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"JÚLIO DE MESQUITA FILHO"
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Câmpus do Litoral Paulista

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CONSERVAÇÃO DO FORMIGUEIRO-DE-CABEÇA-NEGRA *FORMICIVORA ERYTHRONOTOS* (AVES: THAMNOPHILIDAE): ESTIMATIVA POPULACIONAL, ANÁLISE DE VIABILIDADE, STATUS VERDE E PROPOSTA DE UM CAMINHO CONTRA A SUA EXTINÇÃO

SÃO VICENTE - SP

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Conservação do formigueiro-de-cabeça-negra *Formicivora erythronotos* (Aves: Thamnophilidae): estimativa populacional, análise de viabilidade, Status Verde e proposta de um caminho contra a sua extinção

Dissertação apresentada à Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP), Instituto de Biociências, Campus do Litoral Paulista, como requisito para obtenção do título de Mestre em Ciências.
Orientador: Prof. Dr. Marcos R. Bornschein.

São Vicente – SP
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ATA DA DEFESA PÚBLICA DA DISSERTAÇÃO DE MESTRADO DE SABRYNA GROGIA MUHRINGER, DISCENTE DO PROGRAMA DE PÓS-GRADUAÇÃO EM BIODIVERSIDADE DE AMBIENTES COSTEIROS, DO INSTITUTO DE BIOCIÊNCIAS - CÂMPUS DO LITORAL PAULISTA.

Aos 26 dias do mês de agosto do ano de 2025, às 14h, no(a) Salão Nobre do IB/CLP, realizou-se a defesa de DISSERTAÇÃO DE MESTRADO de SABRYNA GROGIA MUHRINGER, intitulada **Busca por populações remanescentes, distribuição geográfica, estimativa populacional e conservação de *Formicivora erythronotos***. A Comissão Examinadora foi constituída pelos seguintes membros: Prof. Dr. MARCOS RICARDO BORNSCHEIN (Orientador(a) - Participação Presencial) do(a) Departamento de Ciências Biológicas e Ambientais / IB/CLP - UNESP, Pesquisador Dr. FABIO SCHUNCK PIRES GOMES (Participação Virtual) do(a) Instituto de Biociências / Universidade de São Paulo, Dr. SERGIO AUGUSTO ABRAHAO MORATO (Participação Virtual) do(a) Logos Pesquisa e Desenvolvimento em Ecologia e Meio Ambiente Ltda. Após a exposição pela mestranda e arguição pelos membros da Comissão Examinadora que participaram do ato, de forma presencial e/ou virtual, a discente recebeu o conceito final: APROVADO. Nada mais havendo, foi lavrada a presente ata, que após lida e aprovada, foi assinada pelo(a) Presidente(a) da Comissão Examinadora.

Prof. Dr. MARCOS RICARDO BORNSCHEIN

Conservação do formigueiro-de-cabeça-negra *Formicivora erythronotos* (aves: thamnophilidae): estimativa populacional, análise de viabilidade, status verde e proposta de um caminho contra a sua extinção.

Dissertação apresentada no formato da revista *Bird Conservation International*.

Conservation urgency for the Black-hooded Antwren *Formicivora erythronotos*: Population reassessment and viabilviability analysis, conservation statuses, and a path against extinction.

Running title: Conservation of the Black-hooded Antwren.

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Resumo

Formicivora erythronotos é uma ave ameaçada de extinção, endêmica das terras baixas do Rio de Janeiro, Brasil, ameaçada pela expansão urbana. Este estudo teve como objetivo atualizar sua distribuição geográfica e tamanho populacional, conduzir uma análise de viabilidade populacional (AVP), reavaliar seu status de conservação, avaliar seu Status Verde e propor estratégias de conservação. Entre 2021 e 2022, os indivíduos foram anilhados para estimar a densidade populacional. Entre 2023 e 2025, levantamentos de reprodução foram realizados em sítios históricos. A AVP foi modelada em três cenários usando VORTEX. A espécie foi registrada em apenas três localidades previamente conhecidas: Ariró, Vale do Rio Mambucaba e Rio Taquari. Estimamos sua extensão de ocorrência em 241.26 km², o limite inferior da área de ocupação (AOO) em 32.00 km², o limite superior da AOO em 76.00 km² e o habitat ocupado em 9,263 km². O tamanho populacional foi estimado em 13 adultos em Ariró e 14 no Rio Taquari. No Vale do Rio Mambucaba, a densidade foi de um indivíduo maduro por 0,056 km² e uma população de 154 adultos, totalizando uma população global de 181 indivíduos maduros. A taxa de perda de habitat em todas as localidades indica potencial erradicação do habitat em menos de 35 anos ou em mais de 100 anos, dependendo do método. No cenário pessimista, a extinção foi projetada em 37 anos. Esses resultados apoiam a classificação da espécie como Ameaçada de Extinção (EN). Todo o habitat ocupado está em áreas planejadas para expansão urbana, impedindo a criação de unidades de conservação. Propomos um programa de conservação incluindo colonização assistida em uma área protegida, onde PVA indica potencial de crescimento, e estabelecimento de uma população ex-situ. A espécie está atualmente Criticamente Ameaçada e tem alta dependência de conservação. O tempo necessário para garantir licenças ambientais para a implementação do programa pode ser decisivo para seu futuro. Reconhecemos *F. erythronotos* como uma espécie não florestal associada a habitats de sucessão inicial moldados por sistemas fluviais dinâmicos de terras baixas.

Palavras-chave: área de habitat ocupado, tamanho populacional, Análise de Viabilidade Populacional, manejo, colonização assistida.

Abstract

Formicivora erythronotos is an endangered bird endemic to lowlands of Rio de Janeiro, Brazil, threatened by urban expansion. This study aimed to update its geographic distribution and population size, conduct a population viability analysis (PVA), reassess its conservation status, evaluate its Green Status, and propose conservation strategies. Between 2021–2022, individuals were banded to estimate population density. Between 2023–2025, playback surveys were conducted in historical sites. The PVA was modeled under three scenarios using VORTEX. The species was recorded at only three previously known localities: Ariró, Mambucaba River Valley, and Taquari River. We estimated its extent of occurrence at 241.26 km^2, the lower bound area of occupancy (AOO) at 32.00 km^2, the upper bound AOO at 76.00 km^2, and occupied habitat at 9.263 km^2. Population size was estimated at 13 adults in Ariró and 14 in Taquari River. In Mambucaba River Valley, density was one mature individual per 0.056 km^2 and a population of 154 adults, totaling a global population of 181 mature individuals. The rate of habitat loss across all localities indicates potential habitat eradication in less than 35 years or in more than 100 years, depending on method. Under the pessimistic scenario, extinction was projected within 37 years. These results support classifying the species as Endangered (EN). All occupied habitat lies in areas planned for urban expansion, preventing the creation of conservation units. We propose a conservation program including assisted colonization in a protected area, where PVA indicates potential growth, and establishment of an *ex-situ* population. The species is currently Critically Depleted and has high conservation dependence. The time required to secure environmental permits for program implementation may be decisive for its future. We recognize *F. erythronotos* as a non-forest species associated with early-successional habitats shaped by dynamic lowland river systems.

Keywords: area of occupied habitat, population size, Population Viability Analysis, management, assisted colonization.

Sumário

1. Introduction

The Black-hooded Antwren *Formicivora erythronotos* (Thamnophilidae) is a small insectivorous bird (9 g, 11 cm) endemic to the state of Rio de Janeiro, in southeastern Brazil. The species lives in pairs and inhabits early successional habitats (Mendonça 2001) that have not yet regenerated into mature forest. Due to its inconspicuous behaviour, small population size, and uncertainty regarding exact type locality, *F. erythronotos* went unrecorded for over 130 years and was presumed extinct (King 1981; Scott and Brooke 1985) until its rediscover in 1987 (Pacheco 1988). Historical records of the species include Serra do Piloto, Baía da Ribeira, Ariró, Bracuí, Frade, Mambucaba River Valley, Taquari River, Barra Grande, and São Gonçalo (Collar et. al. 1992; Buzzetti 1998; Mendonça 2001; Gonzaga 2008; Zimmer et al. 2016; BirdLife International 2020), sites located in the municipalities of Rio Claro, Mangaratiba, Angra dos Reis, and Paraty. However, based on photographs available on the Wiki Aves platform the current population appears to be restricted to lowland areas in Ariró, in the Mambucaba River Valley, and in the Taquari River, sites located in the municipalities of Angra dos Reis and Paraty.

There is also a record from the municipality of Rio Claro, specifically in Serra do Piloto, where an individual was observed at about 500 m above sea level (a.s.l.; Mendonça [2001]). More recently, the species was once again recorded in this municipality through three photographs taken in August 2023 and shared on WikiAves. We propose that the records from Rio Claro should be considered as a case of vagrancy, pending new evidence that confirms the existence of a resident population in the area.

The lowlands of Rio de Janeiro are among Brazil’s main tourist destinations. Therefore, the habitat of *F. erythronotos* is under increasing pressure from real estate speculation, expansion of tourism infrastructure, and conversion of natural habitats into pastures and monocultures (Tobias and Williams 1996; Gonzaga 2008). Due to continued loss of habitat and the species’ limited distribution, *F. erythronotos* is classified as Endangered (EN) at the global level (BirdLife International 2020). In Brazil, it was assessed as Critically Endangered (CR) (Ordinance MMA No. 148, June 7, 2022). Two distinct proposals regarding the species’ threat category are concerning, especially given that both assessments applied the same IUCN methodology (IUCN 2012) for an endemic species. Three significant issues related to the species’ biology may have contributed to the IUCN’s interpretation of a lower risk level (BirdLife International 2020), compared to the classification proposed by Brazilian researches: 1) the assumption of a broader geographic distribution due to the species’ occurrence in arboreal vegetation; 2) an underestimation of the impact of habitat loss, based on the relatively good forest cover in mountainous areas near the species’ known range; and 3) the extrapolation of population density estimates from the 1990s to current conditions, without accounting for environmental changes, resulting in an overestimation of the current population size.

Formicivora erythronotos does not occur within protected areas and ongoing conservation measures include the assessment of its conservation status and its inclusion in Brazil's conservation efforts through the *Plano de Ação Nacional para a Conservação das Aves da Mata Atlântica* (National Action Plan [PAN] for Birds of the Atlantic Forest; BirdLife International [2020]). Proposed conservation actions for the species include estimating its population size and mapping its area of occupancy (BirdLife International 2020). The objectives of the present study encompass these actions, along with a reassessment of its conservation status and the proposition of urgent conservation measures.

2. Methods

Target species

Formicivora erythronotos inhabits the understory (50 to 200 cm above ground) of secondary and regenerating forests, with abundant herbaceous and shrubby vegetation. This habitat is typically found near mangroves, in abandoned meanders, pastures or disused plantations (Tobias and Williams 1996; Mendonça 2001). The species is socially monogamous, forming long-term pairs that share territory defense and reproductive duties, except for nocturnal incubation, which is performed exclusively by females (Mendonça 2001). Nests are cup shaped, built using plant fibers, and attached to herbaceous stems close to the ground, where one to two eggs are laid (Mendonça 2001). Estimated densities were 156 pairs per km² on the right bank of the Mambucaba River, in the municipality of Paraty, and 89 pairs per km² in Ariró, in the municipality of Angra dos Reis (Mendonça 2001). Based on those data, the population size was estimated at 317 to 8,453 mature individuals (BirdLife International 2020).

Study region and habitats

The study region includes all municipalities where the species has been recorded, within the altitudinal range of its known occurrence (from sea level up to approximately 500 m a.s.l.): Rio Claro, Mangaratiba, Angra dos Reis, and Paraty (Collar et al. 1992; Buzzetti 1998; Mendonça 2001; BirdLife International 2020). We mainly searched for the species in non-forest habitats (*sensu* Veloso et al. 1991; see also Bornschein 2015), such as (1) primary and secondary marshes, (2) mangroves, (3) pastures, (4) disused pastures and plantations, now regenerating, with early successional herbaceous and shrubby vegetation, (5) short regenerating arboreal formations, and (6) taller regenerating arboreal formations. We also included (7) forest areas in our sampling, but only when located within or adjacent to the target non-forest habitats. According to the criteria for classifying Brazilian vegetation established by the RADAMBRASIL Project (*sensu* Veloso et al. 1991; see Bornschein 2015), these vegetations are classified as: (a) "Pioneer Formations of Lacustrine Influence" at the herbaceous stage (primary marshes developing in abandoned meanders); (b) "Pioneer Formations of Lacustrine Influence" at the shrubby stage (primary marshes developing in abandoned meanders); (c) "Pioneer Formations of Fluvial Influence" at the herbaceous stage (secondary marshes); (d) "Pioneer Formations of Fluvial Influence" at the shrubby-arboreal stage (naturally developing in river margins and secondary marshes); (e) "Pioneer Formations of Fluvio-Marine Influence" (primary marshes and mangroves); (f) "Pioneer Formations of Marine Influence" (*restinga*); (g) "First stage of natural succession" (grassland-like habitats); (h) "Second stage of natural succession" (*capoeirinha*); (i) "Third stage of natural succession" (*capoeira-rala*); (j) "Fourth stage of natural succession" (*capoeira*); (k) "Fifth stage of natural succession" (*capoeirão*); (l) "Lowland Dense Ombrophilous Forest"; and (m) "Submontane Dense Ombrophilous Forest".

The climate of the study region ranges from a humid subtropical zone (C), with an oceanic climate without a dry season but with hot summers (Cfa) in the lowlands, to a climate characterized by temperate summer (Cfb) in higher altitudes (Alvares et al. 2013). The annual average temperature ranges from 20–22 °C (Alvares et al. 2013), while mean annual rainfall in lowland areas was 2,384.7 mm between 1931–1960 and 1,976.7 mm between 1961–1990 (Salgado et al. 2007).

Density estimation

We surveyed the Mambucaba River Valley, in the municipalities of Angra dos Reis and Paraty, as it hosts the highest known population density of the species (Mendonça 2001). We conducted nine four-day field campaigns, with teams of 3–4 people, between December, 2021 and August 2022. After selecting habitats likely to be occupied by the species *in loco*, we conducted playback surveys using distinct vocalizations of *F. erythronotos*, and banded individuals captured with 12 m mist nets with a 28 mm mesh size. Each captured individual was marked with four bands: one metal band and three colored bands, using unique color combinations to allow for individual identification using binoculars.

The banded individuals were monitored, and detection points were recorded using GPS devices (Garmin eTrex 10 and 30) to determine species density. Many of the banded individuals were no longer located, and others occupied areas with restricted access, which prevented us from continuing their monitoring. Consequently, only one area could be effectively monitored to estimate the density of territorial individuals. In this area, newly detected territorial individuals were also banded. Banding authorization and metal bands were provided by the *Centro Nacional de Pesquisa para Conservação das Aves Silvestres* (National Center for Bird Conservation [CEMAVE]; permit #79270-1).

Search for remaining populations

First, we identified the color and texture patterns of habitats where the species had been recorded in Mambucaba River Valley in satellite images of Google Earth Pro 7.3.6.10201. We then searched for similar patterns throughout the entire study region in the satellite images of Google Earth Pro. We also used Google Earth Pro to search for other non-forest habitats within the study region (see the list of target habitats above), even if they were not present in the Mambucaba River Valley. We then delineated or marked the areas of all such habitats detected. These included: (1) areas with known species records, (2) those lacking records but presenting potential for occurrence, and (3) other non-forest habitats.

Subsequently, we mapped the existing and potential access routes to the areas, either by car, boats, or by walking, also using Google Earth Pro. All areas with potential access were assigned with a numerical point for referencing. These target search points and trails were exported to GPS TrackMaker software (version 13.9.680) and then uploaded to GPS devices. We also printed maps showing them to help navigation during fieldwork.

With teams of 3–5 people, we carried out four campaigns of 3–6 days (totaling 17 field days) to search for the species on target search points, between October 2023 and March 2024 (October 19–24, 2023; November 23–26, 2023; December 19–21, 2023; and February 29 to March 3, 2024). Reaching many of the target search points proved impractical due to poor access conditions, unnavigable terrain, restricted areas, heavy rainfall, and/or personal safety concerns. At the accessible points, we conducted playback of distinct *F. erythronotos* vocalizations, moving slowly and steadily through the access routes and/or habitats. During the search, one team member walked approximately 30 m behind the playback emitter to increase the chances of detecting acoustic responses from the species. Each area where playback was conducted was considered a sampled site, with site sizes varying greatly depending on the extent of suitable habitat available and access possibilities. In some cases, we divided a large continuous area of suitable habitat into two separate sampled sites to facilitate eventual returns visits for further sampling.

