A population census approach to conserving the threatened tree *Xylopia decorticans* (Annonaceae)

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Abstract The tree *Xylopia decorticans* is a rare endemic in the Brazilian Atlantic Forest, a global biodiversity hotspot. Described in 2007 from two protected areas, it was originally categorized as Least Concern but as a result of progressive forest conversion and degradation it is now categorized as Endangered in the Brazilian Red List and IUCN Red List. Ecologically, the search for new populations is important because the species provides resources to a range of wildlife in different forest layers, but there have been no demographic studies on which to base conservation action. To address this lack of information, we surveyed a private protected area in south-eastern Brazil where there was a new record of *X. decorticans*. We located 121 individuals within a minimum convex polygon area of 4.08 ha (density 29.65 individuals/ha), c. 30% of which were juveniles. Mean tree height was 9 m and diameter at breast height ≤ 10 cm. The species is ombrophilous and sensitive to edge effects, as evidenced by desiccation observed in the field. The findings of this study improve our understanding of the ecological characteristics of species within regions afflicted by ongoing forest degradation, and underscores the pivotal role of Reservas Particular do Patrimônio Natural (private natural heritage reserves) in Brazil in the conservation of threatened species such as *X. decorticans*.

Keywords Atlantic Forest, cauliflory, diplochory, ecological corridor, Espírito Santo, monitoring programmes, zoochory

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Introduction

The Atlantic Forest is the most biodiverse phytogeographic domain in Brazil, supporting > 17,000 catalogued species (Mittermeier et al., 2004; Brazil Flora Group, 2022). Annonaceae is a diverse family of flowering plants including *Xylopia*, one of the genera that occur in Brazil (Lobão et al., 2020). *Xylopia* comprises several tree or shrub species, many of which are known as *pindáiwa* by the Indigenous peoples, meaning plants used as fishing nets (Dias, 1988; Lopes & Mello-Silva, 2014).

Xylopia decorticans D.M. Johnson & Lobão (Plate 1), described in 2007, has a restricted distribution and is endemic to the highlands in central Espírito Santo State (Lobão & Johnson, 2007). It is recognized by the reddish-brown bark on its branches (Plate 1a–b), its fleshy flowers that develop from the base of the stem to the branches (Plate 1d–f), and its pink or reddish fruits with arillate seeds (Lobão & Johnson, 2007; Plate 1g–h). In addition, this zoochorous species provides resources for wildlife in different forest strata because of its characteristic cauliflory. The species was originally categorized as Least Concern because it occurs in at least two protected areas of the Atlantic Forest in Espírito Santo State, the Reserva Biológica Augusto Ruschi and the Estação Biológica Santa Lúcia (Lobão & Johnson, 2007). The description was based on specimens from eight localities, six of which were in private areas. Since 2007, the species has been found in four new localities, also in private areas. Despite this increase in the number of recorded localities, as a result of the progressive conversion of the forest for other land use and the damage caused by logging and wood harvesting in the region (Mendes & Padovan, 2000; Thomaz, 2010; CNCFlora, 2018), it is now categorized as Endangered on the Brazilian Red List of Threatened Species (Brazil, 2022) and on the IUCN Red List (Fernandez et al., 2021). Recently, advances in our knowledge of the flora of Espírito Santo State have led to the identification of a new subpopulation in a small private protected area. This study built on that discovery by carrying out an assessment of the abundance of *X. decorticans* locally, with a view to enhancing our understanding of its biology and distribution.

Ecologically, studies on rare and threatened species are important because population data are often scarce, resulting in significant knowledge gaps that hinder effective conservation actions and predictions of future population change (Hortal et al., 2015; Collen et al., 2016; CNCFlora, 2018). Recognizing the critical need for such information (as highlighted by the Brazilian Red List; CNCFlora, 2018; Brazil, 2022), this study investigated the population structure of *X. decorticans* to contribute to its long-term conservation in the face of ongoing declines in habitat quality and extent, whilst providing crucial data for future management and restoration efforts for threatened flora in the region.

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PLATE 1 Identifying features of *Xylopia decorticans* in the Reserva Particular do Patrimônio Natural Macaco Barbado, Santa Maria do Jetibá, Espírito Santo, Brazil: (a) branch and leaves; (b) details of a branch emphasizing the reddish-brown bark; (c) cauliflory tubers; (d–e) flower buds; (f) flower at anthesis; (g) immature fruit; (h) mature and open fruit. Photos: (a–c, e) M.I.A. Horst; (d) L.S.B. Calazans; (f, h) L.O. Bezerra; (g) D.O. Sabbagh.

