Assessment of native fauna in the expansion of the invasive species Hovenia dulcis Thunb. (Japanese grape), in an urban fragment of Atlantic Forest, Municipality of Santa Cruz do Sul, RS, Brazil

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Assessment of native fauna in the expansion of the invasive species *Hovenia dulcis* Thunb. (Japanese grape), in an urban fragment of Atlantic Forest, Municipality of Santa Cruz do Sul, RS, Brazil

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ABSTRACT

Invasive plants natural ecosystems, negatively impacting biodiversity through competition for resources such as light, water, and nutrients. Fauna plays a central role in the dispersion of native and invasive species, facilitating their expansion into new areas. When dispersed by fauna, invasive plants can rapidly colonize new habitats, competing with local flora and aggravating the problem of biological invasion, highlighting that understanding these interactions is essential to developing more effective management strategies. Thus, this research aimed to analyze the role of fauna in the dispersion of the invasive species *Hovenia dulcis* in an urban forest fragment of 465 hectares called Cinturão Verde, located in Santa Cruz do Sul, RS, Brazil. Five sampling points were established in the study area for 10 active sampling campaigns between March and November 2023. For passive sampling, 2,225 day^{-1} camera traps were used during the same period. The results indicated the occurrence of 15 mammal and 170 bird species in the Green Belt, with 40% of mammals and 8.8% of birds recorded consuming the pseudofruit of *H. dulcis*. These data demonstrate a significant interaction between native fauna and invasive species. Based on these results, a plan is suggested to gradually replace *H. dulcis* with native species that bear fruit in the same period, such as *Schinus terebinthifolius* (Brazilian pepper) and *Psidium cattleyanum* (strawberry guava), in order to meet the food needs of local fauna and protect biodiversity. Continuing research with these species is essential to preserve biodiversity and ecosystem services provided by the urban forest to the municipality's population.

Keywords: Atlantic Forest, Invasive Alien Species, Ecosystem Services, Seasonal Deciduous Forest.

1. INTRODUCTION

Brazil has the greatest plant diversity in the world, with special emphasis on the Cerrado and Atlantic Forest biomes, which are considered biodiversity hotspots. These ecosystems are recognized as priorities for conservation due to their rich flora and high levels of endemism, making them essential for the global preservation of biodiversity (Myers et al., 2000; Zagatto, 2023). Initially, more than half of Brazilian territory, approximately 8.5 million km², was covered by the Amazon Rainforest, the largest tropical forest in the world. The other half of the country encompassed diverse ecosystems, such as Atlantic forests, steppes, savannas, wetlands, and semi-arid regions (Veloso et al., 1992; Borghetti et al., 2023). Despite this environmental richness, there are still significant gaps in understanding the threats of invasive alien species to biodiversity and natural resources in these ecosystems (Zenni & Ziller, 2011).

Biological invasions have emerged as one of the main threats to global biodiversity, causing significant economic damage to society (Diagne et al., 2021). This phenomenon has grown substantially globally in recent decades, driven by globalization and climate change (Perrings et al., 2005; Hulme, 2017). Despite the alarming increase in biological invasions, much of the existing knowledge about invasive species focuses on aspects such as colonization, impacts on native biodiversity, and management strategies (Dáttilo et al., 2023). Invasion ecology plays a crucial role in exploring and understanding how invasive species are transported, establish, colonize, and spread across the landscape (Rai & Singh, 2020).

However, the biotic interactions carried out by these species in the environment are often neglected (Traveset & Richardson, 2014), emphasizing that all species are interconnected in the food web. Their interactions represent a crucial component of biodiversity, regulating functions ranging from populations to ecosystems (Tylianakis et al., 2017; Lua & Dáttilo, 2021). Therefore, an isolated approach in the study of invasive species, without considering their biotic interactions, may obscure essential information, making it inadequate to anticipate a comprehensive response to biological invasions (Dáttilo et al., 2023).

The municipality of Santa Cruz do Sul, RS, has a forest fragment of Atlantic Forest known as the Cinturão Verde – (CV), covering an area of 463 hectares, which provides numerous ecosystem services to the population, such as noise control, retention of particulate matter, reduction of average temperature, and erosion containment (Wenzel &

Quadros, 2012). The area is undergoing a process of biological invasion, with the main species involved being the Japanese raisin tree (*Hovenia dulcis*). According to Fetter et al. (2020), a study conducted in the CV in 2015 identified that the invasive species occupied 20.9% of the total area. In this context, this research aimed to investigate the interactions between the fauna and the pseudofruit of this invader, seeking to understand the role of fauna in the dispersion of this plant and propose mitigation measures for this ecosystem.

