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Contribution of tree species to litter production and in the action of terrestrial invertebrates in the Atlantic Forest of Bahia (Brazil)

Simone Amador da Silva

Alagoinhas, Bahia (Brazil)
2023

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SIMONE AMADOR DA SILVA

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Alagoinhas, Bahia, Brazil.
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"We are hard pressed on every side, but not crushed; perplexed, but not in despair, persecuted, but not abandoned; struck down, but not destroyed.”

(2 Corinthians 4:8-9)

ABSTRACT

This study aimed to evaluate the contribution of the tree species *Eugenia candolleana* DC. (Myrtaceae) and *Coccoloba rugosa* Desf. (Polygonaceae) in litter production, the effect of leaf consistency on the invertebrate community and the influence of the seasonal effect of precipitation influence on both in a native fragment of Atlantic Forest at Patioba Farm in Alagoinhas, Bahia (Brazil). In the period from January/2022 to January/2023, the monthly litter production was estimated for trees of the tree species *E. candolleana* and *C. rugosa*, using low and suspended nets as collectors. Through the method of active search for walks in the two plots P1 and P2, twenty trees of *E. candolleana* were marked in P1 and P2, and ten more trees of *C. rugosa* only in P2 where they were found, by the criterion of size of 10 cm ≤ CAP ≤ 60 cm. After the peak of precipitation in the rainy season in May/2022, the contribution of aerial litter from *E. candolleana* (Myrtaceae) trees decreased only in the low net of plot P2 (r^2=0.79), probably carried by rain, and increased in the suspended nets of the two plots P1 (r^2 =0.87) and P2 (r^2 =0.93). The same seasonal effect on the production of aerial litter by C. rugosa (Polygonaceae) trees was not observed (r^2=0.13 and r^2=0.52). The species *E. candolleana* and *C. rugosa* were found only inside the fragment and both provided abundant lignified material to the litter, respectively with the periderm (bark) of the stem of the first and the leathery leaves of the second, interfering in the action of terrestrial invertebrates. The leathery leaf material seems to have a specialized agent in biological fragmentation, given the low diversity of invertebrates and high abundance of leaf-cutting ants found in the nets for the litter of *C. rugosa*. After the peak of the rainy season in May, there was an increase in litter intake of trees of both species, *E. candolleana* and *C. rugosa*, in the low and suspended nets, but no correlation between production and precipitation for the latter species. The biomass of *E. candolleana* retained moisture in the suspended network, favoring the decomposition of the leaf fraction by leaching and colonization of debris by invertebrates. Invertebrates of the orders Isopoda (Malacostraca), Blattaria, Hymenoptera and Orthoptera (Insecta), Araneae (Arachnida), and Stylommatophora (Gastropoda) were collected from the litter of the trees of *E. candolleana* of plot P2. Among the invertebrates collected in the litter of the nets, six functional groups were considered: predator, phytophagous, detritivore, saprophagous, coprophagous and bioturbator.

Keywords: trees, terrestrial invertebrates, litter.

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SUMMARY

1. INTRODUCTION

The Atlantic Forest is one of the richest and most threatened ecosystems in the world and is important for environmental balance and maintenance of biodiversity (SOS Mata Atlântica; INPE, 2021). A fundamental element of this ecosystem is the litter, which consists of the layer of decomposing organic matter that covers the forest floor (Andrade *et al*., 2020). Its composition is made up of leaves, branches, fruits, seeds and remains of dead animals and plays a crucial role in the life cycle of this forest ecosystem (Costa *et al*., 2010).

Litter production in the Atlantic Forest is high due to the density and diversity of the tree layer. Trees are responsible for a large part of the plant biomass and are the main producer of organic matter for the litter (Cunha Neto *et al*., 2013). The seasonal fall of leaves and other plant detritus feeds a complex ecosystem of decomposers, such as fungi, bacteria and invertebrates, which transform this organic matter into nutrients necessary to sustain the forest (Scoriza *et al.*, 2012; Barreto, 2014*)*.

The Myrtaceae and Polygonaceae families have tree species that contribute to the formation of litter in the Atlantic Forest. The Myrtaceae family is notable for its vast global distribution with around 140 genera and 6 thousand species (Flora e Funga do Brasil, 2020). In Brazil, this family stands out as one of the largest in flora with 23 genera and approximately 1,000 species throughout the national territory. In addition to diversity, the Myrtaceae family has economic and ecological importance, providing trophic, medicinal resources and pioneer species for the recovery of degraded areas (Iguatemy *et al.*, 2017; Sobral *et al*., 2020).

The Polygonaceae family, on the other hand, is composed of some small trees, which are widely distributed throughout the world. It is believed that there are around 1,100 species in the world, and in Brazil there are 10 genera and 7 native species belonging to this family. In Brazil, they occur in all regions and in different phytogeographic domains (Melo, 2018). This family also has medicinal importance due to its anti-inflammatory and ornamental properties (Tabosa *et al.*, 2016).

The amount of accumulated litter varies according to several characteristics, such as species composition, intensity of forest cover, successional stage, age, crown proportion and decomposition rate (Lima *et al.*, 2015*)*. Furthermore, factors such as edaphoclimatic conditions, seasonality, temperature and precipitation also influence the accumulation of litter (Paudel *et al.*, 2015).

Litter provides several vital functions in forest ecosystems, such as a protective soil cover, preventing erosion and loss of nutrients (Rodrigues *et al.*, 2021; Caldeira *et al.*, 2019). Moreover, it retains rainwater, contributing to plant hydration and regulating the local climate (Mateus *et al.*, 2013). This layer acts as a source of nutrients for other plants, fungi and microorganisms in the soil, in addition to protecting against erosion processes (Moço *et al.*, 2008; Hättenschwiler *et al.*, 2011). The importance of litter goes beyond the functional, as a supply of nutrients, but also structural, as a shelter for a wide variety of organisms, such as terrestrial invertebrates. They play fundamental roles in the trophic web, acting in the decomposition of organic matter and promoting soil aeration (Fujii; Berg; Cornelissen, 2020). In this way, it contributes to the maintenance and balance of forest ecosystems (Campos *et al.*, 2012).

1.1 Problem

Does the tree species *Eugenia candolleana* DC. (Myrtaceae) and *Coccoloba rugosa* Desf. (Polygonaceae) contribute to the production of litter with a differentiated effect on the diversity of terrestrial invertebrates and are they regulated by seasonality (precipitation) in the native Atlantic Forest fragment?

1.2 Justification

The Atlantic Forest fragment in the Fazenda Patioba is located in the municipality of Alagoinhas and is considered a reference of socioeconomic and ecological importance for the North Coast and Agreste of Bahia. However, analyzes of the landscape, where this remnant is located, show its exposure to an increasing process of fragmentation due to the increase in surrounding eucalyptus monoculture areas, which has led to an increase in the edge effect and consequent environmental degradation (Da Silva Bispo; Barros de Matos; De Jesus, 2022; Santos, 2023).

In this native forest fragment, the two botanical families Myrtaceae and Polygonaceae occur, both of importance: i) ecological, due to the production of biomass and the cycling of nutrients that guarantee resources for the trophic network in the conservation of biodiversity; and ii) socioeconomic, through the extraction of resources by communities that survive close to this ecosystem.

In the phytogeographic domains of the Atlantic Forest, the Myrtaceae family stands out in terms of the number of genera, species and total basal area with a large scope, presenting great importance due to the supply of resistant plant material, such as the bark of the trunk, to the litter and its zoochoric dispersion syndrome for maintaining the trophic network (Castuera-Oliveira; Oliveira-Filho; Eisenlohr, 2020). In contrast, the Polygonaceae family, despite the low representation with seven spontaneously occurring genera, has the genus *Coccoloba* of great interest for different plant formations and species as possible phytogeographic markers (Oliveira *et al.*, 2008). Arboreal species of the genus *Coccoloba* produce large, characteristic leathery leaves, which cover large surfaces around the matrix, demonstrating their ecosystemic role in the production of leaf litter-resistant biomass, despite the low tree diversity in the reminiscent.

The litter produced needs to be decomposed and, therefore, another relevant aspect is the action of invertebrates and their ecosystem role in biological fragmentation, especially of resistant lignified biomass, contributing to the cycling of nutrients in the forest system (Correia, 2002).

Given the importance of these botanical families, the analysis of litter production by arboreal species from the Myrtaceae and Polygonaceae families served to estimate the contribution to the supply of plant biomass and nutrient cycling, the relationship between trophic groups of invertebrates and their contribution to organic matter cycling in the native fragment, consequently producing knowledge about ecosystem processes for the restoration of degraded areas adjacent to fragments of the Atlantic Forest biome.

1.3 Objectives

1.3.1 General objective

To evaluate the contribution of the tree species *Eugenia candolleana* DC. (Myrtaceae) and *Coccoloba rugosa* Desf. (Polygonaceae) in litter production, the effect of this plant material resistant to the action of invertebrates and seasonal influence (precipitation) in a native fragment of the Atlantic Forest, Bahia (Brazil).

1.3.2 Specific objectives

To quantify litter production between the dry (September to February) and rainy (March to August) seasons;

To calculate quantitative biomass indexes among tree species in the forest fragment;

To analyze the sampling efficiency between litter collection methods using low and suspended nets;

To evaluate a possible seasonal effect of precipitation on litter production;

To inventory the community of terrestrial invertebrates collected in the litter produced by each tree species.

1.4 Hypotheses

The two tree species from the Myrtaceae and Polygonaceae families produce litter with lignified plant material that can have impacts on terrestrial invertebrates, which will use the stem and leaf fractions of the collection nets as an artificial niche.