Study area

We conducted our study within the Reserva Particular do Patrimônio Natural Macaco Barbado, a private protected area located in the state of Espírito Santo, south-eastern Brazil (Fig. 1). The reserve encompasses < 50 ha of well-preserved dense ombrophilous forest, lies within the Centro Norte Serrano Ecological Corridor (Espírito Santo, 2010) close to several other protected areas (see Silva et al., 2020), and is designated as an Outpost of the Atlantic Forest Biosphere Reserve (IA-RBMA, 2023). Situated in the municipality of Santa Maria de Jetibá, the Reserve spans elevations of 750–900 m. According to Köppen's climate classification, the region exhibits a warm temperate climate, fully humid with no dry season and a warm summer (Cfb: Alvares et al., 2014). The mean daily temperature is typically below 22 °C in the warmest month and below 18 °C in the coldest month, and mean annual precipitation is 1,259 mm (Incaper, 2023).

We collected some data outside the original boundaries of the Reserve in recently procured forest areas bordering the protected area. Access to the remainder of the forest fragment was limited as we did not have permission to enter other private areas contiguous with the Reserve.

Methods

We identified a subpopulation based on its degree of isolation in an extremely fragmented landscape subject to continuous anthropogenic disturbance (IUCN, 2019). We searched for *X. decorticans* in the Reserve during October 2023–August 2024, following the census protocol defined by Bullock (1996) and the guidelines for threatened tree conservation surveys outlined by the Global Trees Campaign (Brewer, 2013). We utilized existing trails as well as making incursions into the forest interior to carry out our search. The species occurs in well-preserved primary forest (Saiter et al., 2024), so we did not survey forest areas undergoing regeneration.

We recorded all individuals ≥ 1.30 m tall, a sufficient height to measure other parameters (Moro & Martins, 2011), and georeferenced coordinates in the Universal Transverse Mercator system using a GPS (Fig. 1). We also recorded life stage, diameter at breast height (DBH) and tree height (estimated by eye). We calculated height and diameter at breast height using the Spiegel formula (Felfili & Rezende, 2003). We classified any individuals with cauliflory tubers present (Plate 1c) as adults, others as juveniles.

For our population census analysis, we plotted occurrence points in *QGIS 3.32.0* (QGIS Development Team, 2016) to delineate minimum convex polygons for *X. decorticans* in the