1. METHODOLOGY

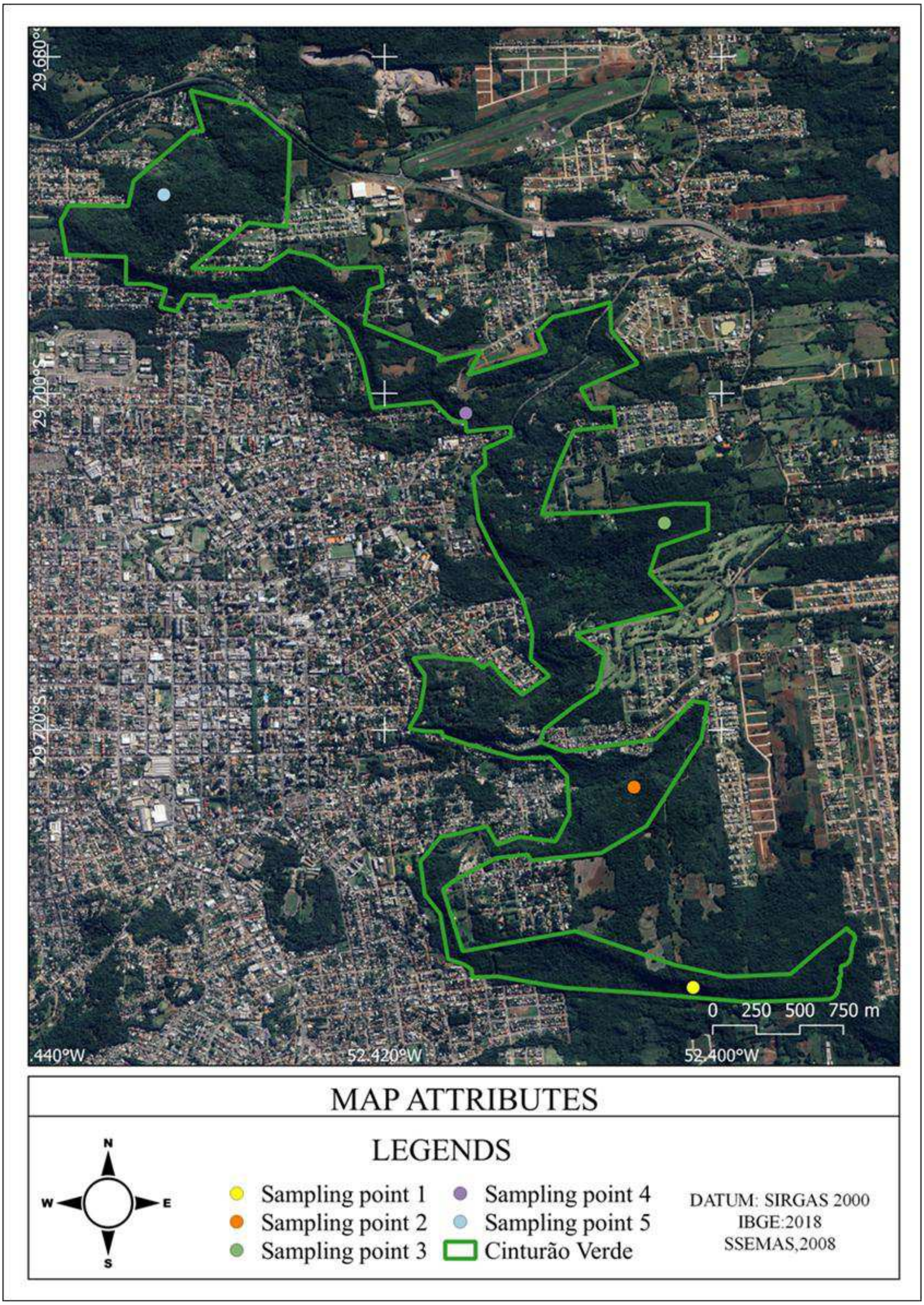
1.1 Study Area

The study was conducted in an urban forest remnant called Cinturão Verde (CV) in Santa Cruz do Sul, RS, Brazil. The CV is a fragment of the Atlantic Forest (AF) with 463 hectares that extends from north to east, cutting through the urban center (Wenzel & Quadros, 2012). The predominant vegetation in this area is classified as a Deciduous Seasonal Forest (DSF), an ecosystem commonly found in regions with seasonal climates, where trees lose their leaves in response to short-term drops in temperature. This forest type is present in several parts of the world, including South America, Africa, Asia, and North America. It is distinguished by its biodiversity, well adapted to seasonal variations (e.g., Longhi et al., 2000; Spathelf et al., 2001; Ruschel et al., 2009; Sccoti et al., 2011). Within the CV area, seven springs give rise to urban streams, important for regional groundwater recharge and other ecosystem services.

1.2 Sampling and Study of the Fauna

The survey was conducted at five sampling points distributed throughout the CV area, aiming to cover all subareas and their phytophysiognomies. The research took place from March 2022 to November 2023, using 2,225 day^{-1} camera traps (Fig. 1).

Figure 1. Sampling points distributed along the Cinturão Verde, Santa Cruz do Sul, RS.



Capture effort (CE) was determined using the following equation:

$$CE = n° \, AF \, . \, n° \, Da$$

$n° \, AF$ = number of camera traps;

$n° \, Da$ = number of sampling days.

Each sampling day corresponded to 24 hours, and sampling success was expressed in trap days, calculated as the ratio between the "number of records/capture effort," following the methodology proposed by Srbek-Araujo & Chiarello (2007) during the fruiting period of *H. dulcis*. Camera traps were strategically positioned, focusing on the base of the trees to document the consumption of pseudofruits fallen on the forest floor, according to the recommendations of De Lima et al. (2015) (Fig. 2).

Suntekcam model HC-802a trap cameras were used, equipped with 42 infrared LEDs for night images, a motion sensor set to medium sensitivity, and a recording interval of five seconds, with a recording duration of 15 seconds. Additionally, clusters of *H. dulcis* pseudofruits collected under the tree were placed before the traps to increase the probability of successful recordings.

Figure 2**.** Placement of camera traps in the Cinturão Verde area at the five sampling points.

Direct observations were also conducted, mainly for the bird group, focusing on the peak fruiting period from March to August 2023, following De Lima et al. (2015). The birds were recorded as consumers only when they held the pseudofruit and not when they used the trees for perching, according to the criteria established by Fadini (2005). The study selected five trees with ripe fruits and well-exposed canopies for observation, preferably close to trails. Using the focal tree method, as Galetti et al. (2003) described, observations were conducted at a distance of 10 meters from each tree. The observation period covered the morning (7:00 to 11:00) and the late afternoon (16:00 to 18:00), totaling 48 hours of observation. During this period, visiting bird species were recorded, and the destination of the fruits was categorized as discarded, consumed, or transported.

1.3 Data Analysis

Records of the same species at the same sampling point, obtained on the same day with intervals of less than one hour, were considered a single record to avoid duplication. Cluster analysis was applied using the Jaccard distance measure with the PAST software to compare similarities between different sampling points and correlate them with fauna (Hammer et al., 2001).

2. RESULTS AND DISCUSSION

During monitoring from March 2022 to August 2023 in the CV area, 15 mammal species from 12 families were identified (Table 1), some illustrated in Figure 3. Among these species, six (40%) were recorded feeding on the *H. dulcis* pseudofruit, indicating an interaction between the native and invasive species. These results are similar to those obtained by De Lima et al. (2015) in Quarta Colônia State Park, located in the central region of Rio Grande do Sul, where species such as *Cerdocyon thous*, *Guerlinguetus ingrami*, and *Nasua nasua* were observed feeding on the pseudofruit. However, discrepancies were observed since *Cuniculus paca* did not feed on the pseudofruit in the aforementioned study but was recorded feeding on it in the Green Belt area. Additionally, the species *Dasypus novemcinctus*, although it feed on the pseudofruit in the previous study, was recorded in the CV area without feeding on it. These observations highlight the nuances of interactions between species and the importance of considering the specificities of each ecosystem.

At sampling points where there was a greater number of interactions with exotic species, such as *Canis lupus familiaris* and *Felis catus* (Fig. 4), a decrease in the diversity of native species was observed. In fact, at sampling point 4, where these exotic species were recorded, the lowest diversity was observed (Table 2). A study by Ramos (2022) emphasized the negative impact of interactions between domestic animals and wildlife through predation and disease transmission. Predation by dogs and cats, competition for resources, and the potential for disease transmission are significant factors contributing to changes in animal communities in urban environments.

Table 1. Mammal records and their interaction with the pseudofruit of *H. dulcis* in the Cinturão Verde, Santa Cruz do Sul, RS.

