Revista Brasileira de Ciências Ambientais
Brazilian Journal of Environmental Sciences

Ant assemblages (Hymenoptera: Formicidae) from areas under the direct influence of two small hydropower plants in Brazil

Assembleias de formigas (Hymenoptera: Formicidae) de áreas de influência direta de duas pequenas centrais hidrelétricas no Brasil

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ABSTRACT

Current energy production has been the subject of studies on environmental impacts and the need to adequately understand that the relationship to biodiversity loss is growing. One of the ways of assessing environmental changes is the use of bioindicator species, and ants represent an alternative in this regard. This study aimed to evaluate ant assemblages occurring in different environments in areas under the direct influence of two small hydropower plants (SHPP). Sampling was carried out using pitfall traps in forest and agricultural fragments, as well as pasture areas, along the Andrada River, municipality of Cascavel, state of Paraná, in July 2016 and March 2017. The sampled ant assemblages were evaluated for richness, abundance, and composition. The rarefaction analysis was used to compare the richness sampled in the two areas under direct influence. Abundance was analyzed based on the number of occurrences. The nonmetric multidimensional scaling (NMDS) was applied to test whether the abundance and composition of ant assemblages differ at the same site when sampled in both seasons. In total, 63 species belonging to 23 genera and 6 subfamilies were identified. The subfamily Myrmicinae was the most species-rich (S = 25), followed by the subfamily Formicinae (S = 21). The most species-rich genus was *Camponotus* (S = 15) followed by *Pheidole* (S =11). A total of 41.3% richness was registered concurrently in the two assemblages. The study contributes to the expansion of knowledge of the ant fauna occurring in the state of Paraná and serves as a basis for monitoring impacts caused by the implementation of SHPP and other developments.

Keywords: biodiversity; bioindicators; conservation; production of energy.

RESUMO

A produção energética vigente tem sido alvo de estudos sobre seus impactos ambientais, e cresce a necessidade de se compreender adequadamente sua relação com a perda de biodiversidade. Uma das formas de avaliação das alterações ambientais é a utilização de espécies bioindicadoras, e as formigas representam uma alternativa nesse quesito. Esta pesquisa objetivou avaliar diferentes ambientes quanto às assembleias de formigas que ocorrem nas áreas de influência direta de duas pequenas centrais hidrelétricas. A amostragem foi conduzida em ambientes de fragmentos florestais, agrícolas e de pastagens, junto das margens do Rio Andrada, no município de Cascavel, estado do Paraná, nos meses de julho de 2016 e março de 2017. Foram utilizadas armadilhas do tipo *pitfall* nas amostras e foram avaliadas a riqueza, a abundância e a composição das assembleias de formigas amostradas. Efetuou-se a análise de rarefação para comparar a riqueza amostrada nas duas áreas de influência direta. A abundância foi analisada com base no número de ocorrências. Foi construída uma análise nonmetric multidimensional scaling (NMDS) para testar se a abundância e a composição das assembleias de formigas diferem em um mesmo ponto quando amostradas nas duas estações. Registraram-se 63 espécies pertencentes a 23 gêneros e a seis subfamílias. A subfamília Myrmicinae foi a mais rica (S = 25), seguida da Formicinae (S = 21). O gênero mais rico foi *Camponotus* (S = 15), seguido por *Pheidole* (S = 11). O total de 41.3% da riqueza foi registrado concomitantemente nas duas assembleias. O estudo contribui para a expansão do conhecimento sobre a mirmecofauna que ocorre no território paranaense e serve de base para o monitoramento de impactos causados pela instalação de pequenas centrais hidrelétricas e de outros empreendimentos.

Palavras-chave: biodiversidade; bioindicadores; conservação; produção de energia.

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Conflicts of interest: the authors declare that there are no conflicts of interest.
Funding: Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).
Received on: 01/14/2021. Accepted on: 10/06/2021.
https://doi.org/10.5327/Z217694781030

Introduction

Human activities such as the conversion of forests into agricultural or pasture areas, the expansion of urban areas, and the implementation of projects that result in river damming are the examples that impact the environment, modify the area where they are developed, cause changes in physical and chemical properties of soils, interfere with watercourses, modify the habitat, and impact the flora and fauna (Tsoutsos et al., 2005; Costa et al., 2019). Environmental impacts, such as the emission of greenhouse gases and, consequently, global warming, from the current energy matrix based on fossil fuels, have been the subject of studies and public policies (Laurent and Espinosa, 2015). Thus, the need to explore renewable energy sources emerges, whose impacts on biodiversity are also observed; however, they are considered minor in relation to the burning of fossil fuels (Gasparatos et al., 2017; Bracco, 2020). The exploration of renewable energy sources modifies the environment, results in river damming, as in the case of hydropower plants (HPP) and in the suppression of vegetation, and alters the local microclimate (Gasparatos et al., 2017). These changes in the directly affected areas result in the loss of habitats for terrestrial organisms, such as invertebrates. The impacts resulting from these processes on biodiversity are still less known.

