VALE

Vale & Biodiversity
2021

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Foreword

Mining is essential for our society, and we work to ensure our operations not only create value for stakeholders, but do so responsibly, by implementing best-practice methods, technologies and initiatives to minimize impacts on natural resources. Making our operations increasingly sustainable is integral to our business model—as articulated in our new pact with society—and to our sustainability strategy, which includes conservation and restoration as one of our 2030 sustainability goals

Our sustainability strategy is guided by a new pact with society

(Protect and Restore 500,000 ha beyond our borders. This goal is aligned with others in our agenda that also contribute to minimizing pressures directly affecting essential ecosystem services and improve positive impacts. Our agenda enhances the commitment to forest conservation and restoration that we have pursued in our Amazon operations for the past 30 years.

We believe that by firmly embedding in our strategy and operations a commitment to reducing pressures and to conserving and restoring biodiversity, we are moving our business toward an increasingly sustainable and promising future, for us and for society.

Biodiversity, and the ecosystem services it provides and maintains, are an integral part of the territories where we operate and are essential for life and for our business. Our operations rely on ecosystem services, but can also impact them. To avoid and manage these impacts, we invest in research on new approaches to prevention, management, mitigation, rehabilitation, restoration and offsets. These efforts go beyond legal requirements to include a wide range of initiatives supporting conservation. We have adopted the mitigation hierarchy framework to ensure we achieve No Net Loss in all new projects and expansions.

In this case-study report, we share real-world examples of this approach and the outcomes of initiatives around the world that have delivered on our Strategies for Sustainability and Biodiversity.


Photo: Geovane Siqueira

Ongoing actions for the future we want

Biodiversity Management & Action Plans

Biodiversity Management & Action Plans

S11D: Lessons learned from applying the mitigation hierarchy to future projects

Photo: João Marcos Rosa

Introduction

The S11D Complex is one of the largest iron ore mining projects in the world and is located in the Carajás region, within the Amazon biome. Like every development project, its implementation had impacts on biodiversity, but also highlights approaches to avoid and minimize impacts, as well as recover and conserve important areas for biodiversity.

In 2017 and 2018 we used the framework of the mitigation hierarchy to reevaluate the planning, licensing and implementation of the S11D project. As the project was already operational at the time of the study, the analysis focused on identifying the elements of good practice and lessons that could be learnt and applied for future project expansions. Outputs included identification, prioritization and mapping of biodiversity risks for the mine complex and a Biodiversity Action Plan (BAP) focused on mitigating and monitoring risks and impacts of future expansions.

Methodology

The evaluation and development of the BAP was based on good practice mitigation approaches including the mitigation hierarchy framework and the International Finance Corporation's Performance Standard 6 guidelines (IFC PS6 2019), customized by The Biodiversity Consultancy (TBC) for Vale's internal management guidelines (TBC, 2017). The evaluation included; engagement with environmental teams, project planning and engineering; analysis of mine design alternatives and their evolution based on discussions with external stakeholders (environmental agencies, specifically IBAMA and ICMBio); information gathering from previous studies conducted in the area; analysis and definition of priority and key biodiversity features; loss-gain biodiversity accounting of direct residual impacts; assessment of the existing mitigation strategy and proposal of actions to minimize and monitor risks of future expansions in alignment with a clear and pre-defined objective of adherence to the mitigation hierarchy as outlined within Vale's internal guidance.

Results

Some species, particularly plants, associated with iron ore rocky outcrops have a restricted range; identifying and mitigating impacts to these species is a priority. The analysis identified 18 plants species and six animal species as priority species and three habitat types that support the priority species. A sub-set of six key features are a focus for specific mitigation and monitoring actions (two habitats, three plant species and one reptile). Additional mitigation actions identified in the BAP, (on top of actions already being undertaken by the project), to improve the management of priority and key features that are now being implemented include: mapping the distribution of priority species across rocky outcrops in

The Biodiversity Action Plan conforms to International Finance Corporation standards (IFC PS6)

Photo: João Marcos Rosa

the southeastern region of Pará; undertaking research and genetic studies; development of protocols for germination and propagation for reintroduction and habitat restoration; and, ex situ conservation actions such as developing and maintaining seed banks.

Key mitigation actions implemented to date by the project and lessons learnt for future projects include:

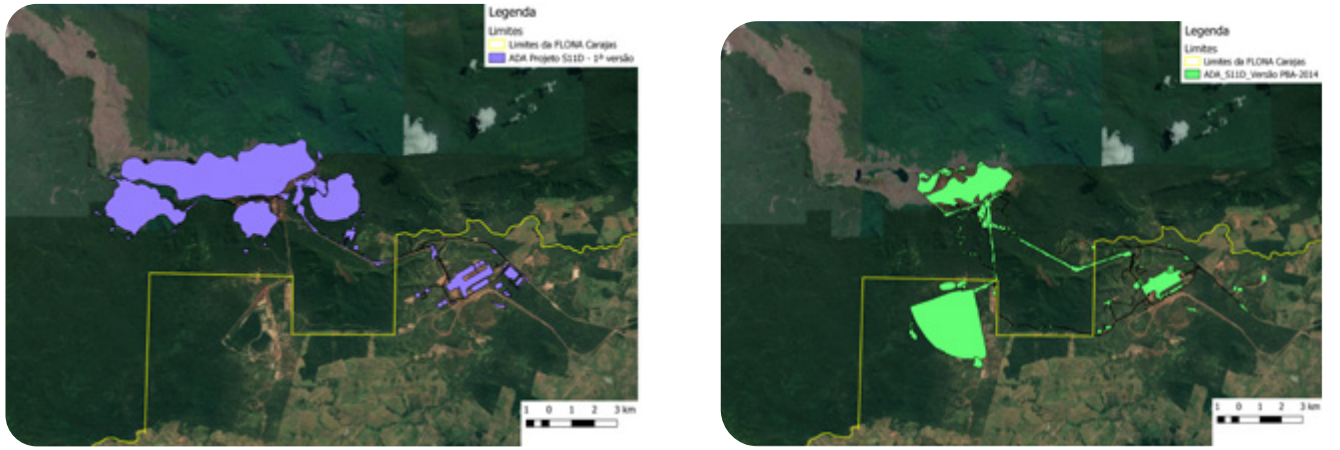
Avoidance and minimisation: The joint work of environmental, engineering, planning and environmental agencies led to several changes in the master plan that avoided impacts to more than 1,100 ha of natural habitat (Figure 1).The Project has committed to not disturb the habitat of a key plant species within the mine footprint until translocation and propagation techniques are proven to enable the project achieve a no net loss for the species.

Lessons learnt : Understanding the biodiversity risks ahead of project development enables: 1. environmental and engineering teams to work closely together to assess the best alternatives for project design, that avoid impacts on priority and critical attributes; 2. environmental and social teams to work together to minimize indirect risks associated with in-migration.

Restoration: The forest habitat restoration programme has been undergoing implementation since 2016 within Vale properties around the mine site (Figure 2). The goal for these areas is to recover degraded areas previously used for agriculture and pasture into forest habitat that will support the formation of wildlife corridors. The programme aims to restore more than 5,000 ha which will more than compensate for direct impacts to forest habitat (Figure 3). Restoration of rocky outcrop habitat will be undertaken at the mine site and at the compensation site (see compensation).

The habitat restoration program has been in place since 2016 and will restore more than 5,000 hectares of habitats

Figure 1. Design changes to prevent impacts



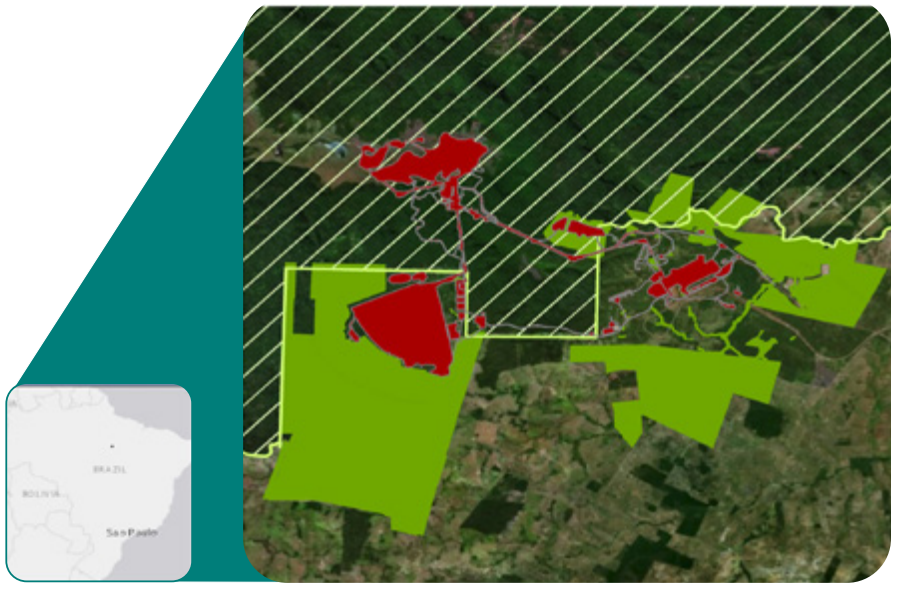


Figure 2. Forest restoration areas

The Biodiversity Consultancy

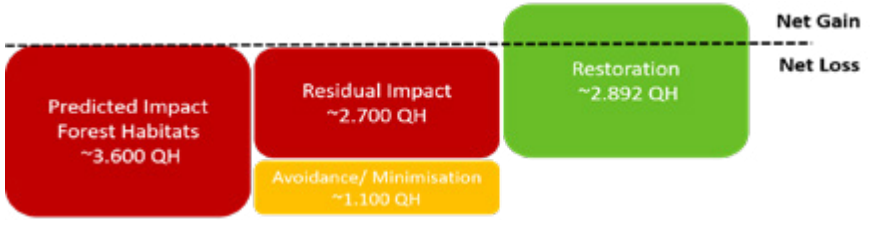


Figure 3: Forest restoration will more than offset direct impacts to forest habitat (measured in Quality Hectares)

Lessons learnt: Accounting for losses and gains should include a measure of habitat quality or condition (e.g. Quality Hectares, QH) to ensure that restoration and compensation measures generate equivalent biodiversity gains to the areas impacted.

Compensation: Bocaina rocky outcrop was selected as the compensation site; this site has been degraded by farming and cattle grazing activities. The site does not contain the full suite of priority and key plant species, but translocation and restoration trials are underway to introduce these species and restore existing populations of priority species and rocky outcrop habitat. In partnership with the Chico Mendes Institute for Biodiversity Conservation (ICMBio) a conservation unit has been established to manage Bocaina and Tarzan rocky outcrops which together form the newly established Campos Ferruginosos National Park (Figure 4). The creation of the park can be considered an additional conservation action as Vale has forgone exploration rights to enable the long-term protection of these important habitats for endemic species.