Species	Family	Brazilian popular name	Consumed *H. dulcis*
Alouatta guariba clamitans	Atelidae	Bugio-ruivo	No
Canis lupus familiaris	Canidae	Cachorro-doméstico	No
Cerdocyon thous	Canidae	Graxaim-do-mato	Yes
Cuniculus paca	Cuniculidae	Paca	Yes
Dasypus novemcinctus	Dasypodidae	Tatu-galinha	No
Didelphis albiventris	Didelphidae	Gambá-de-orelha-branca	No
Felis catus	Felidae	Gato-doméstico	No
Galictis cuja	Mustelidae	Furão	No
Guerlinguetus ingrami	Sciuridae	Serelepe	Yes
Leopardus wiedii	Felidae	Gato-maracajá	No
Nasua nasua	Procyonidae	Quati	Yes
Procyon cancrivorus	Procyonidae	Mão-pelada	No
Rattus norvegicus	Muridae	Ratazana	Yes
Sapajus nigritus	Cebidae	Macaco-prego	Yes
Tamandua tetradactyla	Myrmecophagidae	Tamanduá-mirim	No

Figure 3. Mammal records from the Cinturão Verde, Santa Cruz do Sul: [A] *Leopardus wiedii*, [B] *Cerdocyon thous*, [C] *Sapajus nigritus*, [D] *Didelphis albiventris*, [E] *Nasua nasua*, [F] *Cuniculus paca*.

Figure 4. Trap records for *Felis catus*: [A] nocturnal activity, [B] diurnal activity, and [C] *Canis lupus familiaris*.

Table 2. Species records at the five sampling points along the Cinturão Verde.

Species	Family	Brazilian popular name	P1	P2	P3	P4	P5
Alouatta guariba clamitans	Atelidae	Bugio-ruivo		x	x	x	
Canis lupus familiaris	Canidae	Cachorro-doméstico	x	x		x	x
Cerdocyon thous	Canidae	Graxaim-do-mato	x	x	x	x	x
Cuniculus paca	Cuniculidae	Paca			x		
Dasypus novemcinctus	Dasypodidae	Tatu-galinha	x	x	x		x
Didelphis albiventris	Didelphidae	Gambá-de-orelha-branca	x	x	x	x	x
Felis catus	Felidae	Gato-doméstico				x	x
Galictis cuja	Mustelidae	Furão		x	x		
Guerlinguetus ingrami	Sciuridae	Serelepe			x		
Leopardus wiedii	Felidae	Gato-maracajá		x	x	x	
Nasua nasua	Procyonidae	Quati		x	x		
Procyon cancrivorus	Procyonidae	Mão-pelada			x		
Rattus norvegicus	Muridae	Ratasana				x	
Sapajus nigritus	Cebidae	Macaco-prego	x		x		
Tamandua tetradactyla	Myrmecophagidae	Tamanduá-mirim		x			

According to Lepczyk (2023), a global study of prey consumed by domestic cats revealed that these invasive carnivores significantly impact biodiversity. Of the 2,084 prey types identified, the vast majority, approximately 90%, included birds, reptiles, and mammals, while insects and amphibians were consumed less frequently. Remarkably, 9% of bird, 6% of mammal, and 4% of reptile species known worldwide have been found in the diet of domestic cats. Furthermore, the study highlighted that although 97% of the consumed species had an adult body mass of less than 5 kg, larger species were also affected. These findings emphasize the highly generalist nature of cats as predators, highlighting the importance of understanding and managing their ecological impact. Cat interference in ecological interactions disrupts natural food webs, reducing species diversity and negatively affecting the dispersal of native plants, thus facilitating biological invasions by species such as *H. dulcis*.

The similarity between sampling points 1, 4, and 5 revealed that these fragments contain the smallest areas of the remaining forest and are strongly influenced by anthropic activities. These conditions reduce biodiversity due to the greater difficulty of species migration, particularly among mammals, within ecological corridors restricted by forest mass fragmentation, caused mainly by buildings and road construction. In their study, Corlett (2016) discussed the concept of the Anthropocene and highlighted the implications of human activity on global ecology, including habitat fragmentation. Similarly, Fahrig (2003) provided a comprehensive analysis of the effects of habitat fragmentation on biodiversity, examining how this disturbance impacts populations and communities. These studies emphasize the need for comprehensive approaches to understand and mitigate the harmful effects of habitat fragmentation, which are essential for biodiversity conservation and ecosystem sustainability.

Sampling points 2 and 3 presented the highest species similarity in the Cluster analysis (Fig. 5), with species richness of nine and eleven taxa, respectively (Table 2). This result may be related to the characteristics of these fragments, as they are the best-preserved areas with the largest extension of native forest. Habitat degradation and fragmentation can directly lead to reduced food availability, particularly affecting frugivores that rely on large areas to find resources and do not move easily between fragmented habitats (Forman, 2014).

The results revealed 170 bird species identified in the CV area (Table 3), with some taxa illustrated in Figure 6. However, of the total identified, only 15 species consumed the *H. dulcis* pseudofruit, representing 8.8%. These results indicate a 500% increase in relation to the study conducted by De Lima et al. (2015) in the Quarta Colônia State Park, where only three species were recorded feeding on the invasive pseudofruit. The difference in the number of species that consumed the pseudofruit may be related to the characteristics of the forest fragment and the diversity and abundance of species in the forest remnants studied. Frugivorous birds tend to have greater species diversity in larger forest fragments than smaller ones (Table 4), suggesting that many species have limited ability to fly in open areas, such as grasslands and agricultural fields established between forest fragments.

Figure 5. Cluster similarity analysis of the five active sampling points in the Cinturão Verde, RS, based on the richness of mammal species (Cophenetic Correlation Coefficient = 0.9183).

