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Inventory of Ant Fauna in the Influence Area of a Small Hydropower Plant in the State of Paraná, Brazil

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ABSTRACT: The construction of hydroelectric dams for power generation causes environmental alterations and ecosystem restructuring in directly and indirectly affected areas. This study aimed to survey the ant fauna in the indirect area of influence of a small hydroelectric plant located in Mangueirinha, Paraná State, Brazil. Seven sampling campaigns were conducted, two before and five during the project's implementation, using pitfall traps as the sampling method. A total of 72 ant species were recorded, belonging to 26 genera and six subfamilies. Species richness and abundance did not differ significantly between the pre-implementation and implementation phases. The Chao1 estimator indicated that actual species richness may be approximately 7.6% higher than observed. These findings contribute to understanding ant biodiversity in areas subject to land-use change in Paraná State. The results highlight the value of using insect species richness and abundance, particularly of bioindicator groups such as ants, for environmental impact monitoring.

Keywords: Bioindicators; Diversity; Environmental impact; Power production; Richness

1. Introduction

The increasing anthropogenic alteration of natural environments has resulted in habitat simplification, a decline in biodiversity, and, in some cases, species extinction [1,2]. Assessing species richness and abundance is widely used to evaluate ecosystem changes [3,4]. Insects have proven effective ecological indicators in environmental impact assessments [4,5]. The growing pressure on natural habitats highlights the importance of conducting biodiversity surveys alongside relevant environmental descriptors [3,6].

Environmental changes such as forest fragmentation [2], hydroelectric dam construction, and urban expansion are well-established threats to biodiversity conservation [5,7,8]. The development of hydropower projects typically involves vegetation removal, land clearing, soil compaction, and reservoir creation, all of which can eliminate habitats critical to various species [9]. Once operational, these facilities may alter ecosystem dynamics by modifying microclimatic conditions, including temperature and humidity [10,11]. Nevertheless, the effects of such changes on invertebrate communities, particularly in tropical and subtropical regions, remain poorly understood.

In southern Brazil, 48 Hydroelectric Power Plants (HPPs) and 146 Small Hydroelectric Power Plants (SHPPs) are currently in operation [12]. Although hydropower is considered a lower-impact energy source compared to fossil fuels

[11], its environmental consequences include habitat loss, species displacement, and ecosystem restructuring in adjacent areas [13].

In the State of Paraná, early entomofaunistic surveys conducted by Sakagami, Laroca, and Moure [14], as well as Laroca, Cure, and Bortoli [15], laid the groundwork for understanding the effects of deforestation, habitat fragmentation, the introduction of exotic species, and unsustainable agricultural practices on insect communities. Notably, Paraná was the first state in southern Brazil to mandate invertebrate surveys as part of Environmental Impact Studies (EIS) and Environmental Impact Reports (EIR), thereby contributing valuable insights into insect occurrence and distribution [8]. However, significant gaps remain, particularly concerning the inventory of ant fauna in areas directly or indirectly affected by the construction of small hydroelectric plants.

Ants are among the most commonly used bioindicator organisms due to their ecological sensitivity and functional diversity [3,16,17]. Metrics such as species richness and frequency of occurrence provide valuable insights into ecosystem health and can reflect vegetation structure, litter accumulation, and the diversity of other invertebrate taxa [4,18]. These parameters also enable comparisons of ant assemblages across different habitat types [17]. In the context of Environmental Impact Studies (EIS) and Environmental Impact Reports (EIR), ant surveys are especially effective for assessing the ecological impacts of anthropogenic activities in both directly and indirectly affected areas [8,19]. Their effectiveness stems from their wide geographic distribution, high local abundance, ecological significance across trophic levels, sensitivity to habitat disturbance, and the relative ease with which they can be identified to the morphospecies level [20–22].

In this context, the objective of the present study was to inventory the ant fauna occurring in the area of indirect influence (AII) of a small hydroelectric plant in the municipality of Mangueirinha, Paraná State.

