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TWO HUNDRED YEARS OF BOTANICAL RECORDS: LEGUMINOSAE TREE SPECIES DIVERSITY IN A BRAZILIAN ATLANTIC FOREST HOTSPOT

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The Reserva Biológica do Tinguá (REBIO Tinguá) is a protected area in the state of Rio de Janeiro comprising around 26,000 ha of Brazilian Atlantic Forest. We present an updated floristic inventory of Leguminosae tree species in the REBIO Tinguá. Pre-existing herbarium collections and field expeditions carried out in 2021 and 2022 were used as the basis for (i) assembling a comprehensive taxonomically verified checklist of the legumes, (ii) revealing species distribution patterns across the Submontane ('tingua_s') and Montane/High Montane Dense Ombrophilous ('tingua_ma') Forest physiognomies of the REBIO Tinguá, and (iii) an UPGMA-based floristic similarity analysis to compare the REBIO Tinguá with 28 other areas of Atlantic Forest in Rio de Janeiro state. Of the total 67 legume tree species identified, 35 are endemic to the Atlantic Forest, six are new occurrences for the area, and seven are listed under different threat categories. The legume-based similarity analysis showed clusters that largely reflect the environmental heterogeneity of the region, where 'tingua_ma' is grouped with Macaé de Cima, Mendanha and Santo Aleixo, while 'tingua_s' is grouped with Paraty Mirim, Pedra Branca, Poço das Antas, Tijuca and REBIO Union. Our study shows that new records can be made for the REBIO Tinguá, despite it being one of the most thoroughly inventoried areas in the state. Our results reinforce the importance of the REBIO Tinguá for biodiversity conservation, because of its great extent, altitudinal amplitude, and above all, its central position in the state, integrating the Mosaico Central Fluminense and the Tinguá–Bocaina biodiversity corridor.

Keywords. Biological collections, conservation, Fabaceae, floristic similarity, Reserva Biológica do Tinguá
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Introduction

The Atlantic Forest once constituted 15% of Brazilian territory, with 1.3 million km^2. However, due to anthropic pressures, today it is represented by a highly fragmented landscape, where about 80% of the remaining forest fragments are only 50 ha or less (Ribeiro *et al.*, 2009). Remarkably, these remaining areas have rare, endemic

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and endangered species, making the Atlantic Forest one of the world's most threatened biodiversity hotspots (Hrdina & Romportl, 2017). The state of Rio de Janeiro corresponds to one of these areas of high plant richness, having 21% of the total area of Atlantic Forest remnants and 14.6% of endemic species of angiosperms from Brazil (BFG, 2015; Coelho *et al.*, 2017; Fundação SOS Mata Atlântica & Instituto Nacional de Pesquisas Espaciais, 2019).

The Atlantic Forest of the Reserva Biológica do Tinguá (REBIO Tinguá), located in Rio de Janeiro, is a protected area that has been a focus for conservation, research, and environmental education (MMA–IBAMA, 2006). The REBIO Tinguá contains botanical records from the early nineteenth century to surveys conducted in the 1990s (Saint-Hilaire, 1822 [1974]; Pohl *et al.*, 1827; Glaziou, 1905; Stafleu & Cowan, 1979). During the past century, the Leguminosae were among the main botanical families inventoried (Braz *et al.*, 2004; MMA–IBAMA, 2006; Iguatemy *et al.*, 2017). Iguatemy *et al.* (2017) produced the most recent checklist of tree species from the REBIO Tinguá based on specimens deposited in herbarium collections, from which they cited 70 species of Leguminosae.

The Leguminosae play a significant role in Neotropical forest ecology, contributing significantly to species richness and influencing carbon and nitrogen cycles (Lima, 2000; Yahara *et al.*, 2013). Given their association with the nitrogen cycle, they are important for restoring degraded environments (Yahara *et al.*, 2013; LPWG, 2017; Schultze-Kraft *et al.*, 2018). Most of the observed high floristic richness across the Atlantic Forest of Rio de Janeiro is attributable to Leguminosae tree species with regional and local richness patterns reflecting historical and ecological processes in this physiographic diverse part of the Atlantic coastal mountain chain (BFG, 2015; Coelho *et al.*, 2017; Lima, 2000).

To facilitate conservation efforts in the REBIO Tinguá, it is essential to have a comprehensive understanding of the native Leguminosae species, particularly those that are endemic or endangered. This knowledge, combined with a taxonomically authoritative checklist, can inform conservation priorities and guide efforts to monitor and protect these species from the negative impacts of human activities (Primack & Rodrigues, 2001; MMA–IBAMA, 2006; Coelho *et al.*, 2017). The aim of the present study is to enhance our understanding of Leguminosae tree species found in the REBIO Tinguá, using inventory data collected over almost two centuries.

Material and methods

Study site

The REBIO Tinguá protected area was created through Brazilian Federal Government Decree No. 97,780 of 23 May 1989 to protect its biodiversity-rich Atlantic Forest (MMA–IBAMA, 2006; Leitão *et al.*, 2022). Located on the northern edge of the Baixada Fluminense, about 70 km from the capital of Rio de Janeiro state (22°22'20"S, 43°40'00"W and 22°45'00"S,

43°05'40"W; see **Figure 1A–C**), it protects an area of around 26,000 ha, most of which is concentrated in the municipality of Nova Iguaçu, with smaller stretches in Duque de Caxias, Miguel Pereira and Petrópolis (**Figure 1C,D**).

The area is an important source of fresh water and is located on the watersheds Baía de Guanabara, Baía de Sepetiba and Rio Paraíba do Sul (all the rivers that drain from the REBIO Tinguá are born within its limits), and its forests, rivers and springs are protected (MMA–IBAMA, 2006). The central region of the REBIO Tinguá is characterised by high altitudes with steeper and irregular slopes (Silva & Sousa, 2017), rugged scarps, and rivers (**Figure 1B**), all of which make access difficult.

The vegetation is subject to a high level of protection, and primary and secondary vegetation range from initial to advanced regeneration stages. Altitudes range from almost sea level to around 1600 m at Pico do Tinguá, the highest point (MMA–IBAMA, 2006). The REBIO Tinguá vegetation is considered Dense Rainforest (*sensu* IBGE, 2012), in which four phytophysiognomies can be distinguished: Submontane Forest (from 50 m up to 500 m), Montane Forest (from 500 m up to 1500 m), High Montane Forest (above 1500 m) and Alpine Fields (above 1800 m).

The regional climate is classified as tropical humid (*Cwb*, *sensu* Köppen, 1936), with cool and rainy summers, although the mountain peaks can become quite dry during the dry season. Mean annual temperatures vary between 13 and 23°C, and mean annual rainfall is between 1500 and 2600 mm, but this is unevenly distributed throughout the year, with maximum precipitation occurring during December and February. The regional soils include red and yellow dystrophic argisols and latosols, red eutrophic argisols, and haplic eutrophic cambisols (MMA–IBAMA, 2006; Albuquerque *et al.*, 2010; Gadelha *et al.*, 2015; Iguatemy *et al.*, 2017).