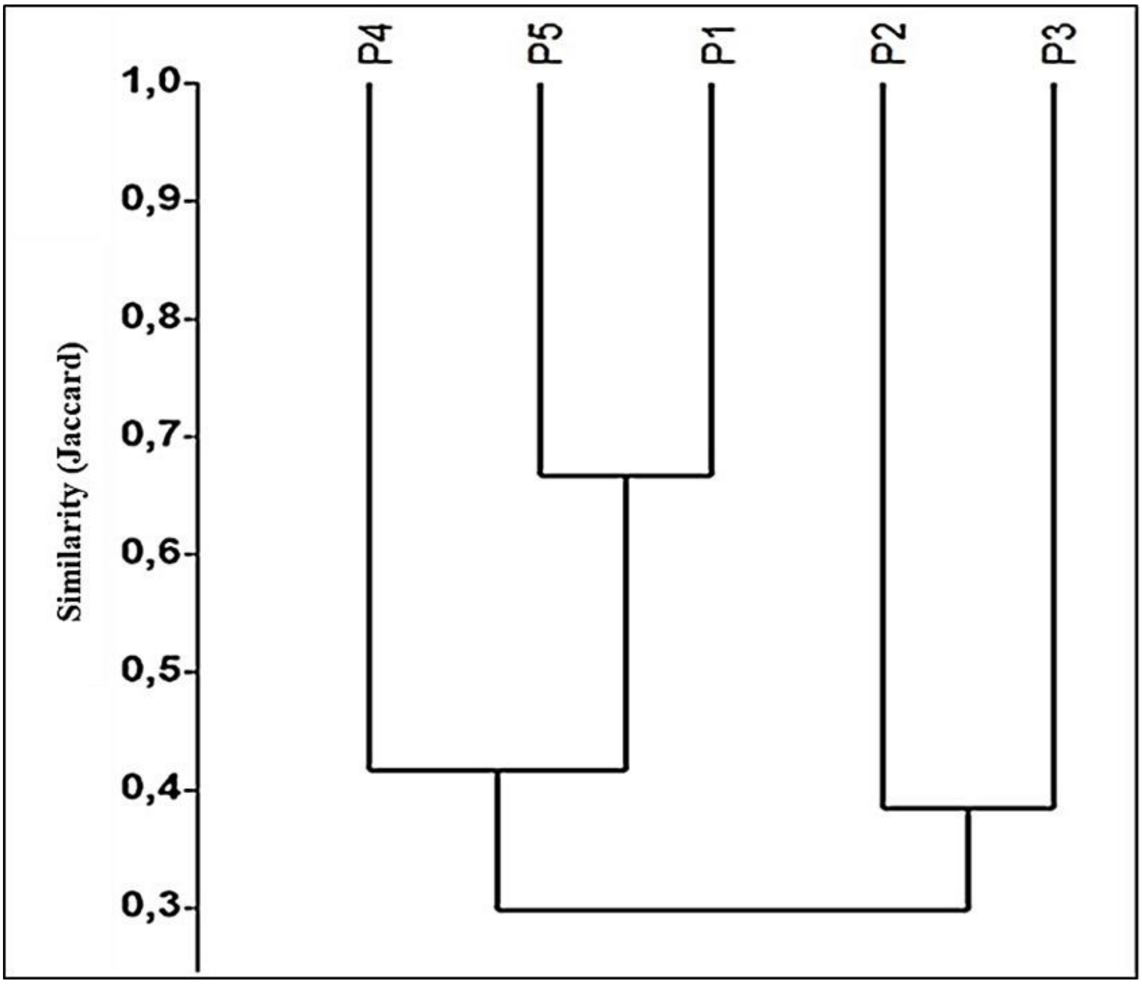


Tabela 3. Recorded birds and their interaction with the *H. dulcis* pseudofruit in the Cinturão Verde, Santa Cruz do Sul, RS. Note: (VO) vocalization; (VI) visualization; (RP) personal report; (BC) bibliography consulted; (AF) camera trap (**) no interaction recorded.

FAMILY GENUS/SPECIES	**Brazilian popular name**	**Consumed *H. dulcis***	**NOTE**
Accipitridae			
Circus buffoni (Gmelin, 1788)	Gavião-do-banhado	**	RP, BC
Elanoides forficatus (Linnaeus, 1758)	Gavião-tesoura	**	RP, BC
Heterospizias meridionalis (Latham, 1790)	Gavião-caboclo	**	RP, BC
Ictinia plúmbea (Gmelin, 1788)	Gavião-sovi	**	RP, BC
Rostrhamus sociabilis (Vieillot, 1817)	Gavião-caramujeiro	**	RP, BC
Rupornis magnirostris (Gmelin, 1788)	Gavião-carijó	No	VI, VO, BC
Alcedinidae			
Chloroceryle amazona (Latham, 1790)	Martim-pescador-verde	**	RP, BC
Chloroceryle americana (Gmelin, 1788)	Martim-pescador-pequeno	**	RP, BC
Megaceryle torquata (Linnaeus, 1766)	Martim-pescador-grande	**	RP, BC
Anatidae			
Amazonetta brasiliensis (Gmelin, 1789)	Marreca-ananaí	**	RP, BC
Anas georgica Gmelin, 1789	Mareca-parda	**	RP, BC
Cairina moschata (Linnaeus, 1758)	Pato-do-mato	**	RP, BC

Callonetta leucophrys (Vieillot, 1816)	Marreca-de-coleira	**	RP, BC
Dendrocygna viduata (Linnaeus, 1766)	Marreca-piadeira	**	RP, BC
Spatula versicolor (Vieillot, 1816)	Marreca-cricri	**	RP, BC
Anhingidae			
Anhinga anhinga (Linnaeus, 1766)	Biguatinga	**	RP, BC
Aramidae			
Aramus guarauna (Linnaeus, 1766)	Carão	**	RP, BC
Ardeidae			
Bubulcus ibis (Linnaeus, 1758)	Garça-vaqueira	No	VI, BC
Butorides striata (Linnaeus, 1758)	Socozinho	**	RP, BC
Egretta thula (Molina, 1782)	Garça-branca-pequena	**	RP. BC
Nycticorax nycticorax (Linnaeus, 1758)	Socó-dorminhoco	**	RP, BC
Syrigma sibilatrix (Temminck, 1824)	Maria-faceira	**	RP, BC
Tigrisoma lineatum (Boddaert, 1783)	Socó-boi	**	RP, BC
Caprimulgidae			
Nyctidromus albicollis (Gmelin, 1789)	Bacurau	No	VI, BC
*Podager nacun*da (Vieillot, 1817)	Corucão	No	VI, BC
Cardinalidae			
Cyanoloxia glaucocaerulea (d'Orbigny & Lafresnaye, 1837)	Azulinho	**	RP, BC
Habia rubica (Vieillot, 1817)	Tiê-de-bando	No	VI, VO, BC
Cathartidae			
Coragyps atratus (Bechstein, 1793)	Urubu-preto	No	VI, BC
Cathartes aura (Linnaeus, 1758)	Urubu-de-cabeça-vermelha	**	RP, BC
Cathartes burrovianus Cassin, 1845	Urubu-de-cabeça-amarela	**	RP, BC
Columbidae			
Columba livia Gmelin, 1789	Pombo-doméstico	No	VI, BC
Columbina picui (Temminck, 1813)	Rolinha-picuí	No	VI, BC
Columbina talpacoti (Temminck, 1811)	Rolinha-roxa	No	VI, BC
Geotrygon montana (Linnaeus, 1758)	Pariri	Yes	AF, BC
Leptotila rufaxilla (Richard & Bernard, 1792)	Juriti-de-testa-branca	No	VI, VO, BC
Leptotila verreauxi Bonaparte, 1855	Juriti-pupu	No	VI, VO, BC
Patagioenas cayennensis (Bonnaterre, 1792)	Pomba-galega	No	VI, BC
Patagioenas picazuro (Temminck, 1813)	Pomba-asa-branca	No	VI, BC
Zenaida auriculata (Des Murs, 1847)	Avoante	No	VI, BC
Conopophagidae			
Conopophaga lineata (Wied, 1831)	Chupa-dente	**	RP, BC
Corvidae			
Cyanocorax caeruleus (Vieillot, 1818)	Gralha-azul	**	RP, BC
Cyanocorax chrysops (Vieillot, 1818)	Gralha-picaça	**	RP, BC
Cotingidae			
*Carpornis cucullat*a (Swainson, 1821)	Corocoxó	**	VO, BC
Charadriidae			
Vanellus chilensis (Molina, 1782)	Quero-quero	No	VI, VO, BC
Ciconiidae			
Ciconia maguari (Gmelin, 1789)	Maguari	No	VI, BC
Mycteria americana Linnaeus, 1758	Cabeça-seca	**	RP, BC
Cracidae			
Ortalis squamata (Lesson, 1829)	Aracuã-escamoso	Yes	VI, BC
Cuculidae			
Crotophaga ani Linnaeus, 1758	Anu-preto	No	VI, RP, BC
Guira guira (Gmelin, 1788)	Anu-branco	No	VI, VO, BC
Piaya cayana (Linnaeus, 1766)	Alma-de-gato	No	VI, VO, BC