Seasonality, due to variation in precipitation, may influence this litter production and consequently the occurrence of invertebrates that will colonize this plant material.

2. THEORETICAL FOUNDATION

2.1 Contribution of the tree layer to the litter

The supply of plant material via litter occurs through the tree layer, which plays a fundamental role in its production in terms of quantity and quality. This diversity of trees guarantees a more abundant and nutrient-rich litter, contributing to the balance of ecosystems (Penna-Firme; Oliveira, 2017). Litter is mainly composed of branches, leaves, flowers, fruits, seeds and other plant detritus, along with organic substrates from animals (Costa *et al.*, 2010). In the context of forest ecosystems, the preservation of this layer is essential for the supply of substances that will contribute to the recycling of nutrients and the balance of existing biological diversity (Nascimento *et al.*, 2018*)*. The leaf fraction contributes the most in terms of productivity to the total litter supply (Silva *et al.*, 2009).

Litter production varies depending on the state of conservation or disturbance of the forest (Schlittler; Marinis; Cesar, 1993). The deposition and amount of litter present have considerable impacts on the structure and functioning of ecosystems, particularly affecting biological processes such as seed germination and development (Nascimento *et al.*, 2018; Portela; Santos, 2007).

The quality of the litter can be influenced by the presence of chemical substances in the deposited material. Branches and leaves, containing tannins, lignins and flavonoids, can inhibit the action of invertebrates in the decomposition of litter and consequent nutrient availability (Nascimento *et al.*, 2018). Species from the Myrtaceae family, with a characteristic detachment of the periderm (bark) from the trunk, contribute to the abundant plant material to compose the litter (Rocha *et al.*, 2008). Through the rate of litter production, the vegetation controls the amount of nutrients that return to the soil and its renewal rate depends on the activity of invertebrates and microorganisms (Fernandes *et al.*, 2006*)*.

Nutrients are transferred from vegetation to the soil after litter decomposition, regulating the flow of energy in forest ecosystems under climatic variations that directly influence production at different stages of forest formation (Delitti, 1995). In the initial stages of succession, the production of primary biomass for the litter is greater, which decreases as the community approaches the climax (Vibrans; Sevegnani, 2000). In humid tropical forests, the presence of deciduous species is greater and produces a large amount of litter compared to forests that have been established for longer. Vegetation in succession changes the species composition, altering its structure and, consequently, the amount of stem and leaf fractions, as well as nutrient cycling (Facelli; Pickett, 1991; Schlittler; Marinis; Cesar, 1993). In disturbed forests, a high deposition of leaves is expected due to the rapid growth and consequent leaf renewal of pioneer species and lianas in clearings, when they occupy open spaces in the canopy (Martins; Rodrigues, 1999).

In the plant community of the Atlantic Forest, the Myrtaceae family stands out for its diversity, abundance and importance in maintaining the trophic network (Castuera-Oliveira; Oliveira-Filho; Eisenlohr, 2020). The Polygonaceae family has a low representation of species that serve as phytogeographic markers, but its genus *Coccoloba* is characterized by large leathery leaves that guarantee prolonged vegetation cover over the soil and the contribution of biomass to the litter (Oliveira *et al.*, 2008).

The Myrtaceae family comprises around 10 to 15% of the total tree species. They appear in humid forests and, despite their dominance, only a few studies until this moment have addressed their phenology and productivity (Camargo *et al.,* 2018). The species present high phenotypic variation with vegetative changes resulting from soil fertility and rainfall. The trees vary between 4 and 12 m in height, the crown is reduced and irregular, the trunk is tortuous and covered with thin bark (Bunger; Lucas, 2015). The simple leaves can vary from chartaceous, glabrous to leathery; with oil glands in cavities adjacent to the epidermis. Leaf characteristics are used to differentiate the genera *Eugenia*, *Myrcia* and *Psidium* (Carvalho, 2008; Donato; Morretes, 2011).

From September to December, flowering occurs, with small, apicultural and fragrant flowers. The fruits ripen from November to January, and have different colors with sweet fleshy pulp and are appreciated by several species of birds, which undergo zoochoric dispersal syndrome. This family is one of the richest sources of trophic resources for maintaining animal biodiversity (Bunger; Lucas, 2015). Due to this strong attraction of fauna and its rapid growth, it is widely used as phytoremediation in degraded areas, although the wood has low resistance and is susceptible to deterioration, harboring small ants (Pereira, 2014).

The Myrtaceae family includes native and exotic tree species, such as *Eucalyptus* sp., *Syzygium aromaticum* (clove), *Psidium guajava* (guava), *Psidium cattleianum* (araçá), *Myrtus communis* (common myrtle), *Syzygium jambos* (jambo), *Eugenia uniflora* (pitanga), *Plinia cauliflora* (jabuticaba), among others. In Brazil, the genera *Eugenia* and *Myrcia* stand out

(Bueno *et al*., 2017). Donato and Morretes (2011) emphasized the economic importance of *Psidium* species in food, wood production, medicinal properties such as anesthetics and fungicides, in addition to their ornamental potential, which can increase the exploitation of native species.

In the Myrtaceae family, fungi are associated in symbiosis with the roots and increase the absorption surface with the hyphae, transferring water and mineral salts to the plant. The hyphae release enzymes that degrade organic matter in the soil and promote cycling. It is reported that environmental impacts often affect the fungal and bacterial diversity of the soil. Therefore, the greater the diversity of the litter, the greater the action of decomposer fungi (Fraga *et al.*, 2012).

The Polygonaceae family contributes to ornamentation, as fodder and medicinal use (Oliveira, 2008). The family can be represented by annual or perennial trees of varying sizes, from small to medium, the stem has a smooth morphology of scaly bark, mostly striations or fissures (Melo, 2016). The leaves are simple with a diverse blade and the disintegration of the inflorescences into calyxes, stamens and fleshy fruits allows nutrients to be supplied to the fauna (Pereira, 2014).

2.2 Leaf diversity and consistency

The edge and core litter in native forest fragments has structure and complexity defined by plant diversity, which affects its production, composition and decomposition (Portela; Santos, 2007).

Plant-animal relationships between tree species and invertebrates and litter microbiota can be mutually affected. With decomposition, essential leaf oils can be released into the litter, affecting invertebrates and microbiota (Carvalho *et al.*, 2018). Upon receiving the fruit as food, the fauna disperses the seed. The leaf fraction serves as forage and shelter, being fragmented by fauna, which accelerates decomposition for nutrient cycling and maintenance of the trophic network. Plant-animal interactions, of the mutualism type, occur between the plant *Myrcia madida* (Myrtaceae) and the ant *Myrcidris epicharis* (Pseudomyrmecinae) (Vicente *et al.*, 2012). The fruits have a phenolic action (tannins) that provides astringency and loss of lubricating power, being considered a protector for the nest (Alves *et al.*, 2015). Among the foliar chemical compounds detected in the genus *Coccoloba* are hydroxybenzoic acids, which include vanillic acid (Oliveira *et al.*, 2008).

In the Polygonaceae family, the genus *Coccoloba* is characterized by trees with simple, large, glabrous and leathery leaves, which can restrict the process of biological fragmentation for subsequent decomposition and cycling in the trophic network. When adults, the leaves have trichomes and long, thickened fruitful pedicels, and their buds are consumed by herbivores (Melo, 2004).

2.3 Action of terrestrial invertebrates and nutrient cycling

The biological fragmentation of forest litter is carried out by associated terrestrial invertebrates, which contribute to colonization by fungi and bacteria (Portela; Santos, 2007). Nutrient cycling is essential for maintaining the productivity of forest ecosystems, especially on low-fertility soils (Henriques, 2012). Terrestrial macrofauna can be associated with litter (liter fauna) and the soil (edaphic fauna), playing a primary role in the biological fragmentation of plant material, supplying the rhizosphere and soil with nutrients, and modifying their composition, structure and functionality. The presence of microarthropods in the soil can demonstrate its quality, serving as a bioindicator through indexes of richness, diversity and equitability (Santos; Cabreira, 2019).

In addition to invertebrates, the presence of fungi is crucial for nutrient cycling. Their presence is more observed in the rainy season when they find environments with humidity conducive to their proliferation and consequent decomposition of the litter (Costa *et al.*, 2010). Delitti (1995) and Costa *et al.* (2011) indicated the relationship between litter decomposition closely linked to humidity and temperature, with subsequent release of potassium that promotes the development of bacteria. Domingos and Moraes (1997) described the foliage of the Atlantic Forest, in comparison to other tropical forests, with high concentrations of nitrogen, manganese and zinc in June; potassium, copper and sodium in December.

2.4 Effect of seasonality

Tropical forests are home to complex plant communities, providing the litter with a diverse composition of organic material, maintaining a more stable nutrient cycle and harboring a diverse community of decomposers between dry and rainy seasons (Sanches *et al.*, 2009). Seasonal forests have as a striking aspect the supply of leaves for the production of litter at a certain time of the year (Vibrans; Sevegnani, 2000).

The litter production of an area depends primarily on the productivity of the plant community, which suffers seasonal variations resulting from factors such as temperature and humidity resulting from precipitation (Yu *et al.*, 2019*)*. In Atlantic forests, the greatest drop in the leaf fraction of the arborial layer occurs during the rainy season due to the mechanical impact of abundant rains on the leafy canopy (Brasil *et al.*, 2017). Meanwhile, the accumulation of litter depends mainly on factors such as humidity and the decomposition process which, together with soil temperature, also play a fundamental role in regulating nutrient cycling in the forest (Carvalho *et al.,* 2018).