Data collection and analyses

Leguminosae tree species diversity in the REBIO Tinguá. A survey of herbarium records was initially conducted using the following online databases: JABOT (2022), Reflora (2021), speciesLink (CRIA, 2021) and *Catálogo Mata Atlântica* (http://catalogo-ppbio.jbrj.gov.br, accessed in March 2021 but now unavailable). A taxonomically verified checklist of Leguminosae based on vouchered herbarium specimens was assembled for the REBIO Tinguá. A nomenclatural review was carried out based on Flora e Funga do Brasil (2021) to correct or update the nomenclature. Names previously circumscribed in *Abarema* Pittier, *Albizia* Durazz., *Enterolobium* Mart., *Pseudopiptadenia* Rauschert and *Stryphnodendron* Mart. were revised based on taxonomic reviews published after *Flora do Brasil 2020* (e.g. Soares *et al.*, 2021; Borges *et al.*, 2022; Lima *et al.*, 2002, 2022; Peraza *et al.*, 2022; Scalon *et al.*, 2022; Soares *et al.*, 2022; Souza *et al.*, 2022). The identification of new records was checked by comparison with the protologue of the species, with material identified by other legume

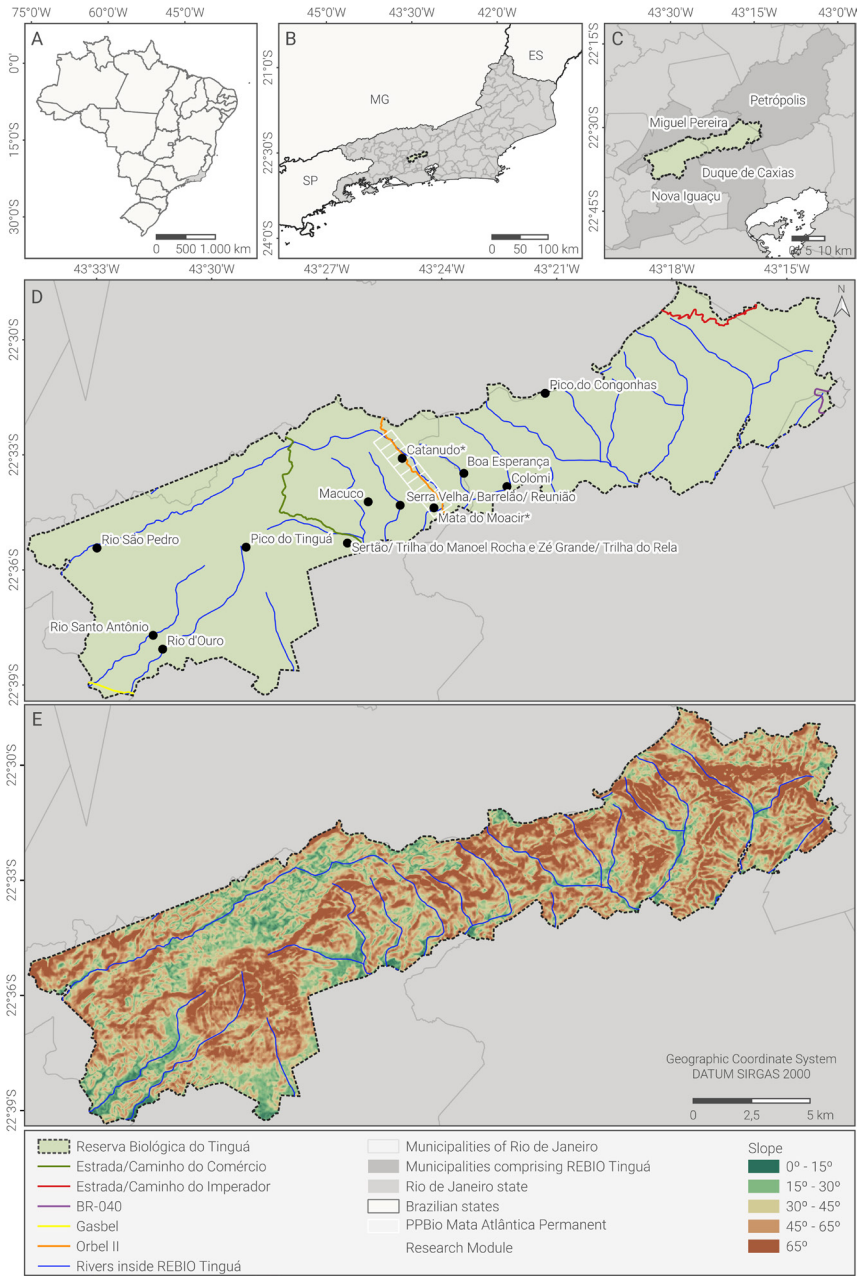

Figure 1. A, Location of Rio de Janeiro state within Brazil. B, The Reserva Biológica do Tinguá (REBIO Tinguá) within Rio de Janeiro state (ES, Espírito Santo; MG, Minas Gerais; SP, São Paulo SP). C, REBIO Tinguá in relation to the municipalities of Nova Iguaçu, Duque de Caxias, Miguel Pereira and Petrópolis. D, REBIO Tinguá, showing major rivers, roads, the BR-040 highway, and major pipelines. E, a topology map of REBIO Tinguá, highlighting slope angles.

taxonomists, and with reference to the specialised bibliography for each taxon. The results were updated on JABOT (2022) and Reflora (2021).

A total of five field surveys were carried out between 2021 and 2022, to gather information on Leguminosae from the area and to determine if data on legume species composition could be used help identify Submontane, Montane, and High Montane Dense Ombrophilous Forest, and also to understand how legume species are shared across these vegetation physiognomies. The following sites were visited: Boa Esperança, Estrada do Comércio, Estrada do Imperador, BR-040, Macuco, Orbel II and Serra Velha/ Barrelão/Reunião (see **Figure 1A**). The herbarium specimens made were deposited in RB with duplicates sent to HB, RBR, K and NY (herbarium codes follow Thiers, continuously updated). Flowers were collected in 70% ethyl alcohol and were deposited in the RB spirit collection.

The assembled dataset was used as the basis from which to track the accumulation of legume species collected in the REBIO Tinguá over time until 2022. To explore the collecting effort of legume specimens across the REBIO Tinguá, maps were made using the R packages *rnaturalearth* (South, 2017), *rnaturalearthhires* (South, 2022), *sf* (Pebesma, 2018) and *ggplot2* (Wickham, 2016). The classification of species according to their conservation status at the national level was based on Brasil (2022). The types of phytophysiognomies recorded were based on field observations and the altitudinal variation registered by coordinates, following IBGE (2012). Legume species not mentioned in other published works focused on the REBIO Tinguá (Lima, 2000; Braz *et al.*, 2004; Iguatemy *et al.*, 2017) were considered as new occurrence records for the area.