Dendrocolaptidae			
Lepidocolaptes falcinellus (Cabanis & Heine, 1859)	Arapaçu-escamoso-do-sul	No	VI, VO, BC
Xiphorhynchus fuscus (Vieillot, 1818)	Arapaçu-rajado	No	VI, BC
Falconidae			
Caracara plancus (Miller, 1777)	Carcará	**	RP, BC
Falco sparverius Linnaeus, 1758	Quiriquiri	No	VI, BC
Milvago chimachima (Vieillot, 1816)	Carrapateiro	No	VI, VO, BC
Milvago chimango (Vieillot, 1816)	Chimango	**	RP, BC
Fringillidae			
Euphonia chlorotica (Linnaeus, 1766)	Fim-fim	**	RP, BC
Euphonia pectoralis (Latham, 1801)	Ferro-velho	No	VI, VO, BC
Spinus magellanicus (Vieillot, 1805)	Pintassilgo	**	RP, BC
Furnariidae			
Anumbius annumbi (Vieillot, 1817)	Cochicho	**	RP, BC
Certhiaxis cinnamomeus (Gmelin, 1788)	Curutié	**	RP, BC
Furnarius rufus (Gmelin, 1788)	João-de-barro	No	VI, VO, BC
Schoeniophylax phryganophilus (Vieillot, 1817)	Bichoita	**	RP, BC
Hirundinidae			
Progne chalybea (Gmelin, 1789)	Andorinha-grande	**	RP, BC
Progne tapera (Linnaeus, 1766)	Andorinha-do-campo	**	RP, BC
Pygochelidon cyanoleuca (Vieillot, 1817)	Andorinha-pequena-de-casa	No	VI, VO, BC
Stelgidopteryx ruficollis (Vieillot, 1817)	Andorinha-serradora	**	RP, BC
Icteridae			
Agelaioides badius (Vieillot, 1819)	Asa-de-telha	No	VI, BC
Cacicus haemorrhous (Linnaeus, 1766)	Guaxe	**	RP, BC
Cacicus chrysopterus (Vigors, 1825)	Tecelão	**	VC, BC
Chrysomus ruficapillus (Vieillot, 1819)	Garibaldi	**	RP, BC
Icterus pyrrhopterus (Vieillot, 1819)	Encontro	No	VI, BC
Leistes superciliaris (Bonaparte, 1850)	Polícia-inglesa-do-sul	**	RP, BC
Molothrus bonariensis (Gmelin, 1789)	Chupim	No	VI, BC
Pseudoleistes guirahuro (Vieillot, 1819)	Chupim-do-brejo	**	RP, BC
Jacanidae			
Jacana jacana (Linnaeus, 1766)	Jaçanã	No	VI, BC
Mimidae			
Mimus saturninus (Lichtenstein, 1823)	Sabiá-do-campo	Yes	VI, BC
Nyctibiidae			
Nyctibius griseus (Gmelin, 1789)	Urutau	**	RP, BC
Parulidae			
Basileuterus culicivorus (Deppe, 1830)	Pula-pula	No	VI, VO, BC
Myiothlypis leucoblephara (Vieillot, 1817)	pula-pula-assobiador	No	VI, VO, BC
Setophaga pitiayumi (Vieillot, 1817)	Mariquita	No	VI, BC
Passeridae			
Passer domesticus (Linnaeus, 1758)*	Pardal	No	VI, BC
Passerellidae			
Zonotrichia capensis (Statius Muller, 1776)	Tico-tico	No	VI, VO, BC
Phalacrocoracidae			
Nannopterum brasilianum (Gmelin, 1789)	Biguá	**	RP, BC
Picidae			
Celeus flavescens (Gmelin, 1788)	Pica-pau-de-cabeça-amarela		RP, AF, BC
Colaptes campestris (Vieillot, 1818)	Pica-pau-do-campo	No	VI, VO, BC
Colaptes melanochloros (Gmelin, 1788)	Pica-pau-verde-barrado	**	RP, BC
Melanerpes candidus (Otto, 1796)	Pica-pau-branco	**	RP, BC