Hydropower is an alternative to fossil fuels; however, environmental impacts resulting from the implementation and operation of HPP on invertebrates, and more specifically on the entomofauna, are still incipient (Kjærstad et al., 2018). The impacts are related to vegetation suppression, land removal, soil compaction, and flooding that can destroy remnants of vegetation, change the dynamics of the affected ecosystem, and make it impossible the permanence of animal species (Moran et al., 2018). Insects are affected by this process, and the study of these organisms can reveal the level of environmental quality from which interventions can be determined in order to maintain, recover, or restore the balance of the environment, aiming at the ecological sustainability of ecosystems (Rocha et al., 2015; Moura and Franzener, 2017; Parikh et al., 2021).

Only in the last decade, the invertebrate community became the target of environmental impact studies and reports of these impacts (EIA/RIMA) when such projects are implemented in Brazil, and in only a few Brazilian states, such as Paraná. In southern Brazil, approximately 48 HPP and 146 small HPP (SHPP) are in operation (ANEEL, 2016, 2019). Electrical energy represents the main source of energy production in Brazil, which is justified by entrepreneurs due to the low cost of production, low emission of polluting gases, and also for being a source of energy considered clean (Oliveira, 2018). Despite the favorable arguments, studies begin to point out negative environmental and social impacts of the implementation of large HPP, such as the release of greenhouse gases (Carreira, 2016), social transformations in the territory, and impacts on fauna and flora (Marín and Torres, 2013). As SHPP have more accessible legislation and faster implementation, they have been installed in small- and medium-sized rivers (Kusma and Ferreira, 2010; Lutinski et al., 2017b). Despite the smaller impact, the construction of these developments also causes impacts that need to be better understood both to support the planning of such projects and to establish bases for monitoring after the implementation.

One of the ways to assess and monitor changes in biodiversity is the use of bioindicator species (Parmar et al., 2016; Araújo et al., 2018). The presence, absence, or change in the abundance of a population can serve as a parameter to be evaluated (Gerlach et al., 2013; Rocha et al., 2015). Among the bioindicators used, insects have achieved prominence, both for being the most diverse group in terms of richness and for easy sampling (Lutinski et al., 2018).

Predominant in most terrestrial environments, ants are recognized as bioindicators (Tibcherani et al., 2018). The study of their richness and abundance allows the effective assessments of environmental conditions and the level of restoration of impacted areas (Blinova and Dobrydina, 2018). These insects fulfill this function because they have a wide geographic distribution, are locally abundant, functionally important at different ecological and trophic levels, and are susceptible to ecological changes (Lawes et al., 2017; Tibcherani et al., 2018).

Habitats have been and continue to be transformed by human action, and the study of ant assemblages enables us to assess the impact of these activities in these locations (Tibcherani et al., 2018). Some are cited as pests; however, they play essential roles in nutrient cycling, due to feeding on living or dead organic matter. They also act in the construction of underground galleries, aiding in soil drainage, and, consequently, aiding in the penetration of plant roots. In addition, they are important in the trophic chain, as they act as predators and also serve as prey (Hölldobler and Wilson, 1990).

Studies on the ant fauna in Paraná are recent and still restricted (Lutinski et al., 2017a, 2017b; Franco and Feitosa, 2018), with regions and environments still unexplored regarding the biodiversity of these insects. The diversity and richness of ant assemblages are affected by human activities. A reduction in ant richness is observed in forested environments that are transformed into monocrops or pasture areas. In contrast, generalist species tend to be more abundant under such conditions (Baccaro et al., 2015). Considering the bioindicator potential of ants, understanding the changes in assemblages of these insects becomes relevant to support studies and monitoring of environmental impacts. In this context, this study aimed to evaluate the richness, abundance, and composition of ant assemblages occurring in the areas under the direct influence of two small hydroelectric power plants in the southwest region of the state of Paraná.