Similarity analysis. The taxonomically verified REBIO Tinguá checklist was compared floristically with a legume species checklist assembled from 28 areas of rain, semideciduous and restinga forests in the state of Rio de Janeiro (**Table 1**) with more than 30 recorded species of Leguminosae. The species inventories from these areas were initially generated from the NeoTropTree platform (Oliveira-Filho, 2017). NeoTropTree sites are delimited by a radius of 5 km from a centre based on the geographical coordinates provided. However, the circular area not only defines the site but also its environmental heterogeneity, as different vegetation types can co-occur inside this area (Eisenlohr & Oliveira-Filho, 2015). Only native Leguminosae were selected for each site obtained using NeoTropTree, and each species was checked against the herbarium databases, JABOT (2022), Reflora (2021), speciesLink (CRIA, 2021), *Catalogo Mata Atlântica* (http://catalogo-ppbio.jbrj.gov.br, accessed in March 2021 but now unavailable), and published ecological inventory studies to confirm their occurrence. Species not found in the databases or inventory studies were excluded from the analysis. These lists were also supplemented with new occurrence records from our review of herbarium collections. The total number of legume tree species used in the similarity analysis was 186.

Table 1. Details of the 28 localities of the Rio de Janeiro state, Brazil, whose data were used in the similarity analysis for two areas of the Reserva Biológica do Tinguá (REBIO Tinguá)

Code	Name	Maximum altitude (m)	Coordinates
marica	APA da Restinga de Maricá	6	−22.94900, −42.81000
macae_cima	APA de Macaé de Cima	1720	−22.44080, −42.56940
cabofrio	Cabo Frio (Morros Piaçava & Mico)	90	−22.87700, −41.98800
carapebus	Carapebus	15	−22.22280, −41.61030
guaxindiba	Estação Ecológica Estadual de Guaxindiba	25	−21.39330, −41.09580
i_cabofrio	Ilha de Cabo Frio	341	−22.99800, −41.99000
jurubatiba	Jurubatiba	13	−22.14200, −41.39000
itaoca	Maçico do Itaoca	420	−21.79360, −41.44810
r_marambaia	Marambaia, Restinga	13	−23.04830, −43.86940
massambaba	Massambaba	13	−22.94060, −42.13060
bomjesus	Mata do Bom Jesus	15	−21.71600, −41.26400
funil	Mata do Funil	28	−21.55220, −41.20060
a_mourão	Morro Alto Mourão	412	−22.96780, −43.02390
paraty_mirim	Paraty Mirim	6	−23.24060, −44.63720
pbranca	Parque Estadual da Pedra Branca	1024	−22.94060, −43.44810
mendanha	Parque Estadual do Mendanha	964	−22.82100, −43.49500
e_prsul	Praia do Sul, Encosta	271	−23.16190, −44.26080
r_prsul	Praia do Sul, Restinga	15	−23.17300, −44.28300
poco_antas	REBIO de Poço das Antas	200	−22.54100, −42.28700
tingua_ma	REBIO do Tinguá (Montane/High Montane)	1416	−22.59140, −43.48000
tingua_s	REBIO do Tinguá (Submontane)	345	−22.58541, −43.43810
uniao	REBIO União	360	−22.43700, −42.03000
grumari	Restinga de Grumari	12	−23.04750, −43.52530
caruara	RPPN Caruara	6	−21.74500, −41.03610
st_aleixo	Santo Aleixo	277	−22.53810, −43.06580
capoeira_gr	Serra da Capoeira Grande	159	−22.94110, −43.62780
emerencias	Serra das Emerencias	46	−22.81500, −41.95810
sapiatiba	Serra de Sapiatiba	300	−22.82170, −42.15690
tijuca	Tijuca	1021	−22.96360, −43.30140
trindade	Trindade	67	−23.33030, −44.68060

APA, Área de proteção ambiental (Environmental Protection Area); REBIO, Biological Reserve; RPPN, Reserva Particular do Patrimônio Natural (Private Natural Heritage Reserve).

The Jaccard index was used as a measure of similarity between areas, and a dendrogram was generated using the UPGMA clustering method (UPGMA: unweighted pair group method with arithmetic mean). These analyses were performed using the R packages *vegan* version 2.6-4 (Oksanen *et al.*, 2022), *cluster* version 2.1.4 (Maechler *et al.*, 2022), *ggplot2* (Wickham, 2016), *ggdendro* version 0.1.23 (Vries & Ripley, 2022) and *ggord* version 1.1.7 (Beck & Mikryukov, 2022). Although the study area is demarcated by political boundaries, given its vast extension and altitudinal gradient, it was decided to conduct a more ecologically meaningful analysis. Instead of comparing the total list of Leguminosae

tree species from the REBIO Tinguá in terms of similarity, the list was divided into two based on the phytophysiognomies 'tingua_s' (Submontane: from 50 m up to 500 m in altitude, comprised of Boa Esperança, BR-040, Catanudo, part of Estrada do Comércio, Macuco, Rio d'Ouro and Serra Velha) and 'tingua_ma' (Montane/High Montane: from 500 m up to above 1500 m in altitude, comprising part of Estrada do Comércio, Estrada do Imperador, Orbel II and Pico de Tinguá). This division into two phytophysiognomies reflected the fact that that the composition of Leguminosae species relates to altitudinal gradient (Silva *et al.*, 2016). Venn diagrams (Gotelli & Ellison, 2016) were produced to visualise legume species shared between both phytophysiognomies.

Results and discussion

Legume tree species diversity in the Reserva Biológica do Tinguá

The REBIO Tinguá harbours a total of 67 legume tree species, distributed over 40 genera and including representatives of all five subfamilies that occur in Brazil (Caesalpinioideae, Cercidoideae, Detarioideae, Dialioideae and Papilionoideae; **Table 2**). The Caesalpinioideae is the richest subfamily, with 33 species, followed by Papilionoideae with 26 and Detarioideae with five. Cercidoideae and Dialioideae are represented by one species each. The genus *Inga* Mill. is the most species-rich (10 species), followed by *Swartzia* Schreb. and *Tachigali* Aubl., with four species each, and *Machaerium* Pers., with three species.

A floristic checklist of species published by Iguatemy *et al.* (2017) cited 70 Leguminosae species for the REBIO Tinguá. After reviewing the herbarium specimens cited, eight names were synonymised and three identifications were corrected. The lianas cited (*Dalbergia frutescens* (Vell.) Britton, *Machaerium cantarellianum* Hoehne, *Senegalia grandistipula* (Benth.) Seigler & Ebinger and *Senegalia martiusiana* (Steud.) Seigler & Ebinger) were not considered in this study. It was not possible to confirm the occurrence of the tree, *Inga capitata* Desv., or a sterile record of *Abarema* cf. *cochliocarpos* (Gomes) Barneby & J.W.Grimes (*L.P.Queiroz* 15858 [HUEFS 207924]).