For each sampled site, we recorded the following information: initial and final geographic coordinates, start and end times of sampling, existing habitat types, weather conditions (sun, cloud cover, rain, wind, and temperature), site name (if one became known to the team), list of bird species recorded, and presence or absence of the target species. We also looked for signs of anthropogenic environmental impacts and their actual or potential effects on *F. erythronotos*. We recorded evidence of forest fires, soil and/or waste dumping, selective logging, hunting, animal capture, invasion of alien species, and presence of domestic animals, for example. Additionally, to gather information on the land-use history of the surveyed areas, we conducted interviews with local residents and analyzed historical satellite imagery available on Google Earth Pro. During all 13 campaigns, including those focused on density estimates (see above), samplings were conducted from dawn until approximately 12:00 p.m., and again for 3–4 h before sunset.

We estimated the sampling area in Google Earth Pro, provisionally considering a playback influence radius of 25 m from the point where the audio was played. However, this influence was only taken into account when directed toward target habitats (see above).

Geographic distribution estimates

As we identified several areas with habitats potentially suitable for the occurrence of *F. erythronotos*, but did not confirm its presence on them (see Results), we only mapped the habitat where the species was effectively recorded, including nearby areas with a high probability of occurrence that were not sampled due to logistical or access difficulties. Thus, we did not map the full extent of potential habitat. The habitat where the species occurs or is highly likely to occur can be referred to as "area of occupied habitat" (IUCN Standards and Petitions Committee 2024), which is part of the potential habitat, referred to as "area of potential habitat" (IUCN Standards and Petitions Committee 2024). This habitat mapping was performed using Google Earth Pro, with the aid of georeferenced points of all observed individuals of the species.

In QGIS, we overlaid a 2 km grid on the species' current records, adjusting the grid to get the fewest number of cells possible (IUCN 2012; IUCN SSC Red List Technical Working Group 2024; IUCN Standards and Petitions Committee 2024). For each grid cell containing a confirmed current record, we added 4 km² to estimate the species' lower bound area of occupancy (AOO; IUCN Standards and Petitions Committee [2024]). A similar analysis was carried out by overlaying a 2 km grid on the mapped area of occupied habitat, producing the upper bound AOO (IUCN Standards and Petitions Committee 2024). Finally, in Google Earth Pro, we delineated a polygon encompassing the entire mapped area of occupied habitat using the minimum convex polygon method (MCP), resulting in the extent of occurrence (EOO) of the species (IUCN 2012; IUCN SSC Red List Technical Working Group 2024; IUCN Standards and Petitions Committee 2024). The EOO was measured in Google Earth Pro, while the mapped area of occupied habitat was calculated in QGIS.

Population estimates

We estimated the population size of *F. erythronotos* in the Mambucaba River Valley by applying the density of individuals obtained there to the total area of the occupied habitat for that locality. In other areas where the species was recorded, we remained at the site for up to 8 h to estimate the number of individuals and to mark their locations. We recorded the sex, presence of bands, plumage characteristics (e.g., tail molt), distance between individuals, and the timing of each observation. When multiple individuals were presumed to be present, the team spread out across the site to improve the ability to distinguish and count separate individuals. Team members communicated via walkie-talkies (Intelbras RC 4100) to confirm how many individuals were being heard and/or observed simultaneously.

Based on the records, we used Google Earth Pro to delineated preliminary home range polygons for territorial pairs and solitary individuals using the minimum convex polygon (MCP) method. We then proportionally compared the species' area of the occupied habitat with these preliminary home ranges to infer the potential number of additional individuals that could occur in the area (see above).

Carrying capacity estimates

We estimated the carrying capacities of individuals (i.e., the maximum possible population size) for the localities of interest by applying the densities reported by Mendonça (2001): 312 adult individuals per km² in the Mambucaba River Valley and 178 individuals per km² in the other localities.

Population viability analysis

We conducted a population viability analysis (PVA) for each population of *F. erythronotos* using the simulation software program VORTEX 10.10.0 (Lacy and Pollak 2025). General life history information used in the model were based on data from the related Paraná Antwren (*F. acutirostris*; Sandretti-Silva et al. [2024]) as well as specific information for *F. erythronotos* (Mendonça [2001]; see Table 1). As *F. acutirostris*, *F. erythronotos* individuals are long-term monogamous (Mendonça 2001), and start breeding at one year of age. Maximum age of reproduction was set at 16 years for females and 17 years for males, and 18 was adopted as maximum lifespan (information from field studies with *F. acutirostris*; M.R. Bornschein, unp. data). In this work we only modeled territorial individuals and thus 100% of adult females could potentially reproduce each year.

We included inbreeding depression effects (6.29 total lethal equivalents per individual), of which 50% are due to recessive lethals, the conservative default setting in VORTEX (O'Grady et al. 2006; Table 1). We also incorporated the possibility of occurrence of a catastrophe, with an annual probability of 2.589% and severity of 0.5 (Sandretti-Silva et al. 2024), representing an event that reduces the population size by half with 14% of chance per each generation time, in accord to Reed et al. (2003). We did not model catastrophes affecting reproduction in order to avoid overestimating their impact on the population, given that the reference data (Table 1), collected over nearly 20 years, were already subject to potential stochastic events such as heavy rainfall and strong winds (M.R. Bornschein, unp. data).

We included in the model three scenarios of distinct possibilities of reproductive and mortality rates: an optimistic, pessimistic, and baseline. The optimistic scenario corresponds to the species-based characteristics (reproductive and mortality rates) observed for *F. acutirostris* on a small island (Jundiaquara Island; < 15 ha), possibly demographically favored by the low presence of predators (Sandretti-Silva et al. 2024). In contrast, the pessimistic scenario represents the poorest performance recorded for *F. acutirostris* across the other two study sites (da Folharada Island and Continente; Sandretti-Silva et al. [2024]). The baseline scenario is such that the mortality rates and the probability of reproductive success are modeled as random variables with uniform distributions, bounded by the values defined in the optimistic and pessimistic scenarios. Additionally, in the baseline scenario, the probability distribution for the number of offspring per female is calculated as the arithmetic mean of the corresponding distributions in the optimistic and pessimistic scenarios. (Table 1).

In all three scenarios, first-year mortality is set to the same value: identical to that of *F. acutirostris* when the population size exceeds 90% of carrying capacity, and half that value otherwise. This mortality rate, which is an important factor in the dynamics of *F. acutirostris* (Sandretti-Silva et al. 2024), was reduced under the premise that the target species populations might be below carrying capacity in its areas of occurrence, thereby favoring recruitment into unoccupied habitat.

The model incorporates environmental variability, with annual mortality rates in all populations subjected to stochastic variation following a binomial process. The standard deviation of this variation was set to 10% of the mortality rate defined for each scenario. Initial population size and carrying capacity were set for each modeled population as described in the previous sections, and remained constant across the optimistic, baseline, and pessimistic scenarios. Finally, we ran the model in VORTEX for 5,000 iterations over a 100-year projection.

Conservation

To assess potential conservation issues and strategies for the species, we conducted PVAs in VORTEX under additional alternative scenarios. Initially, we evaluated current annual habitat loss rates. To do this, we mapped all habitats potentially suitable for the occurrence of *F. erythronotos*, using historical satellite imagery available in Google Earth. We also considered small habitat patches within urban areas. Therefore, when considering habitats that were not necessarily occupied by the species in the past and isolated patches that are not necessarily occupied by the species in the present, this habitat loss mapping is not the same as the habitat mapping used to estimate the species' geographic distributions (see above). To avoid confusion, when we refer to "habitat loss" hereafter, we will be referring to a general environment, which includes both environments actually used by the species and others that may have been part of its range ("area of potential habitat"; IUCN Standards and Petitions Committee [2024].

We fitted the historical values of habitat loss to two alternative models, a linear model (constant absolute annual declines) and an exponential model (constant proportional annual declines), using respectively the lm() and nls() functions from R version 4.5.1 (R Core Team, 2024). We then incorporated these two annual habitat loss models into the PVA model as annual reductions in carrying capacity (K).

Furthermore, we modeled the effect of introducing individuals from remnant populations into suitable areas, considering scenarios involving the removal and then supplementation of 10, 20, or 30 pairs over a five-year period, corresponding to two, four, or six pairs per year, respectively. This population management period was limited to five years due to funding constraints. Translocated populations were modeled under the optimistic scenario (Table 1), assuming that the environmental conditions at the introduction site are better than those at the source population.

For source populations from which individuals were removed, we also simulated the populations dynamics under the optimistic scenario for the first five years, assuming that environmental management actions would be implemented during the five-year period of translocations. These actions include the removal of exotic and domestic species, fire control, and vegetation enrichment.

Finally, we assessed the gene diversity (expected heterozygosity based on a single neutral locus), of the translocated populations and the impact of additional exchange of two individuals per year over a five-year period, between translocated and source populations, beginning in the year after the initial translocation was completed. However, we did not model numerical changes in population sizes of either the source or recipient populations, as this genetic management strategy was modeled as an exchange of individuals between them.

Conservation status

We reassessed the conservation status of the species based on the IUCN criteria and guidelines (IUCN 2012; IUCN SSC Red List Technical Working Group 2024; IUCN Standards and Petitions Committee 2024). We used data on geographic distribution, population size estimates, and extinction probability. Following IUCN (2012), we defined locations as distinct sets of habitats where the species occurs that are isolated, or potentially isolated, from other such sets. Each location is also sufficiently cohesive so that a potential impact, such as a contaminant spill in a river, a fire, or a windstorm, could affect its entire area, but not that of other locations.

Green Status

We assessed the Green Status of the species based on IUCN (2021) and IUCN Green Status of Species Working Group (2024). For delimitating the spatial units (SUs) in the indigenous range, we associated information on current locations (*sensu* IUCN [2012]; see above) and natural geographic features (high elevation areas) that would prevent the connection of locations even in the benchmark (IUCN 2021). We assessed the regional conservation status of each location (see above) to get their current states and incorporated field data to estimate their potential functionality, based on abundance and density of the species. To improve the precision of the conservation impact calculation, we applied fine-scale weight values (0, 1.5, 2.5, 3.5, 4.5, 5.5, 6.5, or 10). Using the state of each spatial unit, we calculated the species' Green Score. We assessed the Current scenario, but and also the Long-term Future-without-conservation and the Long-term Future-with-conservation Green Scores to calculate the conservation impact metrics. When calculating the score for the Long-term Future-with-conservation, we considered ambitious, but plausible and feasible conservation actions based on our modeling and conservation results. Directional actions were included, while actions that are unrealistic due to political or economic constraints, highly relevant for the region, were not considered. This considered actions could include an expected additional range and new location(s), which would only be taken into account in future scenarios, but not in the current one (IUCN Green Status of Species Working Group 2024). However, for calculating the Recovery Potential, we used the scores based on the same set of SUs in the denominator (IUCN Green Status of Species Working Group 2024).

3. Results

We sampled 71 sites across the municipalities of Rio Claro, Mangaratiba, Angra dos Reis, and Paraty, covering a total sampling area of 3.754 km^2 (Figure 1, Table 2). Historical localities of species records were sampled, except for one location where native vegetation is no longer present (Table S1). Sampling encompassed a range of environments at altitudes between 0-100 m and 401-600 m a.s.l. (Table S2).

We recorded *F. erythronotos* at three localities with historical records (Table 2, Table S1), namely Ariró (Ariró River, municipality of Angra dos Reis), Mambucaba River Valley (municipalities of Angra dos Reis and Paraty), and Taquari River (municipality of Paraty; Table 3). Individuals were observed in non-forest environments (Figure 2, Table 3), all severely impacted (Figure 3), dominated by shrubs and trees of varying heights (up to about 22 m). These habitats occurred in flooded, floodable, and non-floodable areas (Table 3), all located below 30 m a.s.l. Individuals were seen at heights ranging close to the ground (*c.* 0.3 m) up to about 12 m, but typically between 0.8-3.0 m above ground.

We also recorded invasive alien plant species in sites where individuals of the target species were found, namely: the herbs *Brillantaisia lamium* (Nees) Benth. (native to tropical Africa), *Hedychium coronarium* J.Koenig (native to Asia), *Impatiens walleriana* Hook.f. (native to Africa), *Tithonia diversifolia* (Hemsl.) A.Gray (native to Central America), and *Tradescantia zebrina* Heynh. ex Bosse (native to Central and northern South America); the tree *Clitoria fairchildiana* R.A.Howard (native to northern Brazil); and the vine *Syngonium podophyllum* Schott (native to Central and northern South America).

The EOO of *F. erythronotos* covers 241.26 km² (Figure 4A). The lower bound area of occupancy (AOO) totals 32.00 km² (Figure 4B), the upper bound AOO 76.00 km² (Figure 4C), and the area of occupied habitat 9.263 km² (Table 4; Figure 4D).

In the Ariró and Taquari River localities, where six and five mature individuals were detected, respectively (Table 3), we estimated the occurrence of 13 and 14 mature individuals, respectively (Table 4). In the Mambucaba River Valley, 27 mature individuals (all banded; Table 3) were found occupying 1.50 km², resulting in a density of 18 adults per km^2 (or one adult per 0.056; Table 4). Based on the 8.606 km^2 of area of occupied habitat in this locality, we estimate a population of 154 adult individuals in this population (27 banded), contributing to a total estimated population of 181 adult individuals for the species (Table 4).

Population viability analysis

A population growth trend was obtained for *F. erythronotos* under the optimistic and baseline scenarios (Figure 5A-D), whereas a decline was projected under pessimistic scenarios (Figure 5A–D). Extinction is predicted under both the baseline and pessimistic scenarios for the Ariró and Taquari River populations (Figure 6A, D, respectively), but not for the Mambucaba River Valley population or the entire population (Figure 6C, A, respectively). Under the baseline scenario, the probability of extinction for the entire population and for the Mambucaba River Valley population within the next 50 years is 12.5% and 12.6%, respectively (Table S3). The Ariró and Taquari River populations have an extinction probability of 96.2% and 94.5%, respectively, within the next 50 years (Figure S3).

Conservation

No portion of the species' area of occupied habitat is located within a protected area. A small part of the *Parque Nacional da Serra da Bocaina*, although falling within the species' EOO, does not overlap with its area of occupied habitat. Of the total area of occupied habitat, 40.23% (3.727 km²) lies within the municipality of Angra dos Reis, while the remaining portion is located in the municipality of Paraty. Within Angra dos Reis, 31.18% of the area of occupied habitat (1.162 km²) is classified as urban area, and the rest is designated as rural land under special use zoning. This includes planned low-density urban expansion within the "ZORDE" zone (*Zona Rural de Desenvolvimento Especial* – Special Rural Development Zone, according to Municipal Law No. 2,091 of Angra dos Reis, dated January 23, 2009). In Paraty, 100% of the area of occupied habitat is classified as urban area intended for expansion of human occupation, primarily for tourism development (Prefeitura Municipal de Paraty 2023). In summary, 100% of the species' area of occupied habitat is designated for human occupation, with 72.31% officially classified as urban area.

Table 5 shows that between 50.3% and 82.7% of the species' habitat was lost per locality from 1985 to 2024, representing an average annual loss of 0.042 to 0.244 km² per locality. Figure 7 indicates that a linear projection of the annual mean habitat loss per locality would result in complete habitat eradication in less than 35 years. However, when considering the percentage-based of annual habitat loss relative to the remaining habitat, the decline would occur more gradually, and complete eradication would not be expected within the next 100 years (Figure 7).

In the models considering the percentage-based decrease in habit loss as an annual reduction in carrying capacity in the PVA, the population trend curves intersect with the decreasing K threshold (Figure 8). This approach only slightly increases the extinction risk (Figure 9; Table S3). In turn, when modeling population trajectory with the linear decrease in habitat, populations sizes show an abrupt decline when they intersect the K threshold (Figure 10), leading to very short extinction time estimates (Figure 11). The baseline scenario predicts a probability of complete extinction of the species occurring within the next 37 years, as in the case for the Mambucaba River Valley population, whereas the Ariró population is expected to become extinct in less than 10 years and the Taquari River population in less than 20 years (Figure 11; see also Table S3).

Given the scenarios outlined above, we propose an action plan for the conservation of the species, structured around four main fronts: 1) the environment and population management of the largest population of *F. erythronotos* in the Mambucaba River Valley, 2) assisted colonization, 3) maintenance of a safeguard *ex situ* population under human care, and 4) environmental education. For the first front, we recommend leasing urban areas within the Mambucaba River Valley, specifically in properties where the species has been recorded, in order to remove domestic animals and potential predators, control invasive exotic plant species, prevent vegetation suppression, and manage nests to increase reproductive success. Regarding assisted colonization, we propose translocating individuals from the Mambucaba River Valley to a site at approximately 36.0 km southwest of the current known rage, in the municipality of Ubatuba, São Paulo (Figure S1). Based on analyses of Google Earth Pro imagery and field observations, four areas in Ubatuba contain habitat similar to those found in the species' currently area of occupied habitat, totaling 13.849 km^2. We suggest an introduction in Puruba (8.398 km^2; Figure S1), of which 90.31% of the area (7.584 km^2) lies within the Serra do Mar State Park (*Parque Estadual da Serra do Mar*).