2. Materials and Methods

2.1. Study Area

This study was conducted in the municipality of Mangueirinha, located in the southwestern region of Paraná State, as part of the Environmental Impact Study (EIS) and Environmental Impact Report (EIR) for the implementation of a Small Hydroelectric Power Plant (SHPP) (25°58′15″ S; 52°09′05″ W). The Marrecas River, where the dam is situated, is part of the Paraná River basin. The total flooded area covered 6.44 ha, of which 3.96 ha corresponded to the natural riverbed. Based on the recommended 30 m strip, the minimum environmental protection buffer encompassed 8.89 ha. The total flooded perimeter measured 3.62 km. The SHPP began operations in 2018.

The study area is part of the Atlantic Forest Biome, characterized regionally by Deciduous Seasonal Forest phytophysiognomy. The sampled portion of the watershed consists of conventional agricultural crops and pasturelands, interspersed with small forest fragments. Seven sampling events were conducted: the first two prior to project implementation (before construction began), and the subsequent five during the implementation phase (construction and pre-reservoir formation). Sampling dates were as follows: (1) 12–13 January 2016 (summer); (2) 10–11 April 2016 (fall); (3) 3–5 June 2017 (fall); (4) 18–20 September 2017 (winter); (5) 6–8 December 2017 (spring); (6) 1–3 March 2018 (summer); and (7) 12–14 June 2018 (fall). All samples were collected in the indirect influence areas of the SHPP. Three transect sites were selected within the area projected to become riparian vegetation following reservoir filling, including:

Site 1: Located downstream of the powerhouse (25°57′56″ S; 52°08′29″ W) on the right bank of the river. This area features secondary vegetation in early to mid-stages of natural regeneration, surrounded by agricultural crop fields.

Site 2: Situated within the reservoir area (25°58′20″ S; 52°09′05″ W) on the right bank of the river, encompassing an upstream portion of the reservoir and the powerhouse. This site consists of a forest fragment in the mid-stage of regeneration.

Site 3: Located upstream of the reservoir (25°58′31″ S; 52°09′08″ W) on the left bank of the river. This site includes a riparian vegetation strip along the river as well as a preserved forest fragment at the transect's end.

2.2. Sampling

Pitfall traps used for sampling consisted of 500 mL plastic cups (10 cm in diameter and 11 cm in height), fully buried so that the openings were flush with the ground surface. Each trap was filled with 100 mL of water and two drops of detergent to reduce surface tension, causing insects to sink upon falling. At each of the three sampling sites, 200-m transects were established. Along each transect, 10 traps were placed linearly, spaced 20 m apart, and remained active for 48 h [23,24]. A total of 70 samples were collected per site, resulting in 210 samples over the course of the study.

2.3. Identification

Collected specimens were transferred to bottles containing 70% ethanol. In the Entomology laboratory at Unochapecó, specimens were sorted and mounted for subsequent identification using a binocular stereoscopic microscope. Ants were identified by a specialist myrmecologist employing taxonomic keys from Gonçalves [25], Kempf [26,27], Watkins [28], Della Lucia [29], Lattke [30], Taber [31], Fernández [32], Longino [33], Longino and Fernández [34], and Wild [35]. Taxonomic classification followed Bolton [36].

2.4. Data Analysis

Species richness was defined as the number of ant species recorded in each sample. Abundance was determined based on relative frequency, *i.e.*, the number of occurrences of a given species in each trap, rather than the number of individuals [37]. This measure helps minimize the influence of foraging behavior and colony size and is considered more appropriate for studies of ant communities [38].

Estimates of overall species richness and richness per site were calculated and compared with the corresponding observed richness. For this purpose, the non-parametric Chao1 estimator was applied, which uses the number of species occurring in only one sample (uniques) and those occurring in exactly two samples (duplicates) to estimate undetected richness [39]. All analyses were performed using PAST software [40–42].