Six new occurrence records were found through our survey of herbarium materials: *Barnebydendron riedelii* (Tul.) J.H.Kirkbr., *Hymenolobium janeirense* Kuhlm., *Inga lenticellata* Benth., *Platypodium elegans* Vogel, *Swartzia simplex* (Sw.) Spreng. and *Zollernia glabra* (Spreng.) Yakovlev (**Figure 2**). *Barnebydendron riedelii* was recorded from just one collection made by Glaziou in 1873 (deposited in the P herbarium) and referred to by Glaziou as from the Serra de Tinguá on both the collecting tag and in his collecting notes (Glaziou, 1905). There is also a single sterile collection of *Hymenolobium janeirense* made in 1995 at Serra Velha by P. R. Farag and H. C. Lima. The records of *Inga lenticellata*, *Platypodium elegans* and *Swartzia simplex* were made by H. C. Lima in 2017, after publication of the Iguatemy *et al.* (2017) checklist, and the presence of *Inga lenticellata* (*L.S.J. Deccache* 64) and *Swartzia*

Table 2. Checklist of Leguminosae tree taxa (67 spp.) in the Reserva Biológica do Tinguá (REBIO Tinguá), Rio de Janeiro, Brazil, including information on IUCN conservation status, phytophysiognomy recorded in the REBIO Tinguá, and distribution in the REBIO Tinguá

Species	Conservation status[a]	Phytophysiognomy[b]	Distribution[c]	Voucher
Andira fraxinifolia Benth.*	–	S	CA	RB 322322
Andira ormosioides Benth.*,†	–	S	BE	RB 434233
Apuleia leiocarpa (Vogel) J.F.Macbr.	VU	S	EC, SV	RB 419642
Barnebydendron riedelii (Tul.) J.H.Kirkbr.‡	–	–	–	P 00281338
Bauhinia forficata Link*,†	–	S, M	EC, SV	RB 360205
Cassia ferruginea (Schrad.) Schrad. ex DC.*,†	–	S, M	EC, SV	RB 424059
Centrolobium robustum (Vell.) Mart. ex Benth.*	–	S, M	EC, O2, SV	RB 764236
Chamaecrista ensiformis (Vell.) H.S.Irwin & Barneby	–	S, M	BE, CA, MC, PT, SV	RB 354507
Copaifera lucens Dwyer*,†	–	M, H	CA, EI, O2, PT	RB 419649
Copaifera trapezifolia Hayne*,†	–	S, M	EC, SV	RB 773768
Dahlstedtia pinnata (Benth.) Malme*,†	–	S, M	EC, MC, SR	RB 668191
Dalbergia foliolosa Benth.*	–	M, H	EI, O2	RB 438121
Dalbergia nigra (Vell.) Allemão ex Benth.*,†	VU	S	SV	RB 751873
Dimorphandra exaltata Schott*,†	EN	–	MM	RB 322280
Erythrina verna Vell.*,†	–	S	EC	RB 358794
Exostyles venusta Schott*,†	–	S	O2	RB 773793
Hymenaea altissima Ducke*,†	–	S	CA, SV	RB 493438
Hymenolobium janeirense Kuhlm.*,†,‡	–	S	SV	RB 322328
Inga bullata Benth.*,†	–	S	BE, MC	RB 360883
Inga edulis Mart.	–	S	CA, EC	RB 322299
Inga flagelliformis (Vell.) Mart.	–	M	SV	RB 419732
Inga lanceifolia Benth.*,†	–	S, M	CA, EC, PT	RB 324998
Inga lenticellata Benth.*,†,‡	–	M	EC, MC, O2	RB 657156
Inga marginata Willd.	–	S, M	CA, EC, O2, SR, SV	RB 778778
Inga mendoncaei Harms*,†	EN	M	EC, O2	RB 574926
Inga sessilis (Vell.) Mart.*	–	M	EC, O2	RB 632486
Inga striata Benth.	–	S	CA, EC, MC, SV	RB 322298
Inga tenuis (Vell.) Mart.*,†	–	S	CA, SR	RB 322301
Jupunba langsdorffii (Benth.) M.V.B.Soares, M.P.Morim & Iganci*	–	M, H	CA, EI, PT	RB 419646
Jupunba villosa (Iganci & M.P.Morim) M.V.B.Soares, M.P.Morim & Iganci*	–	S	CA, EC, MC, SV	RB 322295
Machaerium brasiliense Vogel	–	M	MM, O2	RB 544948
Machaerium hirtum (Vell.) Stellfeld	–	S	EC, MC, SV	RB 322333
Machaerium nyctitans (Vell.) Benth.	–	S	CA, EC, EI, O2, SV	RB 438111
Marlimorimia contorta (DC.) G.P.Lewis & M.P.Lima*	–	S	EC, SV	RB 322314
Marlimorimia warmingii (Benth.) L.P.Queiroz & P.G.Ribeiro*,†	–	S	SV	RB 322319
Moldenhawera polysperma (Vell.) Stellfeld*,†	VU	S, M	BE, CA, CL, EC, O2, PT, SR	RB 613520

Species	Conservation status[a]	Phytophysiognomy[b]	Distribution[c]	Voucher
Muellera filipes (Benth.) M.J.Silva & A.M.G.Azevedo*,†	VU	S	EC	RB 359783
Myrocarpus frondosus Allemão	–	S	MC, SV	RB 645043
Ormosia fastigiata Tul.*	–	S, M	BE, CA, EI, O2, SV	RB 419638
Peltogyne angustiflora Ducke*,†	–	S	CA, EC	RB 322285
Peltophorum dubium (Spreng.) Taub.	–	S	EC	RB 422435
Piptadenia gonoacantha (Mart.) J.F.Macbr.	–	S	EC, MC, SV	RB 322310
Piptadenia paniculata Benth.*	–	S	CA, SV	RB 419634
Pityrocarpa inaequalis (Benth.) L.P.Queiroz & Marc.F.Simon*,†	–	S, M	BE, EC, O2, PT, SV	RB 773796
Pityrocarpa schumanniana (Taub.) L.P.Queiroz & L.M.Borges*,†	–	S, M	CA, EC, PT, SV	RB 358792
Platycyamus regnellii Benth.*	–	S	CA, EC, SV	RB 378627
Platymiscium floribundum Vogel*,†	–-	M	EC, O2	RB 423363
Platymiscium pubescens Micheli	–	M	O2	RB 438155
Platypodium elegans Vogel‡	–	S	EC, BR-040	RB 755706
Pseudalbizzia polycephala (Benth.) E.J.M.Koenen & Duno*	–	S	EC, SV	RB 419734
Pterocarpus violaceus Vogel	–	S	MC, SV	RB 378623
Robrichia glaziovii (Benth.) A.R.M.Luz & É.R.Souza*,†	–	S, M	BE, EC, MC, SV	RB 373297
Schizolobium parahyba (Vell.) Blake*,†	–	S	EC	RB 358816
Senna macranthera (DC. ex Collad.) H.S.Irwin & Barneby	–	M	O2	RB 438154
Senna multijuga (Rich.) H.S.Irwin & Barneby	–	M	BR-040, EC, O2	RB 438132
Stryphnodendron dryaticum Scalon*,†	–	S	EC, MM	RB 322321
Swartzia apetala Raddi*	–	S, M, H	BE, EI	RB 419647
Swartzia flaemingii Raddi*	–	S	EC, MC, SV	RB 829902
Swartzia myrtifolia Sm.*,†	–	S	CA, EC, SV	W 0026967
Swartzia simplex (Sw.) Spreng.*,†,‡	–	S	EC, MC	RB 773770
Tachigali beaurepairei (Harms) L.G.Silva & H.C.Lima*,†	EN	M, H	BR-040, EC, EI	RB 666416
Tachigali paratyensis (Vell.) H.C.Lima*,†	–	S, M	EC, SV	RB 490739
Tachigali pilgeriana (Harms) Oliveira-Filho*,†	–	S, M	BE, CA, EC, O2	RB 438158
Tachigali urbaniana (Harms) L.G.Silva & H.C.Lima*,†	–	S	EC, MC, MM, RO, SV	R-Tipos 8767
Vatairea heteroptera (Allemão) Ducke*,†	–	S	MC, SV	RB 359761
Zollernia glabra (Spreng.) Yakovlev*,†,‡	–	S	EC	RBR 26406
Zollernia ilicifolia (Brongn.) Vogel	–	M	EC	RB 359782