The arboreal stratum can have its litter production regulated through the effect of the microclimate, which influences the rate of evapotranspiration and consequently the availability of water in the soil (Nascimento *et al.*, 2018). A dense native flora retains humidity, which contributes to the formation of humus and regulation of soil pH, influencing the population density and diversity of edaphic invertebrates (Santos; Cabreira, 2019*)*. Plant biocenosis can be regulated by changes in the physical environment, nutrient availability, soil temperature and luminosity, which can affect litter deposition and accumulation. Furthermore, it provides a greater contribution to the cycling of nutrients to the forest soil and directly influences seed germination, with the humidity it retains, helping in the formation of seedlings and natural revegetation (Portela; Santos, 2007).

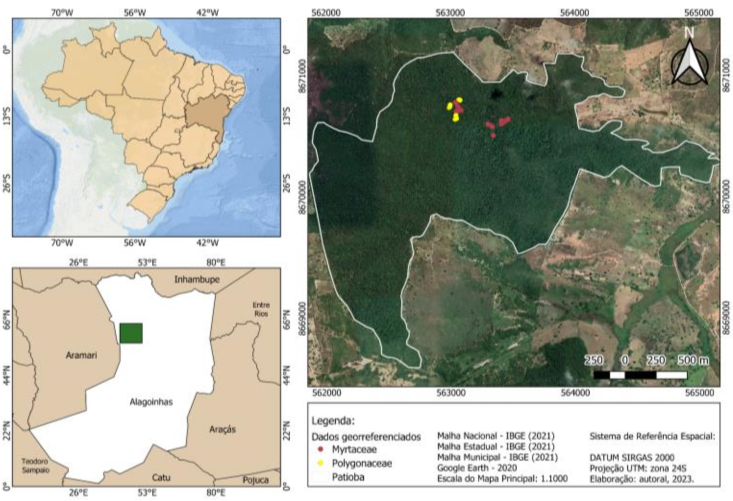
3. MATERIAL AND METHODS

3.1 Study area

This work was performed in a native fragment of approximately 343 hectares of Atlantic Forest at Fazenda Patioba, municipality of Alagoinhas, Bahia (Brazil). Two plots of 100 m x 20 m were marked inside the fragment: P1 on low, flat terrain 522 meters from the edge (24 563.388 E; 8.670.530 S) and P2 on elevated terrain at 264 meters of altitude and 804 meters away from the edge of the fragment (24,563,052 E; 8,670,745 S) (Figures 1 and 2).

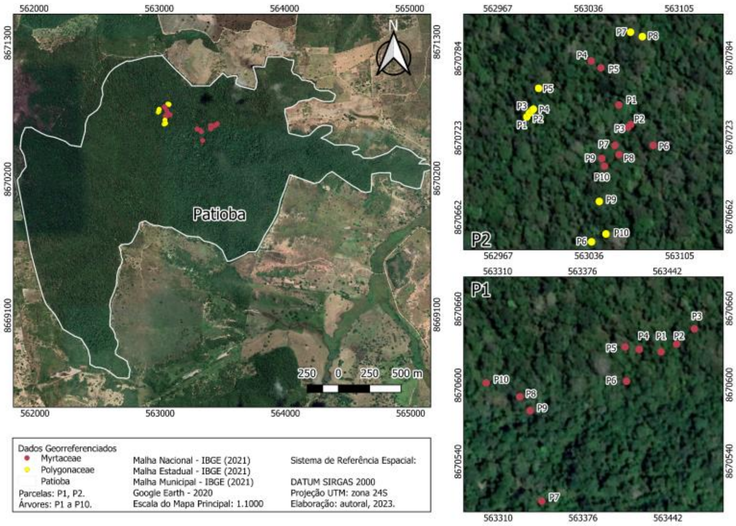
The remainder is surrounded by pasture, which minimizes the impact of degradation and the edge effect, in addition to extensive homogeneous eucalyptus plantations (green desert) which increases the impact of soil degradation. The native fragment is crossed by roads that connect the edge to the core, allowing the extraction of large trees (Figure 3).

Figure 1. Study area with an indication of plots P1 and P2 at the interior of the Atlantic Forest fragment at Fazenda Patioba. Alagoinhas, Bahia (Brazil). January/2022 to January/2023.



Source: José Gabriel Ferreira dos Santos, 2023.

Figure 2. Location of trees in plots P1 and P2 at the interior of the Atlantic Forest fragment at Fazenda Patioba. Alagoinhas, Bahia (Brazil). January/2022 to January/2023.



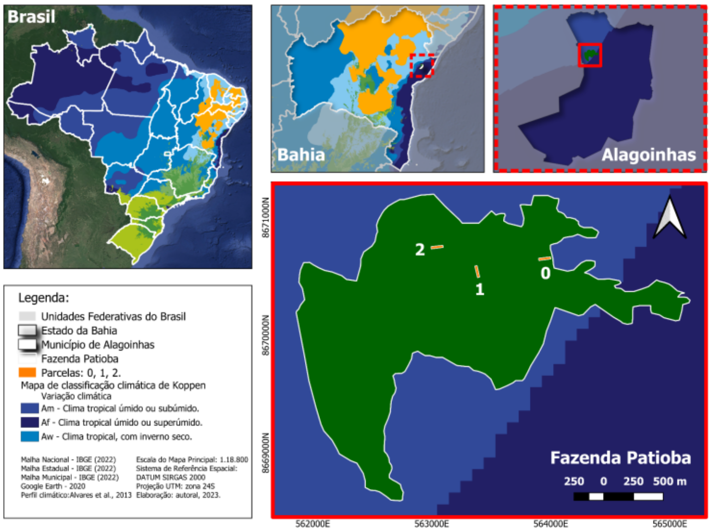
Source: José Gabriel Ferreira dos Santos, 2023.

Figure 3. Outdoor area with pasture (A) adjacent to the entrance (B) and the trail at the interior (C) of the native forest fragment of Fazenda Patioba, Alagoinhas, Bahia (Brazil). January/2022 to January/2023.

Source: Proposed by author, 2023.

In the Köppen-Geiger classification, the study area is under the humid or subhumid tropical climate Am (tropical monsoon), a transition between the climate types Af (tropical forest) and Aw (tropical wet/winter)/As (tropical savanna), characterized by the presence of an average temperature of the coldest month always >18ºC with a dry season of short duration, compensated by high precipitation totals. This type of climate predominates in the interior coastal strip of Bahia. The study area is influenced by the humid tropical or super-humid coastal Atlantic forest Af type, with a dry season in summer (December to February) and a rainy season in autumn-winter (April to August). The driest period occurs between November and January, with January being the driest month. The rainy season begins in April and lasts until August, with the heaviest rainfall occurring in May and June (Brazil, 1992; Alvares *et al.*, 2013) (Figure 4).

Figure 4. Distribution map of climatic types occurring in the Atlantic Forest fragment of Fazenda Patioba. Alagoinhas, Bahia (Brazil).



Source: José Gabriel Ferreira dos Santos, 2023.

Only the climatic environmental variables precipitation (mm) and temperature (ºC) were considered for the municipality of Alagoinhas in the correlation analyses and the data were obtained from the website Weather Spark (2023) (Table 1). No parameters were measured in the study area, which is why humidity was not considered, as the atmosphere in the municipality of Alagoinhas shows records of saturation over previous years. The humidity can be supplied to the environment through precipitation and maintained by the action of leaf litter on the ground.

Table 1. Average monthly precipitation (mm) and temperature (ºC) in Alagoinhas, Bahia (Brazil). January/2022 to January/2023.

Months	2022												2023
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Precipitation (mm)	40.8	50.1	53.2	91.7	131.1	122.5	97.4	67.6	47.2	40.0	47.0	53.0	40.0
Temperature (ºC)	27.5	28.2	27.8	25.3	25.0	21.4	21.7	24.0	24.4	26.5	26.0	27.5	28.0

Source: adapted from the website Weather Spark (2021, 2022, 2023).

3.2 Litter analysis

In the period from January/2022 to January/2023, the monthly litter production was estimated for trees of two species, *Eugenia candolleana* (Myrtaceae) and *Coccoloba rugosa* (Polygonaceae), using low, suspended nets as collectors. Using the active search method for paths in the two georeferenced plots P1 and P2, twenty *E. candolleana* (Myrtaceae) trees were marked in P1 (n=10) and P2 (n=10), plus ten *C. rugosa* (Polygonaceae) trees, marked only in P2 (n=10) where they were located (Figure 5). The trees were selected using the size criterion of 10 cm $\leq$ CAP $\leq$ 60 cm, adapted from Moraes, Conceição and Nascimento (2014); Penna-Firme and Oliveira (2017); Santos, Camargo and Oliveira Junior (2018).