Lessons learnt: Selection of compensation sites should consider the social, political and technical feasibility of generating biodiversity gains. The most appropriate site, from a technical perspective, is an area that supports

all the priority biodiversity attributes and can generate sufficient gains to compensation for the scale of residual impacts predicted.

This evaluation has resulted in the elaboration of the S11D Biodiversity Action Plan and Vale's Biodiversity Normative Document with Guidelines and Processes for Biodiversity Management that guides the performance of our teams in the management of new projects and mine expansions. Whilst the greatest opportunities for improved management practice will be in applying the norm and guidance to new projects and expansions, this study has also demonstrated that evaluating existing operations can also result in identifying additional improvements for biodiversity management; it is never too late to improve management practice!

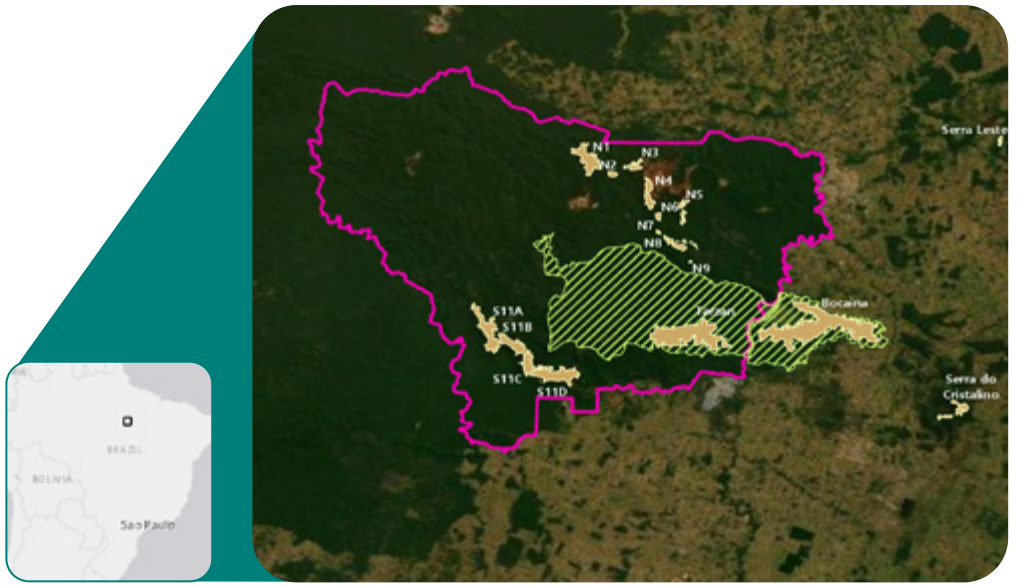


Figure 4: The Campos Ferruginosos National Park and ironstone outcrops

Strategic alignment

For further information

Cesar Neto[1], Emma Tatum-Hume[2], Fernando Marino Gomes dos Santos[3], Helio Laubenheimer[5] Letícia Guimarães[4], Luiz Felipe Campos[4], Mario Luiz Oliveira[1], Mayla Barbirato[1] (leticia.guimaraes@vale.com; emma.hume@thebiodiversityconsultancy.com)

1. Vale, Diretoria Corredor Norte/ Gerência de Meio Ambiente Relacionamento Institucional e Socioeconomia; 2. The Biodiversity Consultancy (TBC); 3. Vale, Diretoria Cadeia de Valor Ferrosos/ Gerência de Estudos Ambientais; 4. Vale, Diretoria de Sustentabilidade e Investimento Social/ Gerência Executiva de Gestão Ambiental; 5. Fundo Vale

Biodiversity Management & Action Plans

The Carajás Biodiversity Management Plan

Introduction

Development of a Biodiversity Management Plan (BMP) for the Carajás region was recommended when the local environment team detected environmental vulnerabilities and the need for more structured actions for biodiversity conservation surrounding Vale's iron ore operations in the region. A planning and management team was created with both internal and external experts. This team was tasked with developing a document outlining strategic actions for managing biodiversity, and then following up on/monitoring recommended actions. The BMP covers both existing operations and expansions in the region, and is centered on four strategic pillars:

Methodology

The elaboration of the document involved wide participation of executive teams for the alignment of goals and indicators

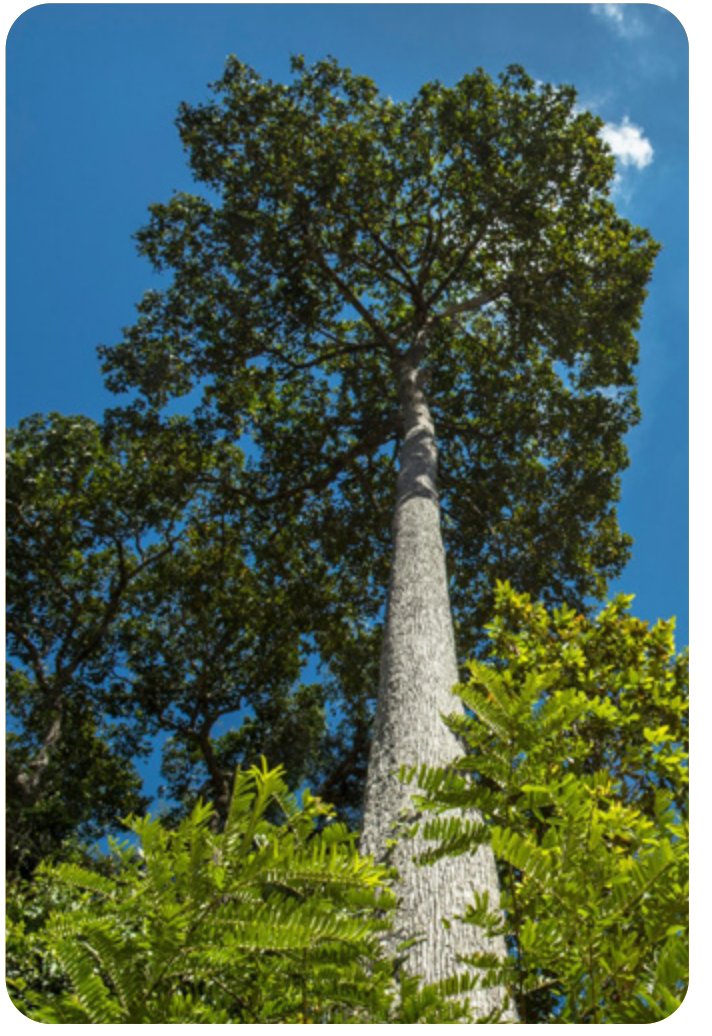
1) increasing/managing knowledge about biodiversity, assessing associated risks and prioritizing features using the impact mitigation hierarchy;

2) outlining conservation strategies for biodiversity features, especially those defined as priority features or features of interest for conservation;

3) defining strategies for incorporating biodiversity conservation into mined land rehabilitation activities;

4) recommending additional actions as part of environmental offsets to improve environmental quality and ecosystem services in the region.

Following development, the Biodiversity Management Plan was validated by the teams assigned to execute planned activities. Bilateral meetings were held for alignment on targets and indicators, as a way to make planning more practical. Conformity to the BMP is assessed through monthly reporting by execution teams to the biodiversity management team, which monitors activity outcomes against indicators measuring progress toward set goals.



Results

Several strategic initiatives are already being implemented for each pillar in the BMP. The Risk and Impact Mitigation Hierarchy Assessment initially focused on the N3 plateau, from which data on important and priority features for conservation were collected and collated.

A total of 151 taxa, including 51 flora and 100 fauna taxa, were identified for this area. For prioritized flora species, risk assessments were conducted using probability and consequence impact matrix. The entire prioritization exercise was conducted in conformity to a Vale standard on Biodiversity Management. Four species were classified as very high priority (C1), 1 as high priority (C2), 22 as medium priority (C3) and 3 as low priority (C4). A dedicated action plan is being developed for C1 and C2 species using the mitigation hierarchy framework. This will subsequently be used to identify the impacts prevented and mitigated, restoration recommendations and potential offset sites.

The classification of species into priority levels based on conservation risks from new projects/expansions informed the development of "Threatened Species Conservation Strategies" and training programs for germplasm collection teams at the East Range, North Range and South Range sites for these taxa. Training was also administered to the Carajás National Forest Extractivists Cooperative on selecting parents for collection of seeds of these species. Collected seeds will be supplied to the Mined Land Rehabilitation Program to increase the presence of these species in revegetation areas, thus optimizing conservation efforts. Field and desktop research was also conducted on the species to expand knowledge about their distribution and extent of occurrence (figure 1 on the following page).

Classification of species into priority levels based on conservation risks from new projects/ expansions informed the development of "Threatened Species Conservation Strategies"

To fill knowledge gaps identified during the development of the Carajás BMP, studies/projects were also recommended to generate information on species conservation and habitat restoration, including the following: Southeast Pará Herpetofauna, Threatened Species Searches Using UVAs and VNI Cameras, Canga Biocementation and Canga Gardens at the Vale Zoobotanical Park in Carajás.

