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PÓS-GRADUAÇÃO DINÂMICA DOS OCEANOS E DA TERRA UFF

BLATTELLA GERMANICA, *TITYUS STIGMURUS*, AND *RATTUS NORGEVICUS* AS POTENTIAL BIOINDICATORS OF ENVIRONMENTAL QUALITY IN THE SCAVENGERS ASSOCIATION OF THE MUNICIPALITY OF IGUATU – CE

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ABSTRACT

Anthropic activities cause negative environmental impacts on the environment. These practices include the accumulation of solid waste improperly, which results in public health problems. An example of this is the possible presence of fauna in an unbalanced way, posing a risk to the health of workers who provide services in the collection of recyclable materials. This research aimed to evaluate the possibility of the presence and the level of bioindication of the environmental quality of the species *Blattella germanica*, *Tityus stigmurus*, and *Rattus norgevicus* in the Recyclable Materials Collectors Association (*Associação de Catadores e Catadoras de Materiais Recicláveis* - Ascmari) of the Municipality of Iguatu-CE. The methodology used was descriptive and deductive, and from there, the three species were evaluated for bioindication. Thirteen parameters were considered for assessing the species, and three of them referred to the degree of danger of these animals. *R. norgevicus* was the one with the best bioindication results among the species studied, although the presence of these animals may result from the presentation of the others already mentioned in this research. Despite the need for further studies on bioindicators of environmental quality, they are an aid tool for management, evaluation, and environmental monitoring. The main limitation to the research was the impossibility of site visits due to the Covid-19 pandemic. The present work addresses the assistance in improving the environmental quality, health, and working conditions of scavengers and the possibility of applying scientific methodologies at a distance to benefit a given community.

Keywords: Bioindication; Solid Waste; Recyclable Materials; Environmental Quality.

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INTRODUCTION

As stated in Law No. 6.938 (Brazil, 1981), a balanced environment is characterized by the physical, chemical, and biological interactions that allow for the maintenance of life in all its aspects. However, the concept of environmental sustainability includes the natural environment and the social and economic environments, where one influences the other (Svensson *et al.*, 2018). In addition, the concept of resilience is revealed, as it determines the ability of a given system to recover, adapt, or absorb impacts after a stressful situation that can naturally regenerate or not, depending on the conditions to which it is exposed (Marchese *et al.*, 2017).

Anthropic activities can be characterized as impacting agents since the environment is composed of various environmental aspects (biotic and abiotic factors) that can be negatively affected by these practices, resulting in degradation and loss of local biodiversity. Thus, based on the National Environmental Council Resolution 001 (Conama, 1986), environmental impact is defined as any physical, chemical, or biological alteration of the environment caused by human interference that directly or indirectly affects the natural, social, and economic environments. This term can also be defined as any impact that directly affects the area of influence of a project, partially or totally, and/or the territory of two or more locations, as recorded in Resolution No. 237 (Conama, 1997). For example, we can include the decline of vegetation cover, soil infertility, and water and air pollution (Mahmoud and Gan, 2018). Regarding the environmental impacts caused by the inadequate disposal of solid waste, we highlight the changes in the landscape, generating visual impact, air contamination, unpleasant odors, surface and groundwater pollution, and, finally, the proliferation of disease vectors (Ferronato and Torretta, 2019).

Several environmental and social conditions can define the proliferation of vectors that negatively affect human health and represent adverse environmental changes. The inadequate allocation of waste causes the proliferation of flies, cockroaches, scorpions, mosquitoes, and rodents. This fauna indicates an environmental imbalance and can transmit dengue, malaria, and other infectious diseases that cause public health problems (De and Debnath, 2016). Such conditions include the lack of sanitation, collection, and proper solid waste disposal.

There are populations that are more vulnerable to these vectors due to demographic conditions, such as those who live in regions near inadequate waste disposal sites and the workers who deal directly with these materials, the collectors (Cruvinel *et al.*, 2020). The scavengers' occupational conditions, even when they are organized into associations, are precarious due to the degraded environmental quality and the scarcity of hygiene and personal protective equipment that result in exposure to health and environmental risks (Wittmer, 2020).