Material and Methods

Study area

Sampling was conducted in transects established in forest fragments, agricultural areas, and pastures, along the banks of the Andrada River, municipality of Cascavel, state of Paraná. In that river, the implementation of two SHPP, namely, AL and SM, among others, was planned. The two SHPP were designed one continuous with the other, with SHPP 2 upstream of SHPP 1. In the areas under the direct influence (DIA) of each of these two SHPP, five sampling sites were defined, on both banks of the river, equidistant from each other, in order to cover the greatest possible heterogeneity of environments in the DIA, as described below:

- SHPP 1 (AL): *Site 1* (S 25°10′25″; W 53°24′53″), in early and medium stages of natural restoration with native vegetation, surrounded by agricultural cultivation areas, located at the final portion of the reservoir and upstream of the flooded area; *Site 2* (S 25°10′44″; W 53°25′07″), with native and arboreal vegetation, consisting of a forest fragment, located in the final portion of the reservoir and upstream from the flooded area; *Site 3* (S 25°11′12″; W 53°24′59″) located in the middle portion of the area expected to be flooded. Low-density tree vegetation limited by pastures and crops and a forest fragment; *Site 4* (S 25°11′25″; W 53°25′44″) also located in the middle portion of the area expected to be flooded. Low-density tree vegetation limited by pastures and crops; *Site 5* (S 25°11′29″; W 53°25′59″), where the installation of a powerhouse was planned, sloped relief with native arboreal vegetation;
- SHPP 2 (SM): *Site 1* (S 25°08′25″; W 53°24′06″) located in the final portion of the reservoir and upstream of the flooded area, With native and secondary vegetation, surrounded by agricultural cultivation areas; *Site 2* (S 25°08′59″; W 53°25′06″) located in the final portion of the reservoir and upstream of the flooded area, with arboreal native vegetation, composing a forest fragment bordering the river bed; *Site 3* (S 25°08′18″; W 53°24′04″) located in the middle portion of the area expected to be flooded. Low-density arboreal vegetation limited by pastures and crops; *Site 4* (S 25°10′12″; W 53°24′08″) located in the middle portion of the area expected to be flooded. Low-density arboreal vegetation limited by pastures and crops; *Site 5* (S 25°08′46″; W 53°24′07″), downstream of the development with native vegetation and at an advanced stage of succession.

Sampling

Two seasonal samplings were carried out, covering the predefined sampling sites. The samplings were carried out in July 2016 (winter) and March 2017 (summer), during the study to obtain licenses for the two projects.

Pitfall traps were used for sampling, which consisted of plastic cups with a capacity of 500 mL (7.5 cm in diameter by 11.5 cm in height), fully buried, so that their openings are at the ground level. Each cup was added with 200 mL water with a drop of detergent to break the surface tension of the water, leading the ant to sink as it fell. At each of the sampling sites, five pitfall traps were installed, equidistant 20 m from each other, which remained open for 48 h (Bestelmeyer et al., 2000) in each of the samplings. A total of 25 pitfalls were installed in each DIA, in each sampling (summer and winter), 50 for each SHPP, i.e., 100 in total.

The use of pitfall traps is justified by the heterogeneity of the sampled environments, aiming at standardizing the sampling effort. Areas devoid of vegetation prevent the use of sampling techniques for canopy ants, nor do they have a uniform litter that allows the use of some extraction method.

Screening and identification

Specimens sampled were transferred to flasks containing 70% alcohol. In the laboratory, they were screened and mounted for later identification under a binocular microscope. Ants were identified according to the keys proposed by Gonçalves (1961), Kempf (1964, 1965), Watkins (1976), Della Lucia (1993), Lattke (1995), Taber (1998), Fernández (2003), Longino (2003), Longino and Fernández (2007), and Wild (2007).

Statistical analysis

Richness was defined as the number of ant species occurring in each of the samples. Abundance was defined based on the number of occurrences of each species in each pitfall (Tavares et al., 2008). The number of records minimizes the effect of foraging habits and colony size and is more appropriate for studies of ant assemblages (Romero and Jaffe, 1989). The percentage relative frequency was defined by the number of occurrences (i.e., the sum of records of the presence of a particular species in each pitfall) divided by the sum of occurrences of all species in the respective DIA and multiplied by 100 (percentage).

