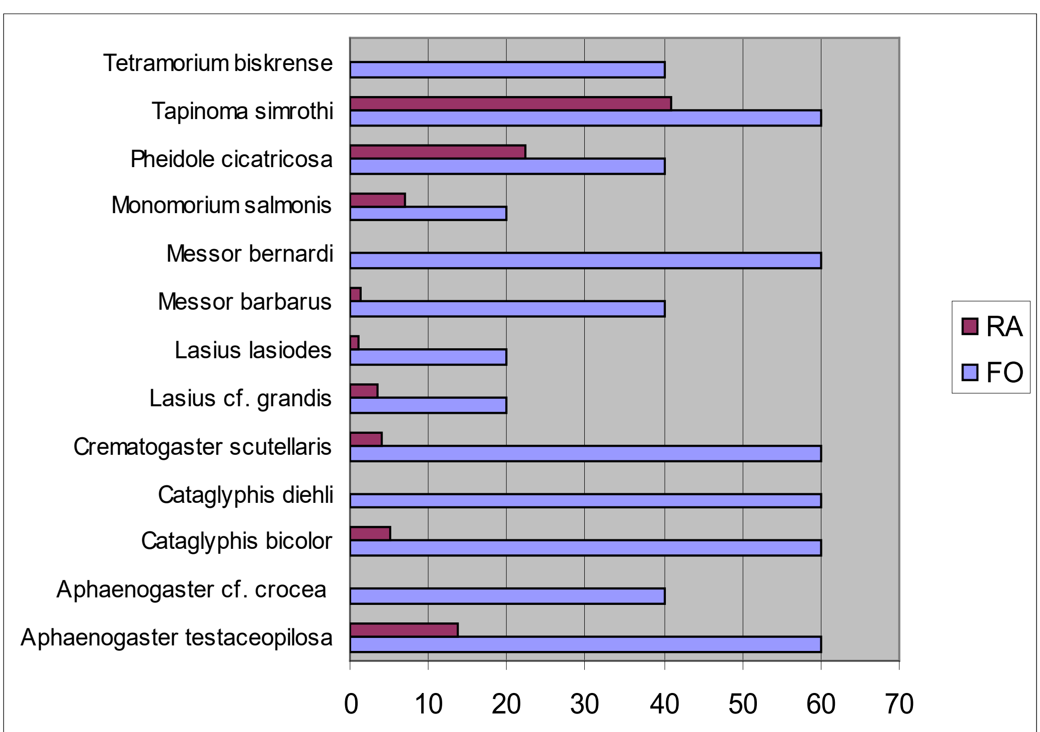

Fig 7. Relative of frequency occurrences (FO %) and Relative abundance (RA %) of ant community in urban sites.

The Jaccard similarity index value is 0.45, indicating an essential turnover of ant species between urban and suburban habitats. The NMDS shows two separated groups representing sites of urban and suburban habitats without overlap (Fig 9). According to PERMANOVA, differences in the ant community composition of urban and suburban habitat sites were highly significant (F = 2.94; p = 0.01). The average dissimilarity (as per SIMPER) was 90.37%. Table 4 illustrates the contribution of each ant to the dissimilarity between sites of both habitats. Four species (*T. simrothi*, *L.* cf. *grandis, P. cicatricosa*, *and L. myops*) contributed to 70% of the differences between sites of urban and suburban habitats. *L.* cf. *grandis* and *L. myops* represented most urban sites*, while T. simrothi* and *P. cicatricosa* represented most suburban sites.