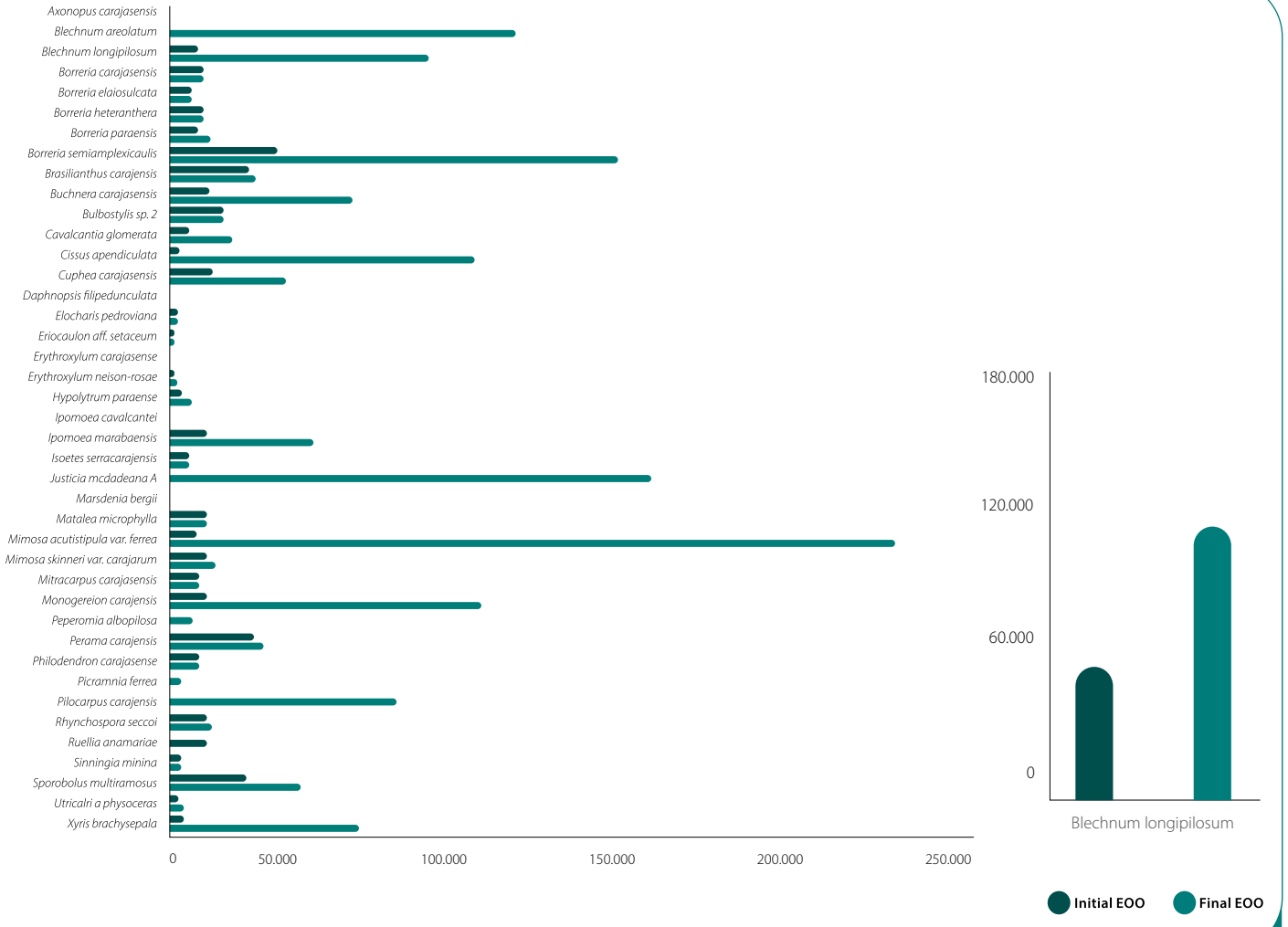


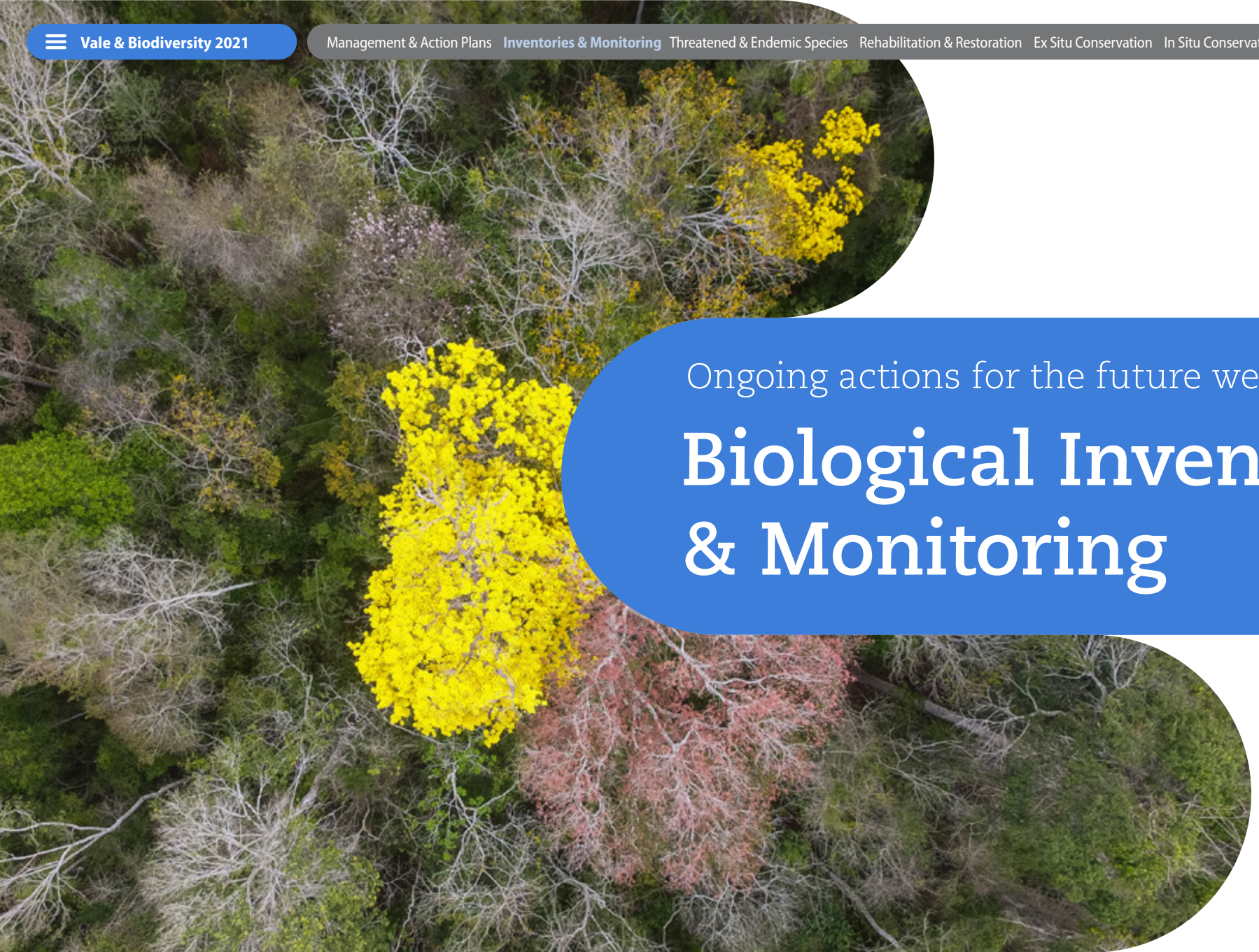
Figure 1: Species' known extent of occurrence expanded as a result of efforts to improve knowledge about the range of regional flora species

Strategic alignment

For further information

Wilker Araujo[1]; Alexandre Castilho[2]; André Cardoso[2]; Gisele Teixeira[2]; Giselly Mota[2]; Lourival Tyski[1], César Neto (cesar.carvalho.neto@vale.com)[1].

1. Diretoria Corredor Norte/ Ger. Exec. Ssma.G. Risc. Corr.Norte / Gerência de Meio Ambiente Rel Inst Soc Eco Com; 2. Sete Soluções e Tecnologia Ambiental.



Ongoing actions for the future we want

Biological Inventories & Monitoring

Biological Inventories & Monitoring

Expanding knowledge about the geographic distribution of amphibians in protected areas within the Minas Gerais Iron Quadrangle, Brazil

Photo: Adriano Silveira

Introduction

The Iron Quadrangle is a geomorphological region located in south of the Serra do Espinhaço, in the center-southeast portion of Minas Gerais State. The region has a thriving mining industry in which Vale S.A. has had a presence since its foundation in 1942. As a mountainous region, it has a large altitudinal range, up to a maximum of 2,072 m (Pico do Sol, in the Caraça Mountains). Its mountains form a divide between two large basins—the São Francisco and the Doce river basins—in a transition zone between the Atlantic Forest and *Cerrado* (wooded savanna) (Fernandes, 1998; Rizzini, 1979). These biomes are globally important for conservation of biodiversity and have been classified as conservation hotspots due to their biological richness and the high degree of anthropic pressure tto which they have been exposed (Myers et al., 2000).

Methodology

The region is known for its diversity of amphibian species, many of them endemic (Leite et al., 2008; Nascimento et al., 2005). Nascimento et al. (2005) have listed 73 species of anuran amphibians in the region, 28 of which are considered rare in this territory. These authors also report that in Minas Gerais, 12 species are on state and national lists of threatened species, and 19 anuran amphibians and 2 caecilian species are considered rare in the wild.

Brazil's megadiversity of amphibians is threatened by anthropogenic stressors. Habitat loss is the primary threat to amphibians (ICMBio, 2018), especially to restricted-range species. This underscores the need for increased research on Brazilian amphibian species (ICMBio, 2018) and, in particular, the need to maintain protected areas hosting extensive natural remnants and a diversity of aquatic microhabitats used by amphibians for breeding.

16 protected areas
sampled in Minas Gerais / Brazil

As a first step in preventing impacts, in 2016 a set of initiatives was launched, with funding from Vale S.A., to assess the situation of target species and ensure that the Company's operations operations could be carried out in line with the conservation of these species. The assessment was conducted using the mitigation hierarchy framework, reflecting the presence and importance of threatened, rare and endemic amphibian species in areas surrounding the Company's operations.

Field sampling programs were carried out in Conservation Units (CUs) and other protected areas managed by Vale S.A. (Figure 1), across a total of 16 sampling areas (Figure 2). Research was also performed in scientific collections of amphibians at the Laboratory of Vertebrate Zoology at the Federal University of Ouro Preto (LZVU-FOP) and the Taxonomic Collection Center at the Federal University of Minas Gerais (UFMG).