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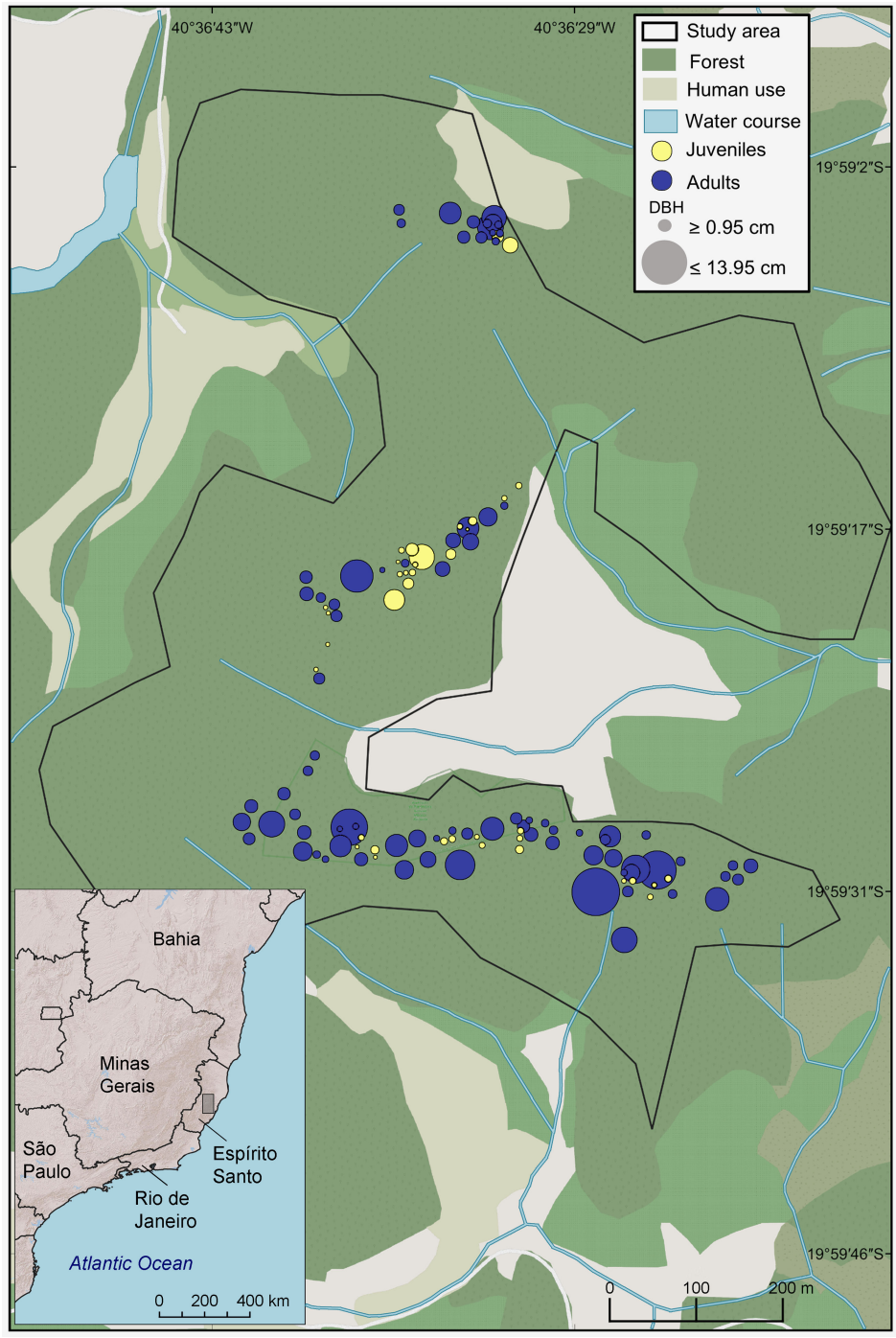


FIG. 1 The study site in Reserva Particular do Patrimônio Natural Macaco Barbado, Santa Maria do Jetibá, Espírito Santo, Brazil, showing the distribution and size (DBH, diameter at breast height) of the *Xylopia decorticans* trees recorded.

area. The sum of the area of the polygons represents the total area occupied by the subpopulation. We calculated population density by dividing the total number of individuals found by the total area occupied by the subpopulation.

We analysed qualitative indicators provided by the Brazilian Law for the Protection of Native Vegetation (Brazil, 2012) to assess the degree of habitat preservation in the survey area. We assessed the occurrence and condition of individual *X. decorticans* found near the edge of the forest fragment in a 10 m strip extending from the edge to the interior. We defined this limit based on qualitative indicators typically associated with edge effects, such as fallen trees, herbaceous strata dominated by heliophylous bamboos, discontinuous leaf litter, and high light intensity or luminosity (e.g. Murcia, 1995; Rodrigues & Nascimento, 2006; Laurance et al., 2007). We assessed the vitality of individuals based on the condition of the crown and leaves, and the presence of any disease or damage indicators such as cavities in the trunk or fungal growths (Gill & Daltry, 2013).

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Results

Our habitat assessment showed that *X. decorticans* thrives in minimally disturbed forest remnants or areas of advanced regeneration/successional stages. We identified the following indicators of suitable habitat: thick, continuous leaf litter; the presence of woody vines; a high density of epiphytes; palm indicator species such as *Euterpe edulis* Mart., *Attalea dubia* (Mart.) Burret, *Syagrus insignis* (Devansaye) Becc., *Bactris timbuiensis* H.Q.B.Fern. and *Geonoma schottiana* Mart.; an average canopy height of 25 m, including emergent specimens; and a high floristic richness with diverse life forms.

We located and measured 121 specimens of *X. decorticans* within the study area, occupying 4.08 ha, and comprising 38 juveniles and 83 adults with diameter at breast height ≥ 0.9 cm (Supplementary Table 1). We grouped our sample into two height classes (0–9.25 m and 9.26–18.50 m) and two DBH classes (0.95–12.95 cm and 12.96–25.9 cm). The majority of individuals (91.7%) were 2–9 m tall, and nearly all had a DBH of 0.95–10.5 cm. We calculated *X. decorticans* density as 29.65 individuals/ha.