Among the disease vectors present in the poor disposal and storage of solid waste, we highlight the presence of cockroaches (Carvalho *et al.*, 2020), scorpions, and rats. The cockroach of the *Blattella germanica* species is considered an urban pest of difficult remediation, directly linked to lack of hygiene and, consequently, public health problems (Pan and Zhang, 2019). The species *Tityus stigmurus* is the major cause of accidents in the Northeast Region (Brazil, 2009), and the species *Rattus norvegicus* is a major cause of Leptospirosis disease in humans (Udechukwu, 2021). Given these issues, this study evaluated the presence of *B. germanica*, *T. stigmurus*, and *R. norgevicus* as bioindicators of the environmental quality of the collectors' workspace, based on the case study of the Recyclable Materials Collectors Association (*Associação de Catadores e Catadoras de Materiais Recicláveis de Iguatu* - Ascmari) of the Municipality of Iguatu-CE. Thus, this study seeks to contribute to raising the environmental quality of these spaces through bioindicators of environmental quality.

THEORETICAL BACKGROUND

The Scavengers' Condition

According to Gutberlet (2020), in several places in the world, there are waste pickers who work in unsanitary conditions without recognizing the benefits to society and the environment attracted by the service they provide. Waste pickers constantly risk their physical and psychological health and well-being due to exposure to possible diseases caused by contaminated materials and the presence of disease vectors (Schenck *et al.*, 2019). According to the National Movement of Waste Pickers (MNCR), in 2020, there were 800,000 scavengers performing collection activities for recyclable materials in Brazil.

According to Coelho *et al.* (2018), waste pickers can present diseases related to the absence of ergonomics and safety appropriate to the work environment and, mainly, diseases associated with pathogenic microorganisms, which the presence of a vector can transmit. Furthermore, these comorbidities may be linked to waste accumulation and living and working conditions. Such comorbidities can also be linked to exposure to contaminated materials that, associated with the absence of sanitation, result in diseases such as diarrhea, hepatitis A, and leptospirosis, most of them transmitted through contaminated water and food, thus highlighting the unhealthy and precarious conditions of waste pickers (Cruvinel *et al.*, 2019). Fattor and Vieira (2019)

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reiterate that leptospirosis, headaches, nausea, stress, and accidents such as cuts and contact with venomous animals, among other symptoms, are common among waste pickers.

The risks mentioned above are mainly classified as biological risks, such as bacteria, fungi, viruses, and other microorganisms that can cause pathogens and damage to the worker's health, as stated in Regulatory Norm no. 9 of the Ministry of Labor and Employment (MTE), approved by Ordinance no. 3,214 (Brazil, 1978). Furthermore, considering Regulatory Standard No. 15 (Brazil, 1978) and highlighting the physical (heat, cold, and solar radiation), chemical (materials present in the waste), biological (viruses, bacteria, fungi), and ergonomic (physical effort and excessive lifting of weights) risks, the collectors' workday can be classified as unhealthy to a maximum degree.

The reality reflected in the precarious living and working conditions experienced by the collectors of recyclable materials could be positively modified, with the establishment of conditions that result in more dignity, if the government demanded the necessary attention to meet the needs of these individuals (Vasconcelos *et al.*, 2020).

Bioindicators of environmental quality

The ecological interactions existing between living things and the habitat can negatively affect the ecosystem when affected by anthropic interference (Nishiwaki *et al.*, 2017). A study conducted by Garuana *et al.* (2020) stated that the increase in environmental degradation and pollution could cause the decrease or loss of diversity of living beings, resulting in the decrease of the original biodiversity since only the most resilient individuals will survive, in addition to allowing the introduction of opportunistic or R-strategic species. Due to this ability to respond to stimuli and changes in the environment, living beings can be considered indicators of environmental changes (Neumann-Leitão and El-Deir, 2009). Nishiwaki *et al.* (2017) also highlighted that in environmental monitoring studies, some species are used due to particularities that assist in identifying environmental stress situations.