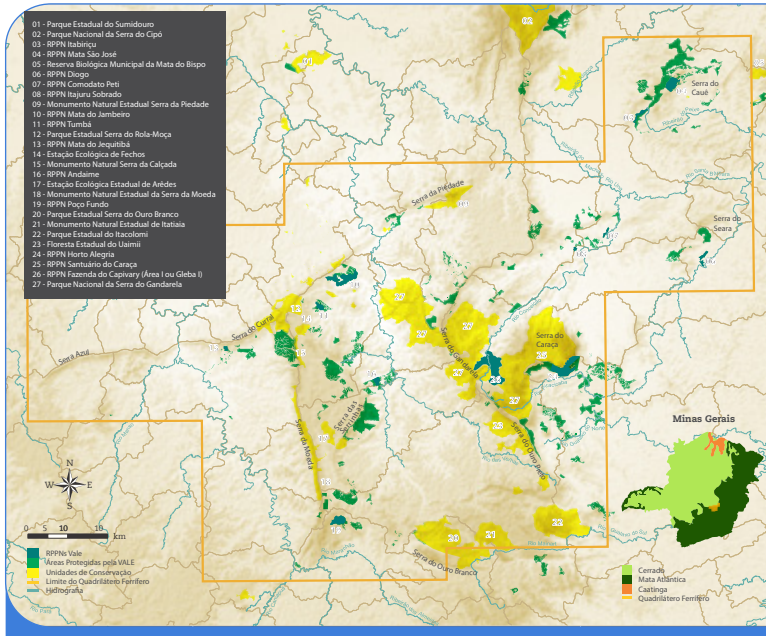


Figure 1. Vale and third-party protected areas where field sampling was carried out

Results

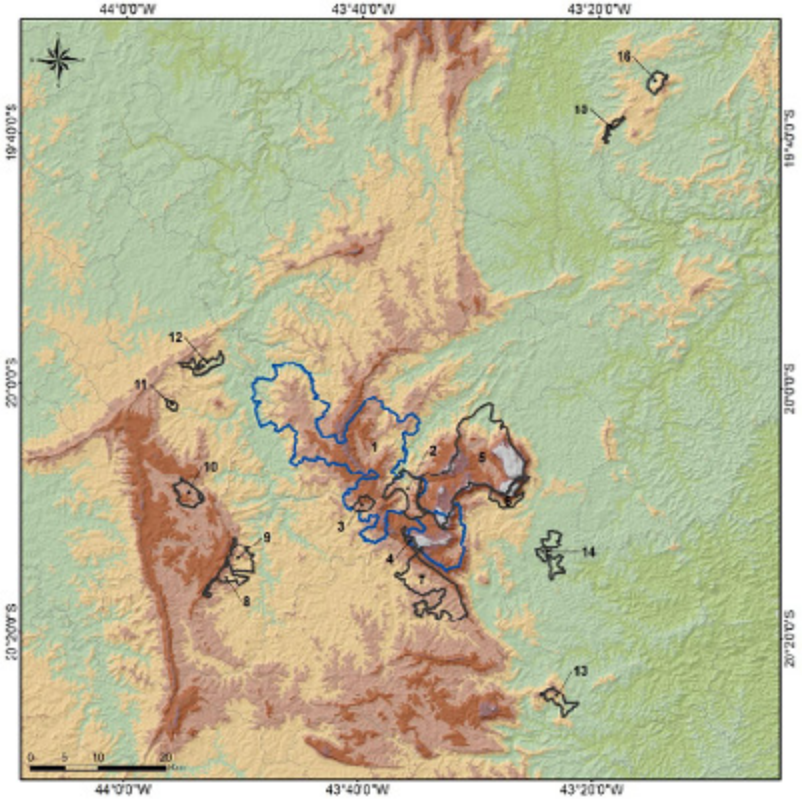


Figure 2. Map of protected areas sampled in the Iron Quadrangle, Minas Gerais.

1 – Serra do Gandarela National Park
2 – Fazenda do Capivary Private Natural Heritage Reserve (RPPN) I
3 – Capivary Reserve II
4 – Fazenda Capanema
5 – Santuário do Caraça RPPN
6 – Horto Alegria RPPN
7 – Uaimii State Forest
8 – Córrego Seco Reserve
9 – Cata Branca Reserve and Cata Branca Archaeological Site
10 – Capitão do Mato Reserve
11 – Tumbá RPPN
12 – Mata do Jambreiro RPPN
13 – Fazenda Itacolomi
14 – Fazenda Patrimônio and Fazenda Fábrica Nova Leste
15 – Itabiruçu RPPN
16 – Mata São José RPPN.

The assessment compiled a list of 96 amphibian species, including 92 species from 14 families of the order Anura (frogs and toads) and 4 species of the order Gymnophiona (caecilians), with 61 species having some conservation concern. These figures represent the largest field survey ever carried out in the region in terms of species richness. Of these species, 2 are on threatened species lists, 24 are endemic to mountainous habitats, 28 are rarely found in the wild, 21 are regionally rare and 38 are indicators of high environmental quality.

In addition to expanding knowledge about the region, the survey provided the first records in the Iron Quadrangle of the species *Adelophryne glandulata, Leptodactylus cupreus, Bokermannohyla saxicola, Scinax crospedospilus and Siphonops hardyi*, and of the then-undescribed species *Aplastodiscus* aff. *arildae and Chiasmocleis sp.* The known geographic distribution of many other species was also expanded.

96 amphibian species were identified. The known geographic distribution of many species was expanded

In 2017 the team realized that providing society with a comprehensive and publicly available record of the vast knowledge that had been gathered and organized through the initiatives could help to raise public awareness of the environmental value of biodiversity, thereby supporting conservation. This led to the publication of six scientific articles and the book "Amphibians of the (Minas Gerais) Iron Quadrangle: new insights, annotated lists and a photographic guide" (Silveira et al., 2018a, 2018b, 2019a, 2019b, 2019c, 2020a, 2020b), all publications of high educational and scientific value.

The team's efforts and experience in conservation initiatives led to Vale S.A. being selected by the Brazilian government as a member of ICMBio's Technical Advisory Group (GAT) for the National Action Plan for Conservation of Threatened Herpetofauna in the Espinhaço Mountains of Minas Gerais (PAN Herpetofauna do Espinhaço Mineiro). Through this partnership, the outputs from these initiatives have been translated into public policy on conservation, as part of a national, participatory, contemporary strategy. In addition to technical inputs and the publications mentioned above, Vale S.A. produced as an input for the PAN an important planning instrument titled "Selection of Areas for Protection, Restoration and Habitat Connectivity, Supporting the Conservation of Species Covered by the National Action Plan for Conservation of Herpetofauna in the Espinhaço Mountains." (Amplo, 2020).

Photo: Adriano Silveira

Building on the important contributions that have been made to knowledge about amphibian fauna, Vale S.A. has since continued and extended the initiatives to new protected areas, now with a greater emphasis on reptiles.

Strategic Alignment

For Further Information

Taís Nogueira Fernandes[1], Adriano Silveira Lima[2], Lucas Soares Vilas Boas Ribeiro[3], Tiago Teixeira Dornas[3] (tais.fernandes@vale.com)

1. Vale, Diretoria Cadeia de Valor Ferrosos/ Gerência de Licenciamento Ambiental; 2. Biótica Estudos Ambientais. 3. Amplo Engenharia e Gestão de Projetos.

Biological Inventories & Monitoring

Rapid progress on flora and vegetation research in Pará

Photo: João Marcos Rosa

Introduction

Serra dos Carajás, one of the largest mineral provinces in the world, has a peculiar ecosystem known as ferruginous canga or ironstone outcrops. Floristic studies in this area have contributed to the rapid advancement of knowledge about the flora in the region. In this case study, we present in chronological order the progress that has been made in the studies and their key findings.

Results

2015 to 2018 – The Flora of Carajás Cangas: Over 1,000 plant species, representing 15% of the flora in the state of Pará

The "Flora of Carajás Cangas" (FCC) project is considered the most recent and most structured botanical study undertaken in the Brazilian Amazon. Published in four special editions of the journal ***Rodriguésia***, the study comprises 164 monographs of botanical families, including 22 bryophyte monographs, 22 pteridophyte and lycophyte monographs, 1 gymnosperm monograph and 119 angiosperm monographs, totaling 1094 species. This represents a significant portion (15%) of the flora in the state of Pará, which is currently home to nearly 7,000 species. In all, 145 botanical taxonomists from 30 Brazilian and international institutions collaborated on the FCC project.

2017 to 2018 – Cangas in Carajás differ from those in the Iron Quadrangle

Research revealed the absence of a recent floristic link between the cangas of Carajás and those of the Iron Quadrangle. Almost 900 canga species in the Serra dos Carajás were compared against a database of more than three thousand species from different canga fields on different substrates in Bahia and Minas Gerais.

2017 to 2020 – Research and conservation of Carajás cangas

Floristic analysis of species recorded on the outcrops of each canga body in Carajás showed affinity between some blocks in the North and South, as well as similarity between the two areas within the Campos Ferruginosos National Park (PNCF).

Research carried out by ITV at PNCF has made a considerable contribution to floristic studies and has detected populations of rare, endemic and invasive plants in this region's cangas. Further sampling is expected to increase the species listed for these areas by 20%.

Expeditions to cangas in the westernmost portion of the Carajás formation, in São Félix do Xingu (SFX), recorded 245 species of vascular plants including 17 edaphic endemic canga species. In this study, a comparison was

Figure 1. Vegetation in Serra da Bocaina, at Campos Ferruginosos National Park [photo by J.M. Rosa]

Expeditions have provided new insight into open vegetation areas in the Amazon

made across 16 canga outcrops in the region. We found that the number of species occurring in cangas increases with area. Similarity between pairs of mountain ranges is also positively correlated with increasing outcrop area. Conversely, the number of endemic species shared by pairs of mountain ranges decreases with distance between them. These are important inputs into the planning of environmental initiatives in the region.

The research results also show an evident floristic dissimilarity between cangas in the Serra Arqueada (SA) and other canga fields in Carajás. The specificity of SA is also evidenced by the recording of two angiosperms not previously known to occur in Pará, in addition to eight species endemic to the substrate of Carajás cangas.

2018 to 2020 – Canga does not fit the definition of Amazon savanna

Expeditions to savanna areas in western Pará have provided new insight into open vegetation areas in the Amazon, for which there remains a large knowledge gap. Two areas of Monte Alegre were investigated in a floristic survey that listed 460 species of angiosperms. These data were consolidated with other flora lists representing the main open vegetation formations in Brazil, in order to explore the biogeographic relationships between them. Among the most significant results was the discovery of 23 angiosperms not previously known to occur in the state of Pará, of which seven were also new to the Amazon more broadly. In addition, two entirely new species were discovered.

Multivariate analysis of a consolidated database, including five other types of vegetation, revealed that Amazon cangas form a very distinct and cohesive group that does not fall under the definition of Amazon savannas. These formations, hitherto grouped together under the designation of "Amazon savannas", in fact have little floristic affinity to them. Instead, the "Amazon *cerrado*" could be more fittingly described as Amazon savanna, as it is more closely associated with the northeast vegetation of the Amazon than with the *Cerrado* proper in midwestern Brazil.

Strategic Alignment

For Further Information

Daniela C. Zappi[1,4], Alice Hiura[1], Juliana Lovo[1], Caroline O. Andrino[1], Rafael G. Barbosa-Silva[1], Maurício T.C. Watanabe[1], Pedro L. Viana[2], Ana M. Giulietti[3] (mauricio.watanabe@itv.org)

1. Diretoria de Sustentabilidade e Investimento Social/ Instituto Tecnológico Vale Desenvolvimento Sustentável; 2. Museu Paraense Emílio Goeldi; 3. Universidade Estadual de Feira de Santana; 4. Universidade de Brasília

Biological Inventories & Monitoring

Using eDNA analysis for Amazonian biodiversity characterization Amazon biodiversity

Introduction

Molecular approaches such as DNA metabarcoding, which is based on analysis of environmental DNA (eDNA) recovered directly from the environment (water, soil, feces or tissues), have demonstrated enormous potential in biological monitoring studies. These approaches are not confined to analysis of a single specimen—they allow simultaneous identification of multiple species by sequencing target regions of DNA from environmental samples (Hebert et al. 2003, Lynggaard et al. 2019).

