

Ecosystem services of frugivory and seed dispersal provided by the lowland tapir (*Tapirus terrestris* Linnaeus, 1758) in the Uatumã Sustainable Development Reserve, Amazonas, Brazil

Serviços ecossistêmicos de frugivoria e dispersão de sementes prestados pela anta (*Tapirus terrestris* Linnaeus, 1758) na Reserva de Desenvolvimento Sustentável do Uatumã, Amazonas, Brasil

Servicios ecosistémicos de frugivoría y dispersión de semillas proporcionados por el tapir (*Tapirus terrestris* Linnaeus, 1758) en la Reserva de Desarrollo Sostenible del Uatumã, Amazonas, Brasil

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RESUMO

Considerando que a dispersão de sementes é um processo ecológico essencial para a regeneração florestal e que grandes frugívoros, como *Tapirus terrestris*, têm papel central na manutenção da diversidade vegetal amazônica, este estudo buscou avaliar os serviços ecossistêmicos de frugivoria e dispersão realizados por essa espécie na Reserva de Desenvolvimento Sustentável do Uatumã. Objetivou-se identificar, por meio da análise de fezes, as espécies consumidas, quantificar sementes intactas e predadas e analisar possíveis variações sazonais no consumo. Foram coletadas 22 amostras fecais em áreas de baixios de terra firme, campinarana e ramais, durante a estação seca de 2016 e a chuvosa de 2017, as quais foram triadas. Observou-se que *T. terrestris* consumiu predominantemente material vegetal não reprodutivo, mas 714 sementes de cinco espécies foram registradas. *Sacoglottis guianensis* representou cerca de 80% das sementes consumidas. Houve aumento do número de amostras e da quantidade de sementes no período chuvoso, indicando maior disponibilidade de frutos. Os pesos de sementes intactas e predadas foram semelhantes, sugerindo que a espécie atua tanto como dispersora quanto como predadora. Conclui-se que *T. terrestris* desempenha importante função ecológica na região, apresentando dieta oportunista e variações sazonais marcantes, além de registrar pela primeira vez *Endopleura uchi* em sua dieta local.

Palavras-chave: megafauna, Amazônia, ecologia alimentar.

ABSTRACT

Considering that seed dispersal is a key ecological process for forest regeneration and that large frugivores such as *Tapirus terrestris* play a central role in maintaining Amazonian plant diversity, this study aimed to evaluate the ecosystem services of frugivory and seed dispersal provided by the species in the Uatumã Sustainable Development Reserve. The objective was to identify consumed plant species, quantify intact and predated seeds, and assess seasonal variations in diet. A total of 22 fecal samples were collected in “baixios” of terra firme forests, campinarana and secondary road branches during the 2016 dry season and the 2017 rainy season. Samples were analyzed for seeds. *T. terrestris* consumed mostly non-reproductive plant material, but 714 seeds belonging to five species were recorded. *Sacoglottis guianensis* represented nearly 80% of all seeds consumed. A greater number of feces and seeds was recorded in the rainy season, indicating increased fruit availability. Intact and predated seed masses were similar, indicating dual roles as both disperser and seed predator. These findings allow us to conclude that *T. terrestris* provides important ecological functions in the region, exhibits an opportunistic and seasonally variable diet, and includes *Endopleura uchi* as a newly recorded food item in this area.

Keywords: megafauna, Amazon, feeding ecology.

RESUMEN

Considerando que la dispersión de semillas es un proceso ecológico esencial para la regeneración forestal y que los grandes frugívoros, como *Tapirus terrestris*, desempeñan un papel clave en el mantenimiento de la diversidad vegetal amazónica, este estudio tuvo como finalidad evaluar los servicios ecosistémicos de frugivoría y dispersión de semillas realizados por la especie en la Reserva de Desarrollo Sostenible del Uatumã. Para ello, se identificaron las especies vegetales consumidas, se cuantificaron semillas intactas y predadas y se analizaron variaciones estacionales en la dieta. Se recolectaron 22 muestras fecales en áreas de “baixios” de tierra firme, campinarana y ramales durante la estación seca de 2016 y la lluviosa de 2017. Las muestras fueron examinadas en busca de semillas. *T. terrestris* consumió principalmente material vegetal no reproductivo, aunque se registraron 714 semillas pertenecientes a cinco especies. *Sacoglottis guianensis* representó aproximadamente el 80% de las semillas consumidas. Se observó un mayor número de muestras y semillas en la estación lluviosa, indicando mayor disponibilidad de frutos. Las masas de semillas intactas y predadas fueron similares, evidenciando un papel dual como dispersor y depredador. Se concluye que *T. terrestris* cumple una función ecológica relevante en la región, presenta una dieta oportunista con marcada variación estacional e incluye *Endopleura uchi* como un nuevo registro alimentario en el área.