We identified five dead or desiccated individuals in the edge strip of the study area. They were located in sections exposed to the prevailing north-east winds following conversion of adjoining areas to monoculture plantations of eucalyptus trees *Eucalyptus* spp. Although our sample is small, our observations are supported by the increase in luminosity, strong development of a heliophyte *Chusquea* spp. (Poaceae) community, discontinuity in the accumulation of leaf litter and the presence of large fallen trees. It is of note that we also recorded up to three fallen trees of *X. decorticans* with large stems (DBH ≥ 10 cm) in the edge strip. Overall, the species exhibited a strong preference for forest patches not exposed to edge effects.

Discussion

This study provides the first ecological data on *X. decorticans*, building on information gathered in earlier studies of the tree community in the highlands of Espírito Santo (e.g. Saiter et al., 2024) and establishing initial parameters for more targeted conservation efforts. One of the targets set by the Global Strategy for Plant Conservation (BGCI, 2024) is that at least 20% of threatened species should be included in restoration and recovery programmes. However, the ecological characteristics of *X. decorticans* suggest that it should be recognized as a climax species and planted in the more advanced stages of regeneration, known in Brazil as forest enrichment. In Brazil, it is common to plant ombrophilous species such as *X. decorticans* in regenerating areas where forest strata are diagnosable but low in richness. We recommend that reintroduction efforts in areas undergoing regeneration within the study area should be limited to enrichment in forest patches at advanced successional stages.

In addition to our data providing the location of future collection matrices for ex situ propagation, they also contribute to our knowledge of the ecology, distribution and abundance of *X. decorticans* (Cardoso et al., 2011; Hortal et al., 2015). However, there is a continuing need for dispersion and ex situ conservation studies that can provide insights into germination and development, and protocols for in situ planting.

The predominance of individuals with a DBH of < 10 cm suggests that the legal inclusion criterion currently employed to assess forest vegetation within the Centro-Norte Serrano Corridor (Brazil, 2012) does not accurately reflect the population size of *X. decorticans*. For example, in the case of environmental permits for major infrastructure works, only trees with a DBH above this threshold are included in the species list presented to the inspection agency, which means that smaller *X. decorticans* would be omitted. The species list is directly related to future environmental mitigation actions, which could include germplasm rescue of declining species (Brazil, 2012).

Monitoring programmes are included as one of the mitigating actions specified in Brazilian legislation (Brazil, 2012). Based on our findings, population monitoring programmes for *X. decorticans* should use a DBH threshold of 5 cm, so that both young and adult individuals are included. Although we recorded some individuals high up in the canopy (c. 18 m at average canopy height), this species demonstrates a reproductive strategy closely linked to the understory. The prevalence of small trees in our study area aligns with patterns observed in understory species in tropical forests generally (Bohlman, 2015), including other Annonaceae (Gomes-Westphalen et al., 2012). Thus, our findings suggest that *X. decorticans* is a specialist species adapted to specific ecological conditions with a variety of trophic niches and more intricate ecological networks (Losapio et al., 2019). Collectively, our results indicate that the species is an understory component of more advanced successional forest stages, where community structure is more complex and thus conducive to species that are sensitive to desiccation in more exposed habitats.

Cauliflory increases the supply of flowers and fruits to seed dispersers and can occur from the base of the stem to the thinnest branches of the crown (Onstein et al., 2019). Plants in the genus *Xylopia* are associated with diplochory, in which vertebrates (mainly birds) and invertebrates are involved in seed dispersal (Christianini & Oliveira, 2010; Cabral et al., 2025). *Xylopia decorticans* exhibits cauliflory and is important for threatened seed-eating birds throughout its range. We believe it may support both terrestrial birds (Galliformes) and species that feed in the tree canopy, including the following Endangered (EN) and Critically Endangered (CR) species (status according to Espírito

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Santo, 2022): *Odontophorus capueira* (EN), *Asthenes moreirae* (CR), *Grallaria varia imperator* (EN), *Turdus fumigatus fumigatus* (EN), *Crypturellus noctivagus* (CR) and *Tinamus solitarius* (EN). Therefore, conservation of *X. decorticans* will be of benefit to a wide variety of other wildlife.