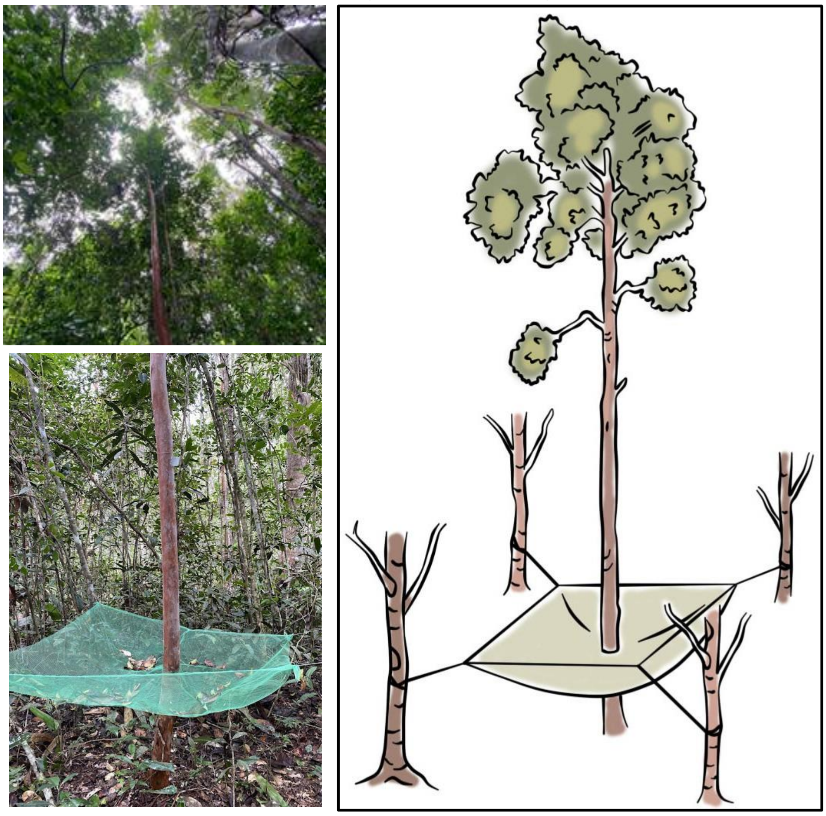
Trees of the species *E. candolleana* (Myrtaceae) and *C. rugosa* (Polygonaceae) had their litter production estimated in plots P1 and P2, using low and suspended collection nets. The low net was set over the leaf litter at the base of the tree as a low-cost method, while the suspended net was attached by strong rope to other nearby trees (Figure 6). The suspended net is not affected by wind and rain to disperse the litter, which is deposited and slides towards the center of the net, preventing its loss and retaining humidity.

The natural fragment of Fazenda Patioba has trees of varying sizes, with *Eugenia candolleana* **(**Myrtaceae) measuring 4 to 13 meters and *Coccoloba rugosa* (Polygonaceae) from 2 to 14 meters high. Low nets were used in the initial 5 months (January-May/2022) and suspended nets in the following 8 months (May/2022-January/2023), with the month of May overlapping.

Figure 5. Vegetation in plots P1 and P2 where trees (left) of *E. candolleana* (Myrtaceae) in red dots and *C. rugosa* (Polygonaceae) in yellow dots; Myrtaceae (center) and Polygonaceae (right) trees at the interior of the Atlantic Forest fragment at Fazenda Patioba. Alagoinhas, Bahia (Brazil). January/2022 to January/2023.

Source: Proposed by author, 2023.

Figure 6. *Eugenia candolleana* (Myrtaceae) with a suspended net installed around the trunk and under the canopy of the tree in the interior plot of the Atlantic Forest fragment at Fazenda Patioba. Alagoinhas, Bahia (Brazil). January/2022 to January/2023.



Source: Proposed by author, 2023 (left) and Ueverton Santos Neves, 2023 (right).

The *Coccoloba rugosa* (Polygonaceae) species had litter production initially estimated for only four trees, as they were the only ones found in the pre-established area, followed by another six trees marked later to complete the sampling universe of ten trees of each species.

The monthly litter collection was made in 1 m^2 low nylon nets fixed with sticks on the litter and suspended 1 meter from the ground, tied at the corners with string/nylon thread to the nearest trees. The detachment of the bark from the reddish trunk is characteristic of *Eugenia candolleana* (Myrtaceae) trees in spring (October-November) and the detachment of large leathery leaves (~30 cm) from *C. rugosa*, these respective plant materials form an extra dense layer over the previously deposited litter (Figure 7).

Figure 7. Litter collection in low and suspended nets under *Eugenia candolleana* (Myrtaceae) trees (above) and *Coccoloba rugosa* (Polygonaceae) (below) in plots P1 and P2 of the Atlantic Forest fragment at Fazenda Patioba. Alagoinhas, Bahia (Brazil). January/2021 to January/2023.

Source: Proposed by author, 2023.

The plant material naturally deposited in the nets was collected in previously identified plastic bags and taken to the laboratory. During the manual sorting, the constituent fractions were separated, taking care to verify the contribution of the leaves from the tree canopy under which the network was installed for monitoring.

The plant material had its fresh biomass (g) recorded on an analytical balance, then it was placed in paper envelopes for drying in the oven at 60ºC for 72 hours to record the dry biomass (g) used in the preparation of graphs and data analysis (Figure 8).

The quantification of litter was performed using the indirect method, based on the estimate of the biomass of each tree, using equations with dry mass data (biometric) and correlating with the plot size of 10 m x 20 m. The indirect method is environmentally friendly as it does not require the destruction of specimens during the study. According to Santos, Camargo and Oliveira Júnior (2018), this method facilitates research due to its greater speed, easy measurement and low cost compared to the direct method (destruction of the study specimen).

Analyzes were performed with the open source software *Paleontological Statistics* (*PAST Analyst*) 4.10.

Figure 8. Manual sorting, recording and drying of litter fractions from collectors in the Atlantic Forest fragment at Fazenda Patioba. Alagoinhas, Bahia (Brazil). January/2021 to January/2023.

Source: Proposed by author, 2023.

3.3 Terrestrial invertebrates

During manual sorting of the fractions, the invertebrates found in the litter were counted and preserved in 70% alcohol with 5 drops of concentrated glycerin and separated into morphotypes. The identification was made by Neves (2023) based on specific literature by Paoletti and Hassall (1999), Baccaro (2006), Cardoso (2017), Brusca, Moore and Shuster (2018) and by comparisons with images from virtual collections. With these taxonomic data in hand, the functional grouping of invertebrates was carried out, according to their eating habits and their presumed role in the litter, into: predators, parasites, phytophages, detritivores, saprophages and coprophages according to Podgaiski, Mendonça Jr. and Pillar (2011) and Parron *et al.* (2015).

The indexes of diversity (Shannon-Wiener), dominance (Simpson), equity (Pielou) and richness (Chao-1, iChao-1 and ACE) were obtained using the open-source software *Paleontological Statistics (PAST Analyst*) 4.10 and used to estimate the ecological status of the terrestrial invertebrate community associated with litter (Table 2).

Table 2. Parameters, index and reference values for population data analysis.

Parameters	Indexes	Reference values
Dominance	Simpson	0 - 1
Diversity	Shannon-Wiever	1.5 – 3.5
Richness	Margalef	3.81
	Menhinick	2.05
	Chao	2.5 – 97.5
Equity	Pielou	0.76

Source: Proposed by author, 2023.

These indexes are calculated based on the following equations:

$$D = \Sigma Pi^2$$

In which: D, Simpson index (1949); *Pi*, relative abundance (proportion) of species *i* in the sample. The Simpson index indicates the probability of two individuals randomly selected belonging to the same species.

$$H = -\Sigma Pi * \ln Pi \quad \text{and} \quad Pi = ni/N$$

In which: H, Shannon-Wiener index (1949); Pi, relative abundance; Ln, natural logarithm; N, total number of individuals; *n*i, number of individuals of each order.

The rarefaction curve values were obtained through combinatorial analysis, using the Hurlbert (1971) equation, to verify how many possible combinations can be made and how many subsets can be obtained:

$$E(S_n) = \sum_{i=1}^{S} \left[1 - \frac{(N - Ni\ n)}{(N\ n)} \right]$$

In which: N, the total number of individuals in the community; Ni, the number of individuals of the ith species; n, the number of individuals standardized for rarefaction.

The Chao-1 index is an abundance estimator of individuals belonging to a given class and estimates species richness in a given ecological community based on a sample. The estimator proposal is based on the frequency of rare species, that is, those that occur only once or twice in samples (Chao, 1987). This index is useful for comparing biological diversity between habitats or areas and for evaluating the sufficiency of the sampling effort in capturing the majority of species present in the community (Sanos, 2006). The equation can be described as follows:

$$\text{Chao-1} = S_{\text{obs}} + F_1^2/2F_2$$

In which: S_{obs}, number of species observed; F_1, number of species that occur only once in the samples; F_2, number of species that occur twice in the samples.

The iChao-1 index assumes that the frequency of unique and duplicate individuals is proportional to the abundance of rare species in the community and that these rare species contribute most to species richness. The iChao-1 is a robust and simple estimator that can be applied to different types of ecological data and has good performance compared to other species richness estimators (Baldrian *et al.*, 2022). The iChao-1 can be calculated by the formula:

$$i\text{Chao-1} = S_{\text{obs}} + [\ n_1(n_1\text{-}1)/2(n_2\text{+}1)\ ]$$

In which: S_{obs}, number of species observed; n_1, number of unique individuals; n_2, number of duplicated individuals.

Classical mathematical modeling of ecological systems was carried out by applying the simple Lotka-Volterra model to the case where there is interaction between detritivores (prey) and carnivores (predators), using the free software *Populus* 6.0 (Alstad, 2001). The dynamics of the predator-prey interaction was modeled in continuous flow and dependence on the prey (prey-dependent) for plots P1 and P2 over 100 days, a period used as a comparative standard for monthly collections. The quarterly data were not modeled by incipient or non-existent abundance.

4. RESULTS AND DISCUSSION

4.1 Litter production

The tree species *Eugenia candolleana* (Myrtaceae) and *Coccoloba rugosa* (Polygonaceae) were only observed in the interior of the fragment and not in the border strip. Both species contributed with abundant lignified material to the litter, respectively with the periderm (bark) of the stem of the first and the leathery leaves of the second, interfering with the action of terrestrial invertebrates.