Methodology

DNA metabarcoding has been widely used as an alternative method for assessing the biodiversity of invertebrates (Cowart et al 2015), plants (Yoccoz et al. 2012), vertebrates (Andersen et al. 2012), and soil fungal communities (Schmidt 2013), as well as for diet assessments (Pompanon et al. 2012) and for reconstructing baseline plant and animal communities following anthropic interventions (Epp et al. 2012).

This method can also be used to measure fluctuations in species richness, helping to inform conservation and management strategies (Kelly et al. 2014). Given the effectiveness and the advantages of using the method in environmental studies and monitoring, the Vale Institute of Technology (ITV) has used DNA metabarcoding not only in fauna and flora surveys in Carajás, but also in assessing the distribution of species within a given environment.

The Carajás cangas—savanna-like ecosystems on ironstone outcrops—are unique, mega-diverse environments that harbor both endemic and rare flora and fauna species (Zappi 2017, Giulietti et al. 2019). The recently completed Flora of Carajás Cangas (FCC) project (Viana et al. 2016, Zappi 2017) provided a detailed description of the species occurring in the area. Concurrently, a DNA barcode database referenced by taxonomists was developed, supporting more accurate identification of species using methods such as DNA metabarcoding (Zappi et al. 2017).

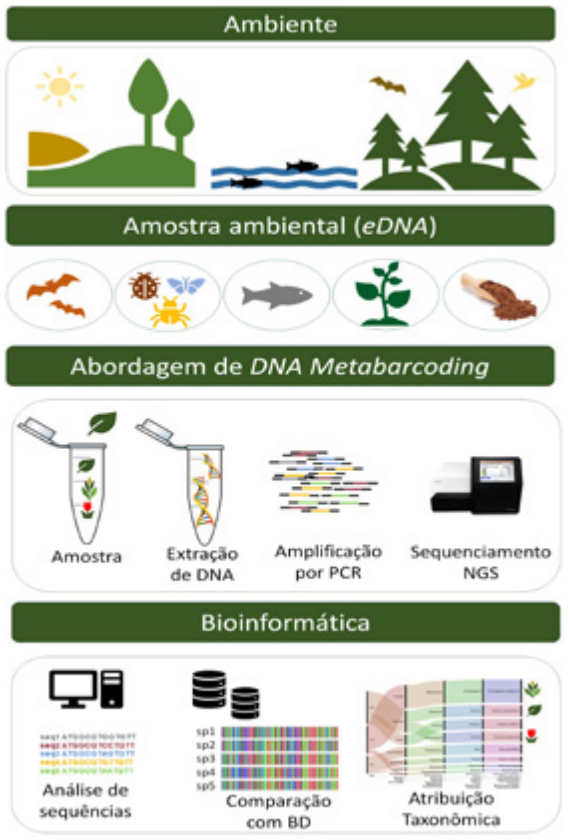
Similar studies are currently underway for cave invertebrates, bats and fishes. The DNA metabarcoding approach has been used extensively in Carajás. For plant studies, soil samples have been used to collect trace DNA and re-create the current composition in specific canga areas. DNA metabarcoding has enabled flora diversity and distributions in different canga phytophysiognomies in Carajás to be rapidly and accurately assessed using plant-specific molecular markers.

Results

The study results had high taxonomic resolution thanks to the use of the genetic database described above. In addition, a comparison of DNA metabarcoding technology with traditional methods showed that the molecular approach is able to detect a larger number of species, genera and families than conventional methods. This demonstrated the potential benefits and usefulness of using DNA metabarcoding in surveying and monitoring activities in Carajás.

DNA metabarcoding allowed the rapid and accurate assessment of flora diversity and distribution in Carajás cangas using plant-specific molecular markers

Figure 1. A summary illustration of the DNA metabarcoding technique, which assesses species diversity using eDNA recovered from environmental samples.



Similar results were observed in a study of ichthyofauna in canga lakes and surrounding streams. More fish species were identified from DNA recovered from the lake water than in the list of fish generated by traditional methods. However, in this case species could only be identified to a lower taxonomic level due to the lack of genetic references in public databases. This shows the importance of generating local references when implementing monitoring programs, in order to increase taxonomic resolution and facilitate biodiversity monitoring in the future.

DNA metabarcoding is also being applied to assess the diversity of cave invertebrates in Carajás. Given that Carajás contains the largest wealth of ferruginous caves in the world, studies such as these are of paramount importance. Several studies have shown that these caves have a high degree of biological endemism. However, there is limited data available at both the taxonomic and the molecular level. Thus, research has been intensified at ITV to expand available data on cave fauna and contribute to a better understanding of the biodiversity of these unique environments.

Strategic Alignment

For Further Information

Gisele Lopes Nunes, Santelmo Vasconcelos, Rafael Valadares, José Augusto Bittencourt, Eder Soares Pires, Vitória Catarina Cardoso Martins, Amanda Manuelly da Silva Oliveira, Ronnie Alves, Markus Gastauer, Guilherme Oliveira (gisele.nunes@itv.org).

Diretoria de Sustentabilidade e Investimento Social/ Gerência Executiva de Investimento Social, Cultura e Inovação/ Instituto Tecnológico Vale, Desenvolvimento Sustentável (ITV-DS)

Ongoing actions for the future we want

Threatened & Endemic Species

Threatened & Endemic Species

Biodiversity forecasting as a management tool: bat occupation of caves in the Carajás Mosaic

Photo: Leonardo Trevelin

Introduction

Any modern business model includes a strategy for managing the biodiversity associated with the organization's operations. A baseline is first established as a basis for strategic management using the mitigation hierarchy and continuously monitored indicators. Biodiversity modeling and forecasting across space and time can be a powerful tool for planning strategic initiatives. It can support impact prevention, mitigation and even offsets, and help to establish a sound scientific consensus around management practices that is based on robust, technically current, transparent and reproducible criteria.

A partnership established between Vale's Speleology and Technology department and the Vale Institute of Technology (ITV-DS) has advanced important efforts in this area. Outputs from ecological modeling in the ferruginous caves of Carajás are helping to build a body of knowledge that can support environmental licensing processes and provide greater operational security for Vale.

An accurate description of bat occupation of caves is crucial in achieving a balance between conservation and production

Methodology

The following case study features species that are ubiquitous members of the cave fauna of this region, and the resulting findings can be useful in planning mine development in a way that minimizes impact on cave colonies, as well as in planning future offsets.

Caves provide their dwellers with a stable shelter that is conducive to relationships of close dependence with the organisms they house. This is such a distinguishing characteristic that cave-dwelling fauna is classified in terms of degree of dependence. Bats, for example, are species whose lifecycle is dependent on connections between the surface and the underground. In the mineral province of Carajás, the number of caves associated with ferruginous canga is almost as remarkable as the number of bat colonies associated with those caves. This complex of caves houses colonies ranging from dozens to hundreds of individuals of different species, including stable populations of three threatened species: *Lonchorhina aurita Tomes*, 1863, *Furipterus horrens* (Cuvier, 1828) and *Natalus macrourus* (Gervais, 1856).

The presence of these species is one of the criteria for classification of a cave as being of "maximum relevance" and requiring protection against suppression, as well as a surrounding buffer area. In some cases, cave classifications can conflict with mining interests, and because caves are abundant in Carajás, an accurate description of their bat occupants is crucial in achieving an optimal balance between conservation and production.

To investigate bat occupation patterns in caves across Carajás, 3 years of bat monitoring data for 400 caves were compiled and organized in a database. Within the database, species were grouped into ecological groups, with the assumption that their use of cave environments is linked to these species' survival strategies, which are in turn characteristic of their natural history. The study groups included phytophagous species (group 1), hematophagous species (group 2), small insectivores (which includes two of the threatened species—group 3) and larger animalivores (which includes the third threatened species—4) (Figure 1A-C).

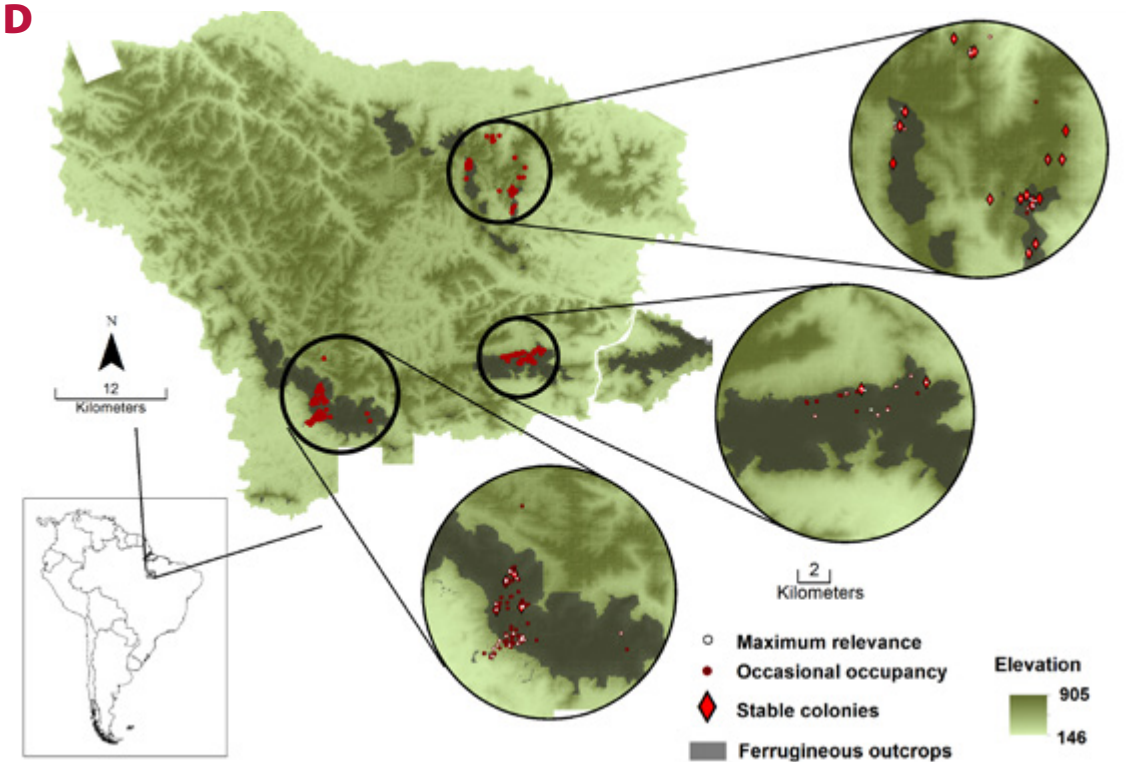


Figure 1. Threatened species of cave bats with significant populations in Carajás: (A) *Natalus macrourus* (Gervais, 1856); (B) *Furipterus horrens* (Cuvier, 1828); (C) *Lonchorhina aurita Tomes*, 1863. In (D), a map predicting the occurrence of stable colonies, occasional occupancy and caves classified as being of maximum relevance in Serra dos Carajás, for the ecological group of small insectivores (which includes *N. macrourus* and *F. horrens*)