Before implementation, it will be necessary to carry out on-site assessments to compare environmental features, as microhabitat, between the source population in the Mambucaba River Valley and the proposed colonization area, to order to confirm habitat similarity. The removal of potential predators from Puruba is also recommended to support successfully reproduction. For the *ex situ* front, we recommend developing the necessary planning and expertise using *F. acutirostris* as a model species. Finally, environmental education is essential to raise awareness among local communities and promote behaviours that support the conservation of the species and its habitat. Community involvement may strengthen local stewardship and ensure the long-term success of the proposed conservation actions.

Figure 12C shows a projected continuous population growth in Puruba, reaching 1,250 individuals in 100 years in the scenario with 30 introduced pairs. However, extinction is also projected. The extinction probability reaches less than 1% in 100 years when 30 pairs are introduced and 50% in 100 years when only 10 pairs are introduced (Figure 12D). The Mambucaba River Vally population, source of the translocated individuals, would experience a decrease in population size during the five years of removal, but would subsequently recover (Figure 12A). The extinction projections (Figure 12B), however, reach values similar to those of the Mambucaba River Valley population without individual removal (Figure 6C) when environment and population management actions are implemented in association with the removal (see also Table S3), or slightly higher without the implementation of managements (Figure 12B).

The gene diversity of individuals in Puruba would steadily decline after the end of the introductions, reaching 93% in 100 years when 30 pairs were introduced (Figure 13). The annual exchange of two pairs over an additional five years shows negligible effect after 100 years when 30 pairs are introduced, but a positive effect when 20 or 10 pairs are introduced (Figure 13).

Conservation status

Based on the above results, the species qualifies as Endangered (EN) under criterion B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v); C2a(i); D.

Green Status

With a Species Recovery Score of 6.43%, *F. erythronotos* is currently Critically Depleted. For the Future-with-conservation scenario, we considered the assisted colonization as the only ambitious but plausible conservation actions in a long-term future. Although the recovery potential of *F. erythronotos* with these actions is low (4.37%), the species shows high conservation dependence, as its recovery score under the Future-without-conservation scenario is 0.00% (Extinct in the Wild; Table 6).

4. Discussion

Our results support classifying the species as Endangered (EN) due to its restricted range, very small and declining population, and ongoing deterioration in both habitat extent and quality. Its population size and geographic distribution, however, are so limited that these parameters, by themselves, meet the criteria for Critically Endangered (CR; IUCN 2012) rather than EN. At present, though, the species does not fully qualify for CR because it occurs in three rather than a single location, and its probability of extinction within one generation (5.65 years; baseline scenario, not previously cited in the Results) is below 25% (IUCN 2012). Nonetheless, projections indicate that within a short time frame (< 20 years), the species could become restricted to a single location, the Mambucaba River Valley (Figures 11B and D), which would justify its uplisting to CR. Earlier assessments by the IUCN (BirdLife International 2020) and Brazil's 2000s national assessment (Gonzaga 2008) also listed the species as EN based on geographic distribution, whereas a later Brazilian assessment (CEMAVE 2018) classified it as CR based on population size and the percentage of mature individuals per population, but without supporting data.

Knowing the extent of geographic distribution is crucial for a more realistic assessment of population size (IUCN 2012; IUCN Standards and Petitions Committee 2022). In this regard, understanding the species' habitat is key. The association of *F. erythronotos* with "secondary forests", altered environments, and elevations around 500 m a.s.l. in Serra do Piloto, municipality of Mangaratiba (Mendonça 2001; CEMAVE 2018; BirdLife International 2020), may have resulted in an overestimation of its geographic range in past assessments (e.g., Gonzaga 2008; CEMAVE 2018; BirdLife International 2020). The assumption that the species occurs in forests ranging from sea level to at least 500 m greatly expands the EOO, AOO, and occupied habitat to include large, continuous, and relatively undisturbed forested areas of the Serra do Mar in Rio de Janeiro. We contacted the photographer Paulo J. Marques, who informed us that the record was made inside the Cunhambebe State Park, at 500 m a.s.l., but no additional details were provided. The Serra do Piloto mountain range is crossed by the Saco River, which flows into the coastal plain of the municipality of Man-garatiba, where there is a historical record of the species (Gonzaga 2008; CEMAVE 2018).Possibly, these individuals moved along the banks of the Saco River, perhaps following deforestation of their original lowland habitat. However, a group of trees does not necessarily constitute a forest (Veloso et al. 1991;

Bornschein 2015). For a habitat to qualify as a forest, trees must be more developed and the environment older, allowing the formation of a four-layered structure (Veloso et al. 1991). It is highly likely that all sources claiming that *F. erythronotos* occurs in forests (e.g., CEMAVE 2018; BirdLife International 2020) misinterpreted non-forest arboreal environments as forests. Secondly, areas that once held forests but were cleared often regenerate in a way that resembles certain stages of pioneer environments (*sensu* Veloso et al. 1991). Mendonça (2001) was accurate in suggesting that young river meander habitats could represent the original environment of *F. erythronotos*. This is the only plausible scenario for hosting a semi-forest specialist species (*sensu* Bornschein 2001) within its range of occurrence. Therefore, all records from secondary habitats and abandoned plantations are likely the result of colonization from river meanders. In this context, environmental changes may have benefited the species, up to a certain point. In addition, the records at 500 m a.s.l. in the municipality of Mangaratiba (Mendonça 2001) should be considered accidental (see Introduction). We sampled points at this elevation in this municipality, without success (Table 1).

Based on the above, we propose that *Formicivora erythronotos* be considered an endemic species of Fluvial-influenced and Fluviomarine-influenced Pioneer Formations (*sensu* Veloso et al. 1991) at the shrub-tree stage, which develop in river meanders, both on the accretion margins and in abandoned meanders. The floodable habitats it occupies would not be exclusively arboreal pioneer formations, such as mangroves, possibly due to the lack of dense herbaceous vegetation in the lower strata, nor purely shrubby, possibly due to insufficient shading, which appears to be important for the species. Forests might be too shaded, and *restinga* vegetation (Marine-influenced Pioneer Formations, *sensu* Veloso et al. [1991]) might be too well-drained, with a different structure of understory shrubs. Secondarily, the species would have colonized human-altered environments that at least partially replicate the vegetation structure of the original habitats, though always near its original areas of occurrence.

This limited set of environments, restricted to floodable areas and non-forest secondary formations, nonetheless represents an expressive area along the EOO of *Formicivora erythronotos*, despite the species currently being known from only three localities (Table 4). For the assessment of its lower bound AOO, the simplification of assigning 4 km² per grid cell with species occurrence (IUCN SSC Red List Technical Working Group 2024; IUCN Standards and Petitions Committee 2024) eliminates the challenges of habitat interpretation and mapping but may result in significant overestimation (Bornschein et al. 2024). Regarding the recommended assessment of occupied habitat (IUCN SSC Red List Technical Working Group 2024), a critical decision was required: either to map the entire broad extent of potential habitats or to restrict measurements to the actual sites of species occurrence, in order to avoid another possible overestimation. We chose to restrict the assessment of the occupied habitat to environments where the species was recorded, and to adjacent environments that we were unable to sample. Adjacent environments without confirmed records of the species were not included in the occupied habitat. As a result, the estimated occupied habitat corresponds to only 28.9 of the species' lower bound AOO.

In fact, suitable habitats for *F. erythronotos* within its EOO are, for the most part, unoccupied by the species (Figure 1). *Formicivora erythronotos* has not been recorded again in several historically known localities (Table S1). There has been a sharp decline in population density in the Mambucaba River Valley, and, in other localities with records, only a few individuals have been detected (Table 4). Population density in the Mambucaba River Valley was estimated at 312 adult individuals per km² in the 1990s (Mendonça 2001), but currently stands at 18 individuals per km² (Table 4). Despite the apparent advantage of the species having colonized human-modified landscapes (see above), this benefit is not counterbalancing the processes driving population declines and local extinctions, as suggested by the PVA, even in areas where suitable habitats still exist.

It is worth noting that the optimistic scenario used for modeling *F. erythronotos* is based on data that are considerably more "favorable" than those obtained in three other localities studied for the reference species, *F. acutirostris* (Sandretti-Silva et al. 2024). Furthermore, in the optimistic scenario for *F. erythronotos*, mortality during the first year of life was considered to be half of that observed in *F. acutirostris*, while the population remained below 90% of the carrying capacity (Table 1). Thus, this optimistic scenario should be regarded as unrealistic for *F. erythronotos*, as was the case in the PVA assessment of *F. acutirostris* (Sandretti-Silva et al. 2024). The reason for this "extreme optimism" is that the data of the optimistic scenario were collected on a small island (<15 ha), possibly lacking many predators. The baseline PVA scenario for *F. erythronotos*, which combines parameters from both the optimistic and pessimistic scenarios, likely produced overly optimistic projections due to the assumption of reduced first-year mortality while the population remained below 90% of the carrying capacity. Therefore, it is possible that the scenario most realistic for the current environmental and population conditions of *F. erythronotos* is, in fact, the pessimistic one.

The population decline of *F. acutirostris* was projected in all scenarios of its PVA, based on actual first-year mortality data, which was attributed to two ecological challenges: high reproductive failure due to combined predation and nest flooding by high tides (Sandretti-Silva et al. 2024). In parallel with *F. acutirostris*, in addition to the typically high rates of nest predation in the Neotropics (Oniki 1979; Winkler 2016), *F. erythronotos* may be experiencing even higher levels of reproductive failure resulting from habitat degradation and proximity to urban areas, including nest destruction by domestic animals and human disturbance, as well as predation by exotic species (e.g., dogs, cats, and rats). Environmental degradation may also reduce individual fitness, delaying renesting and decreasing the frequency of renesting attempts, which consequently lowers the chances of producing offspring.

Regarding the degradation of *F. erythronotos* habitat due to the invasion of alien species, the herbaceous plants *B. lamium* and *T. zebrina* and the vine *S. podophyllum* show very high coverage of the herbaceous stratum in many areas, potentially impacting food availability, shelter, nesting material, and vegetation suitable for nest support. *Brillantaisia lamium* has been recorded in Brazil as a cultivated plant at least since 1975, in Rio de Janeiro, and as an alien species at least since 1978 in that state, and at least since 1987 in São Paulo (https://reflora.jbrj.gov.br/reflora/herbarioVirtual/ConsultaPublicoHVUC/BemVindoConsultaPublicaHVConsultar.do?modoConsulta=LISTAGEM&quantidadeResultado=20&nomeCientifico=Brillantaisia+lamium). However, to date, no direct impact has been detected on the target species as a result of the invasion of these or other allien plants in its environment.

As the areas of occupied habitat of the species are not protected, it is not surprising that they continued to suffer habitat loss as a consequence of human activities, although some degraded areas have regenerated into environments that could potentially be reoccupied by the species. It is also now surprising that the species is Critically Depleted and highly conservation dependent. The most common conservation measure that would immediately emerge is such a context (Reis et al. 2003), is the establishment of a strictly protected conservation unit (*unidade de conservação de proteção integral*, *sensu* D'Amico et al. [2018]). However, we differ from other authors (Gonzaga 2008; CEMAVE 2018; BirdLife International 2020) in believing that it is unlikely a protected area can be established where the species currently occurs, as these areas are either urban areas or rural lands designated for real estate development. The creation of a conservation unit in areas designated for urban development presents significant challenges, as it would conflict with the existing land-use zoning plans of the municipalities involved. Moreover, proposing a conservation unit within an urban area would require substantial revisions to municipal development plans, a process that could take decades, if achieved at all. In sum, even if a protected area were eventually established in a zone slated for urbanization, the legal hurdles involved would take many years to resolve, potentially compromising the species' persistence. In addition, urbanization surrounding such a conservation unit would render it environmentally unsustainable in the long term. It is very likely that previous authors (Gonzaga 2008; CEMAVE 2018; BirdLife International 2020) were unaware of these obstacles when supporting such a proposal. An alternative would be the creation of conservation units by private landowners, known as Private Natural Heritage Reserves (*Reservas Particulares do Patrimônio Natural* – RPPNs; see D'Amico et al. [2018]). However, such reserves are typically limited to small land parcels (see https://consultapublica.car.gov.br/publico/imoveis/index), which may also undermine the long-term viability of *F. erythronotos* populations within these units as surrounding areas become urbanized.

The assisted colonization of the species into a nearby protected area, beyond its current extent of occurrence, is crucial for ensuring its long-term survival (Table 6). This measure was also proposed for *F. acutirostris*, another non-forest bird species from pioneer formations, like *F. erythronotos* (Bornschein et al. 2024; Sandretti-Silva et al. 2024). These authors cautioned that environment and population management actions not commonly implemented by Brazilian authorities may take many years to be approved, thereby increasing the extinction risk of the species (Sandretti-Silva et al. 2024). This reality also applies to *F. erythronotos*. Brazilian authorities need to acknowledge their critical role in enabling conservation actions, especially for species from pioneer formations, which are highly susceptible to the impacts of biological invasions and climate change (Sandretti-Silva et al. 2024).

The PVA projected continuous gain in number of individuals for the population established through assisted colonization, approaching carrying capacity within 100 years with the introduction of 30 pairs (Figure 12C). Under this same introduction size, the probability of extinction within 100 years was predicted to be only about 2% (Figure 12D). Similarly, the removal of individuals from the donor population did not affect its overall size (compare Figure 12A with Figure 8C, baseline scenario), but it slightly increased the extinction probability (compare Figure 12B with Figure 9C, baseline scenario) in the absence of management. The genetic diversity of the introduced population declines over time but remains at approximately 93% after 100 years with the introduction of 30 pairs (Figure 13). The exchange of individuals after introduction does not increase this value, showing a beneficial effect only when smaller numbers of individuals are initially introduced (Figure 13).

5. Conclusion

Formicivora erythronotos is a micro-endemic, non-forest species associated with successional habitats shaped and rejuvenated by the hydrological dynamics of meandering rivers along a small stretch of the Rio de Janeiro coastline, in southeastern Brazil. Microhabitat conditions linked to hydromorphic and flood-prone terrains may be key to its presence. Historically, pioneer formations of coastal meandering rivers in Brazil have had their distribution influenced over the past several thousand years by sea level fluctuations (Reinert et al. 2007). During periods of lower sea levels than today, their distribution would have expanded and become more connected as rivers formed deltas over the vast, flat continental shelf. Conversely, during periods of higher sea levels, when mountain slopes directly bordered the sea, the occurrence of these environments would have been greatly reduced (Reinert et al. 2007). This may explain, at least in part, the species' original geographic distribution. Currently, extensive environmental degradation has drastically reduced the species' population numbers, and there are now suitable habitats where it no longer occurs.

Our proposed conservation measures align with those previously suggested (Gonzaga 2008; CEMAVE 2018; BirdLife International 2020), with necessary modifications. Earlier assessments consistently emphasized the establishment of a strictly protected conservation unit, but they overlooked the constraints imposed by land-use zoning. Because the species' occupied habitat lies within urban areas or rural zones designated for urban expansion, such a proposal is not feasible. Instead, we adapted the recommendation by proposing the species' introduction into an existing protected area. *Formicivora erythronotos* is highly conservation-dependent, and ensuring its presence within a protected area represent the most important measure for securing its long-term survival.

The proposal of assisted colonization was strongly supported by the PVA, both by the favorable performance of the donor and recipient populations and by the Green Status assessment. Owing to the benefit of greater genetic diversity, the introduction of 30 pairs is the most desirable option, whereas the exchange of individuals after the completion of the introduction provides no additional advantage for this purpose. Environment and species management in the donor population is desirable but not essential. Securing environmental permits from federal, state, and municipal authorities for assisted colonization in the short term will be crucial, as will obtaining funding to develop a conservation program.

Establishing insurance populations of insectivorous species under human care is a challenge that Brazil is well positioned to address. The use of model species is desirable (Benton, 2003; Azevedo et al. 2010; Develey & Phalan, 2021; this study). *Formicivora acutirostris* serves as a model species for PVA analyses for the *F. erythronotos*, through which it will be possible to advance in addressing the challenges of food provision and the use of spider silk for nest construction.

Finally, the use of the Green Status is an important tool for evaluating the effectiveness of conservation units and assessing the degree to which species depend on conservation actions. Its application in Brazil is still limited (Nadaline et al. 2023; Bornschein et al., 2024, 2025; this study), but it should be encouraged.