Palabras clave: megafauna, Amazonía, ecología alimentaria.

1 INTRODUCTION

Seed dispersal, the mechanism responsible for expanding the spatial distribution of plants, is a key process in the life cycle of most plant species in tropical environments (Sinu *et al.*, 2020). It is estimated that approximately 95% of tree species produce seeds that can be dispersed by vertebrates (Jordano *et al.*, 2006). Among birds and mammals, about 20–50% of species consume fruits and/or seeds at least during part of the year, acting as important dispersal vectors (Wehcnke, 2010).

Seed dispersal patterns are strongly influenced by disperser body size, space use, feeding strategy, and defecation patterns (Bodmer, 1991). Large ungulates, such as the lowland tapir (*Tapirus terrestris*), represent a crucial functional group in tropical forests, feeding on a wide variety of leaves, shoots, flowers, fruits, and seeds (Tobler *et al.*, 2010; O’Farrill *et al.*, 2013). The tapir is the largest frugivorous mammal in South America, weighing between 180 and 300 kg (Medici, 2012), and plays an important ecological role by consuming large fruits and dispersing large quantities of seeds over long distances, thereby contributing to gene flow and the maintenance of plant diversity (Wotton & Kelly, 2012; Giombini *et al.*, 2016).

In recent decades, however, these large frugivores, remnants of the Pleistocene megafauna, have been severely affected by anthropogenic pressures such as deforestation, habitat loss, and illegal hunting, particularly in biomes such as the Atlantic Forest, Cerrado, Pantanal, and parts of the Amazon (Medici *et al.*, 2012; Santos *et al.*, 2022). Reductions in their populations may increase

the likelihood of dispersal failure for large-seeded plants, thereby affecting essential ecological processes and forest structure (Fragoso et al., 2003; Tobler *et al.*, 2009).

Although *T. terrestris* has a wide distribution in the Brazilian Amazon, concerns remain regarding its future in the biome, as the species has already become extinct in the Caatinga and is threatened in other biomes due to defaunation and habitat fragmentation. The loss of this species in the Amazon would compromise fundamental ecological processes related to frugivory and seed dispersal, activities intrinsically linked to its diet and behavior (Medici & Foerster, 2002; Galetti *et al.*, 2006).

Despite substantial knowledge of the species' biology and feeding ecology in other biomes, important gaps remain regarding its diet in Amazonian wetland phytophysiognomies, where few studies have addressed frugivory and seed dispersal (Barcelos *et al.*, 2013). Studies based on fecal analyses across different Amazonian vegetation types have reported high richness of consumed plant species (Barcelos *et al.*, 2013), in contrast to biomes such as the Pantanal (Medici *et al.*, 2014) and the Atlantic Forest (Galetti *et al.*, 2001; Burs *et al.*, 2022).

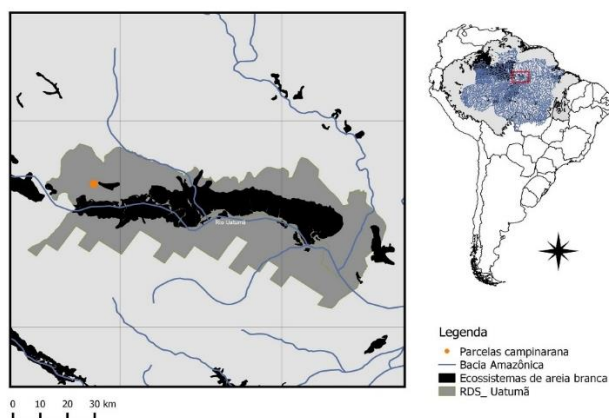
In this context, the present study aimed to expand knowledge on aspects related to frugivory and seed dispersal by *Tapirus terrestris* across different environments within a Sustainable Development Reserve in Central Amazonia.