2.5. Ethical Aspects

This study was authorized by the Paraná Environmental Institute (IAP) under the "Authorization for Activities with Scientific Purpose" No. 35378, issued on 31 October 2013.

3. Results

In total, 72 species belonging to 26 genera and six subfamilies were recorded. The most species-rich genera were *Camponotus* (S = 12) and *Pheidole* (S = 11). The most frequently recorded species in the samples were *Pachycondyla striata* Smith, 1858 (*n* = 68), *Pheidole pubiventris* Mayr, 1887 (*n* = 56), *Pheidole* sp. 1 (*n* = 48), *Gnamptogenys striatula* Mayr, 1884 (*n* = 42), *Pheidole risii* Forel, 1892 (*n* = 35), *Linepithema gallardoi* (Brèthes, 1914) (*n* = 31), *Acromyrmex subterraneus* (Forel, 1893) (*n* = 19), *Pheidole* sp. 2 (*n* = 19), *Pheidole* sp. 5 (*n* = 18), *Pheidole* sp. 3 (*n* = 17), *Hypoponera distinguenda* (Emery, 1890) (*n* = 17), and *Crematogaster corticícola* Mayr, 1887 (*n* = 16) (Table 1).

Species richness was similar across the three sampling sites. The highest richness was observed at Site 3 (S = 57), followed by Site 1 (S = 52) and Site 2 (S = 51). Abundance (number of occurrences) followed the same pattern, with Site 3 recording the highest value (*n* = 253), followed by Site 1 (*n* = 209), and Site 2 (*n* = 191). The Chao1 estimator suggested the potential occurrence of up to 77 species. Site 3 exhibited the highest number of exclusive species (S = 9), while Sites 1 and 2 each recorded five exclusive species. In total, 35 species (48.6%) were shared across all three sites (Table 1).

Table 1. Species richness, total occurrences, percent frequency, and Chao1 estimates for ant assemblages sampled at three sites within the Indirect Influence Area (AII) of a Small Hydroelectric Plant (SHP) in Mangueirinha, Paraná State, Brazil, before and during project implementation (2016–2018).

Taxon	**Ocurrence**	**AII**	**Site 1**	**Site 2**	**Site 3**
		Percent Frequency			
Dolichoderinae					
Leptomyrmecini					
Dorymyrmex brunneus Forel, 1908	14	2.14	2.39	1.05	2.77
Linepithema gallardoi (Brèthes, 1914)	31	4.75	5.74	3.66	4.74
Linepithema humile (Mayr, 1868)	12	1.84	0.48	1.05	3.56
Linepithema micans (Forel, 1908)	6	0.92	0.48	1.57	0.79
Linepithema sp. 1	3	0.46		1.57	
Linepithema sp. 2	2	0.31	0.48		0.40
Tapinomini					
Tapinoma melanocephalum (Fabricius, 1793)	2	0.31	0.48		0.40
Ectatomminae					
Ectatommini					