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Competing interests

The authors have no relevant competing interests to disclose.

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Table 1. Ecological and environmental parameters used as input in VORTEX for the population viability analysis (PVA) of the Black-hooded Antwren (*Formicivora erythronotos*), excluding population size and carrying capacity estimates (see Results). The baseline scenario represents the average between the optimistic and pessimistic scenarios, or a random draw between these values, when they differ. Abbreviations: EV = environmental variation; LTM = long-term monogamy; SD = standard deviation.

Parameters	Optimist	Pessimist	Baseline scenario	Source
Lethal equivalents	6.29	6.29	6.29	O'Grady et al. (2006)
Percent due to recessive lethal alleles (%)	50	50	50	O'Grady et al. (2006)
EV correlation between reproduction and survival	0.0	0.0	0.0	This study
EV correlation among populations	1.0	1.0	1.0	This study
Reproductive system	LTM	LTM	LTM	Mendonça (2001)
Age of first offspring females (years)	1.0	1.0	1.0	Mendonça (2001)
Maximum age of female reproduction (years)[1]	16	16	16	This study
Age of first offspring males (years)	1.0	1.0	1.0	Mendonça (2001)
Maximum age of male reproduction (years)[2]	17	17	17	This study
Maximum lifespan (years)[2]	18	18	18	This study
Maximum number of broods per year[3]	1	1	1	Sandretti-Silva et al. (2024)
Maximum number of progeny per brood[4, 5]	4	4	4	Sandretti-Silva et al. (2024)
Sex ratio at birth – in % males	50	50	50	Sandretti-Silva et al. (2024)
% adult females in breeding pool	100	100	100	Sandretti-Silva et al. (2024)
SD in % breeding due to EV	0	0	0	Sandretti-Silva et al. (2024)
% of pairs without broods per year	58.61	74.81	58.61–74.81	Sandretti-Silva et al. (2024)
% of pairs that produced one offspring per year	44.55	38.24	41.40	Sandretti-Silva et al. (2024), this study

Parameters	Optimist	Pessimist	Baseline scenario	Source
% of pairs that produced two offspring per year	41.58	55.88	48.73	Sandretti-Silva et al. (2024), this study
% of pairs that produced three offspring per year	11.88	5.88	8.88	Sandretti-Silva et al. (2024), this study
% of pairs that produced four offspring per year	1.98	0.00	0.99	Sandretti-Silva et al. (2024), this study
First-year mortality rate (%), up to 90% of carrying capacity	27.2	27.2	27.2	This study
First-year mortality rate (%), above 90% of carrying capacity	54.4	54.4	54.4	Sandretti-Silva et al. (2024)
SD on first-year mortality rate	5.44	5.44	5.44	This study
Mortality after one year of age (%)	12.91	17.73	12.9–17.73	Sandretti-Silva et al. (2024)
SD of the mortality after one year of age	1.29	1.77	1.53	This study
Number of types of catastrophes	1	1	1	This study
Frequency and extent of occurrence (%)	2.589	2.589	2.589	Reed et al. (2003)
Severity of the catastrophe on reproduction	0	0	0	Sandretti-Silva et al. (2024)
Severity of the catastrophe on survival	0.50	0.50	0.50	Reed et al. (2003)
% males in breeding pool	100	100	100	Sandretti-Silva et al. (2024)

[1]Data from a female of *F. acutirostris* (#163) still alive in July 2025.

[2]Data from a male of *F. acutirostris* (#Fi8) still alive in July 2025.

[3]The maximum number of broods per year for *F. acutirostris* is usually two, and only rarely three (Sandretti-Silva et al. 2023). However, VORTEX assumes an equal probability of both outcomes, thereby overestimating the likelihood of a second brood compared to what is observed in nature. A second nesting attempt, following a successful first brood, occurs, at best, two months before the end of the breeding season, whereas the species can attempt to produce offspring from a first brood for up to six months (Sandretti-Silva et al. 2023).

[4]As we adjusted the maximum number of broods per year to one instead of two, we also adjusted the number of offspring to four instead of two (see Sandretti-Silva et al. 2024).

[5]Mendonça (2001) reported finding nests with only one egg, rather than the usual two observed in *F. acutirostris*, which could potentially affect the value of this parameter. However, there was no evidence that only one egg had actually been laid. In *F. acutirostris*, we observed nests with two eggs in which only one egg was preyed upon (M.R. Bornschein, unp. data).

Table 2. Sites sampled for the detection of Black-hooded Antwren (*Formicivora erythronotos*) in Rio de Janeiro State, southeastern Brazil. Sites are listed from northeast to southeast (see Figure 1).

Site number	Site name	Geographic coordinates (at the center of the site)	Area sampled (m^2)	Altitude (m above sea level)	Environment sampled	Sampling start time (total time of sampling)	Date	Presence of the species
1	Rio Claro, municipality of Rio Claro	22°48’33”S, 44°1’45”W	82,952	423-451	Fourth stage of natural succession (*capoeira*)	11:04 (68 min)	20/10/2023	No
2	Rio Claro, municipality of Rio Claro	22°49’42”S, 44°01’46W	24,349	551-564	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*), pastures	17:28 (37 min)	19/10/2023	No
3	Serra do Piloto, municipality of Rio Claro	22°50’28”S, 43°58’10”W	33,231	462-466	Disturbed forests, Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*), pastures	07:50 (26 min)	20/10/2023	No
4	Serra do Piloto, municipality of Rio Claro	22°50’37”S, 43°58’30”W	11,252	513-533	Fifth stage of natural succession (*capoeirão*), pastures	07:07 (36 min)	20/10/2023	No
5	Serra do Piloto, municipality of Rio Claro	22°50’45”S, 43°58’50”W	33,685	544-551	Pastures	06:15 (41 min)	20/10/2023	No
6	Serra do Piloto, municipality Rio Claro	22°51’00”S, 43°59’20”W	11,456	491-500	Disturbed forests, Fourth stage of natural succession (*capoeira*), pastures	05:28 (33 min)	20/10/2023	No
7	Serra do Piloto, municipality of Rio Claro	22°50’57”S, 44°00’09”W	24,980	453-456	Disturbed forests, Second and third stages of natural succession (*capoerinha*), Fifth stage of natural succession (*capoeira*)	08:50 (45 min)	20/10/2023	No
8	Serra do Piloto, municipality of Mangaratiba	22°51’15”S, 44°00’40”W	45,355	454-471	Disturbed forests, Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*)	09:47 (47 min)	20/10/2023	No
9	Estrada Imperial, municipality of Mangaratiba	22°55'32"S, 44°1'39"W	11,536	3-5	Fourth stage of natural succession (*capoeira*), pastures	15:15 (12 min)	20/10/2023	No
10	Estrada Imperial, municipality of Mangaratiba	22°55’52”S, 44°2’5”W	10,548	4-7	Second and third stages of natural succession (*capoerinha*)	12:12 (36 min)	20/10/2023	No
11	Estrada Caputera, municipality of Angra dos Reis	22°59’33”S, 44°13’35”W	97,538	2-7	Second and third stages of natural succession (capoerinha), Fifth stage of natural succession (capoeirão)	05:30 (86 min)	23/10/2023	No
12	Jacuecanga, municipality of Angra dos Reis	23°0’4”S, 44°13’56”W	16,337	1-3	Fifth stage of natural succession (*capoeirão*)	07:22 (23 min)	23/10/2023	No

Site number	Site name	Geographic coordinates (at the center of the site)	Area sampled (m²)	Altitude (m above sea level)	Environment sampled	Sampling start time (total time of sampling)	Date	Presence of the species
13	Pé de Galinha, municipality of Angra dos Reis	22°53’41”S, 44°20’8”W	7,624	10-21	Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*)	16:30 (16 min)	22/10/2023	No
14	Pé de Galinha, municipality of Angra dos Reis	22°53’50”S, 44°20’12”W	7,564	7-10	Second and third stages of natural succession (*capoerinha*), Fifth stage of natural succession (*capoeirão*)	15:49 (28 min)	22/10/2023	Yes
15	Ariró, municipality of Angra dos Reis	22°54’11”S, 44°20’14”W	79,028	5-21	Second and third stages of natural succession (capoerinha), Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*), marshes	09:29; 16:00; 17:06 (155 min)	21/10/23; 22/10/2023, 23/10/2023	Yes
16	Ponte sobre Rio Ariró, municipality of Angra dos Reis	22°54’28”S, 44°19’50”W	3,779	3-7	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*), marshes	15:40 (180 min)	21/10/2023	Yes
17	Base Operacional Bracuí, municipality of Angra dos Reis	22°55’3”S, 44°19’43”W	20,733	3-7	Fourth stage of natural succession (*capoeira*)	06:46 (42 min)	22/10/2023	No
18	Rio Florestão, municipality of Angra dos Reis	22°54’52”S, 44°20’49”W	7,727	5-7	Fifth stage of natural succession (*capoeirão*)	07:16 (16 min)	21/10/2023	No
19	Rio Jacuecanga, municipality of Angra dos Reis	22°54’43S, 44°21’2”W	90,103	5-11	Disturbed forests, Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (capoeira), Fifth stage of natural succession (*capoeirão*)	13:56 (99 min)	23/10/2023	No
20	Rio Florestão, municipality of Angra dos Reis	22°55’12”S, 44°21’12”W	16,333	1-4	Mangroves	07:57 (135 min)	21/10/2023	No
21	Rio Florestão, municipality of Angra dos Reis	22°55’17”S, 44°21’22”W	12,564	3-10	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*), marshes	10:15 (95 min)	21/10/2023	No
22	Estrada Praia do Engenho, municipality of Angra dos Reis	22°55’24”S, 44°21’10”W	32,276	1-4	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*), mangroves	11:04 (13 min)	21/10/2023	No
23	Bracuí, municipality of Angra dos	22°56’2”S, 44°22’56W	38,717	3-5	Disturbed forests, Second and third stages of natural	16:20 (55 min)	02/03/2024	No

Site number	Site name	Geographic coordinates (at the center of the site)	Area sampled (m^2)	Altitude (m above sea level)	Environment sampled	Sampling start time (total time of sampling)	Date	Presence of the species
	Reis				succession (*capoerinha*), Fourth stage of natural succession (*capoeira*)			
24	Bracuí, municipality of Angra dos Reis	22°56’16”S, 44°22’38W	53,296	1-4	Mangroves	18:09 (38 min)	02/03/2024	No
25	Bracuí, municipality of Angra dos Reis	22°56’27”S, 44°22’39W	39,102	1-4	Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*), mangroves	17:20 (30 min)	02/03/2024	No
26	Bracuí, municipality of Angra dos Reis	22°56’34”S, 44°23’35”W	13,831	4-10	Disturbed forests, Second and third stages of natural succession (*capoeirinha*), Fifth stage of natural succession (*capoeirão*)	15:14 (8 min)	21/10/2023	No
27	Bracuí, municipality of Angra dos Reis	22°56’45”S, 44°23’30”W	19,973	2-4	Second and third stages of natural succession (capoerinha), Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*)	14:31 (39 min)	21/10/2023	No
28	Mambucaba River Valley, municipality of Paraty	23°00’20”S, 44°32’49”W	1,500,400	2-100	Disturbed forests, Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*), marshes	Not accounted	2021, 2022, 2023	Yes
29	Prainha de Mambucaba, municipality of Paraty	23°2’53”S, 44°34’37”W	10,646	3-21	Disturbed forests	07:21 (105 min)	25/11/2023	No
30	Palmital São Gonçalo, municipality of Paraty	23°1’49”S, 44°37’10W	56,711	20-50	Disturbed forests, Second and third stages of natural succession (*capoeirinha*), Fifth stage of natural succession (*capoeirão*), pastures	07:12 (105 min)	21/12/2023	No
31	Trilha Palmital, municipality of Paraty	23°2’16”S, 44°37’13”W	71,369	1-5	Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*)	09:16 (52 min)	25/11/2023	No
32	Trilha Palmital, municipality of Paraty	23°2’11”S, 44°37’24”W	125,778	8-49	Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*)	11:03 (49 min)	25/11/2023	No
33	Praia do Humaitá, municipality of Paraty	23°3’1”S, 44°39’32”W	51,653	2-8	Mangroves	14:06 (71 min)	25/11/2023	No
34	Taquari Esquerda, municipality of Paraty	23°2’59”S, 44°40’34”W	11,150	3-8	Fourth stage of natural succession (capoeira)	15:45 (21 min)	25/11/2023	No

Site number	Site name	Geographic coordinates (at the center of the site)	Area sampled (m^2)	Altitude (m above sea level)	Environment sampled	Sampling start time (total time of sampling)	Date	Presence of the species
35	Rio Taquari, municipality of Paraty	23°3’23”S, 44°40’32”W	173,061	3-7	Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*), pastures, mangroves	16:48 (90 min)	21/12/2023	Yes
36	Praia do Taquari, municipality of Paraty	23°3’48”S, 44°40’47”W	28,896	3-6	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*), mangroves	15:41 (59 min)	21/12/2023	No
37	São Roque Esquerda, municipality of Paraty	23°4’25”S, 44°42’23”W	22,427	17-30	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*)	13:46 (27 min)	02/03/2024	No
38	São Roque Esquerda, municipality of Paraty	23°4’32”S, 44°42’4”W	6,293	8-11	Disturbed forests, Second and third stages of natural succession (capoerinha), Fourth stage of natural succession (*capoeira*)	12:19 (14 min)	02/03/2024	No
39	Fazenda São Roque, municipality of Paraty	23°4’34”S, 44°41’48”W	34,288	14-26	Disturbed forests, Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*)	17:04 (83 min)	20/12/2023	No
40	Praia São Roque, municipality of Paraty	23°4’30”S, 44°41’13”W	42,236	4-6	Fourth stage of natural succession (*capoeira*), mangroves	15:00 (70 min)	26/11/2023	No
41	Barra Grande, municipality of Paraty	23°5’26”S, 44°43’9”W	26,632	9-15	Fourth stage of natural succession (*capoeira*)	09:04 (26 min)	20/12/2023	No
42	Barra Grande, municipality of Paraty	23°5’53”S, 44°42’52W	22,905	15-26	Fourth stage of natural succession (*capoeira*)	09:41 (22 min)	20/12/2023	No
43	Barra Grande, municipality of Paraty	23°5’52”S, 44°42’32”W	9,613	1-6	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*)	10:13 (24 min)	20/12/2023	No
44	Barra Grande, municipality of Paraty	23 °5’58”S, 44°42’19”W	132,947	1-5	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*)	12:48 (95min)	24/11/2023	No
45	Barra Grande municipality of Paraty	23°6’26”S, 44°42’49”W	55,352	5-7	Fourth stage of natural succession (*capoeira*)	16:46 (51 min)	24/11/2023	No
46	Barra Grande, municipality of Paraty	23°6’44”S, 44°43’22”W	12,647	9-20	Disturbed forests, Fifth stage of natural succession (*capoeirão*), pastures	17:40 (25 min)	24/11/2023	No
47	Estrada Rio Pequeno, municipality of Paraty	23°7’7”S, 44°43’45W	28,987	49-59	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*)	11:26 (14 min)	01/03/2024	No

Site number	Site name	Geographic coordinates (at the center of the site)	Area sampled (m^2)	Altitude (m above sea level)	Environment sampled	Sampling start time (total time of sampling)	Date	Presence of the species
48	Estrada Rio Pequeno, municipality of Paraty	23°7’15”S, 44°42’57”W	4,947	9-12	Second and third stages of natural succession (capoerinha), Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*)	11:07 (12 min)	20/12/2023	No
49	Graúna, municipality of Paraty	23°7’18”S, 44°42’15”W	48,657	4-5	Second and third stages of natural succession (capoerinha), Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*), pastures	11:07 (58 min)	29/02/2024	No
50	Graúna, municipality of Paraty	23°7’37”S, 44°42’33”W	29,695	5-10	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*), pastures, mangroves	10:32 (35 min)	29/02/2024	No
51	Graúna, municipality of Paraty	23°7’59”S, 44°43’12”W	53,912	5-11	Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*), pastures	05:48; 06:26; 09:08 (182 min)	24/11/23; 20/12/23; 29/02/24	No
52	Graúna, municipality of Paraty	23°7’55”S, 44°43’4”W	45,441	9-11	Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*)	07:28 (85 min)	24/11/23; 29/02/24	No
53	Mangue Praia do Rosa, municipality of Paraty	23°10’7”S, 44°42’34”W	5,051	7-9	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*), mangroves	08:14 (26 min)	29/02/2024	No
54	Trilha Praia do Rosa, municipality of Paraty	23°10’16”S, 44°42’10”W	64,115	40-50	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*)	06:23 (100 min)	29/02/2024	No
55	Bairro Ponte Branco, municipality of Paraty	23°13’39”S, 44°46’12”W	25,490	24-31	Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*)	07:08 (52 min)	26/11/2023	No
56	Rua das Seringueiras, municipality of Paraty	23°13’25”S, 44°45’11”W	7,412	10-12	Fourth stage of natural succession (capoeira)	06:32 (13 min)	26/11/2023	No
57	Bairro Condado, municipality of Paraty	23°13’13”S, 44°44’49”W	14,368	7-9	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession	05:30 (24 min)	26/11/2023	No