Results

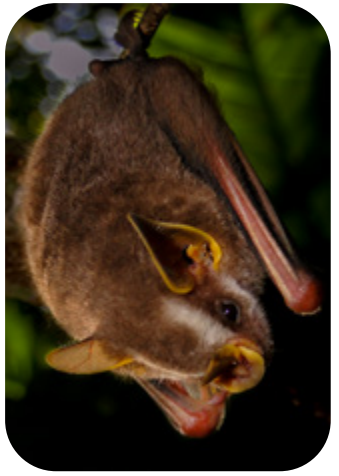


Photo: Leonardo Trevelin

Over a period of three years, each cave was assessed for the occurrence of each of the ecological groups. Caves that were continuously occupied throughout the sampling period were classified as stable colonies for that group. We then used hierarchical modeling to model cave occupation by each group. Both the biological process (occupation) and the sampling process (bat detection) were modeled in an integrated manner, providing an understanding of what characteristics are conducive to cave occupation by each group.

The models selected were assessed on their ability to predict the likelihood of occupation of caves previously recognized as stable colonies. A practical output from this process was the use of these models to identify other cavities with a higher likelihood of containing stable colonies of each ecological group in the study.

The modeling results showed that, in general, internal cave dimensions are a key predictor of occupation and that external landscape characteristics, such as the number of natural habitats and distance between caves, were secondary factors explaining occupation. These findings reflect the relationship between these animals and the underground environment and their role in integrating the underground with the outside environment.

We also built maps predicting the occurrence of colonies of threatened species, with stable colonies distinguished from occasionally occupied caves (Figure 1D). These maps can now be used to plan mine pit development in a way that minimizes impact on likely colonies of threatened species, and to identify caves as potential candidates for offsets.

Strategic Alignment

For Further Information

Leonardo Carreira Trevelin[1]*; Mariane Soares Ribeiro[2]; Xavier Prous[2]; Matheus Henrique Simões[2]; Iuri V. Brandi[2]; Tereza Cristina Giannini[1]; Guilherme Oliveira[1]; Rodolfo Jaffé[1] (leonardo.trevelin@itv.org)

1. Instituto Tecnológico Vale; 2. Diretoria de Cadeia de Valor de Ferrosos/Gerência de Espeleologia e Tecnologia

Threatened & Endemic Species

The “Carajás flower”, a species endemic to canga outcrops

Introduction

More than 500 species of plants and flowers flourish in the canga landscapes of the Carajás National Forest. Among the species endemic to the canga vegetation, one of the most threatenedis *Ipomoea cavalcantei*, known locally as *Flor de Carajás*, or the “Carajás Flower”. This species is found only on five canga islands measuring around 20 km^2 in aggregate area, while other cangas are populated by *I. marabaensis*, a more widespread species (Figure 1). Although *I. cavalcantei* is a very rare species globally, it is abundant in several canga habitats.

Methodology

In planning the management and conservation of priority restricted-range, endemic species, it is important to answer key questions about the species' lifecycle, genetics, natural history, and related ecosystem services. Conventional approaches to conservation management use a concept of species as a unit of conservation. But recent research has shown that phenotypic variation within species is also essential for the functioning of an ecosystem.

In addition, continuous phenotypic variance within species is crucial for their ability to adapt to and survive the climate change that is predicted to occur throughout the modern Anthropocene. Thus, our study also investigated the degree and origins of intraspecific variance in *I. cavalcantei*.

Results

Our findings show that animals feed not only on the leaves, flowers, seeds and roots of *I. cavalcantei*, but also on the abundant nectar in its sugar-rich flowers. Measured quantities of nectar have been found to be among the highest observed among Brazilian flowering plants. The nectar produced by *I. cavalcantei* attracted more than thirty species of animals, demonstrating the importance of this species to the canga ecosystem and to maintaining its diversity of vertebrates and invertebrates.

For the first time, we showed that *I. cavalcantei* does not produce seeds through pollination within the same flower or between flowers on the same plant (self-pollination). To produce seeds, this species requires pollination across individuals (cross-pollination) mediated by animals attracted by the flowers. The reproductive success of *I. cavalcantei* depends entirely on the presence, abundance and activity of pollinators.

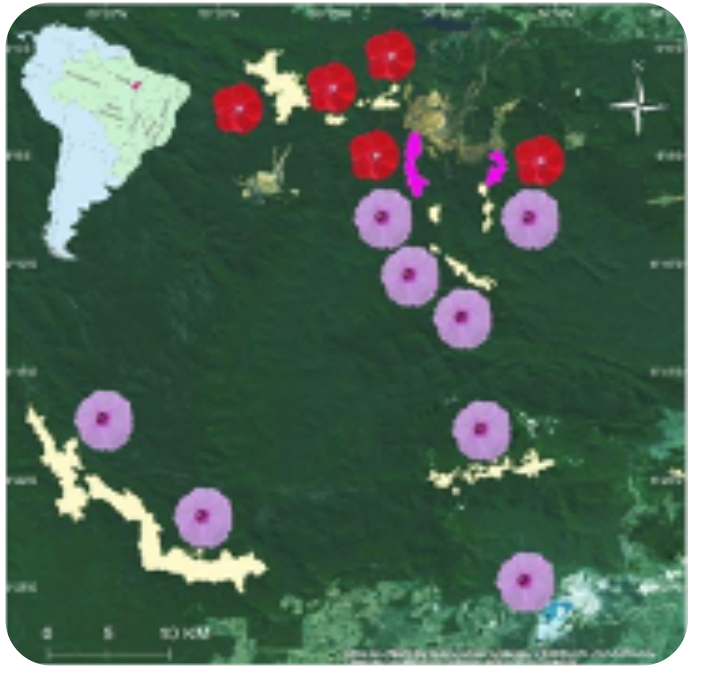


Figure 1. Distribution of *Ipomoea cavalcantei* (red) and *I. marabaensis* (lilac) among cangas in the Carajás National Forest.

Our study shows that as many as ten hummingbird species, two large orchid bee species, bumblebees, several native bee species, as well as alien bees are potentially pollinators of *I. cavalcantei*. Over the last four years, new flower visitors have been discovered each year. This underlines how pollinator communities vary in space and time, and suggests

Figure 2. Pollinators of *I. cavalcantei* and *I. marabaensis*

that the current understanding of species and their connectivity with the ecosystem is still incomplete.

In a comparative analysis of pollinator assemblages, *I. cavalcantei* and *I.marabaensis* exhibited specific and shared plant-pollinator connectivity. Hummingbird species were observed to nearly exclusively forage on nectar from *I. cavalcantei*, the same being true of other specific visitors of *I. marabaensis*. Bumblebees, orchid bees and honeybees were observed to visit flowers of both species (Figure 2).

This overlap of pollinator assemblages could result in the transfer of pollen between *Ipomea* species. Artificial hybridization was undertaken to determine whether interspecific pollen transfers may have had implications in the natural history of these species. Our findings show that *I. cavalcantei* and *I.marabaensis* are able to generate hybrids producing viable interspecies offspring. In localized cangas in the north portion of the Carajás National Forest, where *I. cavalcantei* and *I. marabaensis* are coexistent, plant individuals were found with very unusual magenta-colored flowers. Molecular analysis confirmed that these individuals are naturally occurring interspecific hybrids. In addition, the hybrids with magenta-colored flowers—both male and female—were confirmed to be totally fertile. The fertility of natural hybrids sustains intraspecific gene flow, which contributes to phenotype variance and natural mutations.

Consistent with these findings, subsequent fieldwork confirmed notable phenotypic variation within species. In addition to standard red-flowered individuals of the species *I. cavalcantei* and standard lilac-flowered individuals of the species *I. marabaensis*, wild canga populations also include individuals varying in flower color, shape and size (Figure 3 on the following page). Thus, another important benefit of numerous visitors is the potential for intraspecific pollen transfer, which can lead to the formation of interspecific hybrids. Plants with different flowers are better adapted to the innate preferences of visiting animals, which could improve individual reproductive success. Alternatively, this variation could help some individuals to evade seed herbivores that could cause them damage

Fieldwork revealed notable phenotypic variance within species

Research findings informed step-by-step protocols for large-scale collection of high-quality seeds, effective seed germination and seedling establishment

and reduce their reproductive success. This variability in ecosystem interactions could be crucial to the survival of species in situations such as changes in pollinator species compositions and climate change.

Based on these findings, and to support technical improvements, step-by-step protocols were developed for large-scale collection of high-quality seeds, effective seed germination and seedling establishment. These procedures are being introduced into the conservation plans for *I. cavalcantei*. In addition, at the Vale Zoobotanical Park in Carajás, a living collection of flowers has been established with phenotype variations that, in contrast to specimens kept in herbariums, will provide important information for future generations.

Figure 3. Interspecific hybridization between *I. cavalcantei* and *I. marabaensis* drives phenotypic diversity. Standard flowers are shown respectively left and right, while flowers collected from individuals in our *ex situ* collection are shown in the middle, demonstrating deviations, or phenotypic variance, from the standards

Strategic Alignment

For Further Information

Elena Babiychuk[1], Lourival Tyski[2], Delmo Fonseca da Silva[2], Vera Lucia Imperatriz Fonseca[1], Alexandre Castilho[3]; Sergei Kushnir[4] (babiychuk.elena@gmail.com; vlifonse@ib.usp.br; lourival.tyski@vale.com; alexandre.castilho@vale.com; Serguei.Kouchnir@teagasc.ie).

1. Instituto Tecnológico Vale; 2. Parque Zoobotânico Vale; 3. Diretoria Corredor Norte/Gerência de Meio Ambiente; 4. Teagasc, Crop Science Department.