Melanerpes flavifrons (Vieillot, 1818)	Benedito-de-testa-amarela	**	RP, BC
Piculus aurulentus (Temminck, 1821)	Pica-pau-dourado	No	VI, VO, BC
Veniliornis spilogaster (Wagler, 1827)	Pica-pau-verde-carijó	No	VI, BC
Pipridae			
Chiroxiphia caudata (Shaw & Nodder, 1793)	Tangará	No	VI, VO, BC
Psittacidae			
Amazona aestiva (Linnaeus, 1758)	Papagaio-verdadeiro	Yes	VI, VO, BC
Myiopsitta monachus (Boddaert, 1783)	Caturrita	Yes	VI, VO, BC
Pionus maximiliani (Kuhl, 1820)	Maitaca-verde	Yes	VI, VO, BC
Pyrrhura frontalis (Vieillot, 1817)	Tiriba-de-testa-vermelha	Yes	VI, VO, BC
Triclaria malachitacea (Spix, 1824)	Sabiá-cica	**	VO, BC
Rallidae			
Aramides saracura (Spix, 1825)	Saracura-do-mato	No	VI, BC
Aramides ypecaha (Vieillot, 1819)	Saracuruçu	No	VI, VO, BC
Gallinula galeata (Lichtenstein, 1818)	Galinha-d'água	**	RP, BC
Pardirallus nigricans (Vieillot, 1819)	Saracura-sanã	**	RP, BC
Pardirallus maculatus (Boddaert, 1783)	Saracura-carijó	**	RP, BC
Pardirallus sanguinolentus (Swainson, 1838)	Saracura-do-banhado	**	RP, BC
Porphyriops melanops (Vieillot, 1819)	Galinha-d'água-carijó	**	RP, BC
Ramphastidae			
Ramphastos dicolorus Linnaeus, 1766	Tucano-de-bico-verde	Yes	VO, BC
Recurvirostridae			
Himantopus melanurus Vieillot, 1817	Pernilongo-de-costas-brancas	**	RP, BC
Rhynchocyclidae			
Phylloscartes ventralis (Temminck, 1824)	Borboletinha-do-mato	No	VI, VO, BC
Poecilotriccus plumbeiceps (Lafresnaye, 1846)	Tororó	No	VI, VO, BC
Strigidae			
Asio clamator (Vieillot, 1808)	Coruja-orelhuda	**	RP, BC
Athene cunicularia (Molina, 1782)	Coruja-buraqueira	**	RP, BC
Bubo virginianus (Gmelin, 1788)	Jacurutu	**	RP, BC
Glaucidium brasilianum (Gmelin, 1788)	Caburé	**	RP, BC
Megascops choliba (Vieillot, 1817)	Corujinha-do-mato	No	VI, VO, BC
Pulsatrix koeniswaldiana (Bertoni & Bertoni, 1901)	Murucutu-de-barriga-amarela	**	RP, BC
Strix virgata (Cassin, 1849)	Coruja-do-mato	**	RP, BC
Thamnophilidae			
Thamnophilus caerulescens Vieillot, 1816	Choca-da-mata		VO, BC
Thraupidae			
Coereba flaveola (Linnaeus, 1758)	Cambacica	No	VI, VO, BC
Coryphospingus cucullatus (Statius Muller, 1776)	Tico-tico-rei	No	VI, BC
Hemithraupis guira (Linnaeus, 1766)	Saíra-de-papo-preto	**	RP, BC
Microspingus cabanisi Bonaparte, 1850	Quete-do-sul	No	VI, BC
Paroaria capitata (d'Orbigny & Lafresnaye, 1837)	Cavalaria	**	RP, BC
Paroaria coronata (Miller, 1776)	Cardeal	**	VO, BC
Pipraeidea melanonota (Vieillot, 1819)	Saíra-viuva	**	RP, BC
Saltator similis d'Orbigny & Lafresnaye, 1837	Trinca-ferro	**	VO, BC
Sicalis flaveola (Linnaeus, 1766)	Canario-da-terra	No	VI, VO, BC
Sporophila caerulescens (Vieillot, 1823)	Coleirinho	**	RP, BC
Tachyphonus coronatus (Vieillot, 1822)	Tiê-preto	**	RP, BC
Tersina viridis (Illiger, 1811)	Saí-andorinha	**	RP, BC

Thlypopsis pyrrhocoma Burns, Unitt & Mason, 2016	Cabecinha-castanha	No	VI, BC
Thraupis sayaca (Linnaeus, 1766)	Sanhaço-cinzento	No	VI, VO, BC
Trichothraupis melanops (Vieillot, 1818)	Tié-de-topete	**	RP, BC
Rauenia bonariensis (Gmelin, 1789)	Sanhaço-papo-laranja	**	RP, BC
Stilpnia preciosa (Cabanis, 1850)	Saíra-preciosa	Yes	VI, BC
Volatinia jacarina (Linnaeus, 1766)	Tiziu	**	RP, BC
Threskiornithidae			
Phimosus infuscatus (Lichtenstein, 1823)	Tapicuru	No	VI, BC
Platalea ajaja Linnaeus, 1758	Colhereiro	**	RP, BC
Plegadis chihi (Vieillot, 1817)	Caraúna	No	VI, BC
Theristicus caudatus (Boddaert, 1783)	Curicaca	**	RP, BC
Tinamidae			
Crypturellus tataupa (Temminck, 1815)	Inhambu-chintã	Yes	AT, BC
Trochilidae			
Anthracothorax nigricollis (Vieillot, 1817)	Beija-flor-de-veste-preta	**	RP, BC
Chlorostilbon lucidus (Shaw, 1812)	Besourinho-de-bico-vermelho	**	RP, BC
Chrysuronia versicolor (Vieillot, 1818)	Beija-flor-de-banda-branca	**	RP, BC
Florisuga fusca (Vieillot, 1817)	Beija-flor-preto	**	RP, BC
Hylocharis chrysura (Shaw, 1812)	Beija-flor-dourado	No	VI, VO, BC
Stephanoxis loddigesii (Gould, 1831)	Beija-flor-de-topete-azul	**	RP, BC
Thalurania glaucopis (Gmelin, 1788)	Beija-flor-de-fronte-violeta	No	VI, BC
Troglodytidae			
Troglodytes musculus Naumann, 1823	Corruíra	No	VI, VO, BC
Trogonidae			
Trogon surrucura Vieillot, 1817	Surucuá-variado	Yes	VI, VO, BC
Turdidae			
Turdus albicollis Vieillot, 1818	Sabiá-coleira	Yes	VI, VO BC
Turdus amaurochalinus Cabanis, 1850	Sabiá-poca	Yes	VI, BC
Turdus leucomelas Vieillot, 1818	Sabiá-barranco	Yes	VI, BC
Turdus rufiventris Vieillot, 1818	Sabiá-laranjeira	Yes	VI, VO, BC, AF
Turdus subalaris (Seebohm, 1887)	Sabiá-ferreiro	**	RP, BC
Tyrannidae			
Elaenia flavogaster (Thunberg, 1822)	Guaracava-de-barriga-amarela	**	RP, BC
Elaenia mesoleuca (Deppe, 1830)	Tuque	**	RP, BC
Elaenia parvirostris Pelzeln, 1868	Tuque-pium	**	RP, BC
Empidonomus varius (Vieillot, 1818)	Peitica	**	RP, BC
Machetornis rixosa (Vieillot, 1819)	Suiriri-cavaleiro	**	RP, BC
Megarynchus pitangua (Linnaeus, 1766)	Neinei	**	RP, BC
Myiarchus swainsoni Cabanis & Heine, 1859	Irré	**	RP, BC
Myiopagis viridicata (Vieillot, 1817)	Guaracava-de-crista-alaranjada	**	RP, BC
Pitangus sulphuratus (Linnaeus, 1766)	Bem-te-vi	No	VI, VO, BC
Satrapa icterophrys (Vieillot, 1818)	Suiriri-pequeno	**	RP, BC
Serpophaga subcristata (Vieillot, 1817)	Alegrinho	**	RP, BC
Tyrannus melancholicus Vieillot, 1819	Suiriri	**	RP, BC
Tyrannus savana Daudin, 1802	Tesourinha	**	RP, BC
Xolmis irupero (Vieillot, 1823)	Noivinha	**	RP, BC
Tytonidae			
Tyto furcata (Temminck, 1827)	Suindara	**	RP, BC
Vireonidae			
Cyclarhis gujanensis (Gmelin, 1789)	Pitiguari	**	VO, VI, BC
Xenopidae			