Site number	Site name	Geographic coordinates (at the center of the site)	Area sampled (m^2)	Altitude (m above sea level)	Environment sampled	Sampling start time (total time of sampling)	Date	Presence of the species
					(*capoeira*), marshes			
58	Bairro Condado, municipality of Paraty	23°13’11”S, 44°44’38”W	7,043	9-11	Second and third stages of natural succession (*capoerinha*)	06:02 (19 min)	26/11/2023	No
59	Estrada do Corisco, municipality of Paraty	23°14’3”S, 44°44’55”W	40,875	16-26	Fourth stage of natural succession (*capoeira*)	08:55 (22 min)	26/11/2023	No
60	Estrada do Corisco, municipality of Paraty	23°13’45”S, 44°43’31”W	9,812	7-10	Second and third stages of natural succession (*capoerinha*)	09:42 (13 min)	26/11/2023	No
61	Estrada do Corisco, municipality of Paraty	23°13’39”S, 44°44’6”W	16,340	4-5	Fourth stage of natural succession (*capoeira*)	10:54 (66 min)	26/11/2023	No
62	Estrada Marina Porto Imperial, municipality of Paraty	23°13’55”S, 44°43’18”W	13,242	4-6	Second and third stages of natural succession (*capoerinha*), mangroves	17:40 (13 min)	19/12/2023	No
63	Estrada Marina Porto Imperial, municipality of Paraty	23°14’16”S, 44°43’35”W	11,168	57-76	Disturbed forests, Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*)	18:03 (20 min)	19/12/2023	No
64	Rio dos Meros, municipality of Paraty	23°15’7”S, 44°42’23”W	25,123	6-19	Disturbed forests, Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*)	10:37 (50 min)	19/12/2023	No
65	Rio dos Meros, municipality of Paraty	23°15’32”S, 44°43’6”W	29,471	22-29	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*)	11:33 (39 min)	19/12/2023	No
66	Paraty Mirim, municipality of Paraty	23°14’29”S, 44°38’33W	92,261	5-22	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*)	05:43 (102 min)	19/12/2023	No
67	Paraty Mirim, municipality of Paraty	23°14’55”S, 44°39’4”W	15,483	9-16	Fourth stage of natural succession (*capoeira*)	17:06 (47 min)	23/11/2023	No
68	Paraty Mirim, municipality of Paraty	23°15’0”S, 44°39’22”W	22,557	15-23	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*)	07:40 (48 min)	19/12/2023	No

Site number	Site name	Geographic coordinates (at the center of the site)	Area sampled (m^2)	Altitude (m above sea level)	Environment sampled	Sampling start time (total time of sampling)	Date	Presence of the species
69	Paraty Mirim, municipality of Paraty	23°15’9”S, 44°39’20”W	9,374	23-37	Fourth stage of natural succession (*capoeira*)	16:36 (39 min)	23/11/2023	No
70	Paraty Mirim, municipality of Paraty	23°15’32”S, 44°39’34”W	15,478	76-80	Disturbed forests, Fourth stage of natural succession (*capoeira*), Fifth stage of natural succession (*capoeirão*)	08:35 (25 min)	19/12/2023	No
71	Estrada de Paraty Mirim, municipality of Paraty	23°16’8”S, 44°40’36”W	9,287	68-72	Second and third stages of natural succession (*capoerinha*), Fourth stage of natural succession (*capoeira*)	09:06 (14 min)	19/12/2023	No

Table 3. Number of individuals recorded of the Black-hooded Antwren (*Formicivora erythronotos*) in Rio de Janeiro State, southeastern Brazil.

Locality	Site sampled[1]	Number of individuals recorded	Environments occupied by the species	Observed impacts
Ariró, Ariró River, municipality of Angra dos Reis	14, 15, 16	6 (one banded)	Pioneer Formations of Lacustrine Influence at the shrub stage (primary marshes developing in abandoned meander), Second stage of natural succession (*capoeirinha*), Third stage of natural succession (*capoeira-rala*), Fourth stage of natural succession (*capoeira*), and Fifth stage of natural succession (*capoeirão*), occurred in flooded and floodable areas	Forest clearing, tree cutting, construction of houses, installation of wire fences, construction of drainage channels, landfilling, garbage dumping, presence of horses, regular presence of people, invasion of exotic plant species, and presence of roads
Mambucaba River Valley, municipalities of Angra dos Reis and Paraty	28	34 (27 banded)	Pioneer Formations of Fluvial Influence" at the shrub-arboreal stage (naturally developing in river margins and secondary marshes), Second stage of natural succession (*capoeirinha*), Third stage of natural succession (*capoeira-rala*), Fourth stage of natural succession (*capoeira*), and Fifth stage of natural succession (*capoeirão*), occurred in flooded, floodable, and non-floodable areas	Forest clearing, tree cutting, fires, construction of houses, installation of wire fences, construction of drainage channels, landfilling, garbage dumping, presence of horses, cattle, pigs, and cats, regular presence of people, invasion of exotic plant species, and presence of roads
Taquari River, municipality of Paraty	35	5 (one banded)	Second stage of natural succession (*capoeirinha*), Third stage of natural succession (*capoeira-rala*), Fourth stage of natural succession (*capoeira*), and Fifth stage of natural succession (*capoeirão*), occurred in floodable areas	Tree cutting, installation of wire fences, presence of cattle and horses, regular presence of people, and invasion of exotic plant species

[1]According to Table 2.

Table 4. Estimates of area of the occupied habitat, density, population size (adult individuals), and carrying capacity for the population viability analysis (PVA) of the Black-hooded Antwren (*Formicivora erythronotos*).

Locality	Area of the occupied habitat (km^2)	Habitat similar to occupied habitat (km^2)	Estimated current density (adult per km^2)	Population estimate	Area of potential habitat	Carrying capacity estimate
With records of the species						
Ariró, Ariró River, municipality of Angra dos Reis, Rio de Janeiro	0,512	---	---	13[1]	1.025	182[2]
Mambucaba River Valley, municipalities of Angra dos Reis and Paraty, Rio de Janeiro	8.606	---	18	154[3]	---[4]	2,685[5]
Taquari River, municipality of Paraty, Rio de Janeiro	0,145	---	---	14[1]	0.486	86[6]
Proposal for assisted colonization						
Puruba, Parque Estadual Serra do Mar, municipality of Ubatuba, São Paulo	---	8.398	---	---	---	1,494[7]
Total	9.263	---	---	181	---	4,447

[1]We evaluated how many pairs could be present in the area of the occupied habitat near the recording localities, but which we did not survey due to logistical constraints. For this, we proportionally relied on preliminary estimates of the home range size of pairs detected in the field at the respective locality (see Methods).

[2]Based on a prior density estimate for the locality of 178 adult individuals per km^2 and the area of potential habitat (Mendonça 2001).

[3]Based on estimated current density.

[4]Same as the area of the occupied habitat.

[5]Based on a prior density estimate for the locality of 312 adult individuals per km² (Mendonça 2001).

[6]Based on a density estimate for Ariró of 178 adult individuals per km² and the area of potential habitat (Mendonça 2001).

[7]Based on a density estimate for Ariró of 178 adult individuals per km² (Mendonça 2001).

Table 5. Habitat loss[1] (km^2) of the Black-hooded Antwren (*Formicivora erythronotos*). Average losses from model fitting.

Locality	Year						Total loss (%)	Average loss per year (%)	Average loss per year (km^2)
	1985	2004	2010	2015	2019	2024			
Ariró	11.687	4.222	3.660	3.438	2.580	2.025	82.67	4.57	0.244
Mambucaba River Valley	17.327	13.314	11.735	9.846	8.898	8.606	50.33	1.82	0.236
Taquari River	2.350	1.700	1.126	0.942	0.887	0.827	64.81	2.76	0.042

[1]It includes the area of occupied habitat and the area of potential habitat for the species, but also environments that might have been part of the potential habitat. However, these environments were not considered part of the species' geographic distribution (see Results).

Table 6. Green Status of the Black-hooded Antwren (*Formicivora erythronotos*) across its seven indigenous spatial units' populations and an eighth (Puruba), if the suggested assisted colonization occurs at this site. The status and fine-resolution weights resulting Green Score for the scenarios are presented. Abbreviations: EAR = expected additional range.

Spatial unit	Scenario		
	Current	Future-without-conservation	Future-with-conservation
"Site near Angra dos Reis", municipality of Angra dos Reis, Rio de Janeiro	Absent (0)	Absent (0)	Absent (0)
Ariró, Ariró River, municipality of Angra dos Reis, Rio de Janeiro	Present (1.5)	Absent (0)	Absent (0)
Bracuí / Frade, municipality of Angra dos Reis, Rio de Janeiro	Absent (0)	Absent (0)	Absent (0)
Mambucaba River Valley, municipalities of Angra dos Reis and Paraty, Rio de Janeiro	Present (1.5)	Absent (0)	Absent (0)
Taquari River, municipality of Paraty, Rio de Janeiro	Present (1.5)	Absent (0)	Absent (0)
Barra Grande, municipality of Paraty, Rio de Janeiro	Absent (0)	Absent (0)	Absent (0)
São Gonçalo, municipality of Paraty, Rio de Janeiro	Absent (0)	Absent (0)	Absent (0)
Puruba, Parque Estadual Serra do Mar, municipality of Ubatuba, São Paulo	none	None	Functional (8)
Green Score-Indigenous	6.43%	0.00%	Not applicable
Green Score-with EAR	5.63%	NA	10.00%

Table S1. Historical and current localities with records of the Black-hooded Antwren (*Formicivora erythronotos*).

Locality	Source	Geographic coordinates	Sites sampled[1]
Ariró, Ariró River, municipality of Angra dos Reis	Gonzaga (2008)	No provided	13, 14, 15, 16
Barra Grande, municipality of Paraty	Gonzaga (2008)	Not provided	41, 42, 43, 44, 45, 46
Bracuí, municipality of Angra dos Reis	Gonzaga (2008)	Not provided	23, 24, 25, 26, 27
Fazenda Ariró, municipality of Angra dos Reis	Mendonça (2001)	22°54’S, 44°20’W	13, 14, 15, 16
Fazenda São Gonçalo, municipality of Paraty [same as São Gonçalo]	Buzzetti (1998)	Not provided	30, 31, 32
Frade, municipality of Angra dos Reis	Gonzaga (2008)	Not provided	No
Frade (= Cunhambebe), municipality of Angra dos Reis	Collar et al. (1992), Tobias & Williams (1996)	Not provided	No
Mambucaba River Valley, municipality of Angra dos Reis and Paraty	Buzzetti (1998), Mendonça (2001), Gonzaga (2008)	22°57’S, 44°33’W; 22°66’S, 44°34’W	28
Mangaratiba [same as Serra do Piloto]	Gonzaga (2008)	Not provided	9, 10
São Gonçalo, municipality of Paraty [same as Fazenda São Gonçalo]	Gonzaga (2008)	Not provided	30, 31, 32
Serra do Piloto, municipality of Mangaratiba [same as Mangaratiba]	Mendonça (2001), Gonzaga (2008)	Not provided	3, 4, 5, 6, 7, 8
“Site near Angra dos Reis”, municipality of Angra dos Reis	Pacheco (1988), Tobias & Williams (1996)	23°00’S, 44°18'W	---[2]
Taquari River, municipality of Paraty	Gonzaga (2008)	Not provided	34, 35, 36

[1]According to Table 2.

[2]There is no more native vegetation in the 2020s.

Table S2. Distribution of sampled sites for the search of the Black-hooded Antwren (*Formicivora erythronotos*) across target environments and elevation ranges, Rio de Janeiro State, southeastern Brazil.

Habitat	Number of sampled sites[1] altitudinal range (m above sea level)						Total
	0-50	51-100	401-450	451-500	501-550	551-600	
Disturbed forests (Lowland Dense Ombrophilous Forest and Submontane Dense Ombrophilous Forest)	14	2		4			20
Capoeirão (Fifth stage of natural succession)	37	2		1	1		41
Capoeira (Fourth stage of natural succession)	57	4	1	4	2	1	69
Capoeira-rala and/or *capoeirinha* (Third and Second stages of natural succession)	37	3		3	2	1	47
Pastures (First stage of natural succession)	7			2	2	1	12
Mangroves (Pioneer Formations of Fluvio-Marine Influence)	13						13
Marshes (Pioneer Formations of Lacustrine Influence, Pioneer Formations of Fluvial Influence, and Pioneer Formations of Fluvio-Marine Influence)	5		1				6

[1]According to Table 2.

Table S3. Probability (%) of extinction of the Black-hooded Antwren (*Formicivora erythronotos*).

Carrying capacity (K)	Scenarios	Entire populations					Ariró					Mambucaba River Valley (without removal of individuals)					Taquari River				
		Generations			Years		Generations			Years		Generations			Years		Generations			Years	
		1	2	3	50	100	1	2	3	50	100	1	2	3	50	100	1	2	3	50	100
K according remaining habitat	Optimistic	0.0	0.0	0.0	0.0	0.1	1.9	5.7	14.3	60.4	84.8	0.0	0.0	0.0	0.0	0.1	1.5	4.6	10.7	52.9	82.9
	Baseline	0.0	0.0	0.0	12.5	44.3	4.6	19.6	41.9	96.2	99.6	0.0	0.0	0.0	12.6	44.3	3.8	15.2	36.6	94.5	99.5
	Pessimistic	0.0	0.0	0.2	89.7	100.0	12.7	43.4	77.9	100.0	100.0	0.0	0.0	0.6	89.7	100.0	9.1	40.6	74.2	100.0	100.0
Linear reduction of K	Optimistic	0.0	0.0	0.0	100.0	100.0	1.4	100.0	100.0	100.0	100.0	0.0	0.0	0.0	100.0	100.0	1.2	3.6	9.2	100.0	100.0
	Baseline	0.0	0.0	0.0	100.0	100.0	3.8	100.0	100.0	100.0	100.0	0.0	0.0	0.1	100.0	100.0	2.9	13.2	33.4	100.0	100.0
	Pessimistic	0.0	0.0	0.3	100.0	100.0	8.9	100.0	100.0	100.0	100.0	0.0	0.0	0.5	100.0	100.0	7.9	34.3	71.2	100.0	100.0
Percentage reduction of K	Optimistic	0.0	0.0	0.0	0.0	0.0	1.9	5.5	11.9	60.5	100.0	0.0	0.0	0.0	0.0	0.0	1.0	3.3	8.0	52.8	99.9
	Baseline	0.0	0.0	0.0	10.5	42.1	4.4	17.0	39.0	94.9	100.0	0.0	0.0	0.1	10.7	42.1	3.1	12.5	33.6	93.7	100.0
	Pessimistic	0.0	0.0	0.2	87.0	100.0	9.8	38.3	74.9	100.0	100.0	0.0	0.0	0.5	87.0	100.0	8.4	35.3	71.5	100.0	100.0