[a] EN, Endangered; VU, Vunerable.
[b] H, High Montane; M, Montane; S, Submontane.
[c] BE, Boa Esperança; BR-040; CA, Catanudo; CL, Colomi; EC, Estrada do Comércio or Estrada do Ouro/Orbel I; EI, Estrada do Imperador or Caminho do Imperador; MC, Macuco; MM, Mata do Moacir; O2, Orbel II; PT, Pico do Tinguá; SR, Sertão/Trilha do Manuel Rocha and Zé Grande/Trilha do Rela; SV, Serra Velha/Barrelão/Reunião.
* Endemic to Brazil (48 spp.).
† Endemic to the Atlantic Forest (35 spp.).
‡ New record for the REBIO Tinguá (6 spp.).

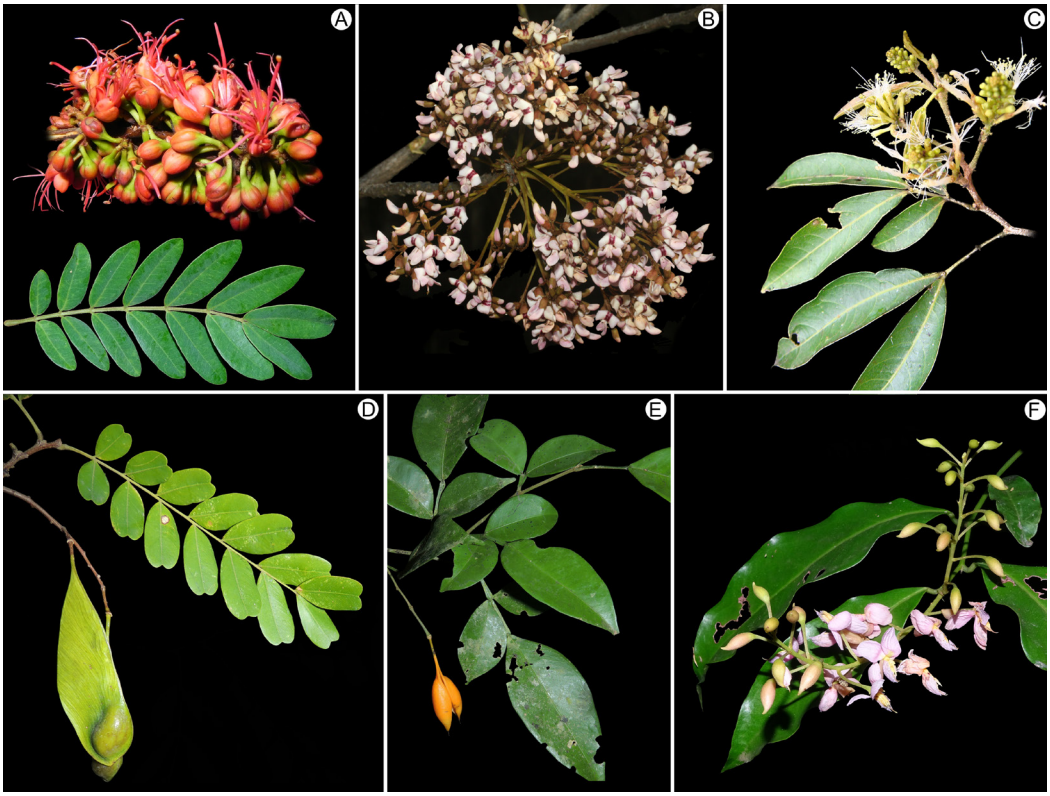

Figure 2. New occurrences of Leguminosae tree species of the Reserva Biológica do Tinguá. A, *Barnebydendron riedelii*; B, *Hymenolobium janeirense*; C, *Inga lenticellata*; D, *Platypodium elegans*; E, *Swartzia simplex*; F, *Zollernia glabra*. Photographs: A, L. S. J. Deccache and C. N. Fraga (inflorescence and leaves, respectively); B, D. Cardoso; C–E, H. C. Lima; F, L. S. J. Deccache.

simplex (*L.S.J. Deccache* 91) were confirmed and they were re-collected during one of our more recent field expeditions. Although *Zollernia glabra* is recorded from only three sterile collections, we were also able to confirm its occurrence. Thus, the occurrence of only *Platypodium elegans* remains unconfirmed.

Approximately 85% of all records of plant species endemic to the state of Rio de Janeiro have been from inside protected areas. It is therefore clear that these areas play an important role in the conservation of the endemic and threatened flora of the state (Rosa *et al.*, 2018; Silveira-Filho & Rambaldi, 2018). The high number of legumes among the REBIO Tinguá flora that are Brazilian endemics (70%) or Atlantic Forest endemics (52%) reinforces the region as an area that safeguards much of the remaining Atlantic Forest legume biodiversity. According to IUCN Red List categories and criteria, version 3.1 (IUCN, 2012), seven of these species are assessed as threatened with extinction: *Apuleia leiocarpa* (Vogel) J.F.Macbr., *Dalbergia nigra* (Vell.) Allemão ex Benth., *Dimorphandra exaltata*

Schott, *Inga mendoncaei* Harms, *Moldenhawera polysperma* (Vell.) Stellfeld, *Muellera filipes* (Benth.) M.J.Silva & A.M.G.Azevedo and *Tachigali beaurepairei* (Harms) L.F.Gomes da Silva & H.C.Lima). Of these, four are categorised as Vulnerable (VU) (*Apuleia leiocarpa*, *Dalbergia nigra*, *Moldenhawera polysperma* and *Muellera filipes*), and the other three are categorised as Endangered (EN) (*Dimorphandra exaltata*, *Inga mendoncaei* and *Tachigali beaurepairei*). The high level of threat to many of these species reinforces the need to preserve the remaining vegetation of the Serra do Mar in Rio de Janeiro state and underlines the high importance of the REBIO Tinguá for conservation in the central corridor of the Atlantic Forest.