2 MATERIALS AND METHODS

2.1 STUDY AREA

The study was conducted in the Uatumã Sustainable Development Reserve (RDSU), which covers 424,430 hectares and is located approximately 330 km from Manaus, in the municipalities of São Sebastião do Uatumã and Itapiranga (2°00'–2°40' S; 58°00'–59°20' W) (Figure 1).

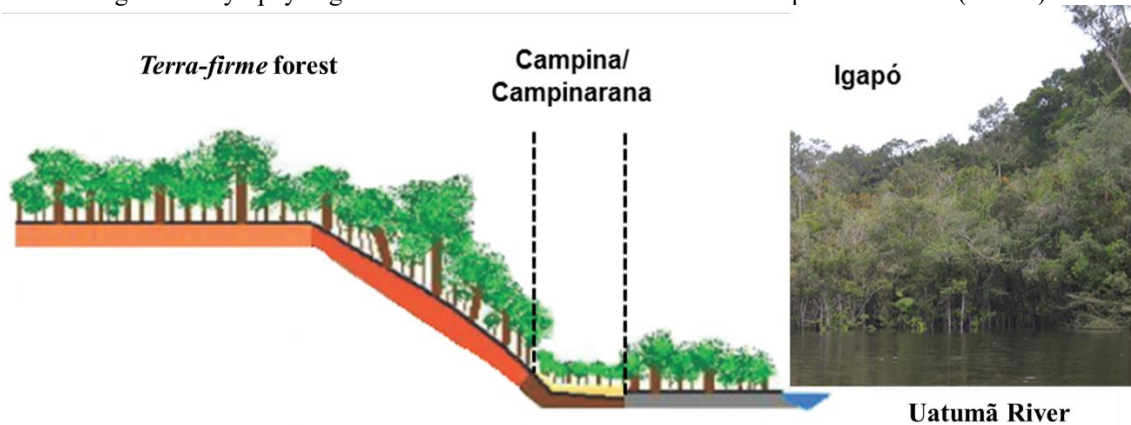
Figure 1. Location of the Uatumã Sustainable Development Reserve (RDSU).



Source: adapted from Adeney et al. (2016).

The region comprises upland (terra firme) forests dominated by Dense Ombrophilous Forest, as well as floodplain areas covered by campinarana and igapó forests (Figure 2). The climate is equatorial and humid, with rainfall concentrated between November and April. Temperature is relatively uniform throughout the year, with a mean of 27 °C, and average annual precipitation of approximately 2,030 mm. Access to the area involves about 240 km of roads from Manaus and an additional ~60 km via the Uatumã River (Koury et al., 2012).

Figure 2. Phytophysiognomies of the Uatumã Sustainable Development Reserve (RDSU).



Source: adapted from IDESAM (2009).

2.2 FECAL SAMPLE COLLECTION

Fecal samples were collected through active searches during two periods: the dry season of 2016 and the rainy season of 2017. Searches were conducted primarily in areas near water bodies, along or close to trails, dirt roads (ramais), and animal paths within upland forests (Figure 3A), lowland areas (baixios) (Figure 3B), and campinarana forests (Figure 3C).

Figure 3. Collection of fecal samples of *Tapirus terrestris*: (A) fecal material collected on dirt roads (ramais); (B) samples found within upland forest lowlands (baixios); (C) samples found within campinarana forests.



For all samples, environmental characteristics were recorded, and collection points were georeferenced and marked with tape indicating the fecal sample number. Only intact feces were

collected, based on criteria such as color and odor, in order to obtain recently defecated samples (Tobler et al., 2009). After collection, samples were stored in shaded conditions and subsequently transported to the laboratory for analysis.

At the Laboratory of Ecophysiology I – Primary Production and Biomass, of the MAUA Research Group at the National Institute for Amazonian Research (INPA), each sample was handled individually and weighed on a precision balance (± 0.01 g) to determine fresh mass (Galetti et al., 2001). Following weighing, fecal material was screened and washed under running water using sieves with 3 mm and 5 mm mesh sizes (Figure 4A, B, and C).