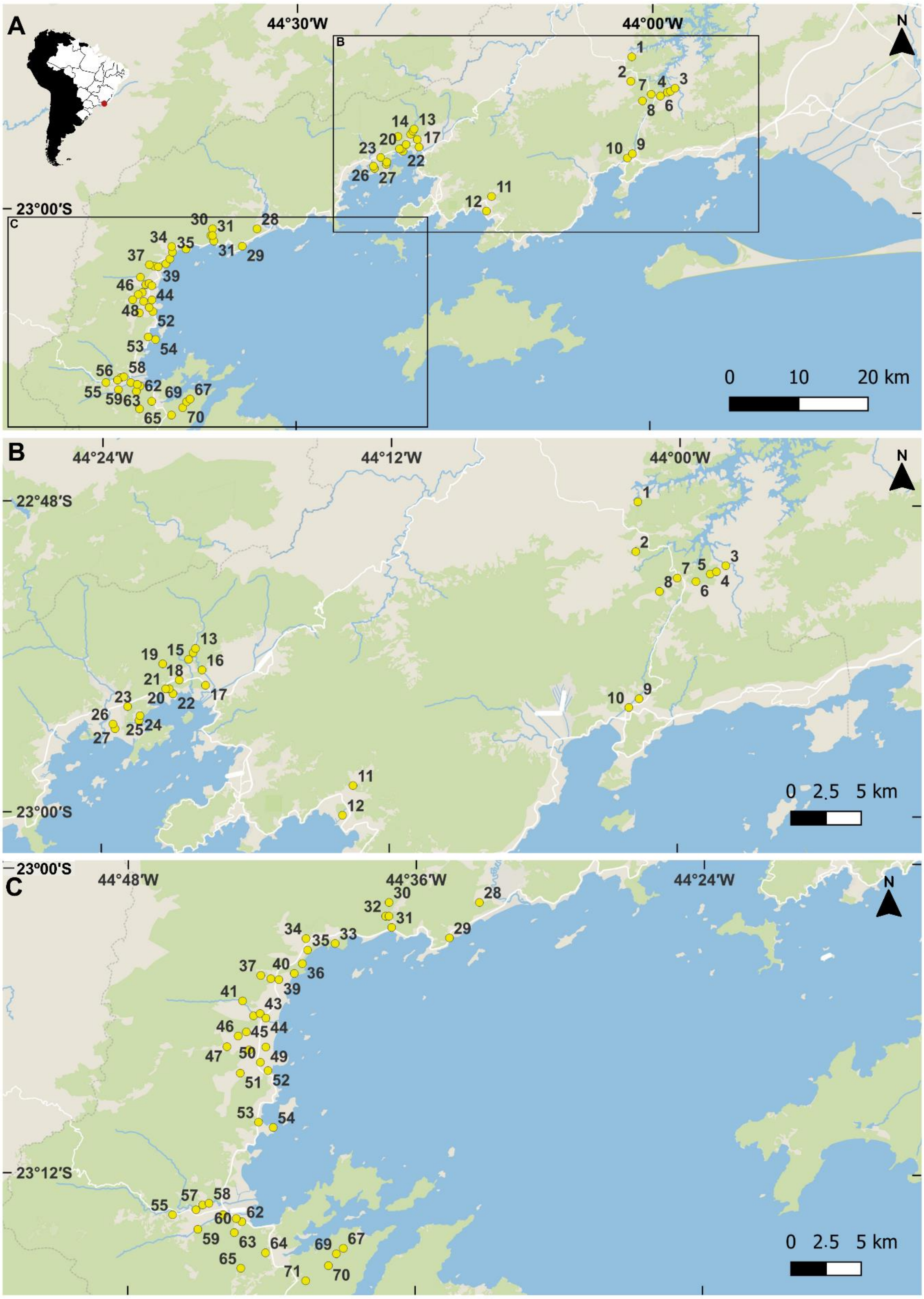

Figure 1. Location of sites sampled for the detection of the Black-hooded Antwren (*Formicivora erythronotos*), Rio de Janeiro State, southeastern Brazil. A. Entire study region. B. Zoom of the northern part of the study region. C. Zoom of the southern part of the study region. Background images obtained from the Cloud-Native Location Intelligence Platform CARTO, using QGIS software.

Figure 2. Examples of habitats where the Black-hooded Antwren (*Formicivora erythronotos*) was recorded, Rio de Janeiro State, southeastern Brazil. A. Taquari River, municipality of Paraty. B. Mambucaba River Valley, municipality of Angra dos Reis. C. Taquari River, municipality of Paraty. D. Ariró, municipality of Angra dos Reis. Photographs: B and D by Sabryna Grogia Mühringer; A and C by Marcos R. Bornschein.

Figure 3. Impacts on habitats where the Black-hooded Antwren (*Formicivora erythronotos*) was recorded, Rio de Janeiro State, southeastern Brazil. A. Presence of cattle in Taquari River, municipality of Paraty. B. Presence of a horse in Ariró, municipality of Angra dos Reis. C. Public road fragmenting the occupied habitat in Ariró, municipality of Angra dos Reis. D. Disposal of debris in Ariró, municipality of Angra dos Reis. Photographs: A and B by Mariana Marques; C by Pedro Marciano; D by Sabryna Grogia Mühringer

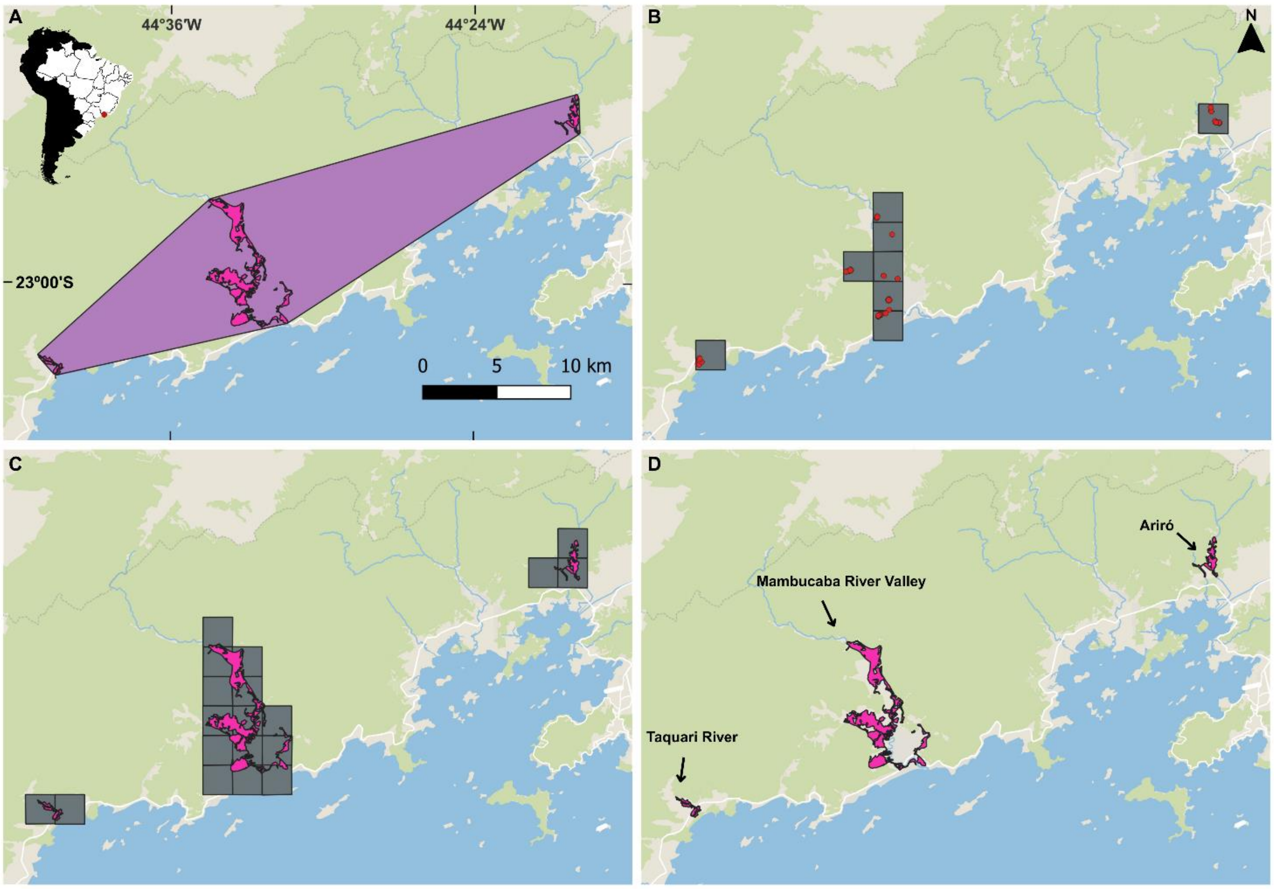

Figure 4. Geographic distribution of the Black-hooded Antwren (*Formicivora erythronotos*) in Rio de Janeiro State, Brazil. A. Extent of occurrence (EOO), based on occupied habitat. B. Lower bound area of occupancy (AOO), based on current records of the species. C. Upper bound AOO, based on occupied habitat. D. Occupied habitat. Background images obtained from the Cloud-Native Location Intelligence Platform CARTO, using QGIS software.

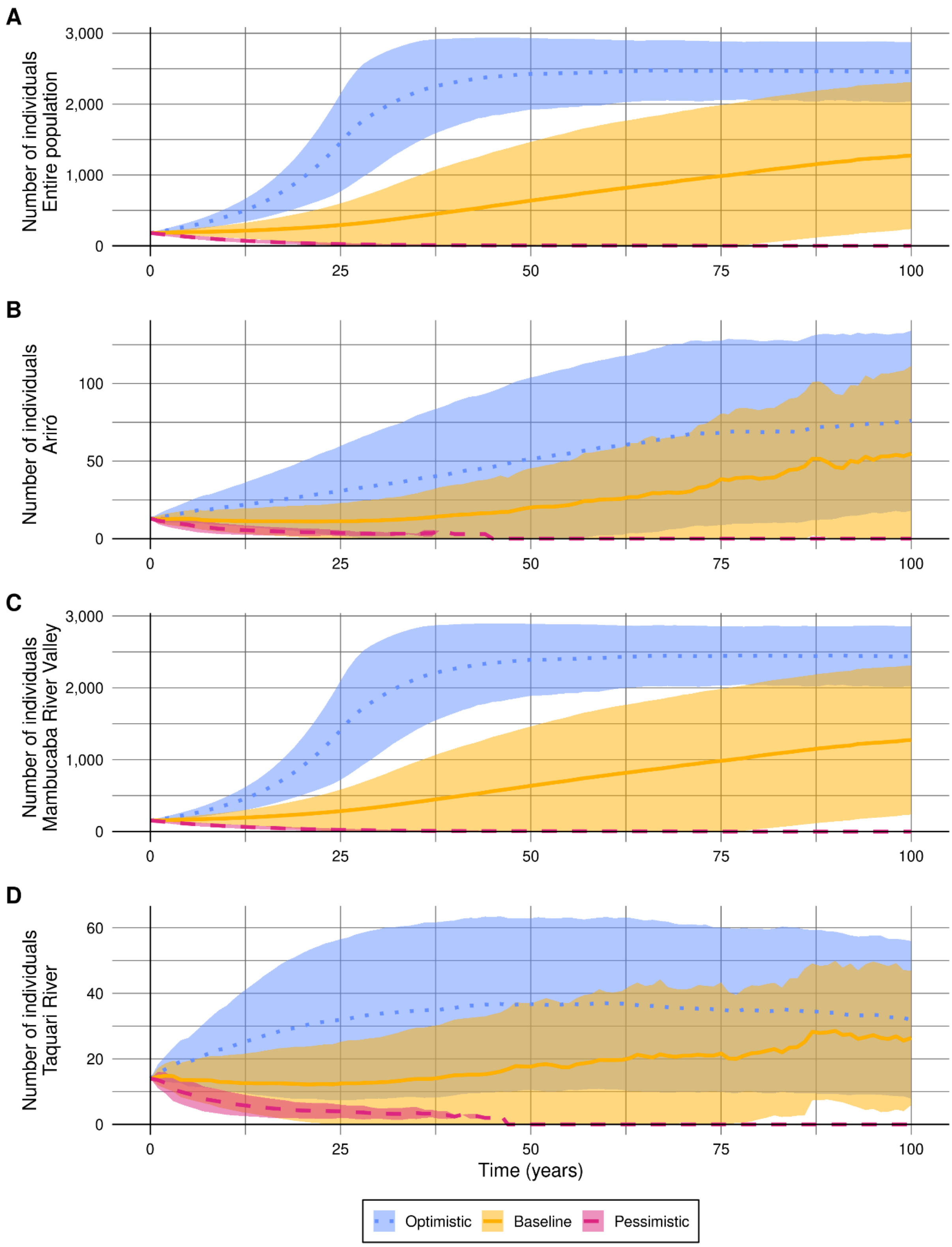

Figure 5. Estimated number of Black-hooded Antwren (*Formicivora erythronotos*) individuals projected using VORTEX, under the Optimistic (blue dotted), Baseline (orange solid), and Pessimistic (dashed magenta) scenarios. A. Entire species population. B. Ariró population. C. Mambucaba River Valley population. D. Taquari River population.

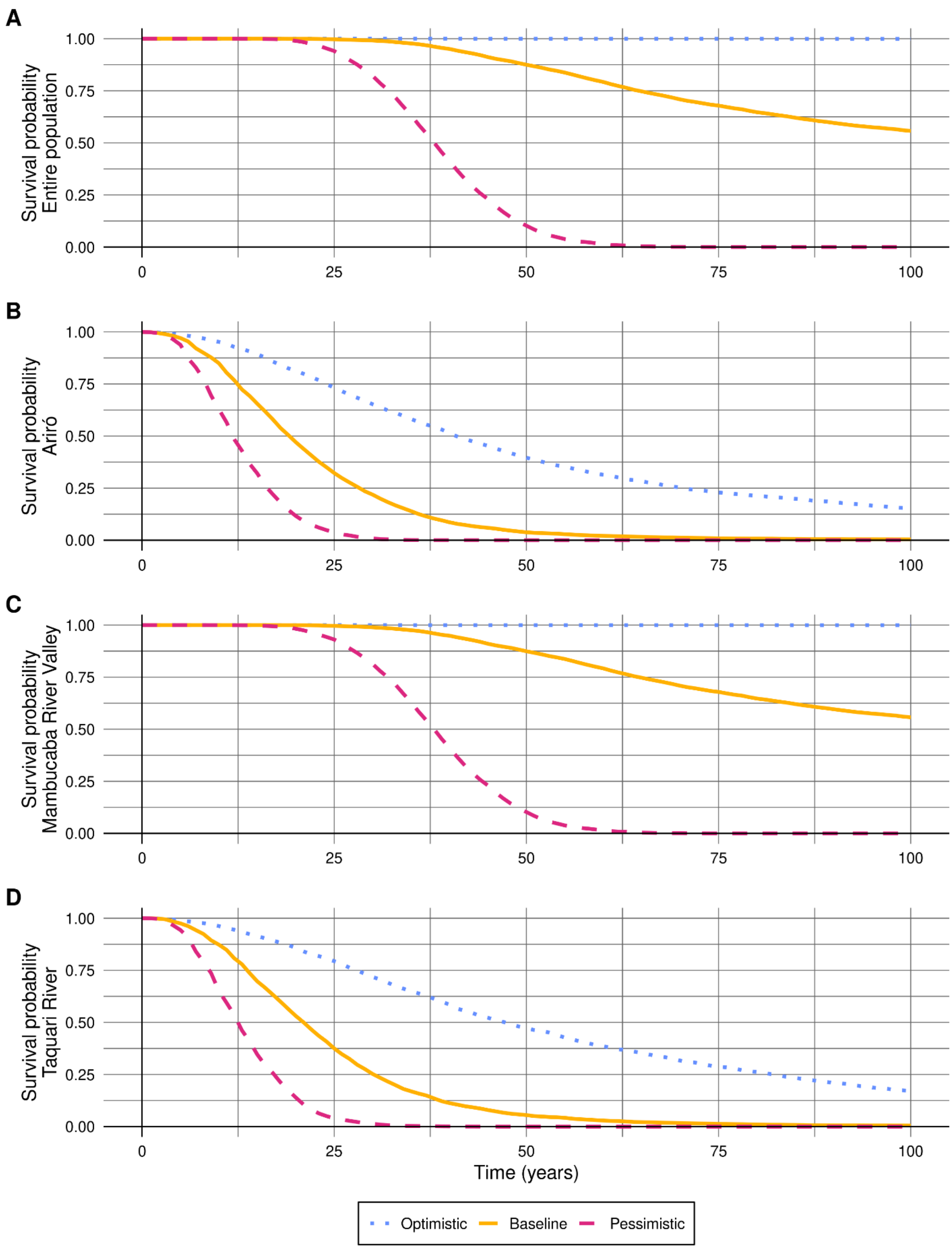

Figure 6. Probability of survival for the Black-hooded Antwren (*Formicivora erythronotos*) projected using VORTEX, under the Optimistic (blue dotted), Baseline (orange solid), and Pessimistic (dashed magenta) scenarios. A. Entire species population. B. Ariró population. C. Mambucaba River Valley population. D. Taquari River population.