Vegetation physiognomies as revealed by legume species composition and similarity

The cluster analysis revealed six well-supported groups at an approximately 0.77 cophenetic correlation coeficient (**Figure 3**). The placement of the two sites in the REBIO Tinguá in different clusters reflects substantial differences in their environments, despite their geographical proximity. The Submontane Forests ('tingua_s') were grouped with Paraty Mirim, Pedra Branca, Poço das Antas, Tijuca and REBIO Union (group 2), whereas the Montane/High Montane Forest ('tingua_ma') grouped with Macaé de Cima, Mendanha and Santo Aleixo (group 5).

Four other floristic groups can be seen in the dendrogram, grouping Região dos Lagos's Seasonal Forests with coastal rocky areas of the Região Metropolitana. These are group 1: Alto Mourão, Cabo Frio, Capoeira Grande, Ilha de Cabo Frio, Massambaba, Serra das Emerencias and Serra de Sapiatiba; group 3: Norte Fluminense's Seasonal Forests (Bom Jesus, Funil, Guaxindiba and Itaoca); group 4: restingas (Carapebus, Caruara, Grumari, Jurubatiba, Marambaia, Maricá and Praia do Sul); and group 6: Região Sul Fluminense's Submontane Forests (Trindade and Praia do Sul/encosta).

These results corroborate the findings of previous studies on the Atlantic forests of the state of Rio de Janeiro (Peixoto *et al.*, 2004; Oliveira-Filho *et al.*, 2005; Carvalho *et al.*, 2008; Nettesheim *et al.*, 2010; Cysneiros *et al.*, 2016; Machado *et al.*, 2021). There is a clear distinction between the flora of the Restingas and that of the forested areas, and also a separation of Ombrophilous Forests from Seasonal Forests in the latter. Furthermore, among the Ombrophilous Forests, there is a differentiation between Montane and Submontane Forests positioned at different altitudinal levels.

Although this paper differs from previous studies in that it does not include an analysis of the similarity of the REBIO Tinguá based on a total floristic list, it offers a unique perspective by dividing the list according to phytophysiognomies. This approach revealed interesting differences, particularly when considering the results shown in the Venn diagram in **Figure 4**. For example, only 16 of the total 67 species were shared between the REBIO Tinguá vegetation physiognomies, a result highlighting the floristic heterogeneity of the Atlantic Forest, even in closely located areas. These species were *Bauhinia forficata*

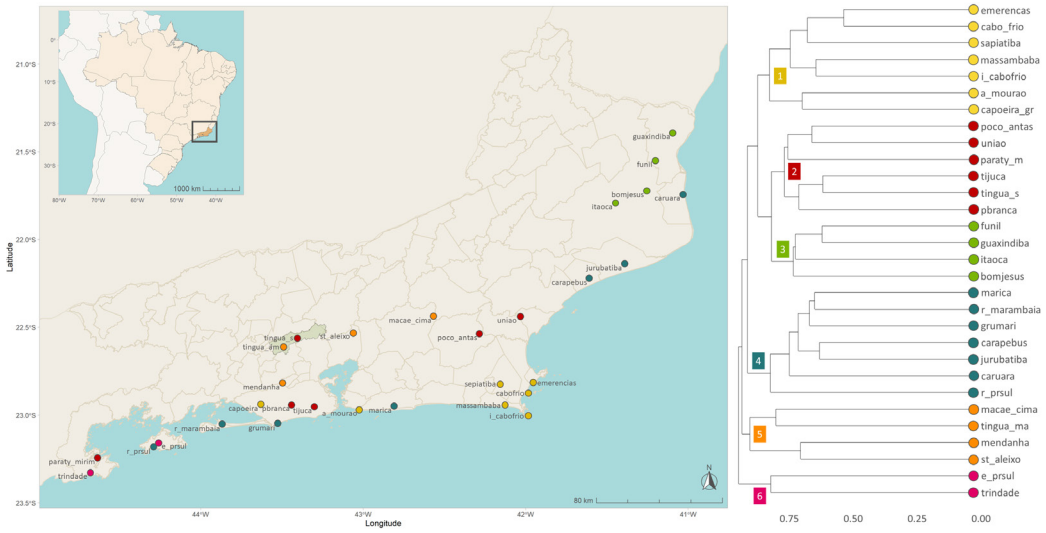

Figure 3. Stretch from the Rio de Janeiro state, with the 28 areas grouped in the similarity analysis, and two of the Reserva Biológica do Tinguá (REBIO Tinguá) (cophenetic correlation coefficient = 0.77). Group 1: Região dos Lagos's Seasonal Forests grouped with coastal rocky areas of the Metropolitan Region. Group 2: Lowland/Submontane Ombrophilous Forests, with High Montane inside Parque Estadual da Pedra Branca and Tijuca. Group 3: Norte Fluminense's Seasonal Forests. Group 4: Restingas. Group 5: Montane/High Montane Ombrophilous Forests. Key to area codes, where necessary (from top to bottom): emerencias, Serra das Emerencias; cabo_frio, Cabo Frio (Morros Piaçava and Mico); sapiatiba, Serra de Sapiatiba; massambaba, Massambaba; i_cabofrio, Ilha de Cabo Frio; a_mourao, Morro Alto Mourão; capoeira_gr, Serra da Capoeira Grande; poco_antas, Reserva Biológica de Poço das Antas; uniao, Reserva Biológica da União; paraty_m, Paraty Mirim; tingua_s, REBIO Tinguá (Submontana); pbranca, Parque Estadual da Pedra Branca; funil, Mata do Funil; guaxindiba, Estação Ecológica Estadual de Guaxindiba; itaoca, Maçico do Itaoca; bomjesus, Mata do Bom Jesus; marica, Área de Proteção Ambiental da Restinga de Maricá; r_marambaia, Marambaia, Restinga; grumari, Restinga de Grumari; caruara, Reserva Particular do Patrimônio Natural de Caruara; r_prsul, Praia do Sul, Restinga; macae_cima, Macaé de Cima; tingua_ma, REBIO Tinguá (Montana/Altomontana); mendanha, Parque Estadual do Mendanha; st_aleixo, Santo Aleixo; e_prsul, Praia do Sul, Encosta.