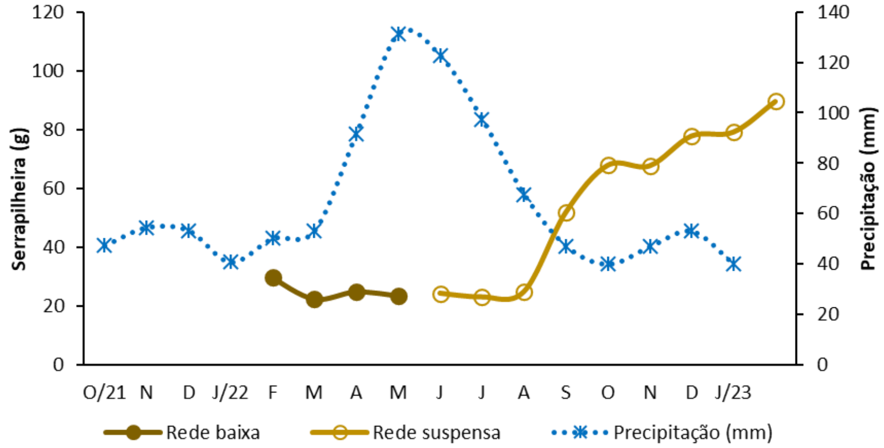
In plot P1, Myrtaceae trees were grouped according to CBH categories (circumference at breast height) in tree 1; trees 8 and 9; trees 2, 4 and 5; trees 3, 6, 7 and 10. Tree 1 stood out in litter production and the others showed a common pattern of peaks in litter production in the two dry seasons of spring (October/2022) and summer (January/2023), especially after the abundant rains in autumn (May/2022) and winter (August/2022) (Figures 9 and 10, Tables 3 and 4).

The peeling of the reddish trunk of some *Eugenia candolleana* trees, in the dry spring and summer season (September/2022 to January/2023), resulted in a large contribution of lignified material to the litter (Figure 9), with probable interference in the action of the functional groups of terrestrial invertebrates in the decomposition process. The high lignin content slows down the decomposition process due to resistance to attack by invertebrates, such as cutters, crushers and detritivores (Margida; Lashermes; Moorhead, 2020).

In plot P1, tree 1 peeled over the entire height of the stem and stood out in the production of greater litter as it had greater CBH and biomass. Tree 5 (CBH = 0.28 m) of P1 peeled off its stem in November/2022, which contributed to biomass despite the reduced canopy. Trees 6 and 7 had little peeling, probably because they were younger individuals (Figure 9).

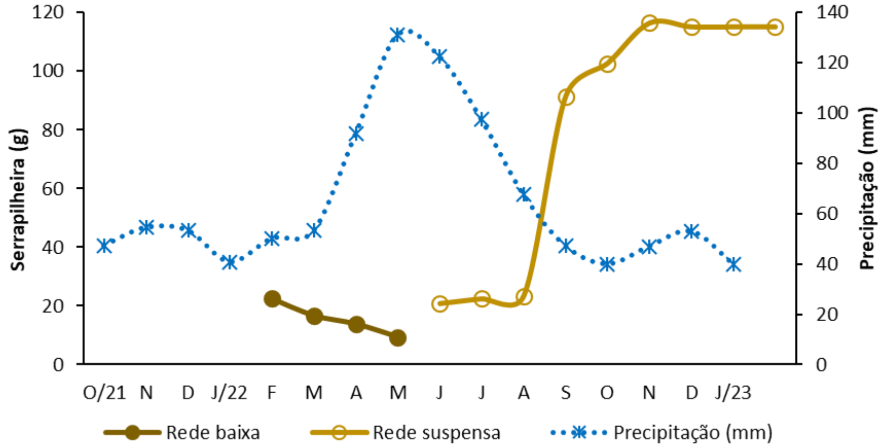
In plot P2, there were no groupings of individuals by CBH and trees 1 to 10 were used as a sample group (Figure 10).

Figure 9. Individual litter production by *Eugenia candolleana* (Myrtaceae) trees in the P1 portion of the native forest fragment of Fazenda Patioba, Alagoinhas, Bahia (Brazil). January/2022 to January/2023.



Source: Proposed by the author, 2023.

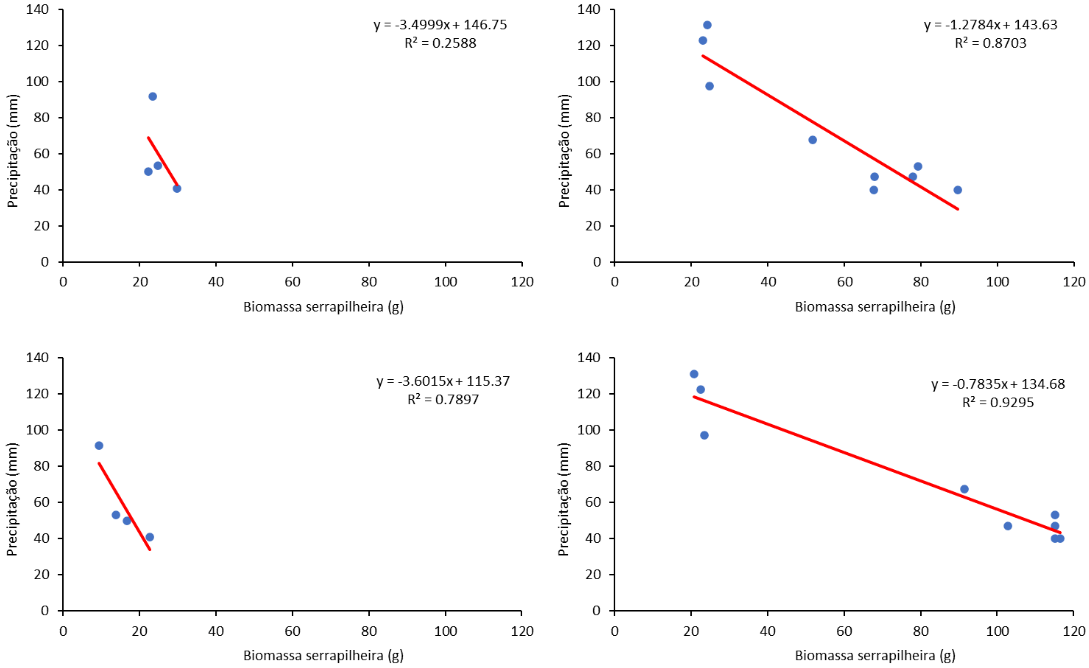
Figure 10. Average litter production by *Eugenia candolleana* (Myrtaceae) trees in the P2 plot of the native forest fragment of Fazenda Patioba, Alagoinhas, Bahia (Brazil). January/2022 to January/2023.



Source: Proposed by the author, 2023.

After the peak of precipitation in the rainy season in May/2022, the supply of aerial litter from *E. candolleana* (Myrtaceae) trees decreased only in the low net of plot P2 (r^2 = 0.79), probably carried away by the rain, and increased in the suspended nets of the two plots P1 (r^2 = 0.87) and P2 (r^2 = 0.93) (Figure 11).

Figure 11. Correlation of *Eugenia candolleana* (Myrtaceae) litter biomass (g) in low (left) and suspended (right) nets with precipitation (mm) in plots P1 (top) and P2 (bottom) of the native forest fragment of Fazenda Patioba, Alagoinhas, Bahia (Brazil). January/2022 to January/2023.



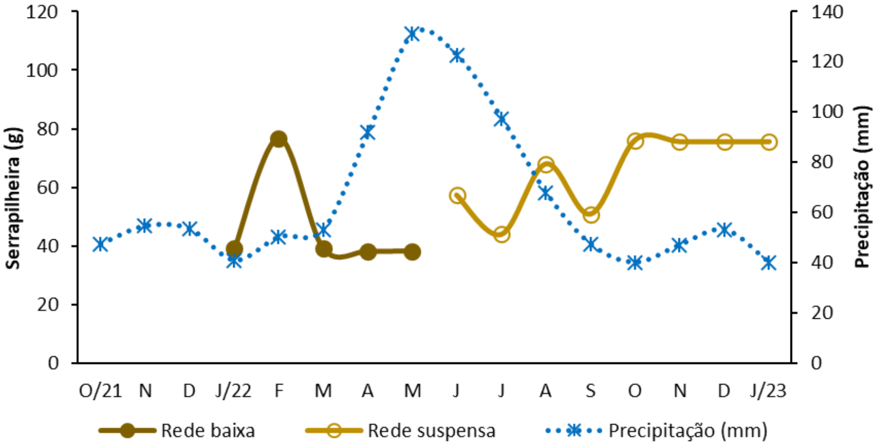
Source: Proposed by the author, 2023.

Myrtaceae trees have trunks with sequential periderms in a flat, reddish rhytidome, which break off into plates (Vergílio, 2019), thanks to schizogenous spaces (tissue rupture). In this tissue, there are some glands that secrete calcium oxalate crystals (Solereder, 1908, *apud* Silva, 2002) and the litter enriched with exudates nourishes terrestrial invertebrates such as gastropods, abundant detritivores found in the plant material of *E. candolleana*.

The same seasonal effect was not observed in the production of aerial litter by *C. rugosa* (Polygonaceae) trees (r^2=0.13 and r^2=0.52) (Figures 12 and 13). This result was attributed to the leathery consistency of the leaves, which are more resistant to the impact of rain and only fall during the senescence phase (Figure 14).