Gnamptogenys striatula Mayr, 1884	42	6.43	6.22	6.28	6.72
Gnamptogenys sp. 1	1	0.15		0.52	
Formicinae					
Camponotini					
Camponotus atriceps (Smith, 1858)	7	1.07	0.96	1.05	1.19
Camponotus cingulatus Mayr1862	9	1.38	1.44	1.57	1.19
Camponotus diversipalpus Santschi, 1922	8	1.23	1.44	1.57	0.79
Camponotus lespesii Forel, 1886	14	2.14	1.44	3.14	1.98
Camponotus mus Roger, 1863	8	1.23	3.83		
Camponotus rufipes (Fabricius, 1775)	7	1.07	1.44	0.52	1.19
Camponotus sericeiventris (G.-Méneville, 1838)	6	0.92	0.48	1.05	1.19
Camponotus sp. 1	4	0.61	0.48	1.05	0.40
Camponotus sp. 2	3	0.46			1.19
Camponotus sp. 3	2	0.31	0.48		0.40
Camponotus sp. 4	1	0.15	0.48		
Camponotus sp. 5	1	0.15	0.48		
Myrmelachistini					
Brachymyrmex coactus Mayr, 1887	3	0.46	0.96		0.40
Brachymyrmex cordemoyi Forel, 1895	1	0.15	0.48		
Brachymyrmex sp.	1	0.15			0.40
Myrmelachista sp. 1	3	0.46	0.48	1.05	
Myrmelachista sp. 2	2	0.31	0.96		
Lasiini					
Nylanderia fulva (Mayr, 1862)	6	0.92		0.52	1.98
Paratrechina longicornis (Latreille, 1802)	4	0.61		1.05	0.79
Myrmicinae					
Attini					
Acromyrmex niger (Smith, 1858)	12	1.84	2.39	2.09	1.19
Acromyrmex rugosus (Smith, 1858)	8	1.23	0.48	1.57	1.58
Acromyrmex subterraneus (Forel, 1893)	19	2.91	3.83	2.09	2.77
Acromyrmex sp. 1	9	1.38	1.91	0.52	1.58
Acromyrmex sp. 2	1	0.15		0.52	
Apterostigma pilosum Mayr, 1865	1	0.15			0.40
Cephalotes pusillus (Klug, 1824)	5	0.77	0.96	0.52	0.79
Cyphomyrmex rimosus (Spinola, 1851)	5	0.77	0.96		1.19
Mycocepurus goeldii (Forel, 1893)	6	0.92	1.44	0.52	0.79
Mycocepurus sp. 1	4	0.61	0.48	0.52	0.79
Mycocepurus sp. 2	1	0.15			0.40
Pheidole pubiventris Mayr, 1887	56	8.58	6.70	7.85	10.67
Pheidole risii Forel, 1892	35	5.36	7.18	7.33	2.37
Pheidole sp. 1	48	7.35	6.22	9.42	6.72
Pheidole sp. 2	19	2.91	3.83	3.14	1.98
Pheidole sp. 3	17	2.60	3.35	1.57	2.77
Pheidole sp. 4	13	1.99	2.87	1.57	1.58
Pheidole sp. 5	18	2.76	1.91	4.19	2.37
Pheidole sp. 6	6	0.92			2.37
Pheidole sp. 7	2	0.31		0.52	0.40
Pheidole sp. 8	4	0.61		1.57	0.40
Pheidole sp. 9	2	0.31			0.79
Procryptocerus adlerzi (Mayr, 1887)	3	0.46	0.96	0.52	
Wasmannia auropunctata (Roger, 1863)	2	0.31	0.48	0.52	
Crematogastrini					
Crematogaster corticicola Mayr, 1887	16	2.45	2.87	2.09	2.37
Crematogaster sp.	2	0.31	0.48		0.40

Pogonomyrmecini					
Pogonomyrmex naegelii Forel, 1878	1	0.15			0.40
Pogonomyrmex sp.	5	0.77	0.96	1.05	0.40
Solenopsidini					
Monomorium floricola (Jerdon, 1851)	4	0.61	0.48	0.52	0.79
Solenopsis invicta Buren, 1972	5	0.77	0.96	1.05	0.40
Solenopsis saevissima (Smith, 1855)	6	0.92		1.05	1.58
Solenopsis stricta Emery, 1896	2	0.31		0.52	0.40
Solenopsis sp.	6	0.92	0.96	0.52	1.19
Ponerinae					
Ponerini					
Hypoponera distinguenda (Emery, 1890)	17	2.60	2.39	2.62	2.77
Hypoponera sp.1	1	0.15		0.52	
Hypoponera sp.2	2	0.31		1.05	
Hypoponera sp.3	1	0.15			0.40
Neoponera villosa (Fabricius, 1804)	2	0.31	0.48	0.52	
Odontomachus chelifer (Latreille, 1802)	1	0.15			0.40
Pachycondyla striata Smith, 1858	68	10.41	9.57	11.52	10.28
Pachycondyla sp.	5	0.77	0.96	0.52	0.79
Pseudomyrmecinae					
Pseudomyrmecini					
Pseudomyrmex flavidulus (Smith, 1858)	4	0.61	0.48	0.52	0.79
Pseudomyrmex gracilis (Fabricius, 1804)	3	0.46	0.48	1.05	
Pseudomyrmex phyllophilus (Smith, 1858)	3	0.46	0.96		0.40
Ecological indicators					
Richness	72		52	51	57
Abundance (occurrence)	653		209	191	253
Chao 1		78	66.2	62.8	70.9
Difference between S(obs) and Chao 1 (%)		7.6	27.3	23.1	24.4