Concerning changes in the ecosystem, there are more tolerant species, called euripotent, and less tolerant species called stenopotent. Considering the existing process of ecological succession, opportunistic living beings, which are more resistant and predominant in disturbed areas, can replace the natural species in that environment, while specialist species are more sensitive to environmental changes (Neumann-Leitão and El-Deir, 2009). According to Odum (2001), steno species are better environment indicators than euri species because they have a smaller tolerance range. Thus, changes in the environment will lead to a decrease or disappearance of species in this locality, and the species that show greater dominance are more stable.

According to Souza *et al.* (2016), a bioindicator of environmental quality is an organism, a part of that organism, or any of its communities that reflects a given ecosystem's level of environmental quality from its presence or absence. Bioindicators also allow for an integrated assessment of impacts caused mainly by multiple sources of anthropogenic pollution in the environment (Prestes and Vincenci, 2019).

For Neumann-Leitão and El-Deir (2009), the determination of a bioindicator of environmental quality is limited to the presence or absence of an individual, i.e., their physiology and biological relations with the environment, but also the ecosystem's reaction to a particular environmental change. Bioindicators can provide signals of environmental problems, identify the cause and effect relationship between the agents causing impact and the biological reaction of the environment, and allow assessment of the success of mitigating actions for anthropic environmental impacts (Carvalho *et al.*, 2015).

METHODOLOGY

Case study

The Recyclable Materials Collectors Association (Associação de Catadores e Catadoras de Materiais Recicláveis de Iguatu - Ascmari) is located in the municipality of Iguatu, in the Center-South region of the state of Ceará. Although the collectors work in the field, the association's headquarters is in the Chapadinha neighborhood in the same municipality, approximately 1.56 km away from the inadequate disposal site for solid waste (**Figure** 1).

According to the National Registry of Legal Entities, the association has been active for 13 years since its opening in October 2007 (RFB, 2021). A study conducted in the same region by Carneiro (2011) found that 42 collectors and their families form the association, and almost all members live in the same neighborhood as the Ascmari headquarters.

Methodological Steps

The research has a descriptive and deductive character, following several methodological steps (**Figure** 2).

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Figure 1. Distance between the Scavengers Association and the municipal solid waste dump

Source: Google Earth, 2021

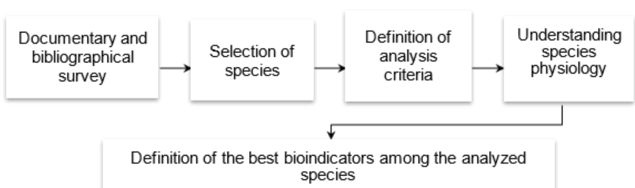

Figure 2. Flowchart of methodological analysis

Source: The authors, 2021

The study development started with the performance of a documental survey on sites of the City Hall of Iguatu and the State Government of Ceará, seeking to know the study area and information about the species to be analyzed. Then, to better understand the topic and the physiology of the species, a literature search was conducted. Then, the following species were selected for the study: *Blattella germanica* (Linnaeus, 1767), *Tityus stigmurus* (Thorell, 1876), and *Rattus norvegicus* (Berkenhout, 1769).

Considering the criteria proposed by Johnson *et al.* (1993) *apud* Santos *et al.* (2016), the species were analyzed according to the bioindication parameters for determining ideal field bioindicators. In addition, weights were assigned according to the level of importance of the parameter, which ranged from 1 to 3 (Table 1).

Table 1. Weights assigned to each ideal bioindicator parameter

Degree of relevance of the parameter	Weight
Low	1
Medium	2
High	3

Source: The authors, 2021

Scores ranging from 1 to 5 (Table 2) were assigned to determine an ideal bioindicator. Then they were arranged in a table model to obtain the results of each parameter in relation to the species from the sum of the values multiplied by the assigned weights. It should be noted that there are ten parameters for analysis; however, three more parameters were added (Degree of morbidity; Degree of lethality; and Degree of transmissibility) given the possibility of linking the species with possible situations of danger to the study object (Table 3). The final result for each bioindicator species was determined from the sum of the final values of each parameter divided by the number of parameters, resulting in a weighted average. It is worth noting that the weights and scores assigned were a consensus among the authors since there is no basis for this type of evaluation. Furthermore, the species with higher final values were considered better bioindicators than those with lower values.