Diversity (richness and abundance) was evaluated using the Shannon–Weaver Diversity Index. This analysis was obtained using the EstimateS 8.0 software (Colwell, 2006). Evenness represents the participation of each taxon in the assemblage and was estimated by the Pielou index (Magurran, 1988). To assess the sample sufficiency, the nonparametric Chao 1 index was used and estimates were generated with the EstimateS 8.0 software (Colwell, 2006). The Chao 1 estimator essentially uses information about species occurring in only one sample (singletons) and those occurring in two samples (doubletons) (Chao, 1987).

Ant richness of the DIA of the two SHPP was compared using the rarefaction test based on the number of occurrences (Gotelli and Colwell, 2001). These analyses were obtained using the EcoSim 7 software (Gotelli and Entsminger, 2001), which allows the comparisons of richness between assemblages that differ in terms of species occurrence.

Nonmetric multidimensional scaling (NMDS) was applied to test whether the abundance and composition of ant assemblages differ at the same site when sampled in both seasons. The data matrix was previously transformed into log(x+1); the Bray–Curtis index was used as an association index, and the analysis was performed with the statistical software Primer 6.1.9 (Clarke and Gorley, 2005). Additionally, PERMANOVA was used to test the difference between groups.

The research was carried out under license ICMBio/SISBio number 50736-1. The sample specimens, as well as the accompanying fauna, were listed in the educational collection of the Universidade Comunitária da Região de Chapecó, Unochapecó.

Results

A total of 196 occurrences of ants were recorded with the sampling effort used. In all, 63 species belonging to 23 genera and 6 subfamilies were recorded. The ant assemblage of DIA of SHPP 1 showed greater richness (S = 47) and abundance (n = 115) compared with the assemblage of DIA of SHPP 2 (S = 42; n = 81). The subfamily Myrmicinae was the most species-rich (S = 25), followed by Formicinae (S = 21), Ponerinae (S = 8), Dolichoderinae (S = 6), Pseudomyrmecinae (S = 2), and Ectatomminae (S = 1) subfamilies. The most species-rich genus was *Camponotus* (S = 15) followed by *Pheidole* (S = 11). The most abundant species in the records were *Pheidole* sp. 2 (n = 18; 9.2%), *Pachycondyla striata* F. Smith, 1858 (n = 13; 6.6%), *Camponotus cameranoi* Emery, 1894 (n = 10; 5.1%), and *Gnamptogenys striatula* Mayr, 1884 (n = 10; 5.1%) (Table 1).

A total of 41.3% (S = 26) of the richness was registered concomitantly in the two assemblages. Altogether 33.3% (S = 21) of the richness was registered exclusively in the DIA of SHPP 1 and 25.4% (S = 16) exclusively in the DIA of SHPP 2. The Chao 1 estimate for the assemblage of SHPP 2 was 96.2 species and for the assemblage of SHPP 1, 74.6. Shannon and Evenness indices were similar for the two assemblages (Figure 1).

The greater richness of the assemblage of SHPP 1 (Table 1) was also demonstrated by the rarefaction analysis (Figure 2). The curves did not reach asymptote (Figure 2), indicating that the richness of both assemblages may be greater than that sampled according to Chao 1 estimates (Figure 1).

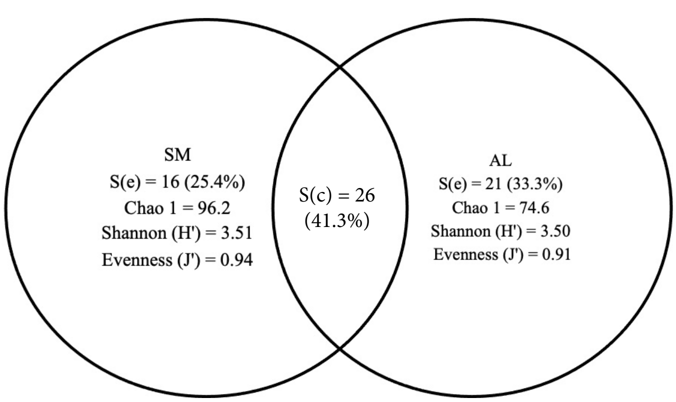

Figure 1 – Exclusive (S(e)), shared (S(c)), and estimated (Chao 1) richness, Shannon diversity index, and Evenness of ant assemblages sampled in DIA, in the pre-implementation period of two SHPP in the municipality of Cascavel, state of Paraná, July 2016 (winter) and March 2017 (summer).
AL: SHPP 1; SM: SHPP 2.