We categorized the individuals present in the Reserva Particular do Patrimônio Natural Macaco Barbado as a distinct subpopulation of *X. decorticans* because of the low genetic flow between the forest fragments that characterize the highlands in the central region of Espírito Santo, particularly within the Centro-Norte Serrano Ecological Corridor. More diverse populations would exhibit greater genetic variation, enhancing their resilience to inbreeding and other genetic bottlenecks (Ridley, 2009; DeWood et al., 2021). An understanding of the population structure of endemic species such as *X. decorticans* is crucial for guiding conservation efforts aimed at reconnecting fragmented forest patches and maintaining ecological function in the landscape.

Population studies are essential for robust analyses of threatened species because there are large gaps in our knowledge of the distribution, evolution, ecology and physiology of even well-studied taxa such as Annonaceae (Hortal et al., 2015; Erkens et al., 2023). Based on our findings, we recommend that *X. decorticans* is used in forest enrichment programmes, aligning with initiatives such as Forest Landscape Restoration (FAO et al., 2021), which are gaining traction regionally (Espírito Santo, 2023). This would also be a positive recommendation within the framework of actions aimed at the UN Decade on Ecosystem Restoration (UNEP & FAO, 2020). This approach would enable stakeholders to accelerate the implementation and monitoring of forest enrichment programmes, advancing global restoration goals and local conservation efforts.

In summary, our population census has provided quantitative data on the abundance and distribution of *X. decorticans* within a small Atlantic Forest fragment. Our findings improve our understanding of the ecological characteristics of species within regions afflicted by ongoing forest degradation, point the way to effective conservation action and underscore the pivotal role of private natural heritage reserves (Reservas Particular do Patrimônio Natural) in Brazil in the conservation of Endangered species such as *X. decorticans*.

Author contributions Study design: MIAH, RTV; fieldwork: MIAH, RTV, LSBC; data analysis: MIAH, RTV; writing: all authors.

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Conflicts of interest None.

Ethical standards This research abided by the *Oryx* guidelines on ethical standards. Research in Espírito Santo State was carried out under IEMA permit NUBIO no. 028-R4A4/2015 - process no. 71911308.

Data availability Data supporting the findings of this study are available within the article and its Supplementary Materials.

References

Alvares, C.A., Stape, J.A., Sentelhas, P.C., Gonçalves, J.L.M. & Sparovek, G. (2014) Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, 22, 711–728.

BGCI (Botanic Gardens Conservation International) (2024) *Global Strategy for Plant Conservation.* Botanic Gardens Conservation International, Richmond, UK. bgci.org/our-work/inspiring-and-leading-people/policy-and-advocacy/the-global-strategy-for-plant-conservation [accessed January 2026].

Bohlman, S.A. (2015) Species diversity of canopy versus understory trees in a Neotropical Forest: implications for forest structure, function and monitoring. *Ecosystems*, 18, 658–670.

Brazil (2012) Lei Nº 12.651. Dispõe sobre a proteção da vegetação nativa. *Diário Oficial da União*, 25 de maio de 2012.

Brazil (2022) Portaria MMA Nº 148. Atualiza a Lista Nacional de Espécies Ameaçadas de Extinção. *Diário Oficial da União*, 07 de junho de 2022.

Brazil Flora Group (Gomes-da-Silva, J., Filardi, F.L.R., Barbosa, M.R.V., Baumgratz, J.F.A., Bicudo, C.E.M., Cavalcanti, T.B. et al.) (2022) Brazilian Flora 2020: Leveraging the power of a collaborative scientific network. *Taxon*, 71, 178–198.

Brewer, S. (2013) *Brief 1. How to Survey an Area for Threatened Tree Species*. Global Trees Campaign. Fauna & Flora International, Cambridge, UK. bgci.org/wp/wp-content/uploads/2023/02/Brief-1-English.pdf [accessed 01 January 2025].

Bullock, J. (1996) Plants. In *Ecological Census Techniques. A Handbook* (ed. W.J. Sutherland), pp. 111–138. Cambridge University Press, Cambridge, UK.

Cabral, A., Bender, I.M., Couvreur, T.L., Faurby, S., Hagen, O., Hensen, I. et al. (2025) Seed-dispersing vertebrates and the abiotic environment shape functional diversity of the pantropical Annonaceae. *New Phytologist*, 246, 2263–2279.

Cardoso, P., Erwin, T.L., Borges, P.A. & New, T.R. (2011) The seven impediments in invertebrate conservation and how to overcome them. *Biological Conservation* 144, 2647–2655.

Centro Nacional de Conservação da Flora (2018) *Annonaceae - Xylopia decorticans* D.M. Johnson & Lobão. proflora.jbrj.gov.br/html/Xylopia%20decorticans_2018.html [accessed 02 January 2025].