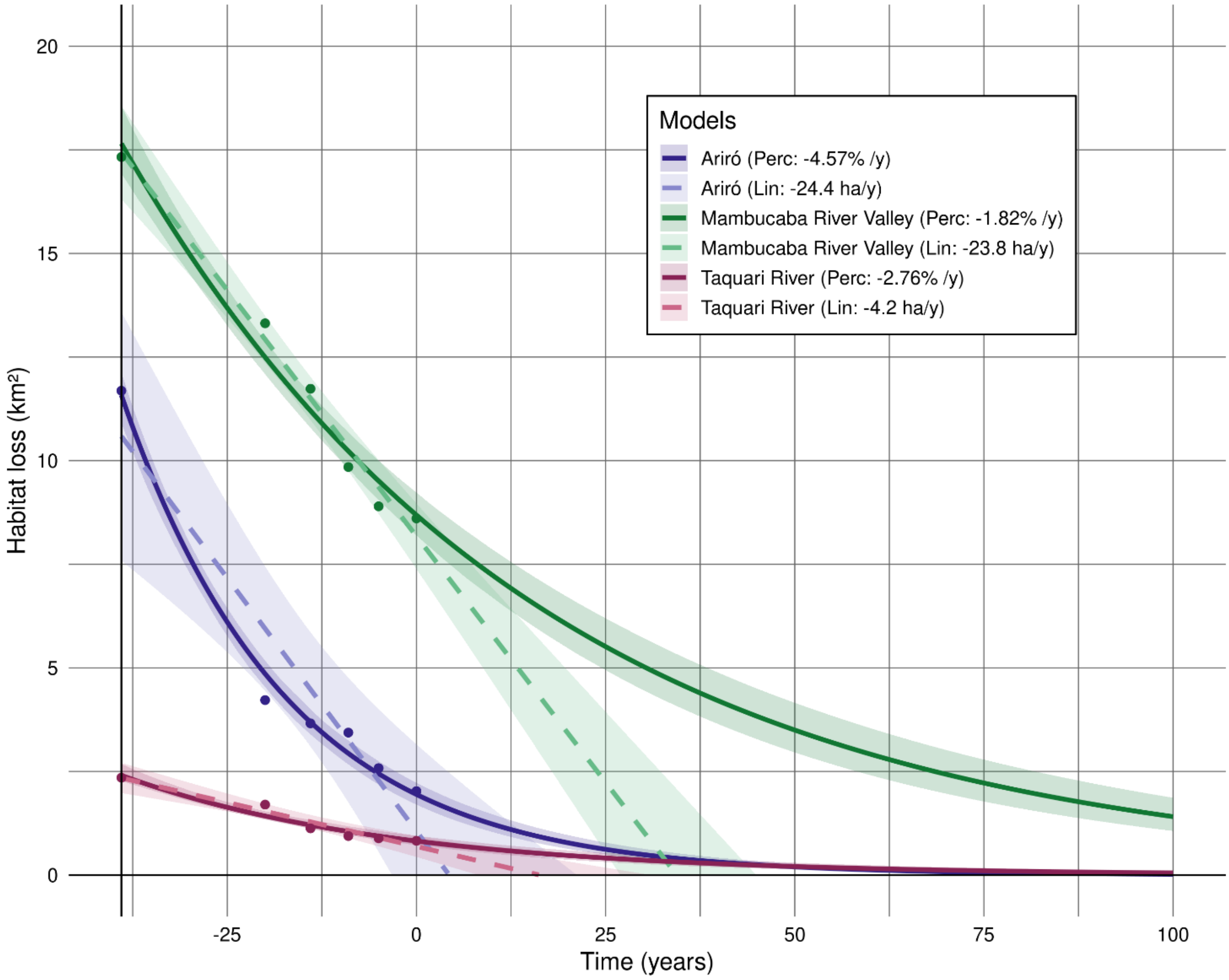

Figure 7. Projections of habitat loss for the Black-hooded Antwren (*Formicivora erythronotos*), based on analysis of Google Earth Pro Satellite imagery from 1985 to 2024, using two approaches: linear habitat loss reduction ("Lin") and percentage-based habitat loss reduction ("Perc"). Ariró is shown in light blue, the Mambucaba River Valley in light green, and the Taquari River in lilac.

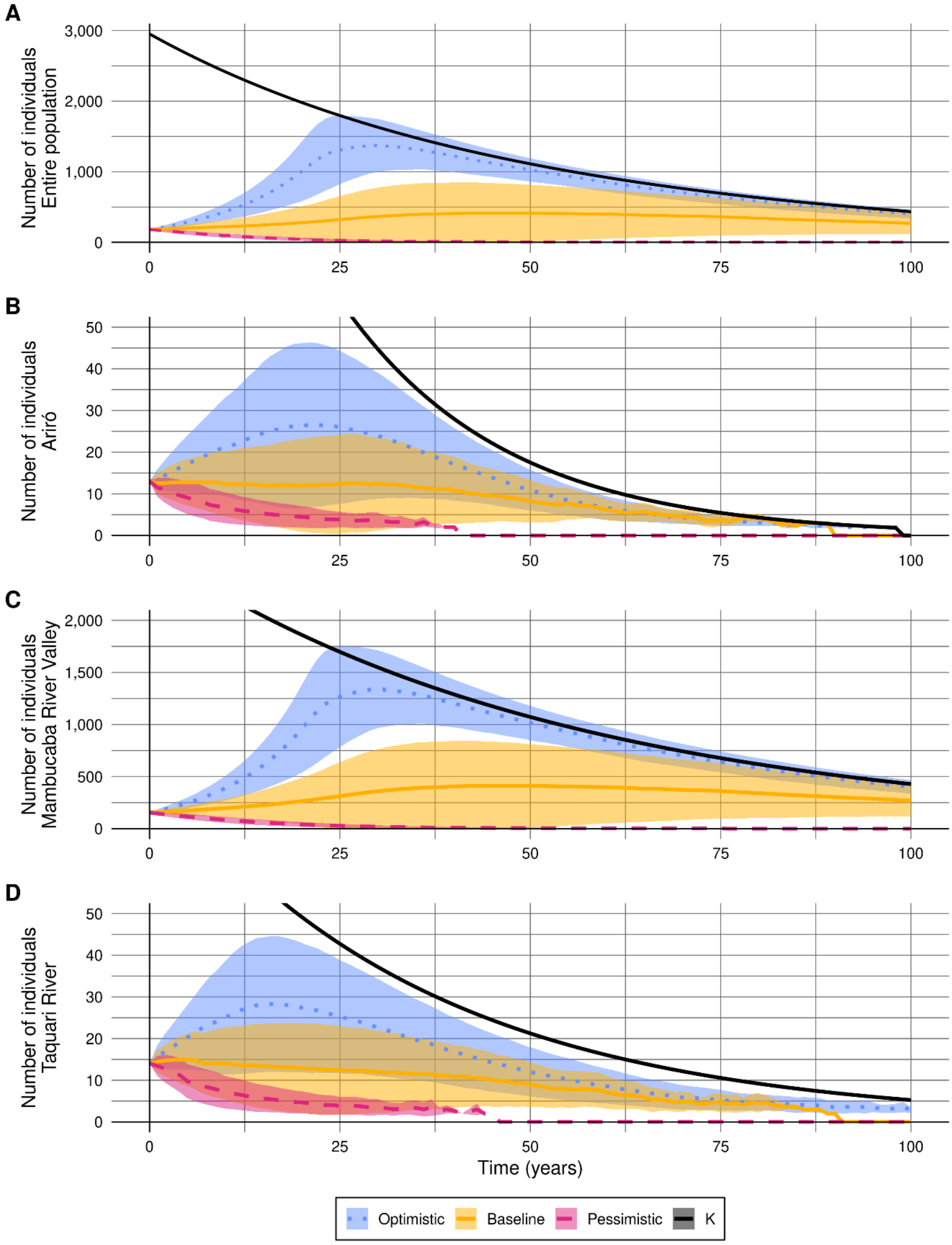

Figure 8. Estimated number of Black-hooded Antwren (*Formicivora erythronotos*) individuals projected using VORTEX, under the Optimistic (blue dotted), Baseline (orange solid), and Pessimistic (dashed magenta) scenarios, incorporating a reduction in carrying capacity (K, solid black) due to habitat loss in the model. This reduction in K was calculated from a percentage-based decrease in habitat (see Figure 7). A. Entire species population. B. Ariró population. C. Mambucaba River Valley population. D. Taquari River population.

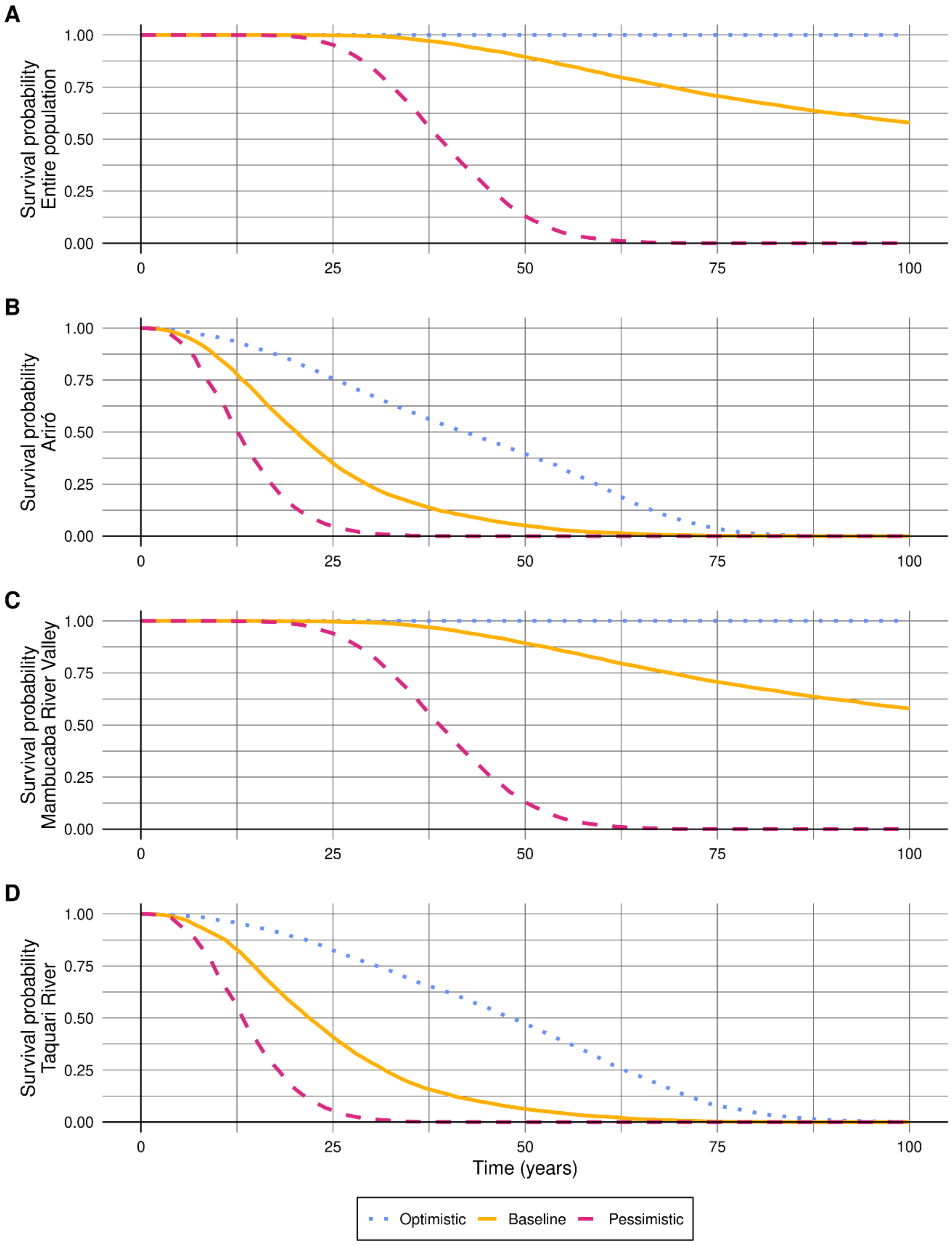

Figure 9. Probability of survival for the Black-hooded Antwren (*Formicivora erythronotos*) projected using VORTEX, under the Optimistic (blue dotted), Baseline (orange solid), and Pessimistic (dashed magenta) scenarios, incorporating a reduction in carrying capacity (K) due to habitat loss in the model. This reduction in K was calculated from a percentage-based decrease in habitat (see Figure 7). A. Entire species population. B. Ariró population. C. Mambucaba River Valley population. D. Taquari River population.

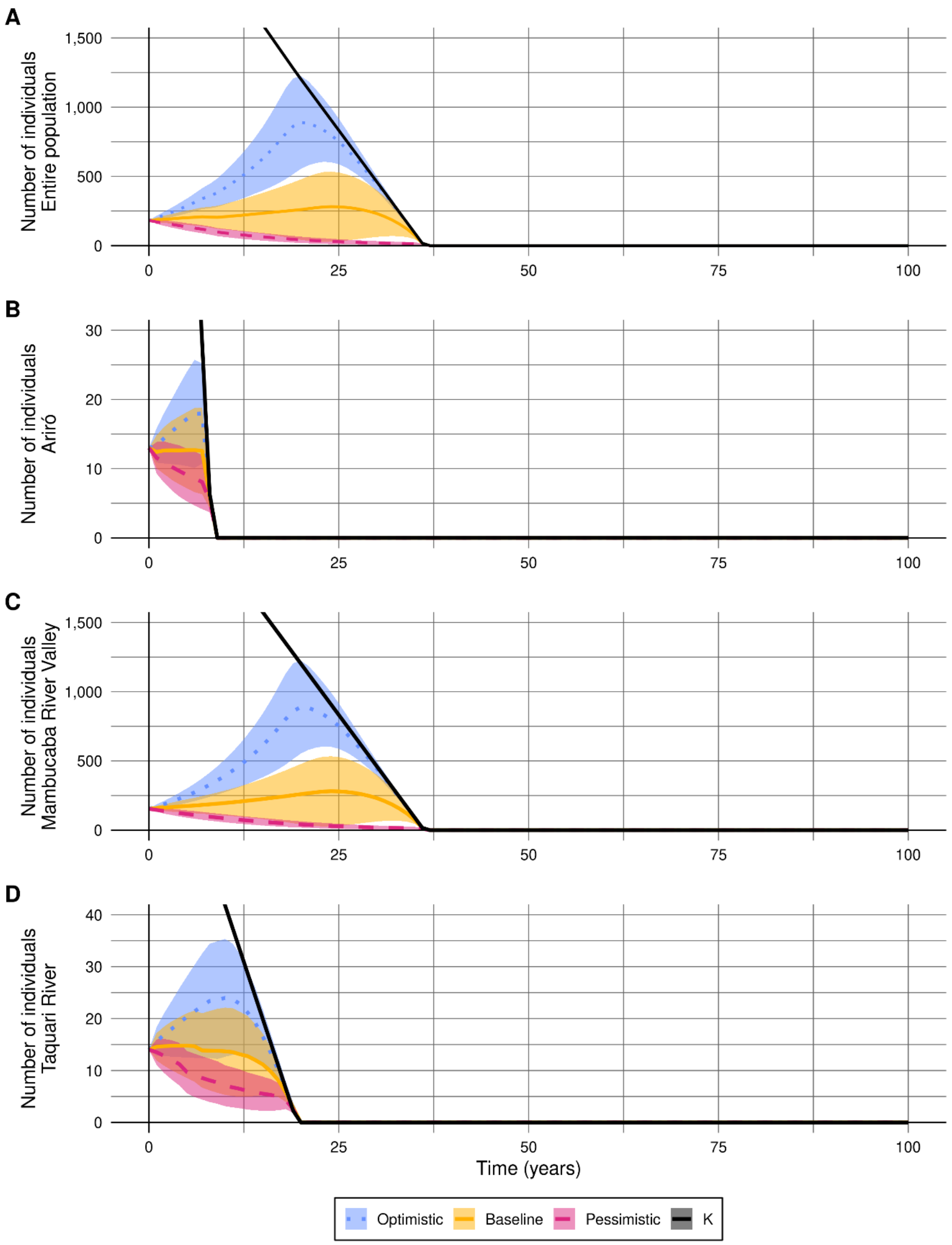

Figure 10. Estimated number of Black-hooded Antwren (*Formicivora erythronotos*) individuals projected using VORTEX, under the Optimistic (blue dotted), Baseline (orange solid), and Pessimistic (dashed magenta) scenarios, incorporating a reduction in carrying capacity (K) due to habitat loss in the model. This reduction in K was calculated from a linear decrease in habitat (see Figure 7). A. Entire species population. B. Ariró population. C. Mambucaba River Valley population. D. Taquari River population.