Table 2. Grades assigned to each ideal bioindicator parameter

Degree of representativeness	Grades
Minimum	1
Low	2
Medium	3
Good	4
Excellent	5

Source: The authors, 2021

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Table 3. Parameters used for the ideal bioindicator, considering dangerous situations from the presence of vectors

Parameters	Weight	Grade	Total
1. Well-defined ecological characteristics	3		
2. Geographical distribution	2		
3. Easily recognized by non-specialist	2		
4. Long life cycle	2		
5. Abundant	3		
6. Well-defined taxonomy	3		
7. Low mobility	1		
8. Low ecological and genetic variability	2		
9. Possibility of use in laboratory studies	1		
10. Preferably be large in size	2		
11. Degree of morbidity	3		
12. Degree of lethality	3		
13. Degree of transmissibility	3		

Source: *Elaborated from Johnson et al. (1993) apud Santos et al. (2016)*

The selected species were characterized so that it was possible to define the ideal bioindicator.

RESULTS AND DISCUSSION

Germanic cockroach (*Blattella germanica*)

Regarding questions of scientific classification of the species *Blattella germanica* (Linnaeus, 1767), one has Kingdom: *Animalia*; Phylum: *Arthropoda*; Class: *Insecta*; Order: *Blattodea*; and Genus: *Blattella*. *Blattella germanica* is a hemimetabolous animal, i.e., it does not have an intermediate stage between larva and adult in its life cycle. This species has only the egg, nymph, and adult stages. Nutrition and hormones regulate the species' life span and its reproductive capacity (N. LI *et al.*, 2019). For Li *et al.* (2018), any species of cockroach belonging to the order Blattodea is considered a serious pest in urban environments. The high adaptive capacity of these individuals provides both survival in different locations and success in resisting sudden changes in the environment.

The *B. germanica* species is one of the best-known urban pests in the world and is linked to environmental and sanitation problems. Quite resistant to technologies to control species proliferation, it is a vector of bacteria, fungi, and viruses and, added to social problems, presents a difficulty in maintaining the quality of public health (Pan and Zhang, 2019). Considered a colonizing species, the reproductive process happens accelerated due to the high capacity of egg development by females and the rapid maturation of males.

This insect has an obligatory symbiotic relationship called commensalism, in which the microorganisms in its physiology digest substances and improve the intestinal absorption of the species (Uzsák and Schal, 2013). *B. germanica* has been recognized as a bioindicator of health and hygiene problems in urban environments by presenting accelerated reproduction, the potential to harbor microorganisms and, consequently, denote pathogenicity (Rezaei *et al.,* 2019). Some representatives of fauna in the environment are associated with the presence of other animals, such as cockroaches. An example of this is the increased proliferation of scorpions, where cockroaches represent one of the food sources for these animals. Thus, environments with a high cockroach population are a food **Source:** for scorpions, attracting these highly dangerous individuals (Brazil, 2009).

North-East Scorpion (*Tityus stigmurus*)

The species *Tityus stigmurus* (Thorell, 1876) has the following systematics: Kingdom: *Animalia*; Phylum: *Arthropoda*; Class: *Arachnida*; Order: *Scorpiones*; Genus: *Tityus*. The scorpion *Tityus stigmurus* is characteristic of Northeast Brazil. It is especially present in the caatinga biome and is responsible for most scorpion attacks in the region (Furtado *et al.*, 2020). The degradation of the natural habitat of these individuals can cause a loss or decrease in genetic quantity and variability, resulting in the homogenization of the species in degraded environments (Lira *et al.*, 2021).

These animals feed on insects, spiders, cockroaches, and other scorpions (Bergeron and Bingham, 2012). Thus, the species has adapted to urban environments, with the presence of effluents, residues, waste, and debris, which enable the proliferation of animals' characteristic of its diet (Nencioni *et al.*, 2018). As for the reproductive activity and life cycle of this individual, the wet and rainy periods, with propitious urban environments, such as waste accumulation, associated with prey availability, increase the reproduction of the species (Araújo *et al.,* 2010). An increase in the reproductive activity and life cycle of the scorpion may lead to cases of accidents in humans due to the poisoning of these individuals, some causing genetic alterations and a high degree of lethality (Silva *et al.*, 2020).