Table 1 – Richness, occurrences, and percentage relative frequency of ants sampled in DIA, in the pre-implementation period of two SHPP in the municipality of Cascavel, state of Paraná, July 2016 (winter) and March 2017 (summer).

Taxon	SHPP AL		SHPP SM	
	(n)	(%)	(n)	(%)
Subfamily Dolichoderinae				
Dorymyrmex brunneus (Forel, 1908)			1	1.23
Linepithema gallardoi (Brèthes, 1914)	1	0.87	1	1.23
Linepithema micans (Forel, 1908)	1	0.87	3	3.70
Linepithema humile (Mayr, 1868)	1	0.87	1	1.23
Linepithema sp. 1			6	7.41
Linepithema sp. 2	1	0.87		
Subfamily Ectatomminae				
Gnamptogenys striatula Mayr, 1884	8	6.96	2	2.47
Subfamily Formicinae				
Brachymyrmex aphidicola (Forel, 1909)	1	0.87		
Brachymyrmex coactus Mayr, 1887	2	1.74	1	1.23
Brachymyrmex sp.			1	1.23
Camponotus cameranoi Emery, 1894	5	4.35	5	6.17
Camponotus cingulatus Mayr, 1862	2	1.74	2	2.47
Camponotus fastigatus Roger, 1863	1	0.87		
Camponotus lespesii Forel, 1886	2	1.74	1	1.23
Camponotus melanoticus Emery, 1894	1	0.87	1	1.23
Camponotus mus Roger, 1863			1	1.23
Camponotus rufipes (Fabricius, 1775)			4	4.94
Camponotus sp. 1	3	2.61	1	1.23
Camponotus sp. 2			1	1.23
Camponotus sp. 3			2	2.47
Camponotus sp. 4			1	1.23
Camponotus sp. 5	4	3.48	1	1.23
Camponotus sp. 6	5	4.35		
Camponotus sp. 7	2	1.74		
Camponotus sp. 8	1	0.87		
Myrmelachista sp.	1	0.87		0.00
Nylanderia fulva (Mayr, 1862)	1	0.87		
Paratrechina longicornis (Latreille, 1802)	1	0.87		

Continue...

Table 1 – Continuration.

Taxon	SHPP AL		SHPP SM	
	(n)	(%)	(n)	(%)
Subfamily Myrmicinae				
Acromyrmex rugosus (F. Smith, 1858)	1	0.87	1	1.23
Acromyrmex subterraneus (Forel, 1893)			1	1.23
Apterostigma pilosum Mayr, 1865	2	1.74		
Apterostigma wasmannii Forel, 1892	1	0.87		
Atta sexdens (Linnaeus, 1758)	3	2.61	2	2.47
Atta sp.	6	5.22	1	1.23
Crematogaster sp.			1	1.23
Monomorium floricola (Jerdon, 1851)	1	0.87		
Mycocepurus goeldii (Forel, 1893)			1	1.23
Mycocepurus sp.			1	1.23
Pheidole pubiventris Mayr, 1887	3	2.61	4	4.94
Pheidole risii Forel, 1892	1	0.87		
Pheidole sp. 1			4	4.94
Pheidole sp. 2	13	11.30	5	6.17
Pheidole sp. 3			4	4.94
Pheidole sp. 4	3	2.61	1	1.23
Pheidole sp. 5	3	2.61		
Pheidole sp. 6	3	2.61	1	1.23
Pheidole sp. 7	2	1.74	1	1.23
Pheidole sp. 8	1	0.87		
Pheidole sp. 9	1	0.87		
Pogonomyrmex naegelii Forel, 1878	1	0.87	1	1.23
Solenopsis saevissima (F. Smith, 1855)	1	0.87	3	3.70
Solenopsis sp.	2	1.74	1	1.23
Wasmannia auropunctata (Roger, 1863)	1	0.87		
Subfamily Ponerinae				
Hypoponera trigona (Mayr, 1887)			1	1.23
Hypoponera sp. 1	1	0.87		
Hypoponera sp. 2	1	0.87		
Neoponera villosa (Fabricius, 1804)	5	4.35	2	2.47
Odontomachus chelifer (Latreille, 1802)	1	0.87	1	1.23

Continue...