After screening, each fecal sample was examined to verify the presence of intact and/or damaged seeds, and to separate seeds from other fruit fragments, lianas, roots, and additional plant parts found in the feces (Figure 5). All seeds and plant remains were quantified and weighed (Bodmer, 1991; Fragoso & Huffman, 2000). This protocol was applied to all collected fecal samples.

Figure 4. (A) Fecal samples of *Tapirus terrestris* submitted to screening; (B) washing process under running water using sieves; (C) separation of fruits and seeds.



Figure 5. (A) Screened material; (B) separation of intact and/or damaged seeds.



After this procedure, the remaining fecal material, consisting of fragmented plant remains, was weighed and quantified, and then placed in 20 × 40 cm trays arranged in a greenhouse (Figure 5), allowing seeds that had not been identified during screening to be determined after germination and seedling development. Seeds were placed in 20 × 40 cm trays and buried in a substrate

composed of sand (60%) and black soil (40%). The trays were arranged on benches in the greenhouse of the MAUA Research Group – INPA/MAUA Project (Figure 6).

Seed identification was carried out with the assistance of a parataxonomist and through comparison with botanical reference material available in the MAUA–INPA Research Group database. Data were analyzed based on mean values and standard deviation.

Figure 6. (A) Greenhouse of the MAUA Research Group – INPA/Max Planck; (B) fecal material residues consisting of fragmented plant remains; (C) germination of seeds of morphospecies 1 (Fabaceae); (D) germination of seeds of *Sacoglottis guianensis*.



3 RESULTS AND DISCUSSION

A total of 22 fecal samples of *Tapirus terrestris* were collected, yielding 714 intact seeds belonging to four families and five genera; two seeds could not be identified and were classified as morphospecies (Table 1). Despite sampling effort in igapó areas, no fecal samples were found in this environment. Samples were recorded only in campinarana forest, along dirt roads (ramais), and in lowland areas of upland (*terra firme*) forest (Table 1).

The movement of individuals across different forest types within the RDS may contribute to increased genetic diversity of plant species through seed dispersal. Among the plant taxa recorded, the family Humiriaceae was represented by two species, followed by Fabaceae, Urticaceae, and Arecaceae with one species each. The species with the highest numbers of seeds per sample were *Sacoglottis guianensis* ($n = 660$), morphospecies 1 (Fabaceae) ($n = 58$), morphospecies 2 ($n = 7$), *Endopleura uchi* ($n = 3$), and *Cecropia* sp. ($n = 3$). Although fragments of fruit pericarp of buriti

(*Mauritia flexuosa*) were found in several samples, their occurrence could not be quantified due to the absence of seeds.

Of the three identified species, *Endopleura uchi*, *Mauritia flexuosa*, and *Sacoglottis guianensis* occur in campinarana areas of the RDS (Targheta et al., 2015). In contrast, none of the recorded species occur in igapó forests according to the PELD MAUA database (2017); they are typical of upland forests and have been reported as food items for other animals such as tortoises and agoutis (Braga, 1979; Ghilardi Jr. & Alho, 1990). Only *Mauritia flexuosa* occurs across all three forest types according to Householder and Wittmann (2016).

Table 1. Plant species found in the feces of *Tapirus terrestris* across different sampled environments in the Uatumã Sustainable Development Reserve (RDS Uatumã).

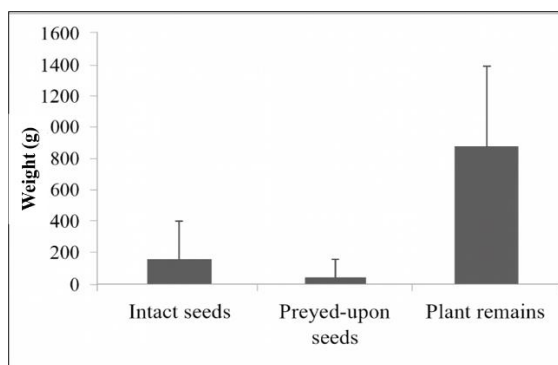
Família	Espécies	Nº de sementes	Ambientes das fezes
Urticaceae	<i>Cecropia</i> sp.	4	Ramal
Humiriaceae	<i>Sacoglottis guianensis</i> Benth	660	Campinarana
Humiriaceae	<i>Endopleura uchi</i> (Huber) Cuatrec.	3	Ramal
Arecaceae	<i>Mauritia flexuosa</i> L. f.	*Pericarp fragments	Baixio
Fabaceae	Morphospecies 1	58	Ramal Campinarana
Unidentified	Morphospecies 2	7	Campinarana