Considering the risk level of the presence of this insect and its control, research carried out by Albuquerque, Barbosa, and Iannuzzi (2009) verified that *T. stigmurus* presents resistance to the insecticide method used in the research and that other types of insecticides have been unsatisfactory in the control of these animals; thus, there is no measure that is totally efficient. It is noteworthy that, although this species is associated with the presence of other species in the environment, the following animal (*Rattus norvegicus*) is not characterized as a natural predator of *T. stigmurus*, according to the Scorpion Control Manual (BRASIL, 2009). Nevertheless, considering the characteristics of the research environment, the presence of *R. norgevicus* may bioindicate a degree of risk to the health of the collectors and the environmental quality.

Norway Mouse or Rat (*Rattus norvegicus*)

The systematics of the species *Rattus norvegicus* (Berkenhout, 1769) is composed of Kingdom: *Animalia*; Phylum: *Chordata*; Class: *Mammalia*; Order: *Rodentia*; and Genus: *Rattus*. The species *Rattus norvegicus* is considered one of the largest urban pests, especially in environments favorable to its proliferation, with abundant water, humidity, food, and shelter. The presence of these animals configures a reservoir of numerous microorganisms responsible for diseases in animals and humans (Alonso, 2020). It is noteworthy that the low environmental quality linked to low sanitation conditions and inadequate disposal of solid residues, waste, and liquid effluents can configure environments with a high possibility of the presence of these individuals (Marcelino *et al.*, 2011). Due to the high reproductive capacity of *Rattus norvegicus*, these rodents are characterized by a high capacity to recolonize areas (Shilova and Tchabovsky, 2009). In addition, this species has a wide variability of ecological niches and can adapt to environments with anthropogenic interference (Galán-Puchades *et al.*, 2018). Therefore, environmental quality management techniques have become efficient in the population control of these animals (Minter *et al.*, 2018).

Among the wild rodent species, the *R. norgevicus* is one of the species responsible for transmitting leptospirosis, a zoonotic disease that affects human health worldwide, becoming an urban health problem (Udechukwu *et al.*, 2021; Koizumi *et al.*, 2019). In addition to leptospirosis, a study using the species in question, conducted by Coomansingh--Springer *et al.* (2019), identified parasite species in the guts of these animals, and these parasites are of zoonotic and non-zoonotic characteristics linked to diseases that affect human health and the health of other species present in an ecosystem, as well as groups of the same species.

Characterization of the species from the analyzed parameters

Bioindication uses organisms that exhibit genetic, structural, physiological changes, behavioral patterns, and other changes in response to stressors in a given environment (Lima *et al.*, 2018). However, the use of microorganisms and/or macroorganisms as tools for monitoring environmental quality and determining optimal bioindicators is in its early stages. Thus, the species studied obtained results above 120 points, considering the 13 parameters already demonstrated. Among the grades given to each species according to the analyzed parameters, the most considered grades were three (average representativeness), four (good representativeness), and five (excellent representativeness), where grade five presented the most abundant frequency, 43.6%.

It is noteworthy that the representation in the grade *excellent* was considered in most parameters, especially in the last three parameters, which correspond to the exposure and danger of the collectors of recyclable materials to these species in degraded environments and inadequate accumulation of solid waste. Moreover, the high grades in most aspects are based on the risk caused by the presence of these species in the environment. In contrast, the degree of representativeness 1 (low representativeness) was considered only in the parameter “preferably large size” for the species *Blattella germanica* because this animal is easily identified and is of high risk to human health, despite its small size (Table 4).

The species *Rattus norvegicus*, popularly known as Norway mouse or rat, obtained 131 points and a weighted average of 10.07. From this, it stands out as the species with the highest bioindicator potential among the species studied. The highest values were given due to the high degree of disease transmissibility, high degree of lethality, high degree of disease production (morbidity), being abundant, and having well-defined ecological characteristics, with values of 15, 15, 15, 12, and 15, respectively.