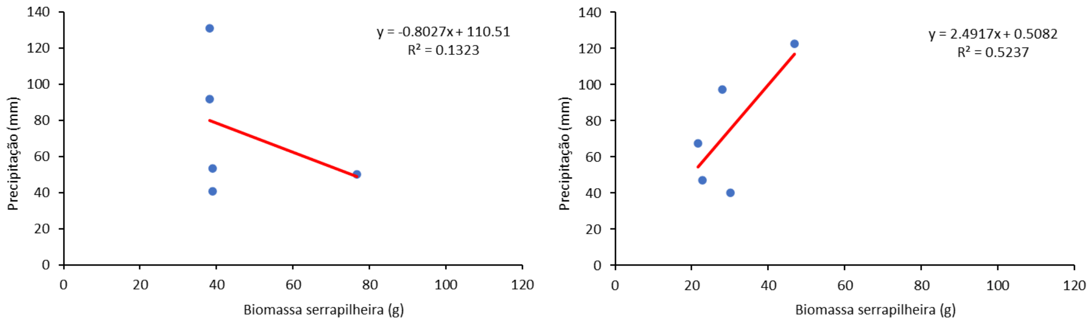
Coccoloba rugosa trees 1, 2, 3 and 4, very close together (0.5-1.0 m), covered a surface of 7 m^2 with large leathery leaves (~30 cm) in the summer of 2022, showing wide dispersion and density of the leathery leaf fraction, resulting in a large contribution of lignified material to the litter in plot P2 where the specimens were found (Figure 14).

Figure 12. Average litter production of *Coccoloba rugosa* (Polygonaceae) trees in the P2 plot of the native forest fragment of Fazenda Patioba, Alagoinhas, Bahia (Brazil). January/2022 to January/2023.



Source: Proposed by the author, 2023.

Figure 13. Correlation between litter biomass (g) of *Coccoloba rugosa* (Polygonaceae) and precipitation (mm) in the P2 plot of the native forest fragment of Fazenda Patioba, Alagoinhas, Bahia (Brazil). January/2022 to January/2023. Low (on the left) and suspended (on the right) nets.



Source: Proposed by the author, 2023.

Figure 14. Detail of the litter and leathery leaf consistency produced by *Coccoloba rugosa* (Polygonaceae) trees in the P2 plot of the native forest fragment of Fazenda Patioba, Alagoinhas, Bahia (Brazil). January/2022 to January/2023.

Source: Proposed by the author, 2023.

The temporal variation of litter responds to the effect of seasonality. In seasonal tropical forests, a drop in litter supply is observed with greater intensity at the end of the dry season, due to the decrease in rainfall (Portela *et al*., 2007). In this study, the increase in this production occurred after the rainy season, which tends to cause changes in the forest interior by washing the canopies and falling leaves that senescence due to water deficit in the dry season. In the dry season, there is greater productivity since, during this period, environmental conditions are more conducive to leaf renewal (Oliveira *et al*., 2008; Vidal *et al.*, 2007).

4.2 Terrestrial invertebrates

In plot P1, the litter in the low and suspended nets under the *Eugenia candolleana* tree sheltered 73 individuals, representatives of at least 13 morphospecies among the orders Isopoda (Malacostraca), Blattaria, Hymenoptera and Orthoptera (Insecta), Araneae (Arachnida) and Stylommatophora (Gastropoda), this last one abundant and varied, with red, white and brown shells. The plant material of *E. candolleana* retained humidity in the suspended net, although it was not directly on the ground, which contributed to the beginning of the decomposition of the leaf fraction by leaching and colonization of detritus by the detritivorous woodlice, cockroaches, crickets and gastropods, which attracted predatory visitors ants (*Pseudomyrmex* sp.) and spiders (Table 3).

Species of the genus *Eugenia* (Myrtaceae) have oil glands and idioblasts that secrete exudates, such as calcium oxalate crystals and tannic phenolic content, characteristic of their vegetative structures (stems and leaves) (Jorge *et al.*, 2000; Donato; Morretes, 2007; Armstrong, 2011; Alvarez; Silva, 2012). Considering the abundance of gastropods in the litter of *Eugenia candolleana*, we can infer this preference of gastropods of the order Stylommatophora for the litter rich in calcium to produce their shells.

In the litter under the *E. candolleana* trees of plot P2, 136 invertebrates were captured and classified into at least 13 morphospecies among the orders Isopoda (Malacostraca), Blattaria/Blattodea and Hymenoptera (Insecta), Araneae (Arachnida) and Stylommatophora (Gastropoda) in plot P2 (Table 4).

Litter samples in low and suspended nets under the *Coccoloba rugosa* tree sheltered the highest abundance and lowest richness with 476 individuals in 8 morphospecies of the orders Isopoda (Malacostraca), Blattaria/Blattodea, Hymenoptera (Insecta), Araneae (Arachnida) and Stylommatophora (Gastropoda) (Table 5).

Low invertebrate diversity was recorded in suspended nets with *C. rugosa* litter colonized by arboreal ants *Pseudomyrmex* sp. (Hymenoptera). The suspended net simulates the aerial stem environment of trees (Table 5). The low occurrence of other invertebrate species may be the result of the aggressiveness of these ants, which attack other organisms in defense of the host plant (Baccaro *et al*., 2015). The leathery leaf material depends on specialized biological agents equipped with crushing mouthparts for plant fragmentation, such as leaf-cutter ants of the genera *Atta* and *Acromyrmex*, which prey on other invertebrates. Crusher ants of the genus *Atta* were captured by Sá (2023) in the litter of low nets in the same native fragment of the Atlantic Forest in 2022.

Table 3. *Eugenia candolleana* (Myrtaceae) litter invertebrates in the low and suspended nets of the P1 plot of the native forest fragment of Fazenda Patioba, municipality of Alagoinhas, Bahia (Brazil). January/2022 to January/2023.

Myrtaceae		Malacostraca	Insecta								Arachnida		Gastropoda		
Eugenia candolleana		Isopoda	Blattaria Blattodea	Hymenoptera				Orthoptera	Nymph	Larvae	Araneae		Stylommatophora		
Tree (P1)	N (Inv)	*Philoscia muscorum*	Blaberidae	*Pseudomyrmex* sp.	Ant sp. 1	Ant sp. 2	Wasp				Spider sp. 1	Spider sp. 2	*Neobeliscus calcareus*	Shell sp. 1	Shell sp. 2
1	29	3		23									3		
2	3	2											1		
3	21	7			3	2	1	5			1	1			1
4	3												3		
5	3								1				2		
6	1												1		
7	0														
8	9		3	1	1						1		1	2	
9	2												2		
10	2												2		
Total N = 73		12	3	31				5	1	0	3		18		

Source: Proposed by the author, 2023.

Table 4. *Eugenia candolleana* (Myrtaceae) litter invertebrates in the low and suspended nets of the P2 plot at the native forest fragment of Fazenda Patioba, municipality of Alagoinhas, Bahia (Brazil). January/2022 to January/2023.

Myrtaceae		Malacostraca	Insecta								Arachnida		Gastropoda		
Eugenia candolleana		Isopoda	Blattaria Blattodea	Hymenoptera				Orthoptera	Nymph	Larvae	Araneae		Stylommatophora		
Tree (P2)	N (Inv)	*Philoscia muscorum*	Blaberidae	*Pseudomyrmex* sp.	Ant sp. 1	Ant sp. 2	Wasp				Spider sp. 1	Spider sp. 2	*Neobeliscus calcareus*	Shell sp. 1	Shell sp. 2
1	9	1	1	4	1									2	
2	11	6	3					1						1	
3	22	7			3	2	5	2			1		2		
4	14	3	1									1		3	6
5	3	1	1										1		
6	16	2	2		1	3							1	3	4
7	22	4	3	3				1		5			1	3	2
8	24	3	3	7	2	2					3	1			3
9	15	5	3										1	2	4
10	0														
Total N = 136		32	17	33				4	0	5	6		39		

Source: Proposed by the author, 2023.

Table 5. *Coccoloba rugosa* (Polygonaceae) litter invertebrates in the low and suspended nets of the P2 plot of the native forest fragment of Fazenda Patioba, municipality of Alagoinhas, Bahia (Brazil). January/2021 to January/2023.

Polygonaceae		Malacostraca	Insecta								Arachnida		Gastropoda		
Coccoloba sp.		Isopoda	Blattaria Blattodea	Hymenoptera				Orthoptera	Nymph	Larvae	Araneae		Stylommatophora		
Tree (P2)	N (Inv)	*Philoscia muscorum*	Blaberidae	*Pseudomyrmex* sp.	Ant sp. 1	Ant sp. 2	Wasp				Spider sp. 1	Spider sp. 2	*Neobeliscus calcareus*	Shell sp. 1	Shell sp. 2
1	3	3													
2	7	3			4										
3	4	3				1									
4	5	3				1							1		
5	8		3			1							4		
6	445		3	442											
7	0														
8	0														
9	2		1					1							
10	2								1				1		
N = 476		12	7	449			0	1	1	0	0		6		

Source: Proposed by the author, 2023.

In the litter of *E. candolleana* trees, in the interior (plot P2) of the fragment, invertebrates classified into at least 10 morphospecies were collected among the orders Isopoda (Malacostraca), Blattaria/Blattodea, Hymenoptera (Insecta), Araneae (Arachnida) and Stylommatophora (Gastropoda) (Figure 15).

Figure 15. Invertebrates found in the litter accumulated in the low and suspended nets under tree 6 of *Eugenia candolleana* (Myrtaceae) in the P2 plot of the fragment at Fazenda Patioba, Alagoinhas, Bahia (Brazil). January/2022 to January/2023.
Caption: 1) ant, 2) nymph, 3) larvae sp. 1, 4) spider sp. 1, 5) spider sp. 2, 6) gastropod shell sp. 1, 7 and 8) gastropods shell sp. 2.

Source: Proposed by the author, 2023.