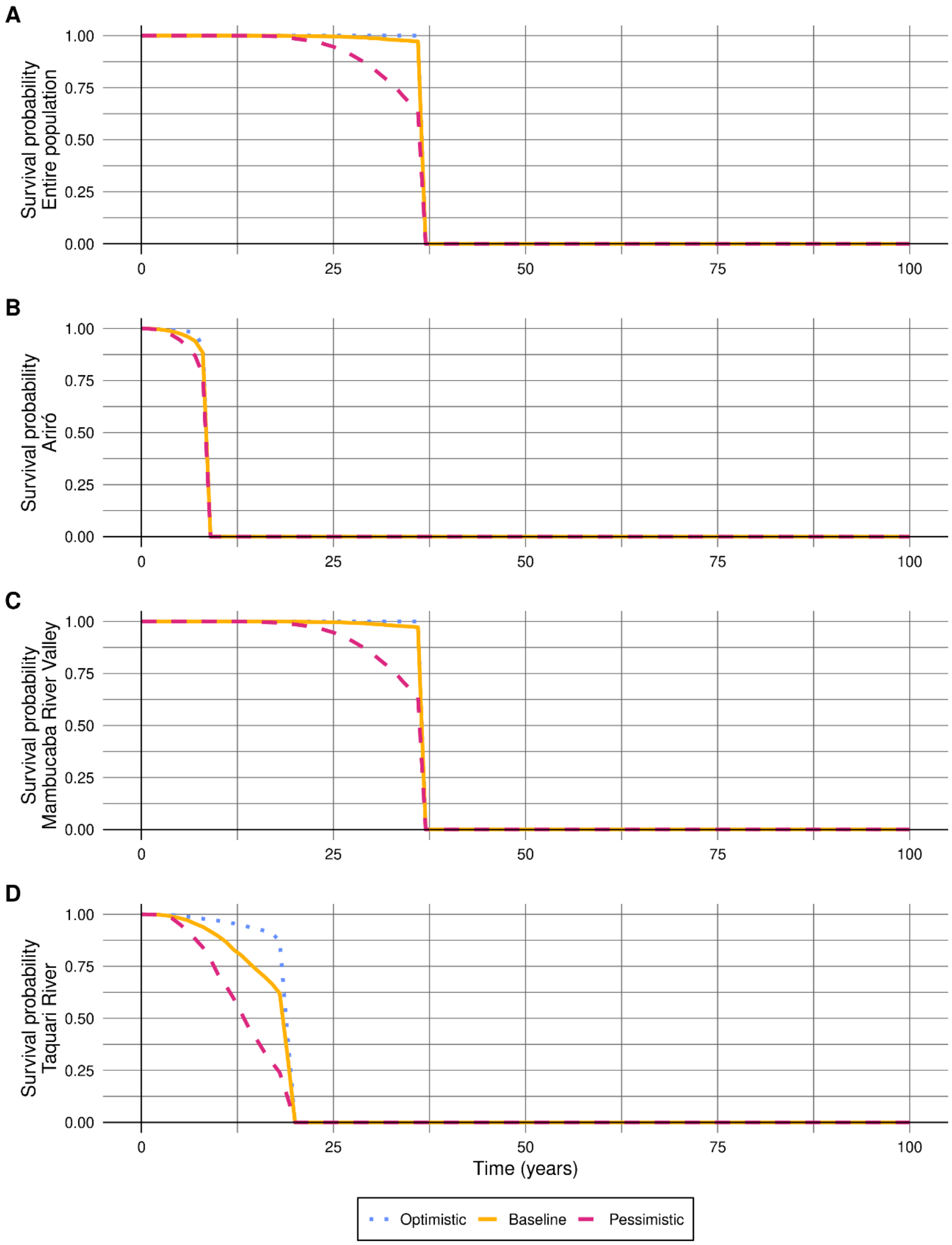

Figure 11. Probability of survival for the Black-hooded Antwren (*Formicivora erythronotos*) projected using VORTEX, under the Optimistic (blue dotted), Baseline (orange solid), and Pessimistic (dashed magenta) scenarios, incorporating a reduction in carrying capacity (K) due to habitat loss in the model. This reduction in K was calculated from a linear decrease in habitat (see Figure 7). A. Entire species population. B. Ariró population. C. Mambucaba River Valley population. D. Taquari River population.

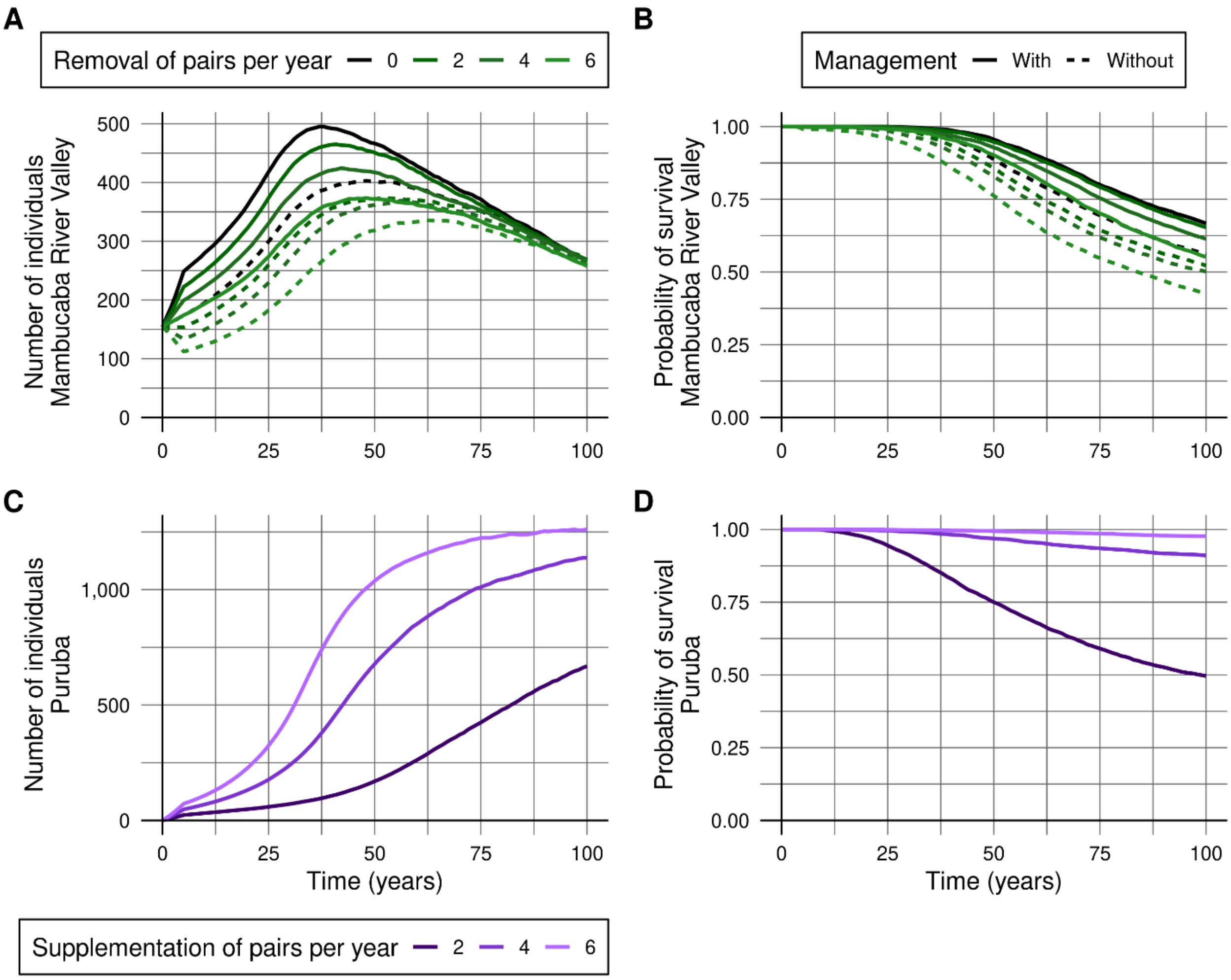

Figure 12. Effects of individual removal and supplementation for the assisted colonization of the Black-hooded Antwren (*Formicivora erythronotos*) over five years in Puruba, municipality of Ubatuba, São Paulo, sourced from the Mambucaba River Valley population, municipalities of Angra dos Reis and Paraty, Rio de Janeiro, projected using VORTEX. The removal of 10 individuals (2 pairs/year), 20 individuals (4 pairs/year), and 30 individuals (6 pairs/year) are considered. The Mambucaba River Valley was modeled using the baseline scenario, while Puruba was modeled under the optimistic scenario. A. Number of individuals from the Mambucaba River Valley under scenarios with (solid lines) and without environmental management (dashed lines). B. Probability of survival in the Mambucaba River Valley under scenarios with (solid lines) and without environmental management (dashed lines). C. Number of individuals in Puruba. D. Probability of survival in Puruba.

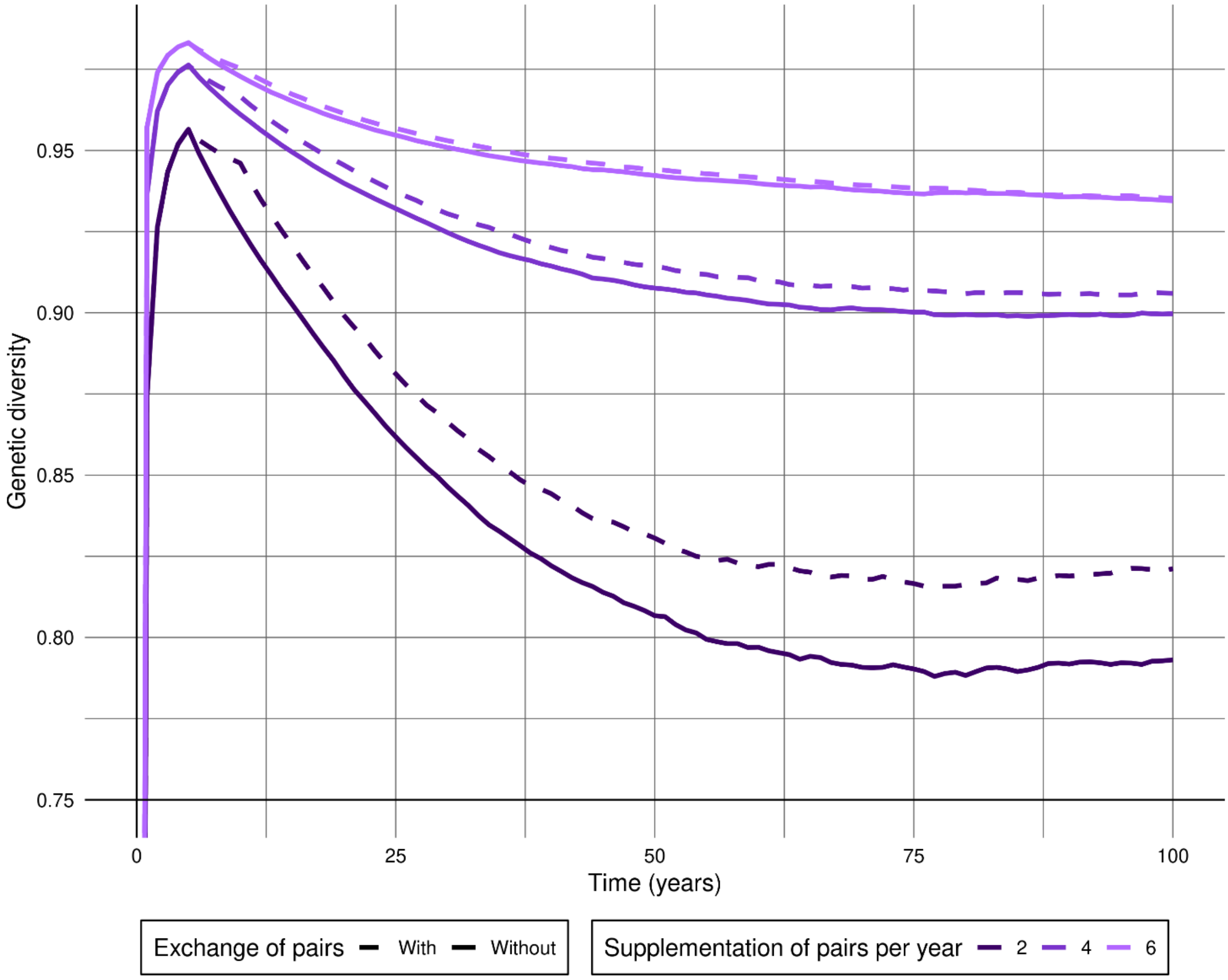

Figure 13. Genetic diversity (solid lines) of individuals in Puruba with the introduction of 10 individuals over five years (2 pairs/year), 20 individuals over five years (4 pairs/year), and 30 individuals over five years (6 pairs/year), projected using VORTEX. Dashed lines indicate the genetic diversity if four individuals (two pairs) are exchanged with the Mambucaba River Valley population per year for five years after the end of the introduction.

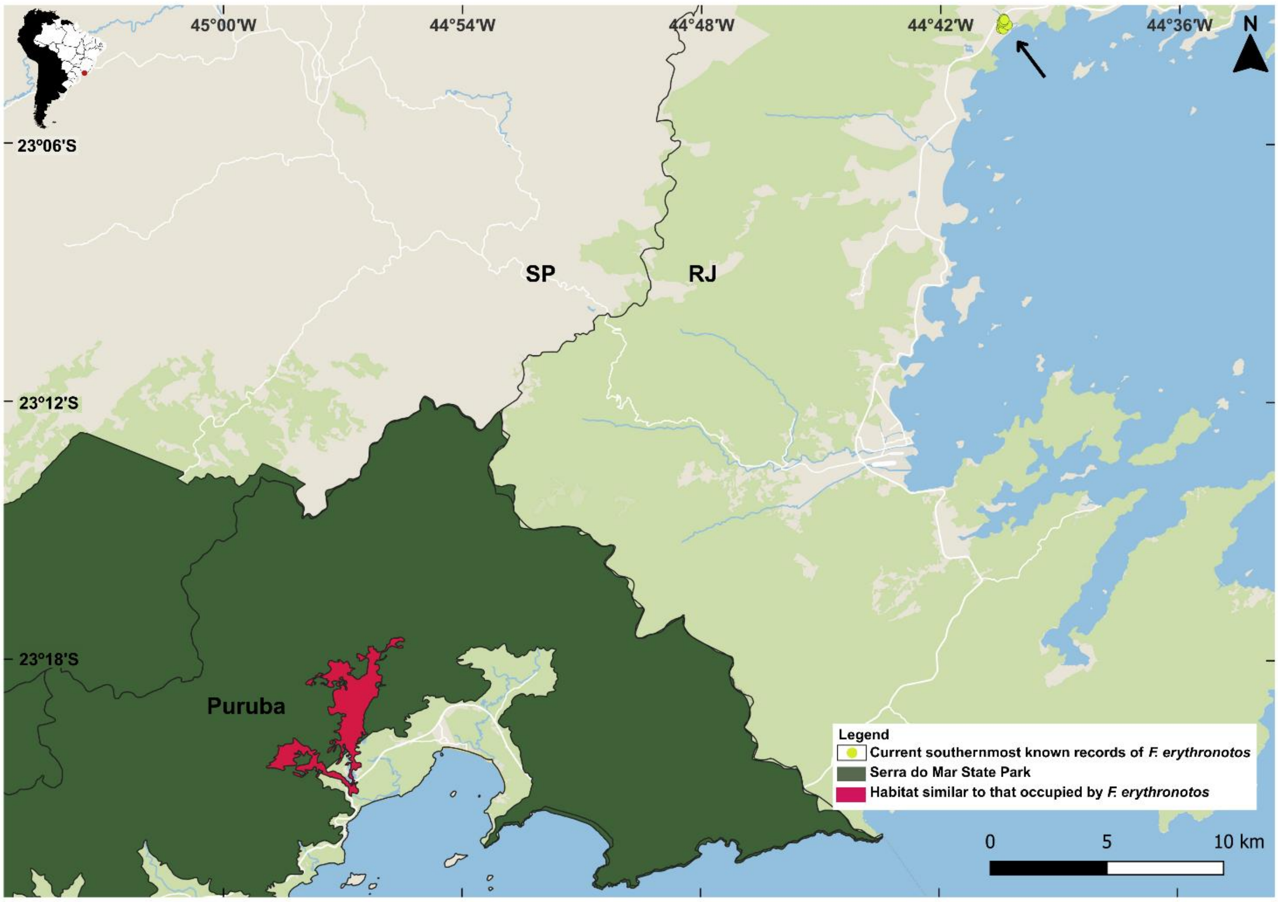

Figure S1. Suggested area for assisted colonization of Black-hooded Antwren (*Formicivora erythronotos*) in the municipality of Ubatuba, São Paulo State, southeastern Brazil (Puruba, in pink). The arrow indicates the current southernmost records (yellow dots) of the species, in Taquari River, municipality of Paraty, Rio de Janeiro State. Background images obtained from the Cloud-Native Location Intelligence Platform CARTO, using QGIS software.