Table 1 – Continuration.

Taxon	SHPP AL		SHPP SM	
	(n)	(%)	(n)	(%)
Pachycondyla striata F. Smith, 1858	9	7.83	4	4.94
Pachycondyla sp. 1	2	1.74		
Pachycondyla sp. 2	1	0.87		
Subfamily Pseudomyrmecinae				
Pseudomyrmex flavidulus (F. Smith, 1858)	2	1.74	1	1.23
Pseudomyrmex gracilis (Fabricius, 1804)			3	3.70
Richness	47		42	
Abundance (occurrences)	115		81	

AL: SHPP 1; SM: SHPP 2.

With 35% similarity, the NMDS analysis grouped the abundance and composition of ant assemblages from the sites sampled in the two DIA into four groups. Site 2 of the DIA of SHPP 2 was similar to sites 1, 2, 3, and 4 of the DIA of SHPP 1, while Site 5 of this DIA was isolated from all others. Sites 1 and 5 and sites 3 and 4 of the DIA of SHPP 2 formed two separate groups (Figure 3). The difference between the sites was confirmed by the PERMANOVA analysis ($F = 1.87$; $p = 0.04$). Ecologically, this difference indicates the heterogeneity and the mosaic of different land uses that make up the sites sampled in the DIA of the two SHPP.

Discussion

The biodiversity (subfamilies and genera) of ants sampled reflects the accumulated knowledge of the ant fauna occurring in southern Brazil (Ulysséa et al., 2011; Franco and Feitosa, 2018). The most species-rich subfamilies in the samples, Myrmicinae, Formicinae, Ponerinae, and Dolichoderinae, corroborate the study of Lutinski et al. (2018). The richness of the subfamily Myrmicinae predominates in samples from southern Brazil (Ulysséa et al., 2011; Franco and Feitosa, 2018; Rizzotto et al., 2019). The richness, abundance, and composition sampled will serve as a parameter for evaluating the impacts caused during the implementation of the two projects. The difference in the evaluated parameters of the ant fauna sampled at different sites reflects the mosaic of environments and land uses that compose them.

Myrmicine ants perform various ecosystem functions, occupy different niches, colonize strata from the subsoil, and litter to the top of the canopy (Baccaro et al., 2015; Cuautle et al., 2020). Some species establish relationships with fungi, plants, and even other ants (Baccaro et al., 2015). The richness of the genera *Pheidole* (S = 11), *Acromyrmex* (S = 2), and *Solenopsis* (S = 2) also corroborates the literature on this

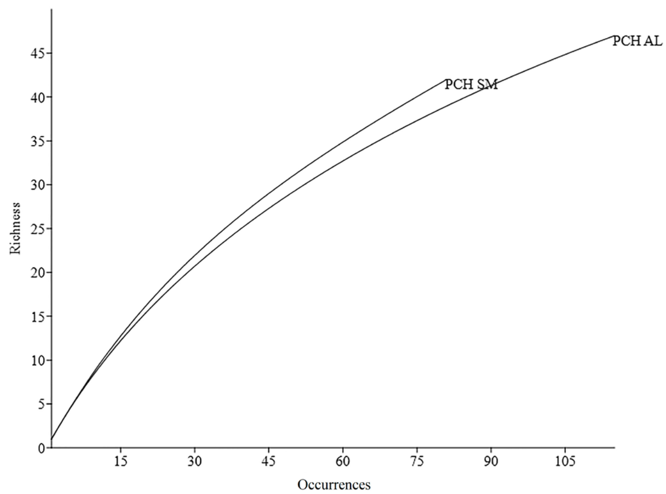

Figure 2 – Comparison, using the rarefaction method, of the richness of ant assemblages sampled in DIA, in the pre-implementation of two SHPP in the municipality of Cascavel, state of Paraná, July 2016 (winter) and March 2017 (summer).
AL: SHPP 1; SM: SHPP 2.