Threatened & Endemic Species

Conservation of *Isoetes cangae*: from research to reintroduction

Photo: Arquivos ITV DS

Introduction

Mining operations in the Carajás Mountains (Serra dos Carajás) are running concurrently with scientific expeditions and botanical research in the area. These studies have led to the description of two new species of the genus *Isoetes* L. (*I. cangae* and *I. serracarajensis*), which are endemic to the ferruginous cangas that occur atop the crests of these mountains (Pereira et al., 2016). *Isoetes* is a cosmopolitan genus, its habitats ranging from aquatic to terrestrial. As the only living remnants of the ancestral order Isoetales, species of this genus are fundamental to an understanding of plant evolution (Hetherington et al., 2016).

While *I. serracarajensis* is known to occur across several areas of canga, a single population of *I. cangae* has been found underwater in a lake in Serra Sul. This, coupled with the potential impacts on its natural habitat, makes *I. cangae* a critically endangered species. Using the mitigation hierarchy framework, Vale has undertaken a range of species conservation initiatives to ensure natural resources in the region are exploited sustainably. Multidisciplinary studies have been carried out in collaboration with the Federal University of Rio de Janeiro (NUPEM-UFRJ) to improve knowledge about *Isoetes*, in order to reconcile economic progress with environmental conservation.

Extensive research has been conducted for morphological, physiological and genetic characterization of *Isoetes cangae* and *Isoetes serracarajensis*

Methodology

Extensive research was conducted for morphological, physiological and genetic characterization of *I. cangae* and *I. serracarajensis*. Although both species have similarities and little variation in their chloroplast genomes, they are distinguishable by different Single Nucleotide Polymorphism (SNP) markers, physiological adaptations and, especially, specific morphological characteristics of their reproductive structures (classical taxonomic methodology). In addition to these differences, our research provides the groundwork for a more in-depth understanding of the evolution of *Isoetes* (Nunes et al., 2018) and underlines the need for conservation measures, in particular for *I. cangae*, which was not found in other areas even after exhaustive investigation.

Habitat characterization and monitoring of biotic and abiotic conditions provided a comprehensive understanding of the ecology of these species and factors limiting their development. Monitoring during the course of the two-year study revealed the importance of environmental factors for plant growth and reproduction, and provided an understanding of the species' reproductive cycle.

In addition, technical knowledge about plant propagation is essential for conservation as it supports plant multiplication activities and can inform the development of biodiversity management plans. Because *Isoetes* plants have no flowers or seeds, their reproduction is mediated by spores. Using *in vitro* fertilization, we developed a propagation protocol for *I. cangae* that produced high yields. Germination rates are higher than 70% when mature male and female spores are used in the process, but nil when young and immature spores are used (Caldeira et al., 2019).

Our *in vitro* studies indicated that this species does not have self-incompatibility, i.e. it is capable of self-fertilization or cross-fertilization. High-resolution genetic studies have shown that cross-fertilization is more frequent in the wild. This information is important in maintaining genetic diversity and for the evolution of the species. Our findings are already being applied in the production of *ex situ* plants and in the development of strategies for assisted species introduction.

Genetic studies are also essential in assessing genetic diversity and gene flow among populations. These studies are useful in ensuring the viability of a species is maintained over time, and in calculating the minimum number of individuals needed for the genetic conservation of the species and for collecting parent stock for propagation and maintenance in living collections. These studies were carried out using Inter Simple Sequence Repeat (ISSR) molecular

markers. A high diversity index and a high gene flow were observed within the population of *I. cangae*.

To build further on our findings, we carried out additional studies using an approach that allows thousands of genetic markers to be identified simultaneously. This methodology confirmed the high level of diversity in the population, as indicated by the high rates of heterozygosity in the sample, and yielded a negative inbreeding coefficient (inbreeding among genetically similar individuals). These findings support the hypothesis that in *I. cangae* sexual reproduction occurs between different individuals. This, coupled with high nucleotide diversity, explains the significant genetic diversity found in the species.

Photo: Arquivos ITV DS

Results

Conservation of genetic resources can be done *in situ*, under the natural conditions in which the species occurs in nature, or *ex situ*, in collections and germplasm banks. Two collections with live plants of the species *I. cangae* are kept at ITVDS and NUPEM-UFRJ. Both collections contribute to preserving genetic diversity and are constantly renewed. Under controlled conditions, plants in these collections were observed to reproduce after about 9-12 months.

Spores collected in the field, or generated under controlled conditions, are stored under varying conditions and are being tested for long-term viability, with a view to the development of a spore bank. Preliminary findings indicate that viability is significantly reduced when spores are kept hydrated at room temperature, whereas cryopreserved spores (-196°C) have shown satisfactory results. In general, these studies have laid important groundwork for the development of conservation strategies for *I. cangae*.

Strategic Alignment

For Further Information

Cecilio Caldeira[1], Guilherme Oliveira[1], Naiara V. Campos[2], Emiliano N. Calderon[2], Mirella P. Santos[2], Daniel B. Zandonadi[2], Rodrigo L. Martins[2], Jeronymo Dalapicolla[1], Keyvilla Aguiar[1], Rodolfo Jaffé[1], Silvio Ramos[1], Markus Gastauer[1], Tasso Guimarães1, Rafael Valadares[1], Cinthia M. Bandeira[1], Aline L. Ferreira[2], Ana C. Fernandes[2], Analy M.O. Leite[2], Anderson R. Gripp[2], Arthur V. de S. Lopes[2], Danielle S. dos Santos [2], Henrique F. dos Santos[2], Janiélio G. Rocha[2], João V. S. R. de Araujo[2], Lais B. Jordão[2], Lísia M.S.Gestinari[2], Luís A.S. Prado[2], Luiz C. F. Ribeiro[2], Lupis R. Gomes-Neto[2], Marcos P. Figueiredo-Barros[2], Mariana H. Marques[2], Paula V. M. Pontes[2], Quézia S. Santos[2], Rafael R. Ferreira[2], Rodrigo N. da Fonseca[2], Sérgio L. Cavalheiro-Filho[2], Vinnícius M. S. Gomes[2], Francisco A. Esteves[2], Tais Fernandes[3], Fernando Marino[3], Osiel Magalhaes[3], Alexandre Castilho[3], Daniela Scherer[3]

1. Instituo Tecnológico Vale Desenvolvimento Sustentável; 2. Instituto de Biodiversidade e Sustentabilidade - NUPEM – UFRJ; 3. Diretoria de Cadeia de Valor de Ferrosos

Threatened & Endemic Species

Conservation of *Isoetes cangae*: integrated efforts support reintroduction in the wild

Photo: Arquivos ITV DS

Introduction

Building on the results from the first phase of studies, a second phase of initiatives was undertaken to expand knowledge about the ecology of *Isoetes cangae* and provide inputs to inform conservation strategies. To mitigate the risk of loss of the species, these activities are designed to increase the occurrence and perpetuity of the species in the wild. Large-scale propagation of *I. cangae* is essential to:

I) obtain plants in sufficient number to support repopulation strategies;

II) maintain genetic stock of the species to ensure genetic diversity;

III) support studies under different environmental conditions to determine the species' potential for development under specific conditions; and

IV) enable assisted recolonization in areas where the species has greatest potential for survival. Adjustments made to the *in vitro* fertilization protocol now allow for the continuous use of the reproductive structures of multiple parent plants and the production of plants with a high level of genetic diversity. More than 3,000 plants have been successfully propagated in the lab so far and are being used in a range of studies, both under controlled conditions and in the field.

When large-scale propagation has been achieved, cultivation of these plants represents the next step in the conservation strategies. To inform the development of cultivation protocols, and assess the species' ability to adapt to new environments, we evaluated the growth of *I. cangae* in different substrates, at different water column levels, with different sources of nutrients, and under different light and temperature levels—factors that affect plant development. The species was able to fully develop under most test conditions, suggesting high plasticity and potential for adaptation to different environments.

Plants completed their reproductive cycles even under higher temperatures and varying levels of nutrient availability (which inhibit the growth of several *Isoetes* species). Under controlled conditions, *I. cangae* individuals survived long periods of water stress, with their leaves outside the water and their corm kept in a moist substrate. In addition to informing the selection of areas with greater potential, these findings were also useful in optimizing the cultivation protocol, with *I. cangae* specimens reaching adulthood in around seven months, providing reproductive structures for propagation.

Isolation of bacteria in *I. cangae* plants in the wild and the use of inoculants on cultivated plants led to improved plant growth, increasing the number of leaves, leaf area and root growth in *in vitro* studies. Endophytic strains of *I. cangae*, which are involved in nitrogen fixation and phosphorus solubilization, increased growth up to 5 fold. These materials can be used to improve cultivation protocols and support colonization in new areas.

To increase the chances of success in the field, where environmental conditions vary and differ from those in the laboratory where they were propagated, the plants undergo an acclimatization process in which the environment is partially controlled and simulates the conditions

Isolation of bacteria in *I. cangae* plants in the wild and the use of inoculants on cultivated plants led to improved plant growth, increasing the number of leaves, leaf area and root growth in *in vitro* studies

of the target site. In ponds with forced water circulation for filtering and temperature control, more than 1,500 plants have now been acclimatized at Vale's seedling nursery in Serra Norte, Carajás. During this period, the plants are kept in a mixture of organic substrate and sediments from the source lake so they interact with biota associated with the species. Although virtually zero mortality was observed during acclimatization, we tested different cultivation and transport containers to increase

Molecular markers, both genes and proteins, are used to monitor plant performance under different environmental conditions

planting efficiency and survival in the field. Based on preliminary results, we selected containers that will not hinder growth, will help to maintain plant integrity during transport and will facilitate root attachment to the bottom of the lake.

Monitoring plants in the field is essential in assessing whether populations can be maintained in the wild or whether interventions are necessary. Molecular markers—both genes and proteins—can be an important tool for monitoring plant performance under varying environmental conditions. Molecular markers were established for *I. cangae* via protein analysis of plants under different conditions, from stressed plants with limited growth and few reproductive structures, to vigorous plants. In this trial, the worst-performing plants had a larger accumulation of proteins involved in the stress response, such as peroxidases, which scavenge free radicals. A single protein (α-mannosidase) was quantified as overexpressed in all stressed plants, and can be used as a good stress marker for *I. cangae*. In another study to assess drought tolerance, genes that encode for antioxidant enzymes, proteins related to bioenergetics and proteins related to hormonal signaling were also found to be good stress markers for monitoring.

In a final phase, in which the research outputs were incorporated into the conservation efforts for *I. cangae*, a plant transport and establishment protocol was developed to allow large numbers of specimens to be handled in a way that minimizes stress and mortality during the assisted reintroduction process. So far, a total of 600 lab-propagated specimens have been introduced in two environments in the Serra dos Carajás. In the first month, the survival rate was 10% in the environment where the plants occur naturally (control), compared with 20% in the new environment. Eight months later, survival in this new environment is approximately 50%, a high rate confirming the success of the protocol.