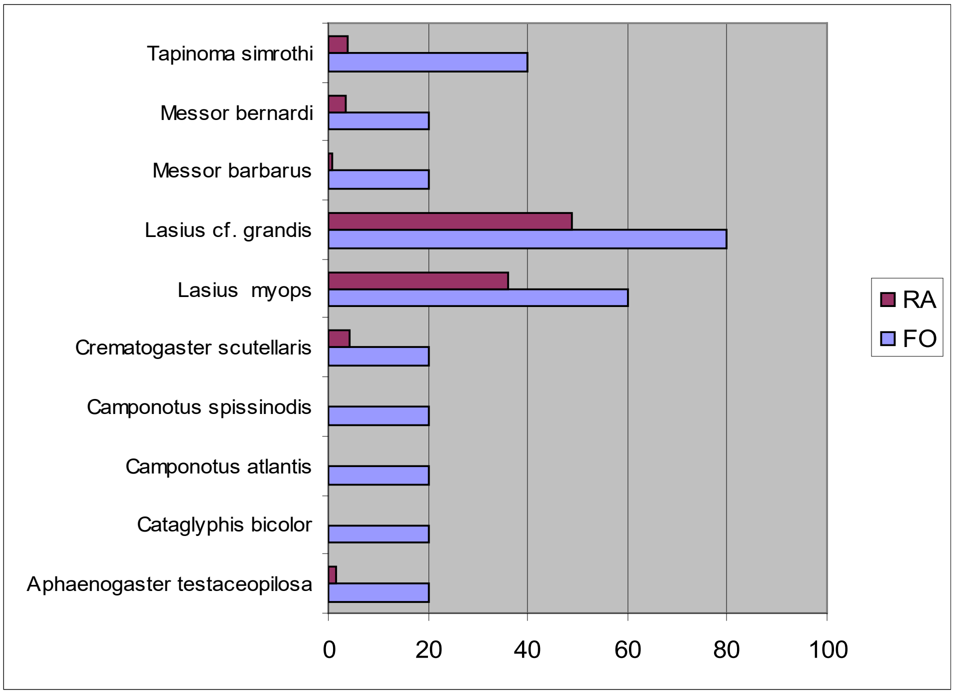

Fig 8. Relative of frequency occurrences (FO %) and Relative abundance (RA %) of ant community in suburban sites.

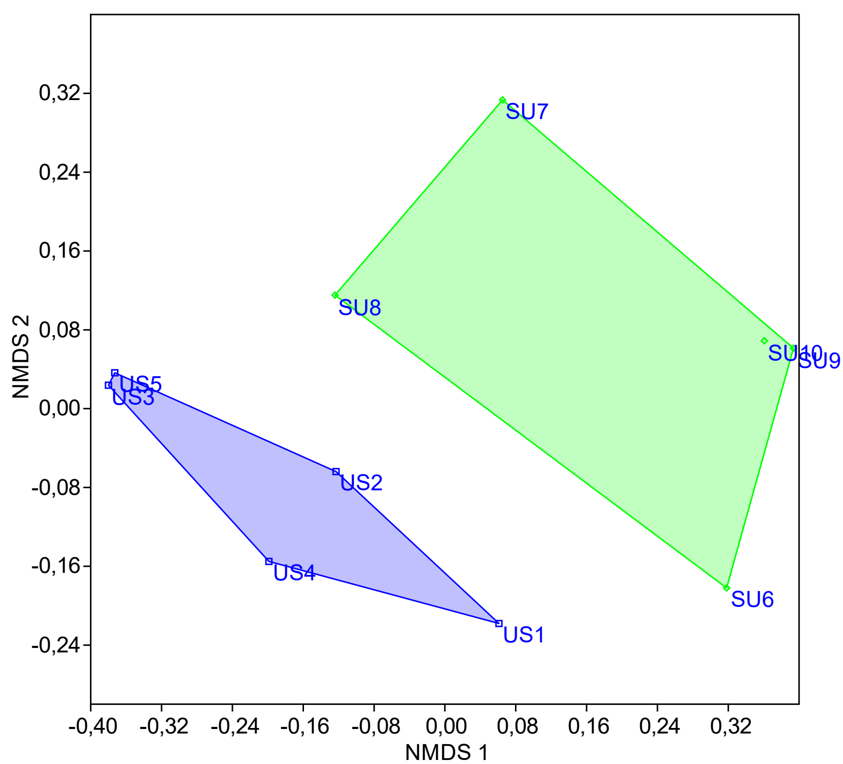

Fig 9. Non-metric multidimensional scale (NMDS) of ants of urban and suburban sites (Stress = 0.022).