Xenops rutilans Temminck, 1821	Bico-virado-carijó	No	VI, BC

Figure 6. Bird recorded from active surveys. [A] *Turdus rufiventris*, [B] *Ictinia plumbea*, [C] *Amazona aestiva*, [D] *Thraupis sayaca*, [E] *Cyanocorax caeruleus*, [F] *Thalurania glaucopis*.

Several studies have addressed the relationship between forest fragments and bird diversity, providing valuable insights into the impacts of habitat fragmentation. For example, Stouffer et al. (2006) investigated the structure and dynamics of bird communities in tropical forest fragments, while Robinson & Holmes (1984) explored foraging behavior, emphasizing the relationships between search tactics, diet, and habitat structure. Barlow et al. (2010) contributed to understanding biodiversity conservation in primary forests, including considerations on the importance of forest fragments. Furthermore, Harrison & Bruna (1999) provided a comprehensive analysis of the impacts of habitat fragmentation at larger scales, highlighting its effects on fauna. These studies underscore the complexity and challenges of bird conservation, demonstrating that bird diversity is closely associated with environmental characteristics and their ecological niches. Changes in these conditions often lead to the migration of species to other areas of ecological interest.

Table 4. Bird recorded in active surveys at five sampling points along the Cinturão Verde, Santa Cruz do Sul, RS.

Species	Brazilian popular name	P1	P2	P3	P4	P5
Amazona aestiva (Linnaeus, 1758)	Papagaio-verdadeiro			x		

Mimus saturninus (Lichtenstein, 1823)	Sabiá-do-campo	x				
Myiopsitta monachus (Boddaert, 1783)	Caturrita		x	x		
Ortalis squamata (Lesson, 1829)	Aracuã-escamoso			x		x
Pionus maximiliani (Kuhl, 1820)	Maitaca-verde		x	x		
Pyrrhura frontalis (Vieillot, 1817)	Tiriba-de-testa-vermelha				x	
Ramphastos dicolorus (Linnaeus, 1766)	Tucano-de-bico-verde		x	x		
Stilpnia preciosa (Cabanis, 1850)	Saíra-preciosa				x	x
Turdus albicollis (Vieillot, 1818)	Sabiá-coleira		x		x	
Turdus amaurochalinus (Cabanis, 1850)	Sabiá-poca	x		x		
Turdus leucomelas (Vieillot, 1818)	Sabiá-barranco		x	x		
Turdus rufiventris (Vieillot, 1818)	Sabiá-laranjeira	x	x			x
Trogon surrucura (Vieillot, 1817)	Surucuá-variado	x		x		

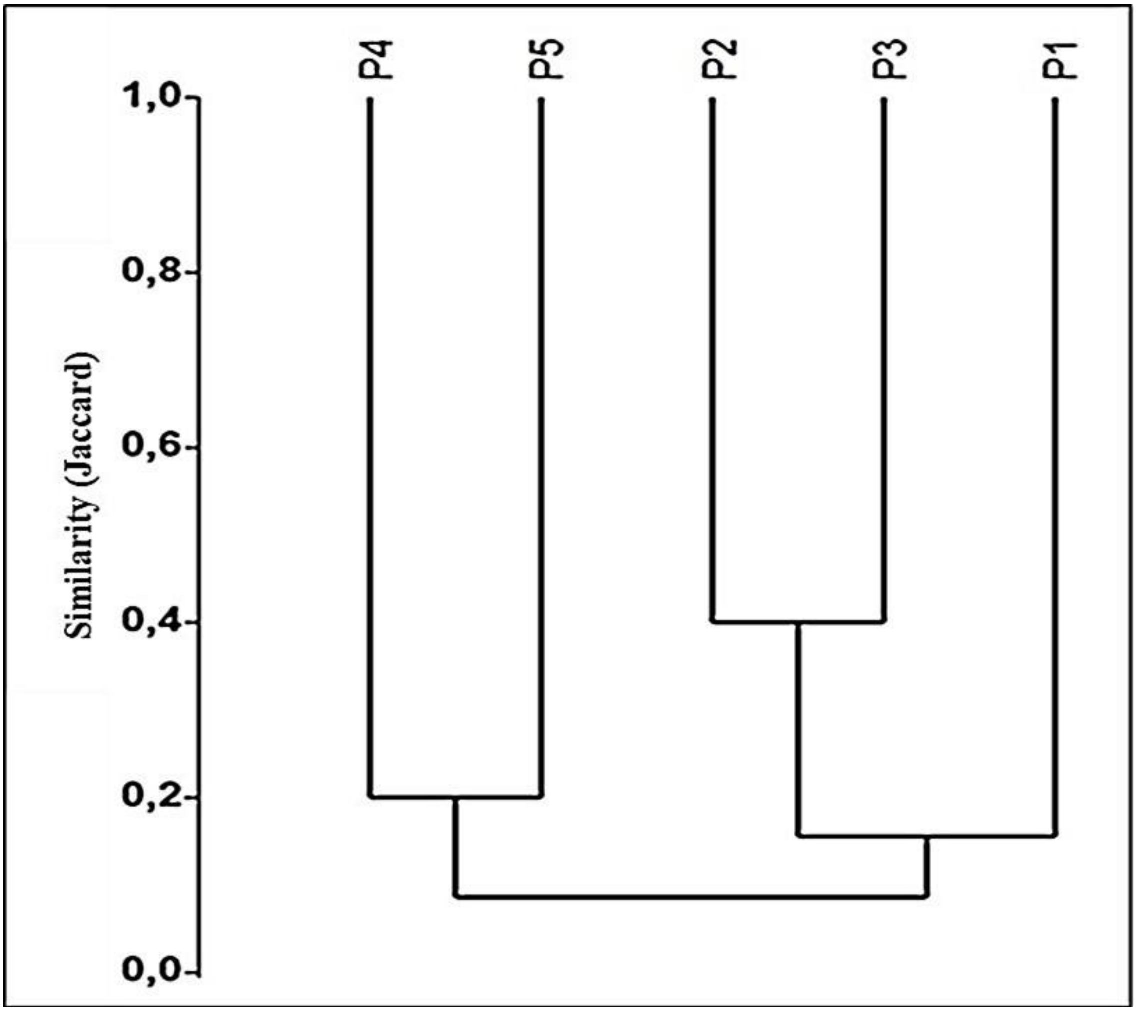
Birds represent the group with the greatest potential for seed dispersal due to their ability to fly, which allows them to transport seeds over long distances and, consequently, enhance the expansion of invasive species. Donatti et al. (2011) analyzed a highly diverse seed dispersal network. They identified modularity as a prominent feature of these networks, suggesting that some bird species may specialize in dispersing specific plants. This specialization can significantly influence the dynamics and stability of plant communities, favoring or limiting the spread of certain species.