4. Discussion

The present study provides additional information on the occurrence of ant species in the southwestern region of the state of Paraná. The most frequent species found in the samples are characteristic of anthropized environments and are commonly reported in studies evaluating ant fauna in southern Brazil [43–46]. Compared to the others, the slightly higher richness and diversity recorded at Site 3 can be explained by the more advanced stage of forest regeneration in this area. The similarity in ecological descriptors across sites suggests that the ant fauna in the more recently regenerating areas (Sites 1 and 2) is beginning to reflect patterns of structural complexity similar to those found in more preserved environments, such as Site 3. The time required for community reestablishment in regenerating areas can vary from five years [47,48] to more than two decades for full recovery [49].

Lutinski et al. [8], in a study conducted in the municipality of Marmeleiro (southwestern Paraná), identified 55 ant species, a lower richness than found in the present study (72 species). The genera *Acromyrmex*, *Brachymyrmex*, *Camponotus*, *Linepithema*, and *Pheidole* were also the most frequent in that study. The environments sampled in Marmeleiro consisted of small forest fragments and agricultural areas, showing similarities in species composition and richness with the sites sampled in the indirect influence area (AII) of the SHPP in Mangueirinha.

Ants of the subfamily Dolichoderinae are typical of anthropized environments in southern Brazil [46]. The genera *Dorymyrmex* and *Linepithema* include species frequently encountered in a wide range of habitats in the region [45,50]. According to Fernández [32] and Baccaro et al. [51], some species within these genera, such as *L. humile*, have pest potential. The omnivorous habits and presence of six such species in this study indicate environmental degradation at the sampled sites.

Camponotus was the most species-rich genus in the samples. Ants in this genus are widely distributed throughout the Neotropical region and are known for their pronounced polymorphism and omnivorous behavior [52]. They forage from the ground to the canopy and are often involved in mutualistic relationships and chemical defense interactions with other organisms [18,51]. *Camponotus mus*, *C. rufipes*, and *C. sericeiventris* are widely distributed in the state of Santa Catarina [45] and are commonly found in anthropized environments [50].

The genera *Brachymyrmex*, *Crematogaster*, *Nylanderia*, and *Wasmannia* are characterized by omnivorous and generalist behavior [18,53]. The presence of these ants may indicate environmental pressure due to adjacent agricultural activity or habitat fragmentation [54]. Their small body size and mass recruitment behavior [18,51] may favor efficient nesting, dominance over food sources, and frequent detection in samples.

The high Neotropical diversity of *Pheidole* and *Solenopsis* is supported by the recording of dozens of species in localized studies [16]. Their broad distribution and dispersal ability make some species locally abundant. According to Silvestre et al. [18], these genera nest in the ground and form large colonies. They are aggressive generalists frequently recorded in disturbed environments [55]. The environmental conditions of the AII, particularly at Sites 1 and 2, may be conducive to the presence of these ants.