The high abundance of ants was mainly due to a small colony of 442 *Pseudomyrmex* sp. ants (Formicidae) (black-brown color measuring 1.2-2.0 cm), collected in the suspended net under tree 6 of *Coccoloba rugosa* in plot P2. The litter samples were accumulated in the suspended nets for 3 months at the end (November/2022 to January/2023) of the work, during the transition between spring and summer, forming an artificial habitat that served as a shelter for the ant *Pseudomyrmex* sp. (Figure 16).

This species has a broad biotic mutualistic relationship with the triplaris americana tree *Triplaris* sp. (Polygonaceae), where it seeks shelter in the stem (Oliveira *et al*., 2008). Species of this genus are considered arboreal, although they can also forage on the ground (Apolinário *et al*., 2019) and in leaf litter (Delabie *et al*., 1990).

Figure 16. *Pseudomyrmex* sp. black and brown ant colony found in the litter accumulated on the suspended mesh under *Coccoloba* tree 6 in the P2 plot of the fragment at Fazenda Patioba, Alagoinhas, Bahia (Brazil). January/2022 to January/2023.

Source: Proposed by the author, 2023.

The contribution of structural tissues, rich in cellulose and lignin, from each tree species to the litter, by the periderm (bark) of the stem of *Eugenia* and large leathery leaves of *Coccoloba*, can interfere with biological fragmentation by detritivores and the creation of habitats for the protection of prey against predators among terrestrial invertebrates. Invertebrates vary in composition in the leaf litter of the forest system, fragmenting it and recycling nutrients.

The Simpson, Shannon and Chao indexes showed greater diversity and richness of invertebrates in the *Eugenia candolleana (Myrtaceae)* litter when compared to *Coccoloba rugosa* (Polygonaceae) (Table 6).

Among the invertebrates collected in the litter of the nets, the following 6 functional groups were recorded: predator, phytophagous, detritivore, saprophagous, coprophagous, and bioturbator (Table 7).

Table 6. Invertebrate diversity indexes collected in the litter of *Eugenia candolleana* (Myrtaceae) and *Coccoloba rugosa* (Polygonaceae) in the native fragment of Fazenda Patioba, Alagoinhas, Bahia (Brazil). January/2022 to January/2023.

Índices	Myrtaceae P1	Myrtaceae P2	Polygonaceae P2
Taxa_S	13	13	8
Indivíduals	73	136	476
Dominance_D	0,1785	0,1171	0,8631
Simpson_1-D	0,8215	0,8829	0,1369
Shannon_H	2,0750	2,3430	0,3841
Evenness_e^H/S	0,6124	0,8010	0,1835
Brillouin	1,7640	2,1360	0,3537
Menhinick	1,5220	1,1150	0,3667
Margalef	2,7970	2,4430	1,1350
Equitability_J	0,8088	0,9135	0,1847
Fisher_alpha	4,6010	3,5370	1,3660
Fisher_alpha	4,6010	3,5370	1,3660
Berger-Parker	0,3288	0,2353	0,9286
Chao-1	14,48	13,00	9,00
iChao-1	16,24	13,00	9,50
ACE	16,02	13,00	9,23

Source: Proposed by the author, 2023.

Table 7. Functional groups of invertebrates collected with litter in the plots (P1 and P2) of the Atlantic Forest fragment at Fazenda Patioba. Alagoinhas, Bahia (Brazil). January/2022 to January/2023.

Order (Class)	**Functional group**						
	Suborder, family, subfamily, genus or specie	**Predator**	**Phyto phage**	**Detritivore**	**Saprophage**	**Copro phage**	**Bioturbator**
Isopoda (Malacostraca)	Philoscidae *Philoscia muscorum*			X	X	X	
Blattaria (Insecta)	Blaberidae			X			X
Hymenoptera (Insecta)	*Pseudomyrmex* sp.	X					
	Ant sp. 1	X			X		X
	Ant sp. 2	X	X		X		X
Orthoptera (Insecta)	Cricket	X	X		X		
Araneae (Arachnida)	Spider sp. 1	X					
	Spider sp. 2	X					
Stylommatophora (Gastropoda)	Stylommatophora			X			
	Neobeliscus calcareus			X			
	Shell sp. 1			X			
	Shell sp. 2			X			

Source: Proposed by the author, 2023.

Detritivores, such as isopods, cockroaches, ants and gastropods are responsible for the biological fragmentation of litter fractions, feeding on plant material, animal feces, and other waste (Parron *et al.*, 2015). This prior action facilitates the action of the microbiota in the decomposition of the organic matter of the forest floor (Melo *et al.*, 2009). Cockroaches and ants also play the role of bioturbators, by moving the leaf litter and soil they accumulate residual organic material as a reserve of nutrients, mix different layers, and contribute to soil fertilization (Offenberg *et al*., 2019; Pinkalski *et al*., 2018).

This activity also increases porosity, favoring soil aeration and allowing the entry of water, which is essential for plant growth and the survival of soil fauna (Brown *et al.*, 2015).

Litter production in the Atlantic Forest is shown to be fractal in the rainy season and the rate of biomass production varies according to the seasonality of precipitation and radiation, which are fundamental for the revitalization and decomposition of plant material in the arboreal layer (Ferreira *et al.*, 2014). Leaf consistency, animal diversity, microclimate and structural complexity of habitats affect decomposition time (Ferreira; Marques, 1998). Lignin and tannin are chemical compounds that inhibit the action of decomposers. Invertebrates constitute resources that channel energy to higher trophic levels and changes in abundance can compromise interactions in functional groups (Hunter *et al.*, 2003; Cebrian; Lartigue, 2004).

The decomposition of litter has arthropods as allies, which carry out biological fragmentation; while fungi and bacteria degrade lignin and cellulose, releasing nutrients and forming humus. Andrade *et al.* (2020) reported that decomposition in the Atlantic Forest has different rates for inorganic elements, such as potassium (90 days), phosphorus (30 days) and carbon (45 days) for the soil and microbial biomass.

Plants of the genus *Coccoloba* present phenotypic variation resulting from physiological processes capable of generating changes in the shape of the plant. Such changes can be influenced by latitude, altitude, soil fertility, quantity and distribution of rainfall throughout the year. This is due to their phenotypic developmental plasticity for survival when exposed to water variations (Kerbauy; Rodrigues, 2009; Pereira, 2014).

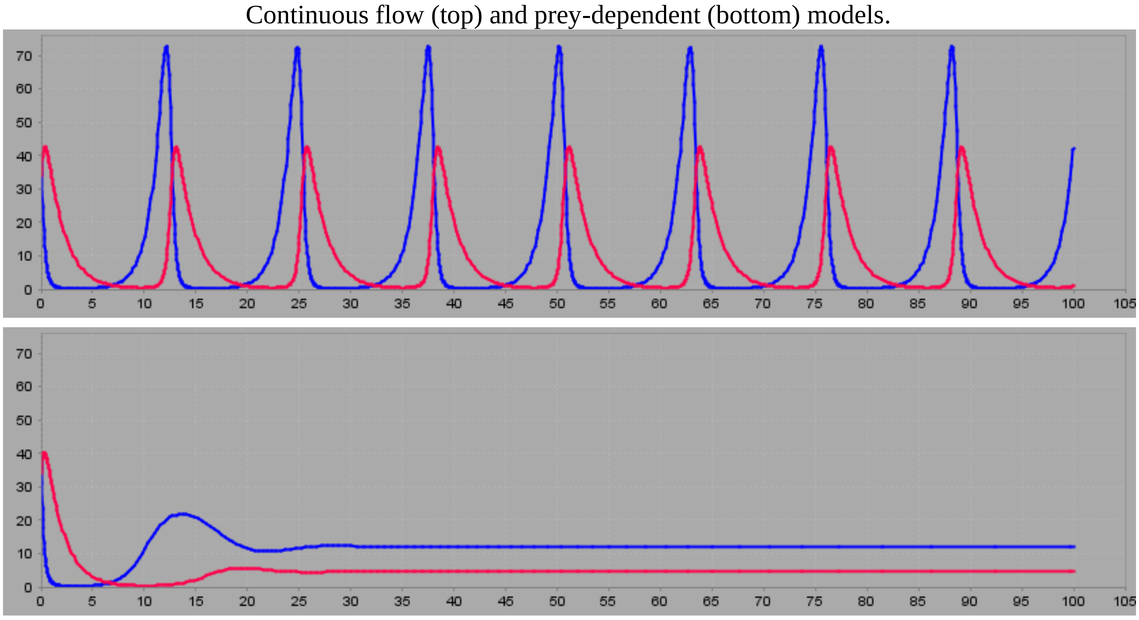
Terrestrial invertebrates developed specific structures and behavior that allowed adaptations to the litter-soil system (Campos *et al.*, 2012; Podgaiski; Mendonça Jr.; Pillar, 2011). The functional groups associated with litter perform fundamental ecosystem services, such as fragmentation of plant material (detritivores), population control (predators), soil cycling and fertilization (bioturbators). Together, they contribute to the natural restoration of the ecosystem (Araújo, 2012).

Among predators, ants and spiders stand out, which play an important role in controlling populations of other invertebrates, helping to maintain balance in the ecosystem (Melo *et al.*, 2009). Spiders act to control the population of several species of invertebrates, including their own, reducing competition for resources (Riechert; Lockley, 1984).

In a hypothetical scenario simulating the predator-prey relationship, there are three possible situations represented based on invertebrate abundance data captured in litter samples of tree species monitored during one year (Figures 17 to 19).