Link, *Cassia ferruginea* (Schrad.) Schrad. ex DC., *Centrolobium robustum* (Vell.) Mart. ex Benth., *Chamaecrista ensiformis* (Vell.) H.S.Irwin & Barneby, *Copaifera trapezifolia* Hayne, *Dahlstedtia pinnata* (Benth.) Malme, *Inga lanceifolia* Benth., *I. marginata* Willd., *Moldenhawera polysperma*, *Ormosia fastigiata* Tul., *Pityrocarpa inaequalis* (Benth.) L.P.Queiroz & Marc.F.Simon, *P. schumanniana* (Taub.) L.P.Queiroz & L.M.Borges, *Robrichia glaziovii* (Benth.) A.R.M.Luz & E.R.Souza, *Swartzia apetala* Raddi, *Tachigali paratyensis* (Vell.) H.C.Lima and *T. pilgeriana* (Harms) Oliveira-Filho.

Studies carried out in the region of Imbé, Campos dos Goytacazes (Moreno *et al.*, 2003), as well as in Serra Negra, Minas Gerais (Valente *et al.*, 2011), also show that, despite close

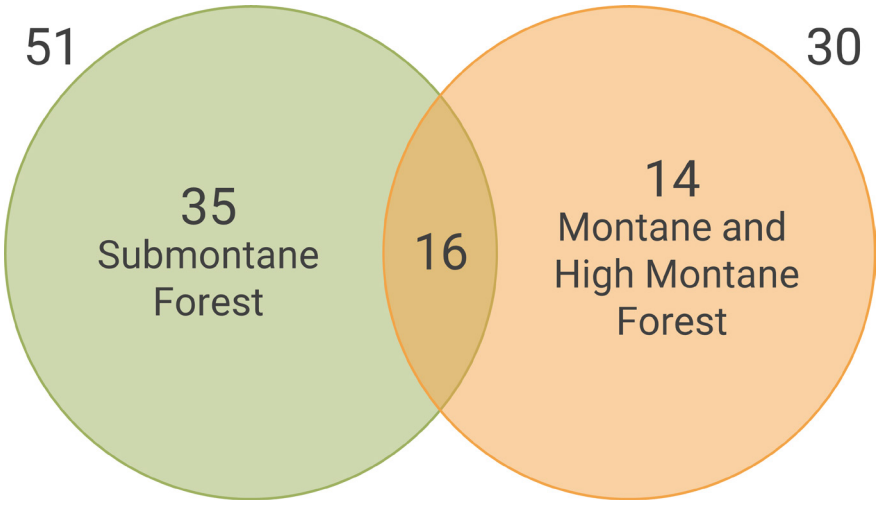

Figure 4. Numbers of Leguminosae shared between the phytophysiognomies of the Reserva Biológica do Tinguá.

geographical proximity, the phytophysiognomies are floristically and structurally distinct, configuring high beta diversity, which may reflect the increase in altitude, topographical differences, and edaphic variations. Variations in altitude are invariably associated with biotic variations, as landscape and climatic changes drive gradual species substitutions or changes in their abundances (Oliveira-Filho & Fontes, 2000). Studies specifically carried out with Leguminosae across the entire southern region of Brazil have underscored the fact that the presence of certain species in lowland areas, higher altitudes, restingas, and coastal or alluvial elevations are related to habitat preference (Lima, 2000; Nunes *et al.*, 2007; Machado *et al.*, 2021), reflecting the climatic and edaphic restrictions to which they are subject.

The present study revealed new records for the REBIO Tinguá, despite it being one of the most thoroughly inventoried areas in the state; the study also highlighted the diversity of tree legume species in the area. These findings reinforce the role of the REBIO Tinguá in conservation, specifically in terms of both its substantial area and its altitudinal range, as well as its central position in the state, connecting the Central Fluminense Mosaic and the Tinguá-Bocaina Biodiversity Corridor. The REBIO Tinguá is the largest protected area in the Biological Reserve category in the state of Rio de Janeiro. Its presence ensures the maintenance of a huge green area in the Baixada Fluminense, which is densely populated and has few protected areas, especially those with full protection. Furthermore, the REBIO Tinguá contains a significant number of springs that form Rio de Janeiro's main hydrographical basins. This protection plays a critical role in preserving these sources, which are responsible for providing water to nearly 80% of the Baixada Fluminense region. In addition, its strategic location in the heart of the state makes it a crucial ecological

corridor that connects protected coastal areas with the highlands. By safeguarding this vital ecosystem, the REBIO Tinguá supports not only local Atlantic Forest biodiversity but also the broader region's ecological well-being.

The green golden path: a brief history of botanical records in the Tinguá mountains

A list of collectors of vascular plant herbarium specimens from Serra do Tinguá and nearby locations, along with associated numbers and years of collections, is provided in **Supplementary file 1**. A total of 156 collectors and 2372 collections were recorded. The first naturalists to visit the Tinguá region and record the local flora were the botanists Heinrich Wilhelm Schott, Johann Christian Mikan and Johann Baptist Emanuel Pohl during an expedition through Brazil between 1817 and 1821 (Pohl *et al.*, 1827; Stafleu & Cowan, 1979). Some specimens collected by Schott in this region were used as type material, such as in the descriptions of the legume species *Swartzia elegans* Schott (**Figure 5A,B,D**) and *Andira ormosioides* Benth. (**Figure 5C**) (Sprengel, 1827; Bentham, 1837). Auguste de Saint-Hilaire, who travelled to Brazil between 1816 and 1822, recorded his journey along the "Caminho do Comércio" in 1822 (Cad. D – no. 28, Saint-Hilaire, 1822 [1974]). Almost 50 years later, the French botanist and landscaper Auguste François Marie Glaziou used the travel books of Saint-Hilaire (Glaziou, 1905) as a guide and explored the areas of the "Estrada do Comércio" and the paths of the "Rio D'Ouro" and "Rio Santo Antônio", "Pico do Tinguá" and "Serra do Couto". Glaziou collected about 60 plant specimens in the Tinguá mountains during his 12 years of fieldwork (1869–1888) in the service of the Empire of Brazil (Stafleu & Cowan, 1979; Reflora, 2021). Specimens collected by Glaziou became type material of 15 species from 12 botanical families, including the basionym of *Tachigali urbaniana* (Harms) L.G.Silva & H.C.Lima, an endemic species from Atlantic Forest collected at Rio d'Ouro, on the west side of the REBIO Tinguá (**Figure 5E,F**).

The Floresta Protetora da União in the Tinguá region was created in 1941 to protect the springs that supply water to the cities of Baixada Fluminense (MMA–IBAMA, 2006). The first records for the twentieth century are from the 1940s, when the botanists Alexandre C. Brade, Aparício P. Duarte, Paulo Occhioni, Luis F. G. Laboriau and Armando de Mattos Filho visited during field expeditions organised by the Rio de Janeiro Botanical Garden. Botanical collections in Tinguá in the following three decades were infrequent. Guido J. F. Pabst (1960 and 1966), Dimitri Sucre and Thomas R. Soderstrom (1968 and 1980), Alberto Castellanos (1969 and 1961) and Luiz Emygdio Mello Filho (1957, 1969 and 1972) each spent limited amounts of time doing fieldwork along the Estrada do Comércio and other places nearby.