Christianini, A.V. & Oliveira, P.S. (2010) Birds and ants provide complementary seed dispersal in a neotropical savanna. *Journal of Ecology*, 98, 573–582.

Collen, B., Dulvy, N.K., Gaston, K.J., Gardenfors, U., Keith, D.A., Punt, A.E. et al. (2016) Clarifying misconceptions of extinction risk assessment with the IUCN Red List. *Biology Letters*, 12, 20150843.

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DeWoody, J.A., Harder, A.M., Mathur, S. & Willoughby, J.R. (2021) The long-standing significance of genetic diversity in conservation. *Molecular Ecology*, 30, 4147–4154.

Dias, M.C. (1988) *Estudos taxonômicos do gênero Xylopia L. (Annonaceae) no Brasil extra-amazônico*. PhD thesis, Universidade Estadual de Campinas (UNICAMP), Campinas, Brazil.

Erkens, R.H.J., Blanpain, L.M.P., Jara, I.C., Runge, K., Verspagen, N., Cosiaux, A. & Couvreur, T.L.P. (2023) Spatial distribution of Annonaceae across biomes and anthromes: knowledge gaps in spatial and ecological data. *Plants, People, Planet*, 5, 520–535.

Espírito Santo (2010) Decreto Estadual Nº 2.529-R/2010. Institui os Corredores Ecológicos Prioritários do Espírito Santo no âmbito do Corredor Central da Mata Atlântica. *Diário Oficial dos Poderes do Estado*, 07 de junho de 2010.

Espírito Santo (2022) Decreto Estadual Nº 5.237-R/2022. Atualiza a lista de espécies da fauna silvestre ameaçadas de extinção no estado. *Diário Oficial dos Poderes do Estado*, 25 de novembro de 2022.

Espírito Santo (2023) COP de Dubai: Plano de Descarbonização e Programa Capixaba de Carbono. Caderno Noticioso, Diário Oficial dos Poderes do Estado, 26.118, 05.

Felfili, R.W. & Rezende, R.P. (2003) *Conceitos e Métodos em fitossociologia*. UNB, Brasília, Brazil.

Fernandez, E., Verdi, M., León, M.L.V., Martinelli, G. & Lopes, J. (2021) *Xylopia decorticans*. In *The IUCN Red List of Threatened Species 2021*. dx.doi.org/10.2305/IUCN.UK.2021-2.RLTS.T189635574A189635576.pt.

Food and Agriculture Organization of the United Nations (FAO), International Union for Conservation of Nature and Natural Resources (IUCN), Commission on Ecosystem Management (CEM) & Society for Ecological Restoration (SER) (2021) *Principles for ecosystem restoration to guide the United Nations Decade 2021–2030*. FAO, Rome, Italy.

Gill, D. & Daltry, J. (2013) *Brief 3. How to Make a Monitoring Plan for Threatened Tree Species*. Global Trees Campaign. Fauna & Flora International, Cambridge, UK. bgci.org/wp/wp-content/uploads/2023/02/Brief-3-English.pdf [accessed 01 July 2025].

Gomes-Westphalen, J.S., Lins-e-Silva, A.C.B. & Araújo, F.S. (2012) Who is who in the understory: the contribution of resident and transitory groups of species to plant richness in forest assemblages. *Revista de Biología Tropical*, 60, 1025–1040.

Hortal, J., De Bello, F., Diniz-Filho, J.A.F., Lewinsohn, T.M., Lobo, J.M. & Ladle, R.J. (2015) Seven shortfalls that beset large-scale knowledge of biodiversity. *Annual Review of Ecology, Evolution, and Systematics*, 46, 523–549.

IA-RBMA. Posto avançado da Reserva da Biosfera da Mata Atlântica (2023) *Conselho Nacional da Reserva da Biosfera da Mata Atlântica aprova três novos postos avançados*. rbma.org.br/n/conselho-nacional-da-reserva-da-biosfera-da-mata-atlantica-aprova-tres-novos-postos-avancados [accessed 3 January 2025].

Incaper (2023) *Programa de Assistência Técnica e Extensão Rural, Santa Maria de Jetibá. 2020-2023*. Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural (Incaper), Vitória, Bazil. incaper.es.gov.br/media/incaper/proater/municipios/Santa_Maria.pdf [accessed 03 January 2025].