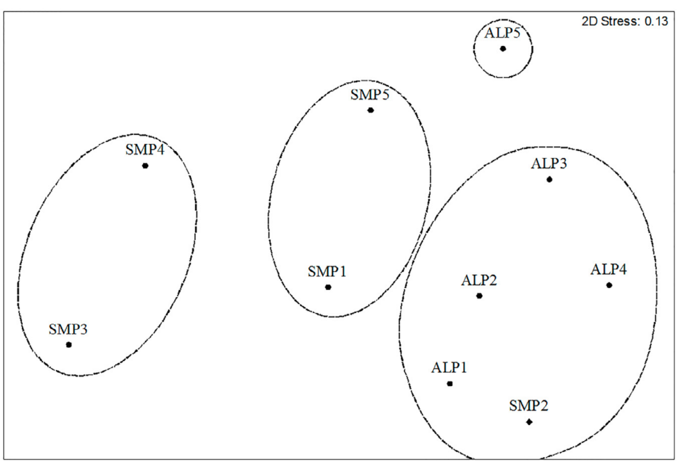

Figure 3 – Distribution, according to NMDS of the abundance and composition of ant assemblages sampled in DIA, in the pre-implementation period of two SHPP in the municipality of Cascavel, state of Paraná, July 2016 (winter) and March 2017 (summer).
AL: SHPP 1; SM: SHPP 2; P1-5: sampling sites.

subfamily in southern Brazil (Ulysséa et al., 2011; Franco and Feitosa, 2018; Dröse et al., 2019). While *Acromyrmex*, *Apterostigma*, *Atta*, and *Mycocepurus* ants feed on fungi grown on plant material, *Crematogaster*, *Monomorium*, *Pheidole*, *Solenopsis*, and *Wasmannia* are generalists (Baccaro et al., 2015). Some species of *Pheidole* and *Solenopsis* are predators and can contribute to biological control (Abeijon et al., 2019). The mosaic of conserved or recovering environments, surrounded by agricultural environments and pasture areas, can explain the occurrence of myrmicine ants in the DIA of the two SHPP, since, among the sampled species, some are tolerant to environmental disturbances, while others require more conserved environments.

The subfamily Formicinae is the second most species-rich among Formicidae in the Neotropical region (Martins et al., 2020). Species-rich genera such as *Camponotus* belong to this subfamily. These are easily sampled ants, usually with arboreal habits; however, some can be found in the soil or litter (Baccaro et al., 2015). The genus *Camponotus*, most species-rich in the samples (S = 15), is constant in the records of the southern Atlantic Forest (Franco and Feitosa, 2018; Lutinski et al., 2018; Dröse et al., 2019). This genus includes generalist ants, although they can establish close relationships with other insects, such as aphids (Hemiptera, Aphididae) (Baccaro et al., 2015), and can also be found in urban environments (Lutinski, 2017). Also highlighted in the samples were the genera *Brachymyrmex* (S = 3) and *Myrmelachysta* (S = 1), ants associated with litter and vegetation, respectively (Baccaro et al., 2015). It is also worth highlighting the records of *Nylanderia fulva* and *Paratrechina longicornis*, ants known for their invasive, generalist, and tolerant habits in disturbed environments (Zenner de Polanía, 2019). As with myrmicine ants, the richness and abundance of Formicinae ants can be explained by the heterogeneous preservation conditions verified in the sampling sites.

The subfamily Ponerinae stands out for its richness and abundance in samples taken in conserved environments in southern Brazil (Franco and Feitosa, 2018; Lutinski et al., 2018; Dröse et al., 2019). The richness of the genera *Hypoponera* (S = 3) and *Pachycondyla* (S = 3) agrees with the literature since these genera stand out in richness among the Ponerinae ants of the neotropical region (Bolton, 2021). Ants of these genera, as well as *Neoponera* and *Odontomachus*, are the specialized predators found in soil and litter, where they prey on small arthropods. It is worth noting that the richness of Ponerinae ants sampled in the two DIA allows us to infer that, despite the anthropogenic disturbance verified from the agricultural and grazing activities practiced in the surroundings, the existing forest remnants harbor a specialized ant fauna.

Dolichoderinae ants are constantly recorded in samples taken in the Atlantic Forest Biome (Freitas et al., 2014). In general, they usually have relationships with some plants, on which feed on sugary liquids from floral nectaries (Baccaro et al., 2015), with an emphasis in this study on the richness of *Linepithema* (S = 5). *Dorymyrmex* and *Linepithema* are the generalist ants and support fragmentation and anthropic environments (Lutinski et al., 2017b), which may explain the richness and abundance in the samples from the two DIA.

The subfamily Ectatomminae was represented in the samples by the records of only one species, *G. striatula*. It is a specialized species of predatory ant that colonizes and forages the litter, where it also finds its prey (Camacho and Feitosa, 2015). The records of this species in the two DIA are associated with the remaining forest fragments.