In the context of biological invasions, birds play a fundamental role in the dispersion of exotic plants producing fruit or pseudofruit, facilitating their dissemination and establishment in new environments. Many species of frugivorous birds consume these fruits and disperse their seeds through regurgitation or excretion, promoting germination and recruitment in distant areas (Gosper, Stansbury & Vivian-Smith, 2005). This process favors invading species such as *Ligustrum lucidum* and *H. dulcis*, which compete with native flora and alter ecosystem structures (Silva et al., 2018). Thus, the risk of biological invasion is even greater in areas with a greater diversity of bird species consuming the pseudofruit, such as sampling points 2 and 3. Furthermore, the high attractiveness of invasive plant fruits to generalist birds can strengthen interactions between dispersers and exotic species, increasing recruitment rates and complicating control strategies (Buckley, Anderson & Catterall, 2006).

Cluster similarity analysis of active sampling points for *H. dulcis* consumption (Fig. 7) demonstrates a strong similarity between points 2 and 3. As highlighted previously, these areas are the most preserved, hosting a greater number of species and, consequently, increasing the probability of mutualism with the invasive species.

Sampling points 4 and 5 are characterized by greater anthropic impact and strong interaction with exotic fauna (dogs and cats). Sampling point 1 represents the smallest forest fragment in the study, a bottleneck in the eastern part of the CV, where the reduction of forest area directly affects the bird community. The interaction between mammals and birds with the invasive *H. dulcis* highlights the need for a species control and replacement plan to avoid negative impacts on biodiversity, bird abundance, and the ecosystem services provided to the local population.

Figura 7. Cluster similarity analysis of the five active sampling points in the Cinturão Verde, RS, based on bird species richness (Cophenetic Correlation Coefficient - CCC = 0.8704).



These interactions highlight that *H. dulcis* is being dispersed by birds and mammals. Studies indicate that their presence can lead to competition for resources with native plant species, resulting in biodiversity loss and a decline in native plant populations (Smith et al., 2020). Furthermore, according to the same authors, the dense formation of

H. dulcis can modify the structure of the forest habitat, affecting the composition and distribution of species.

A recent study by Wiesel et al. (2025), conducted in the same area using remote sensing techniques combined with RGB images to map the distribution of *H. dulcis*, demonstrated that the species is present in all forest fragments and occupies 86.4 hectares of the total CV area, corresponding to 18.7% of the invaded area. Furthermore, the study identified that CV has 28.89 hectares of exposed soil, a condition that favors the proliferation of the invasive plant. This phenomenon can compromise the natural regeneration of native species, interfere with ecological succession processes, and hinder the restoration of degraded areas (Guzmán et al., 2020).

In addition to the impact on vegetation, the changes induced by *H. dulcis* can directly affect local fauna, altering the availability of food and shelter for native species. Furthermore, the accumulation of dry biomass of this species can increase the risk of forest fires, intensifying ecological disturbances (Araldi et al., 2011). Kuester et al. (2022) carried out a study in the Serra do Sudeste region, RS, analyzing the diet of *Cerdocyon thous* and *Lycalopex gymnocercus* by identifying plant remains in their feces. Among the plant species consumed by both canids, *H. dulcis* was recorded, evidencing its inclusion in their diet. This finding corroborates the data obtained in the present study, reinforcing that these species contribute to their dispersion by using it as a food resource. Given these impacts, the studies emphasize the need for continuous monitoring and effective control strategies to contain the spread of *H. dulcis*, minimizing its adverse effects on biodiversity and the integrity of natural habitats.

Therefore, based on our results, implementing a plan for gradually replacing invasive species in CV would be highly relevant, starting with the ecologically most important areas, sampling points 2 and 3. In the course of the monitoring campaigns conducted during the fruiting period of *H. dulcis*, seven native tree species were identified that also bear fruit during this period (Tab. 5), with particular emphasis on *Schinus terebinthifolius* (Brazilian pepper tree) and *Psidium cattleyanum* (strawberry guava), as they produce fruit quickly. In this way, these species could be used to gradually replace invasive species, aiming to meet the food needs of local fauna and, at the same time, protect biodiversity.

Table 5: Species that bear fruit in the same period as *H. dulcis*.

Species	Brazilian popular name
Ficus adhatodifolia Schott	Figueira-de-purga
Ficus cestrifolia Schott	Figueira-de-folha-miúda
Luehea divaricata Mart. & Zucc.	Açoita-cavalo
Schinus terebinthifolius Raddi	Aroeira-vermelha
Syagrus romanzoffiana (Cham.) Glassman	Jerivá
Prunus myrtifolia (L.) Urb.	Pessegueiro-do-mato
Psidium cattleyanum Sabine	Araçá-vermelho
Annona sylvatica A. St.-Hil.	Araticum

3. CONCLUSION

This research highlights the significant influence of native fauna on the dispersal of *H. dulcis*, reinforcing the role of mammals and birds in expanding the area occupied by this invasive species. The presence of this species in the forest fragments of the Green Belt demonstrates its capacity for colonization and competition with native species, threatening local biodiversity and altering the ecological dynamics of the ecosystem.

Given this scenario, management strategies involving the control and gradual replacement of *H. dulcis* by native species that bear fruit in the same period, such as *Schinus terebinthifolius* and *Psidium cattleyanum*, are essential to mitigate the impacts of this invasion. Additionally, maintaining ecological corridors and reducing areas of exposed soil can contribute to the natural regeneration of native vegetation, promoting ecosystem restoration.

Continuous studies on the dispersal and impact of *H. dulcis* are crucial to improving biodiversity control and conservation strategies in the Atlantic Forest. Integrated management measures and permanent monitoring of local fauna and flora can contribute significantly to preserving the ecological integrity of the Green Belt and other urban forest fragments.

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