Several studies have analyzed the diet of *Tapirus terrestris* in the Amazon (Bodmer, 1991; Fragoso & Huffman, 2000; Barcelos et al., 2013); however, this is the first survey conducted in the RDS Uatumã. Despite the relatively small number of samples (n = 22), a seasonal difference was observed: seven samples were collected during the dry season, whereas 15 were obtained during the rainy season. This pattern reflects greater fruit availability during the rainy period (Bodmer, 1991; Bueno et al., 2013).

The mass of intact seeds (1,961 g) was very similar to that of predated seeds (1,838 g) in the rainy-season collection (Figure 6), corroborating findings from the Brazilian Amazon (Fragoso & Huffman, 2000) showing that tapirs act not only as major seed dispersers but also as seed predators in tropical forests (Bodmer, 1991; Galetti et al., 2001; Fragoso & Huffman, 2000).

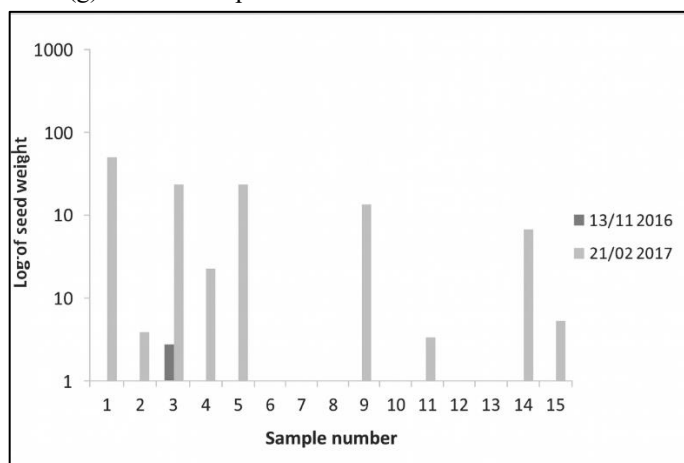
Plant remains (78%), composed of fragments of leaves, fruits, branches, and lianas, greatly exceeded the combined mass of intact and predated seeds (22%) (Figure 7). These values are consistent with Bodmer (1990), who reported that 16.8–37% of dietary items comprised fruits and seeds, whereas 63–83.2% consisted of leaves and fibers. The dietary composition of *Tapirus terrestris* reflects its opportunistic behavior, closely associated with resource availability in the environment (Bodmer, 1991).

Figure 7. Mean $\pm$ standard deviation of the mass of plant material found in the feces of *Tapirus terrestris* during the second sampling period.



Greater fruit richness consumed during the rainy season coincided with the period of higher fruiting by plant species in the region (Targheta et al., 2015) and, consequently, greater food availability. The results for seed mass across periods showed differences both in seed number and, consequently, in sample mass (Figure 8). These differences suggest that the presence of two distinct seasons affects the diet of *Tapirus terrestris* throughout the year. During the rainy season, more plant species bear fruit (Targheta et al., 2015), whereas during the dry season fruit supply and species diversity are reduced. This pattern corroborates previous studies indicating that *T. terrestris* forages according to seasonal variation in fruiting. Such seasonality may also influence habitat selectivity, as these opportunistic animals adjust their diet in response to resource availability (Bodmer, 1991).

Figure 8. Mass (g) of fecal samples collected in November 2016 and February 2017.



4 CONCLUSION

In this study, *Tapirus terrestris* fed predominantly on vegetative material rather than seeds. Among the seeds recovered, the masses of intact and predated seeds were similar, indicating that the tapir acts simultaneously as a seed disperser and a seed predator. A higher number of fecal samples and a greater quantity of seeds were recorded during the rainy season, reflecting increased

fruit availability during this period. *Sacoglottis guianensis* was the most frequently consumed species, accounting for approximately 80% of dispersed and predated seeds. The first record of *Endopleura uchi* in the diet of the species highlights the importance of further studies across different Amazonian phytophysionomies to better understand the seasonal feeding ecology of *T. terrestris*.

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