Pseudomyrmecinae ants are frequent in surveys that were already carried out in southern Brazil (Ulysséa et al., 2011; Franco and Feitosa, 2018; Dröse et al., 2019). Two species belonging to the genus *Pseudo-*

myrmex were sampled, and *Pseudomyrmex flavidulus* was recorded in the two DIA. These ants, although they have already been recorded in urban (Lutinski, 2017) and agricultural (Rizzotto et al., 2019) environments, depend on the vegetation where they find their prey. In this sense, the role of DIA forest fragments in the conservation of this fauna and the biodiversity associated with it is highlighted.

Although 41.3% richness was sampled simultaneously in the two DIA, most species occurred exclusively in one or the other DIA. Myrmecofauna samples are influenced by abiotic factors such as temperature and humidity (Hölldobler and Wilson, 1990) that regulate the foraging activities of these insects. Biotic factors, such as the presence of vegetation that provides them with nesting and food sites, in many cases, and the presence of other animal species, especially other arthropods, with which they interact and obtain food (Baccaro et al., 2015), determine their presence or absence in a given environment. In this sense, the richness shared by the two DIA can be explained by the sharing of biotic and abiotic factors, as they are located in the same hydrographic basin of a small river. The occurrence of unique species in each DIA, in contrast, can be explained by the status of conservation or impact in which each sampling site is. These variations in the status of conservation in which each sampling site is found may also explain the similarity in composition and abundance verified from the NMDS and PERMANOVA. Sites 1 and 2 of each DIA stood out in terms of richness, abundance, and composition, which may be associated with better conditions of native vegetation cover. Sites occupied by crops and pastures showed lower richness and abundance (Sites 3, 4, and 5 of each DIA).

The ant assemblage richness of the DIA of SHPP 1 was 11.9% higher than that of the DIA of SHPP 2. However, Chao 1 estimate for the ant assemblage of DIA of SHPP 2 indicated that the richness of this can be 28.9% higher than the DIA of SHPP 1. These results, associated with the values of the Shannon (H′) and Evenness (J′) indices, do not allow us to infer that the ant richness of the two DIA is different from each other and that the variations found are small and due to chance. Estimates such as Chao 1 help in the analysis of sampling sufficiency (Lemes and Köhler, 2017) and represent a useful tool when the sampling effort is limited.

Final Considerations

The relevance of biodiversity surveys in environments to be impacted by impoundments such as SHPP lies in establishing a basis from which it is possible to carry out further studies and compare the results. In this way, it was contributed to more assertively measure the environmental impacts of these projects. Ants, recognized as bioindicators, allow an inference about the condition of the environment, especially regarding the succession or degradation of the vegetation and, therefore, of the terrestrial invertebrate fauna, with which the ants maintain a close relationship with many taxa.

In this sense, this study fulfills its objective of contributing information about ant assemblages occurring in environments subjected to impacts by the implementation of two SHPP. First, the survey contributes to the expansion of knowledge about the ant fauna occurring in the state of Paraná, and, second, it will serve as a basis for monitoring impacts caused by the implementation of these and other projects.

The ant fauna surveyed here is mostly constituted by genera and species that are abundant in the southern region of Brazil and frequently sampled in anthropized environments. These are resilient species, whose richness and local abundance will be less affected by the implementation of SHPP, in short and medium term. Nevertheless, the occurrence of species of the genera *Gnamptogenys*, *Hypoponera*, *Mycocepurus*, *Myrmelachista*, *Odontomachus*, and *Pseudomyrmex* in the samples stands out. These ants, although abundant in the region, are associated with litter, vegetation, and/or prey (other invertebrates) that serve as food. These species tend to disappear locally as the changes resulting from the implementation of SHPP take place.

Contribution of authors:

Lutinski, J.A.: Conceptualization, Data curation, Investigation, Formal analysis, Methodology, Resources, Software, Writing — original draft, Writing — editing and review, Supervision, Validation, Visualization. Filtro, M.C.: Funding acquisition, Project administration. Baucke, L.: Funding acquisition, Project administration. Dorneles, F.E.: Investigation, Writing – editing and review. Lutinski, C. J.: Investigation, Writing – editing and review. Guarda, C.: Conceptualization, Investigation, Writing – editing and review.

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