The state-owned Brazilian oil company Petrobras installed two oil pipelines in the Tinguá region in the 1960s and 1980s, together called the Rio-Belo Horizonte Oil Pipeline (Orbel I and Orbel II; see **Figure 1A**). The REBIO Tinguá was created in 1989 with the aim of protecting one of the largest remnants of Atlantic Forest on the slopes of Serra do Mar.

Figure 5. Records of Leguminosae tree species at the Reserva Biológica do Tinguá (REBIO Tinguá) and used as type material. A, Lectotype of *Swartzia myrtifolia* var. *elegans* (*Schott* 5897 [W0026967]); B and D, manuscript tag registering "Tingua" as the locality of Schott's specimen; C, holotype of *Andira ormosioides* (*Schott s.n.* [K000118487]); E, syntype of *Tachigali urbaniana* (*Glaziou* 10683 [P00350582]); F, manuscript tag made by Glaziou, registering "Rio d'Ouro"; G, paratype of *Jupunba villosa* (*H. C. Lima* 6549 [RB438130]); F, tag of RB herbaria, mentioning "REBIO Tinguá"; H, tag of RB herbaria, mentioning "REBIO Tinguá"; I, number of records of Leguminosae tree species per year. Gray line, angiosperm records.

Then, with the effective implementation of the REBIO, a collaborative partnership was initiated in 1991 between the Botanical Garden of Rio de Janeiro/Jardim Botânico do Rio de Janeiro (JBRJ) and the Federal Rural University of Rio de Janeiro/Universidade Federal Rural do Rio de Janeiro (UFRRJ) to carry out floristic studies and monitor the impact of oil pipelines on the biodiversity of the conservation unit. Two important projects were implemented from 1991 to 2009, namely *Landscape and Flora of the Tinguá Biological Reserve* and the *Mata Atlântica Project*, both of which involved large collection efforts (**Supplementary file 2**; see **Figure 5I**). The three foremost collectors during this collecting period in the REBIO Tinguá were Haroldo C. de Lima (senior author for the present work), Sebastião J. Silva Neto and Lana S. Sylvestre, who made approximately 450, 160 and 150 herbarium specimen collections, respectively. The results of this fieldwork included the collection of type material of *Abarema villosa* Iganci & M.P.Morim [= *Jupunba villosa* (Iganci & M.P.Morim) M.V.B.Soares, M.P.Morim & Iganci] (**Figure 5G,H**), as well as the discovery of a species new to science, namely *Simira walteri* Silva Neto & Callado (Rubiaceae), and a rich collection of ferns and lycophytes. The permanent forest plots of the Atlantic Forest Biodiversity Research Program (PPBio) were subsequently implemented in 2012 with the aim of providing a dedicated area for long-term studies.

At the REBIO Tinguá, in terms of the collection of herbarium specimens of Leguminosae tree species, certain areas have received greater attention than others (**Figure 6**). The

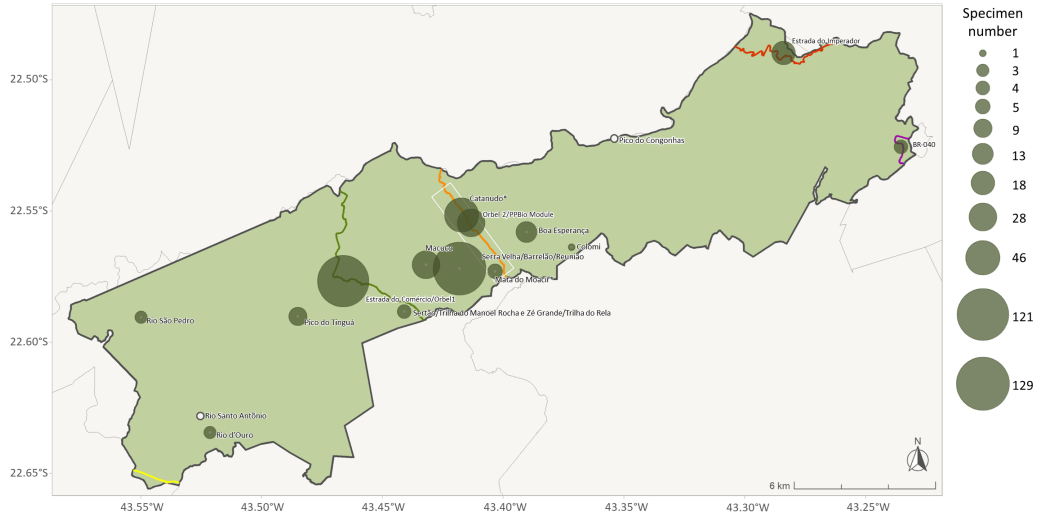

Figure 6. Number of specimens of Leguminosae tree species recorded inside the Reserva Biológica do Tinguá. Green line, Estrada do Comércio/Caminho do Comércio; red line, Estrada do Imperador/ Caminho do Imperador; purple line, BR-040; yellow line, Gasbel; orange line, Orbel II; white line, PPBio Mata Atlântica Permanent Research Module.

greatest number of collections are from Serra Velha (with Barrelão and Reunião dams) and Estrada do Comércio, with approximately 130 and 120 specimens, respectively. Along the Estrada do Comércio, the main path to the Tinguá region, which was known to Saint-Hilaire by 1822 (Novaes, 2008; Borges, 2021), there are old records of Leguminosae from Schott's original exploration of the region. Records from Serra Velha are much more recent, with herbarium specimens only recorded from 1990 onwards. The other areas with specimen records are Catanudo (46 specimens), Macuco and Orbel II (28 specimens), and Estrada do Imperador (18 specimens). The highest densities of records are for the vicinity of the Estrada do Comércio and the dams in Serra Velha, largely due to ease of access to these locations. Another important site with a recent increase in records is close to the Orbel II pipeline, where the permanent PPBio Mata Atlântica plots are located. Major collecting gaps exist mainly for areas in the extreme north and south of the REBIO Tinguá, where high elevations and steep slopes make collecting difficult. Collecting efforts should focus on these areas to advance our floristic knowledge of these parts of the REBIO Tinguá.

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Supplementary material

Supplementary material is available from the *Edinburgh Journal of Botany* online portal.

Supplementary file 1. Collectors of vascular plant herbarium specimens in Serra do Tinguá (Rio de Janeiro state, Brazil) and nearby locations, and associated numbers and years of collections.

Supplementary file 2. Areas inside the Reserva Biológica do Tinguá (Rio de Janeiro state, Brazil) and their respective latitude and longitude coordinates.

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