Predators are represented by ants (Hymenoptera) and spiders (Araneae), while prey belongs to a greater variation between the groups Isopoda, Blattaria, Orthoptera and Gastropoda. The larger the prey group, the less pressure exerted by predators and the faster the recovery of invertebrate populations in this functional group. A group of 34 predators exerts pressure for 15 days on the set of 39 prey in the litter of *E. candolleana* (Myrtaceae) in plot P1 (Figure 17).

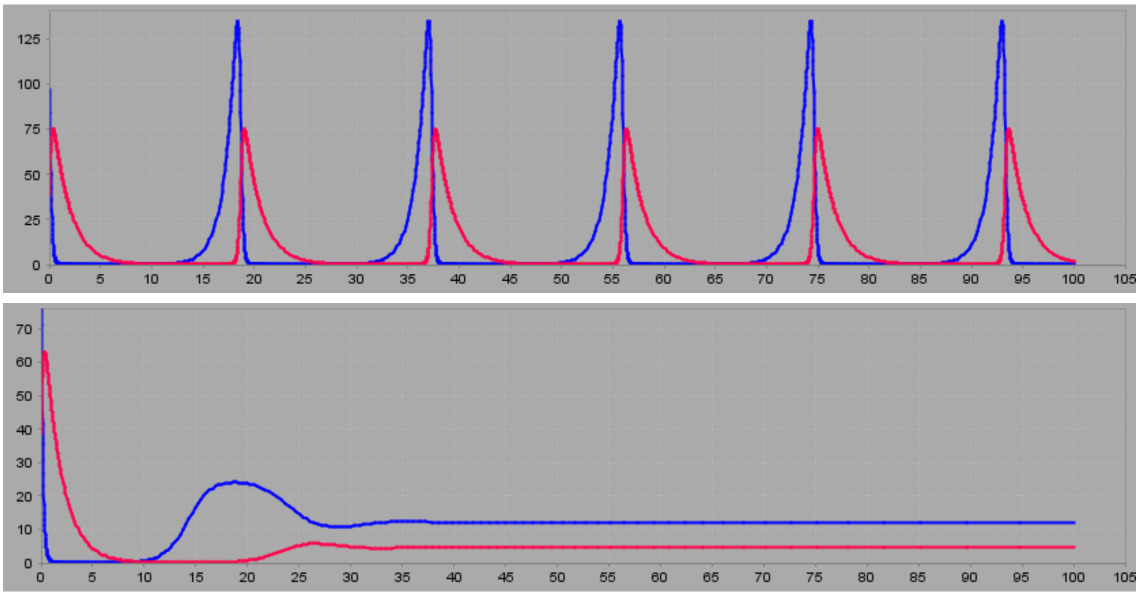
Figure 17. Simple Lotka-Volterra model of the dynamics of 34 predators (red) and 39 prey (blue) in the period of t=100 days in the litter of *Eugenia candolleana* (Myrtaceae) in the interior (P1) of the Atlantic Forest fragment of Fazenda Patioba. Alagoinhas, Bahia (Brazil). January/2022 to January/2023. Continuous flow (top) and prey-dependent (bottom) models.



Source: Proposed by the author, 2023.

A group of 39 predators exert pressure for 20 days on a set of 97 prey in the litter of *E. candolleana* (Myrtaceae) in plot P2 (Figure 18). The expected recovery time will be 20 days if the sources of stress are ceased.

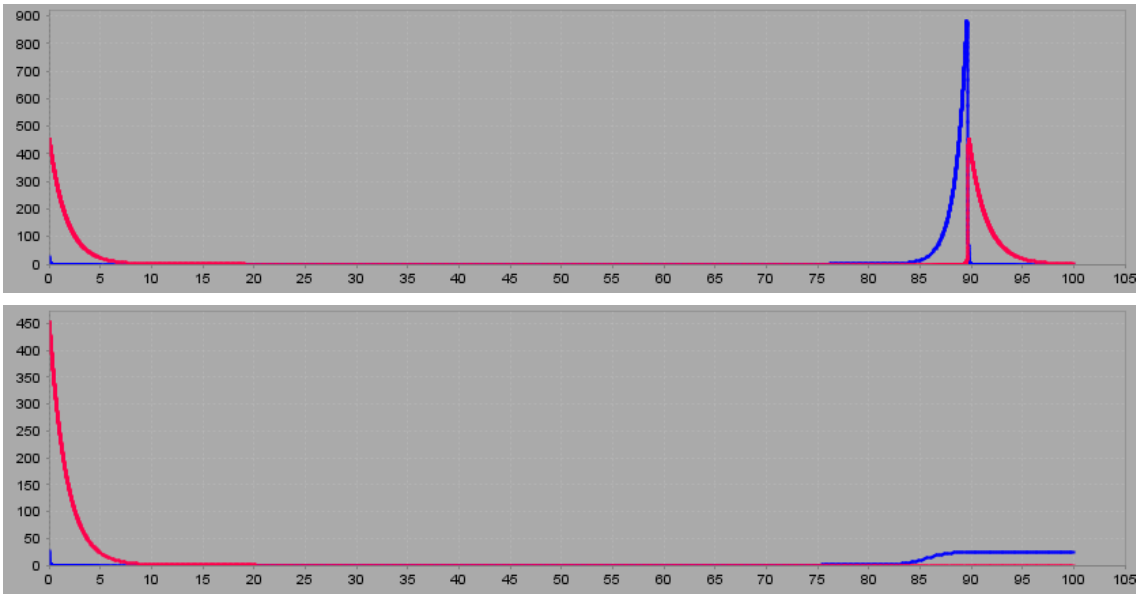
Figure 18. Simple Lotka-Volterra model of the dynamics of 39 predators (red) and 97 prey (blue) in the period of t=100 days in the litter of *Eugenia candolleana* (Myrtaceae) in plot P2 at the interior of the Atlantic Forest fragment of Fazenda Patioba. Alagoinhas, Bahia (Brazil). January/2022 to January/2023. Continuous flow (top) and prey-dependent (bottom) models).



Source: Proposed by the author, 2023.

The colony of 449 predatory ants is capable of decimating a set of 27 prey, of different species including Isopoda, Blattaria, Orthoptera and Gastropoda, in the litter of *C. rugosa* (Polygonaceae) in plot P2 (Figure 19). It is no surprise that ants have colonized the leaf litter in the suspended net freely without competition. In this case, if the pressure from predators ceased, the prey would take around 3 months to recover their abundance if no other environmental factor interfered, which is very unlikely in the natural conditions of a native forest fragment and would be a scenario for predicting chaos!

Figure 19. Lotka-Volterra model of the dynamics of 449 predators (red) and 27 prey (blue) in the period of t=100 days in the litter of *Coccoloba rugosa* (Polygonaceae) in plot P2 in the interior of the Atlantic Forest fragment of Fazenda Patioba. Alagoinhas, Bahia (Brazil). January/2022 to January/2023. Continuous flow (top) and prey-dependent (bottom) models.



Source: Proposed by the author, 2023.

5. CONCLUSIONS

The tree species *Eugenia candolleana* (Myrtaceae) and *Coccoloba rugosa* (Polygonaceae) were found in the interior of the fragment, but not on the edge, and both contributed an abundant lignified material to the litter, respectively with the periderm (bark) of the stem of the first and the leathery leaves of the second, interfering with colonization by terrestrial invertebrates.

The leathery leaves seem to have agents specialized in biological fragmentation, given the low diversity of invertebrates due to the high abundance of leaf-cutter and aggressive arboreal ants of the genus *Pseudomyrmex*, found in suspended nets with *C. rugosa* litter. The suspended net simulated the aerial stem environment of the trees.

There was an influence of seasonality regulating litter production by *E. candellaria* (Myrtaceae). After the peak of precipitation in the rainy season in May/2022, the supply of aerial litter decreased only in the low net of the P2 plot (r^2 =0.79), probably carried by the rain, and increased in the suspended nets of the two P1 plots (r^2 =0.87) and P2 (r^2 =0.93).

However, the seasonal effect on the production of aerial litter by *C. rugosa* (Polygonaceae) (r^2 =0.13 and r^2 =0.52) was not observed.

The biomass of *E. candolleana* retained humidity in the suspended net, favoring the decomposition of the leaf fraction by leaching and colonization of detritus by invertebrates from the functional prey group, which attracted predators.

Invertebrates from the orders Isopoda (Malacostraca), Blattaria/Blattodea, Hymenoptera (Insecta), Araneae (Arachnida) and Stylommatophora (Gastropoda) were collected from the litter of *E. candolleana* trees in plot P2. There was a dominance of gastropods in the litter of *E. candolleana* and a greater abundance of ants in the litter of leathery leaves of *C. rugosa*.

Invertebrate diversity and richness indexes were higher in the litter of *E. candolleana* (Myrtaceae) than in *C. rugosa* (Polygonaceae).

Among terrestrial invertebrates, six functional groups of predators, phytophages, detritivores, saprophages, coprophages and bioturbators were identified.

This study revealed the possible use of gastropods with shells as bioindicators of the presence of Myrtaceae, due to their relationship with the production of litter rich in the nutrient calcium. Basic research like this provides information for the management and preservation of ecosystems in the Atlantic Forest biome.

The importance of the plant-animal relationship between invertebrates and litter was clear, both in ecosystem processes, such as decomposition and nutrient cycling, as a guarantee of the maintenance of the forest fragment; as well as the complex ecological relationships for the conservation of the trophic network and biodiversity.

The influence of seasonality on the colonization of litter by invertebrates was not observed, indicating that more research may be necessary in this aspect.

Studies focusing on different spatial and temporal scales are needed to investigate how changes in microclimate can affect the litter-terrestrial invertebrate relationship, considering patterns of decomposition and nutrient cycling regulated by changes in seasonality patterns.

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