The *Tityus stigmurus*, or northeastern scorpion, had a score of 129 points and a weighted average of 9.9, with emphasis on the parameters of the degree of transmissibility, lethality, morbidity, well-defined taxonomy, well-defined ecological characteristics, and being abundant, with final scores of 15 for all parameters cited, except for score 12 for the parameter related to abundance in the environment.

Finally, the species *Blattella germanica*, with the popular name German cockroach, was the species that presented the lowest score compared to the other species, with 127 points and an average of 9.7. However, it had higher or equal scores in certain parameters compared to the other

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Table 4. Analysis of the parameters for choosing the ideal bioindicator

PARAMETERS	Weight	Value			Total		
		Bg	Ts	Rn	Bg	Ts	Rn
1. Well-defined ecological characteristics	3	4	5	5	12	15	15
2. Geographical distribution	2	5	3	5	10	6	10
3. Easily recognized by non-specialists	2	5	5	5	10	10	10
4. Long life cycle	2	3	4	4	15	8	8
5. Be abundant	3	5	4	4	15	12	12
6. Well-defined taxonomy	3	5	5	3	15	15	9
7. Low mobility	1	5	4	4	5	4	4
8. Low ecological and genetic variability	2	2	2	4	4	4	8
9. Ability to be used in laboratory studies	1	3	4	4	3	4	4
10. Large size preferably	2	1	3	3	2	6	6
11. Degree of morbidity	3	4	5	5	12	15	15
12. Degree of lethality	3	3	5	5	9	15	15
13. Degree of transmissibility	3	5	3	5	15	15	15
TOTAL					127	129	131
MÉDIA					9.7	9.9	10.07

Legend: *Bg = Blattella germânica; Ts = Tityus stigmurus; Rn = Rattus norvegicus.*
Source: *Elaborated from Pinheiro et al. (2015)*

two species, these being the degree of transmissibility, degree of morbidity, well-defined taxonomy, abundance, long life cycle, and well defined ecological characteristics, with respective scores of 15, 12, 15, 15, 15, and 12. Furthermore, it is worth noting that this species was the one that obtained the lowest score in the item corresponding to the degree of lethality because, although this animal can produce and transmit diseases, these are not highly lethal when compared to the other animals already mentioned.

Although *R. norgevicus* has presented itself as the best bioindicator species of environments with the presence and inadequate disposal of solid waste, it is at a level of the trophic web in which, if there is the presence of these individuals, others belonging to the same food chain will probably be included, as in the case of other species present in this study. Moreover, the results showed high and relatively close final and mean scores, thus presenting good results for potential bioindicator species in the environment type researched.

Considering all the information described in this study regarding the species, the living and working conditions of the collectors, and the association in question (Ascmari), the scavengers are probably exposed to health risks, negatively affecting their quality of life, well-being, and even the conservation of life at the expense of species and the accumulation of solid waste in the workplace.

In this sense, it is observed that this theme is relevant for the management of environmental quality; however, further studies are needed due to the variability of species, environments, and anthropogenic interferences, thus allowing for a better understanding of a given biological community and the physical space in which it is inserted.

CONCLUSION

Although the analysis was deductive and descriptive, the study was based on documents, an updated bibliographic survey, and classical authors, adding reliability to the research. The three species analyzed showed high results and were close to each other, not ruling out the possibility of all of them presenting bioindicator potential, highlighting the species *R. norgevicus*, which obtained the best result for bioindicator species for collectors' work environments in associations. Among the species, *B. germanica* showed less potential lethality to the health of local workers.

It is noteworthy that, as in other studies showing the scavengers' reality in Brazil and worldwide, the Association of Recyclable Material Collectors of Iguatu (Ascmari) probably performs services in precarious conditions and with health risks related to the presence of the species studied. The use of bioindicator species of environmental quality represents a tool for management, evaluation, and monitoring of the environment, although it is necessary to raise the level of knowledge and research to improve the use of this technique.

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