Discussion

We used ant assemblages collected from Bejaia city areas to assess how ant communities respond to urban and suburban habitats. These 20 ant species collected in urban and suburban habitats belong to 11 genera and three subfamilies (Dolichoderinae, Formicinae, and Myrmicinae) of the six subfamilies represented in Algeria. Three (3) genera are particularly well represented among the collected ants; they are the genus *Camponotus* (3 species), *Lasius* (3 species), and *Messor* (2 species). In the present study all the sites sampled, the most abundant ant species were: *T. simrothi* followed by *L.* cf. *grandis, Pheidole cicatricosa*, *L. myops* and *A. testaceopilosa.*

Table 4. Ecological indices, Chao1, 1st order Jackknife, Estimated coverage (C) and Estimated CV values for urban and suburban ant community.

Ecological indices and non parametric estimators	Urban	Suburban
Richness (S)	10	19
Individuals	2653	6706
Shannon-Weaver (H')	1.258	1.726
Equitability	0.5461	0.586
Chao-1	10	19,5
1st order Jackknife	10	21
Estimated coverage	1	1
Estimated CV	2.85	2.44

Suburban habitats were the most diverse, while urban habitats were the least diverse. *L.* cf. *grandis* and *L. myops* are two predominant and frequent urban ant species that can easily be found in high abundance in different sites of urban areas. These two species were eurytopic and were more or less xerophilic. The dryness of urban soils should be a manageable factor for them. The ecological success of these two species may be linked to their mode of nourishment. Indeed, these ants can easily satisfy their food needs by consuming aphid honeydew (Saha et al., 2018).

In several countries, many authors have mentioned that genus *Lasius* was associated with urban spaces (Pisarski & Czechowski, 1978; Yamaguchi, 2004; Vepsäläinen et al., 2008; Ślipiński et al., 2012; Carpintero & Reyes-Lopez, 2014; Reyes-Lopez & Carpintero, 2014), and supposed that its predominance is most probably due to the strongly selective effect of specific urban habitat factors, which favor species well adapted to impoverished habitats. For example, according to Carpintero and Reyes-Lopez, 2014, *L. grandis* is numerically dominant in urban green areas at inland sites in Spain.

In suburban habitats, *T. simrothi* and *P. cicatricosa* were the most abundant and frequent. The same trend was observed in several natural ecosystems in Algeria. For example, similar results have been reported by Djioua and Sadoudi Ali-Ahmed (2015) in the region of Tizi Ouzou, Dehina (2009) in two stations in the Algiers region, Sidi-Ali et al. (2021) in two forest sites from Kabylia of Djurdjura and Aissat (2023) in islands of Bejaia. Soil moisture seems to be an essential factor to keep *T. simrothi* alive in suburban sites. This ant is also more or less abundant on two urban sites, the University campus and the Public Garden, which are constantly irrigated. According to Délye (1968), *T. simrothi* was classified among the hygrophilous ants that can only live in the Sahara near open water and in irrigated palm groves.

All cited studies used the scientific name *P. pallidula*, except for our study, where we gave our specimens *P. cicatricosa*. After taxonomic revision, Seifert (2016) divided the hyper-diverse species *P. pallidula* (Nylander, 1849) into four species. One of them, *P. cicatricosa*, has a North African distribution. Its ecological success in our study can be explained by the strong slopes of specific suburban sites (low and high maquis of Gouraya National Park), creating excellent habitats perfectly exposed to the sunshine. Its absence from urban habitats is probably due to the need for suitable habitats for its installation, especially since flat surfaces characterize all the sampled sites.

Ant rarefaction curves and estimated coverage (C) for both urban and suburban habitats reveal that the data obtained represent ant communities that can be collected with both methods (Pitfalls traps and hand collecting).