The occurrence of ants belonging to the genera *Cephalotes*, *Myrmelachista*, *Procryptocerus*, and *Pseudomyrmex* in the AII highlights the role of forest fragments in supporting their populations. These ants require vegetation structures for shelter and nesting. *Cephalotes* ants, in particular, are strongly associated with vegetation, using it as a food source and nesting substrate [32,52]. Pseudomyrmecinae ants are diurnal, visually oriented, agile patrollers that depend on myrmecophilous plants, often visiting nectaries and preferring closed, humid forests, although some species can occur in more open areas [56]. *Myrmelachista* ants are tiny and frequently found inside seeds. Although restricted to the Neotropics, they exhibit a broad geographic distribution [32]. The presence of these genera underscores the importance of conserving forest remnants as refuges for these insects.

Five species of leaf-cutting ants were recorded, all from the genus *Acromyrmex*. These ants are known for their potential economic impact, as they harvest green plant material to cultivate the fungi they consume [57]. Endemic to the Neotropical region and polymorphic, *Acromyrmex* play an important role in soil dynamics. Their underground galleries improve soil aeration, while their waste and feces enrich the soil [18,51].

The occurrence of species from the genera *Cyphomyrmex*, *Gnamptogenys*, *Hypoponera*, *Mycocepurus*, *Neoponera*, and *Pachycondyla* also reinforces the need for conserving forest fragments and maintaining the leaf litter layer, which provides shelter and food for these ants [18,51]. *Gnamptogenys*, *Hypoponera*, *Neoponera*, and *Pachycondyla* are specialized predators that forage in soil litter. According to Lattke [58], these genera are commonly associated with shaded, humid environments and prey on small invertebrates, usually without specificity. *Mycocepurus* ants, in contrast, use decomposing organic matter to cultivate symbiotic fungi used as food [18].

The Chao1 estimator indicated that the true ant richness in the AII is likely higher than the observed richness. This outcome is expected when sites are assessed individually [59]. However, when the AII is considered as a whole, the seven sampling events reduced the gap between observed and estimated richness to less than 10%.

The implementation of the SHPP did not result in a reduction in ant species richness in the AII. Certain ant species are more sensitive to environmental changes [60] and may decline or disappear in altered habitats. In such cases, ecological niches left vacant may be filled by more generalist species, which tend to dominate in anthropized environments.

The diversity recorded in the present study (72 species) reinforces the bioindicator potential of ant assemblages in areas influenced by hydropower developments. Although this richness is considerable, it is lower than that reported in other surveys conducted in the State of Paraná. For example, Franco and Feitosa [61] recorded 163 ant species in the natural grasslands of Campos Gerais using multiple sampling techniques. This difference may be attributed to the type of environment sampled, open and preserved landscapes versus forest fragments under anthropogenic pressure, as well as the broader methodological approach employed in their study. Nevertheless, the species composition observed in Mangueirinha, characterized by generalist species and the presence of forest-associated taxa, demonstrates that even indirectly affected areas can sustain expressive ant communities.

Another relevant study conducted in São Camilo State Park [62] reported 108 ant species, including new records for both Paraná and southern Brazil, in fragments of seasonal semideciduous forest. Although species richness was lower in the present inventory, the results are comparable when considering this study’s standardized pitfall method and smaller spatial scale. Moreover, the number of site-exclusive species and the richness estimate (Chao1) suggest that actual diversity in the study area may be underestimated. Together, these findings indicate that preserved grassland environments and secondary forest fragments play complementary roles in regional ant conservation, highlighting the importance of including varied vegetation types and disturbance levels in environmental impact assessments.

Despite the valuable data obtained, a notable limitation of the present study is the exclusive use of the pitfall trapping method, which may lead to an underestimation of the true species richness and diversity. Recent studies emphasize the importance of combining multiple sampling techniques, such as pitfall traps, Winkler extractors, Malaise traps, and manual collection, to better capture the functional and taxonomic diversity of ant communities, especially in heterogeneous environments [61,63]. For example, Franco and Feitosa et al. [61] conducted a detailed inventory in the natural grasslands of Paraná using pitfall, Winkler, and manual sampling methods, resulting in higher recorded richness and diversity, particularly of species less detectable by single methods. Similarly, Lutinski et al. [63] demonstrated that combining different collection methods allowed for a more comprehensive assessment of ant communities in forest fragments of southwestern Brazil, revealing species that would not have been detected using only pitfall traps.