IUCN Standards and Petitions Committee (2019) *Guidelines for Using the IUCN Red List Categories and Criteria*. Version 14. Prepared by the Standards and Petitions Committee. iucnredlist.org/documents/RedListGuidelines.pdf [accessed 24 August 2025].

Laurance, W.F., Nascimento, H.E., Laurance, S.G. et al. (2007) Habitat fragmentation, variable edge effects, and the landscape-divergence hypothesis. *PLOS One*, 2, e1017.

Lobão, A.Q. & Johnson, D.M. (2007) *Xylopia decorticans* (Annonaceae), a new cauliflorous species from Brazil. *Contributions from the University of Michigan Herbarium*, 25, 207–211.

Lobão, A.Q., Lopes, F.C., Erkens, R.H.J., Mendes-Silva, I., Pontes Pires, A.F., Silva, L.V. et al. (2020) *Annonaceae*. In: *Flora e Funga do Brasil*. Jardim Botânico do Rio de Janeiro, Rio de Janeiro, Brazil. floradobrasil2020.jbrj.gov.br/FB110219 [accessed 03 January 2025].

Lopes, J.D.C. & Mello-Silva, R. (2014) Diversidade e caracterização das Annonaceae do Brasil. *Revista Brasileira de Fruticultura*, 36, 125–131.

Losapio, G., Montesinos-Navarro, A. & Saiz, H. (2019) Perspectives for ecological networks in plant ecology. *Plant Ecology & Diversity*, 12, 87–102.

Mendes, S.L. & Padovan, P. (2000) A Estação Biológica de Santa Lúcia, Santa Teresa, Espírito Santo. *Boletim do Museu de Biologia Mello Leitão* 11/12, 7–34.

Mittermeier, R.A., Hoffmann, M., Pilgrim, J., Brooks, T., Lamoreux, J., Mittermeier, C.G., Gil, P.R. & da Fonseca, G.A.B. (2004) *Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*. CEMEX, Mexico City, Mexico.

Moro, M.F. & Martins, F.R. (2011) Métodos de levantamento do componente arbóreo-arbustivo. In *Fitossociologia no Brasil: métodos e estudos de caso. Vol.* 1 (eds J.M. Felfili, P.V. Eisenlohr, M.M.R.F. Melo, L.A. Andrade & J.A.A. Meira-Neto), pp. 174–212. Universidade Federal de Viçosa, Viçosa, Brazil.

Murcia, C. (1995) Edge effects in fragmented forests: implications for conservation. *Trends in Ecology & Evolution*, 10, 58–62.

Onstein, R.E., Kissling, W.D., Chatrou, L.W., Couvreur, T.L., Morlon, H. & Sauquet, H. (2019) Which frugivory-related traits facilitated historical long-distance dispersal in the custard apple family (Annonaceae)? *Journal of Biogeography*, 46, 1874–1888.

QGIS Development Team (2016) *QGIS: Geographic Information System. Open Source Geospatial Foundation Project*. qgis.osgeo.org [accessed 02 January 2025].

Ridley, M. (2009) *Evolução*. Artmed Editora. Porto Alegre, Brasil.

Rodrigues, P.J.F.P & Nascimento, M.T. (2006) Fragmentação florestal: breves considerações teóricas sobre efeitos de borda. *Rodriguésia*, 57, 67–74.

Saiter, F.Z., Oza, E.F., Freitas, J. et al. (2024) Updated list of long-term monitored tree species in a forest with high diversity and endemism in the highlands of Espírito Santo, Brazil. *Biota Neotropica*, 24, e20241708.

Silva, H.L., Calazans, L.S.B., Valadares, R.T. & Dutra, V.F. (2020) First natural report of *Pabstiella teschiana* Chiron & Xim. Bols. (Orchidaceae) from the Brazilian Atlantic Rainforest: notes on morphology, ecology and conservation. *Brazilian Journal of Botany*, 43, 551–554.

Thomaz, L. (2010) A Mata Atlântica no estado do Espírito Santo, Brasil: de Vasco Fernandes Coutinho ao século 21. *Boletim do Museu de Biologia Mello Leitão*, 27, 5–20.

United Nations Environment Programme (UNEP) & Food and Agriculture Organization of the United Nations (FAO) (2020) *Strategy for the UN Decade on Ecosystem Restoration*. wedocs.unep.org/items/689e0129-9fd4-41fd-bf52-4df151b6969f [accessed 04 January 2025].

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