This study shows differences in species richness, abundance, and diversity index parameters of the ant communities of urban and suburban habitats. Shannon-Weaver index values were high in suburban habitats compared to urban habitats. At the same time, the equitability index between the two habitats was more or less moderate. The abundance of few ant species contributes to decreased diversity and equitability values, for example, the dominance of *L.* cf. *grandis* in urban habitats and *T. simrothi* in suburban habitats.

The Jaccard similarity index value indicates a significant turnover of ant species between urban and suburban habitats. The urban ant communities in this study largely resembled those found in suburban habitats. We found nine fewer species than in the suburban sites of Bejaia city. A single species was found in urban habitats not observed in suburban habitats: *L. myops*. Species found in suburban habitats but not found in urban habitats could be typical of natural habitats that have not been impacted by human activities, such as species that are associated with forests surrounding the city of Bejaia, such as the genera *Aphaenogaster*, *Monomorium*, *Pheidole* and *Tetramorium*. This association may indicate, on the one hand, that the ant fauna of our urban habitats is one of a simplified or nested subset of the ant fauna of our suburban habitats and, on the other hand, that suburban habitats act as sources of species and occupy sink habitats present in the urban area (Amarasekare & Nisbet, 2001). The NMDS ordination analysis showed a significant difference in the ant species composition of the urban and suburban habitats, which were statistically different in PERMANOVA, suggesting that our two habitats offer different ecological conditions for the ant community. Four ant species (*T. simrothi*, *L.* cf. *grandis, P. cicatricosa*, and *L. myops*) were responsible for 70% of dissimilarity among the two habitats, which can be explained, on the one hand, by the lower abundance of *T. simroth* and the absence of *P. cicatricosa* in urban habitats, on the other hand, by the lower abundance of *L. myops* in suburban habitats.

What we have observed in general in this study is that urbanization has dramatically impacted the structure and composition of ant communities. These changes are due, in large part, to the different characteristics of urban and suburban habitats. For example, in urban habitats, most of the sites sampled were manufactured constructions that suffer from large expanses of concrete, leaving only small vegetated plots for installing ants. Another factor that could constrain the development of ant communities is the simplified plant structure and the homogenization of ornamental plants across different urban sites. This homogenization of plant species eliminates the natural variation that ants rely on for nourishment and protection.

Consequently, resources such as nectar, pollen, and suitable nesting sites become severely limited. On the other hand, the suburban habitats are little or not affected by human modifications, and the vegetation is, as a whole, of the native type. The complexity of this habitat (the presence of several strata) should provide more nesting and foraging sites and a greater food supply (Nooten et al., 2019). For example, according to Buczkowski and Richmond (2012), trees serve as important nesting sites for many species of ants, and trees colonized by honeydew-producing Hemiptera provide important feeding sites for many species of ants. Also, the of trees provide, especially on the two sites of Gouraya National Park, can reduce the competition of ant species that peak their activities in scorching weather, such as the ant *C. bicolor* (Toennisson, 2009).

Conclusion

Our results show that urbanization affects ant communities' structure and composition. The ant fauna of urban habitats has fewer species compared to suburban habitats. *L.* cf. *grandis* and *L. myops* are two predominant and frequent ant species in urban habitats. In suburban habitats, *T. simrothi* and *P. cicatricosa* were the most abundant and frequent. Our results suggest an essential turnover of ant species between urban and suburban habitats due to the urban and suburban habitat characteristics. These results can be used in preparing a management plan for conserving biodiversity in an urban environment. In future urban habitat studies, it would be wise to measure ecological variables (habitat surfaces, distance to the urban center) to identify the fundamental factors responsible for changes in the diversity of the ant community in our urban environments.

Acknowledgments

We thank the General Direction of Scientific Research and Technological Development (DGRSDT) Ministry of Higher Education (Algeria) for its support. The authors thank the Editor and the two-anonymous reviewers for their comments.

Authors's Contributions

LN: Investigation, Methodology, writing-original draft
LA: Methodology, software, Formal analysis, writing: original-draft, writing: review & editing
LB: Investigation
CY: Investigation

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