The construction and operation of hydropower dams profoundly alter environmental drivers, with cascading effects on ant assemblages. Flooding and habitat fragmentation eliminate nesting sites and microhabitats, facilitating the replacement of specialist ant species by generalists and opportunists, thereby altering community composition, diversity, and functional structure [8]. Additionally, changes in microclimate (e.g., temperature, soil moisture, light regime), resource availability, and soil connectivity affect abundance and trophic interactions [18]. These responses can be asynchronous, immediate losses of sensitive taxa followed by community reassembly over years or decades, making ant communities sensitive indicators for environmental monitoring and the effectiveness of mitigation strategies [64].

Hydropower development exerts persistent long-term impacts on soil and vegetation, frequently impairing ecosystem recovery. Reservoir-induced inundation alters soil physico-chemical properties, including reduced oxygenation, organic-matter loss, and nutrient alteration, while construction activities accelerate compaction and erosion, reducing infiltration and increasing sedimentation risk [65]. Vegetation is affected through outright removal, shifts in species composition, loss of arboreal strata, and reduced structural heterogeneity, undermining ecosystem services such as carbon sequestration, slope stability, and habitat provisioning. These effects may endure for decades, especially under continuing anthropogenic pressures (e.g., land-use change, fires, invasive species), underscoring the need for long-term restoration planning and sustained ecological monitoring to restore functional resilience [64].

5. Conclusions

This study contributes to the knowledge of ant diversity in environments undergoing transformation and provides new data on the distribution of myrmecofauna in the state of Paraná. It also presents a list of species from an area subject to flooding due to the construction of a small hydroelectric power plant (SHPP). It will serve as a baseline for assessing potential impacts on invertebrate fauna following project implementation.

The role of the Paraná Environmental Institute (IAP) in requiring the inclusion of invertebrates in Environmental Impact Studies and Reports (EIS/EIR) is noteworthy. This inclusion is fully justified, as invertebrates represent the largest known component of biodiversity. Understanding the richness and abundance of indicator insects, such as ants, is essential for monitoring environmental conditions before and after the implementation of infrastructure projects like SHPPs.

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Author Contributions

Conceptualization, J.A.L., M.C.d.F. and L.B.; Methodology, J.A.L. and C.I.; Software, J.A.L. and C.I.; Validation J.A.L., C.I., M.C.d.F., L.B., C.J.L., C.G, M.A.B., D.R.H., A.F. and M.E.M.C.; Formal Analysis, J.A.L. and C.I.; Investigation, J.A.L., C.I., M.C.d.F., L.B., C.J.L., C.G, M.A.B. and D.R.H.; Resources, J.A.L., M.C.d.F. and L.B.; Data Curation, J.A.L. and C.I.; Writing—Original Draft Preparation, J.A.L., C.I., M.C.d.F., L.B., C.J.L., C.G, M.A.B., D.R.H., A.F. and M.E.M.C.; Writing—Review & Editing, J.A.L., C.I., M.C.d.F., L.B., C.J.L., C.G, M.A.B., D.R.H., A.F. and M.E.M.C.; Visualization, J.A.L., C.I., M.C.d.F., L.B., C.J.L., C.G, M.A.B., D.R.H., A.F. and M.E.M.C.; Supervision, J.A.L.; Project Administration, J.A.L.; Funding Acquisition, M.C.d.F. and L.B.

Ethics Statement

This study was authorized by the Paraná Environmental Institute (IAP) "Authorization for activities with scientific purpose" # 35378 as of 31 October 2013.

Informed Consent Statement

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Data Availability Statement

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could haveappeared to influence the work reported in this paper.

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