Photo: Arquivos ITV DS

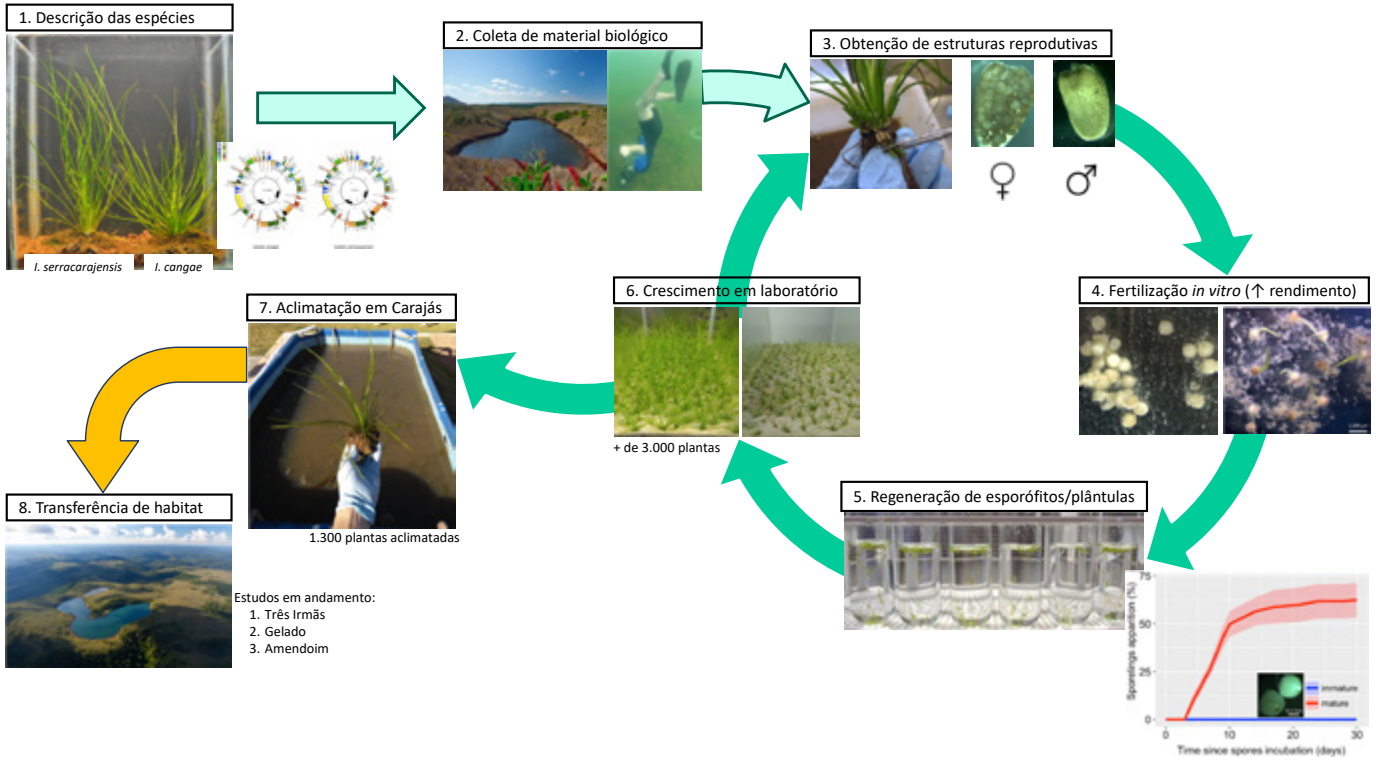


Figure 1. A summary illustration of the conservation studies on *Isoetes cangae*. (1) The two *Isoetes* species occurring in Carajás (*I. cangae* and *I. serracarajensis*) were described in detail, including their complete chloroplast genome sequences (the circular structures on the right. (2) Biological material and sediments were collected from a lake to compile data on *I. cangae* and its habitat via physical, chemical and biological characterization of the sediments. Adult plants provided (3) reproductive structures for morphology studies and to inform the development of propagation protocols, with (4) *in vitro* fertilization using mature spores generating high yields of new plants. (5) The propagation method was optimized to produce plants at large scale, and then replicated across a large number of spores and different plants—more than 3,000 plants have been propagated in the lab. After germination, (6) the first stage of plantlet growth was achieved under controlled (laboratory) conditions, with environmental conditions adjusted to support vigorous growth. Periodically, batches of plants were taken from the laboratory for (7) acclimatization at Vale's seedling nursery in Carajás. Young plants reached the reproductive stage in ponds that simulate field conditions. More than 1,300 plants have reached this phase and are now ready for reintroduction in the natural environment. Lastly, (8) plant reintroduction was initiated on an experimental basis at three sites within the Carajás National Forest.

So far, a total of 600 lab-propagated specimens have been introduced in two environments in Carajás. High survival rates confirm the success of the protocol

Strategic Alignment


Serra de Carajás

For Further Information

Cecilio Caldeira[1], Guilherme Oliveira[1], Naiara V. Campos[2], Emiliano N. Calderon[2], Mirella P. Santos[2], Daniel B. Zandonadi[2], Rodrigo L. Martins[2], Jeronymo Dalapicolla[1], Keyvilla Aguiar[1], Rodolfo Jaffé[1], Silvio Ramos[1], Markus Gastauer[1], Tasso Guimarães[1], Rafael Valadares[1], Cinthia M. Bandeira1, Aline L. Ferreira[2], Ana C. Fernandes[2], Analy M.O. Leite[2], Anderson R. Gripp[2], Arthur V. de S. Lopes[2], Danielle S. dos Santos[2], Henrique F. dos Santos[2], Janiélio G. Rocha[2], João V. S. R. de Araujo[2], Lais B. Jordão[2], Lísia M.S.Gestinari[2], Luís A.S. Prado[2], Luiz C. F. Ribeiro[2], Lupis R. Gomes-Neto[2], Marcos P. Figueiredo-Barros[2], Mariana H. Marques[2], Paula V. M. Pontes[2], Quézia S. Santos[2], Rafael R. Ferreira[2], Rodrigo N. da Fonseca[2], Sérgio L. Cavalheiro-Filho[2], Vinnícius M. S. Gomes[2], Francisco A. Esteves[2], Tais Fernandes[3], Fernando Marino[3], Osiel Magalhaes[3], Alexandre Castilho[3], Daniela Scherer[3] (cecilio.caldeira@itv.org)

1. Instituto Tecnológico Vale Desenvolvimento Sustentável; 2. Instituto de Biodiversidade e Sustentabilidade - NUPEM – UFRJ; 3. Diretoria de Cadeia de Valor de Ferrosos Vale.

Threatened & Endemic Species

Expanding known geographic distribution and control of germination and cultivation techniques for *Ruellia anamariae* A.S. Reis, A. Gil & C. Kameyama, a species endemic to the East Amazon, Brazil

Photo: Sergio Sakagawa

Introduction

Strategic studies on the flora of Carajás have been undertaken since the 2000s, leading to the discovery of species previously unknown to science, as well as species with a larger extent of occurrence than previously thought. Some species end up being forgotten in herbarium collections, and are only described years after they were first collected. This was the case of *Ruellia anamariae* A.S. Reis, A. Gil & C. Kameyama, which was first collected in 1984, but was only officially described in 2017 by Reis and collaborators as part of the Flora of Carajás project.

The study aimed to revisit herbaria, search for new records in the potential area of occurrence and detail the distribution of *R. anamariae*, a species so far known only by two disjunct populations

Ruellia anamariae is a shrub species up to 5m tall with pale yellow flowers (Figures 1 and 2). It was previously thought to be endemic to the state of Pará, and only two discrete populations had been found, on the plateaus of the Carajás National Forest and in the Serra das Andorinhas. However, the study in which the species was described investigated only the limited set of records available in the herbarium in assessing the extent of occurrence and classifying the species based on IUCN criteria. The extent of occurrence was 741,437 km2 (polygon of occurrence) and the area of occupancy was 20 km^2 (dots within the polygon), resulting in a critically endangered conservation status (Figure 3).

Figure 2. A *Ruellia anamariae* individual in the field

Methodology

The purpose of this study was to revisit herbariums to find new records of *R. anamariae* within its potential area of occurrence and better map its distribution. In addition, *ex situ* conservation strategies were developed, including transplantation, cultivation and germination protocols for seedling production, to improve knowledge and conservation of the species.

The herbarium search found new records in Carolina (MA), in the Chapada das Mesas National Park, on a substrate of quartz outcrops, as well as records associated with sandstone in Cumaru (PA) and ferruginous cangas in the Serra Leste in Curionópolis (PA). As a result, the extent of occurrence (EOO) has been updated to 45,190.107 and the area of occupancy (AOO) to 76 km^2, resulting in an endangered (EN) conservation status – (Figure 4).

Further searches for new records of the species have been undertaken via meander walks on the plateaus of the Carajás National Forest and surrounding areas since 2015.

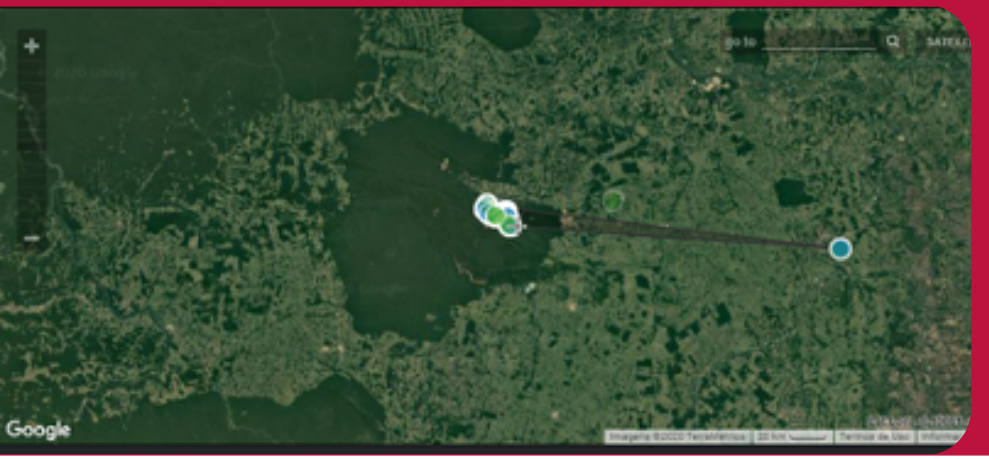


Figure 3. Global distribution of *Ruellia anamariae* according to Reias et al. 2015

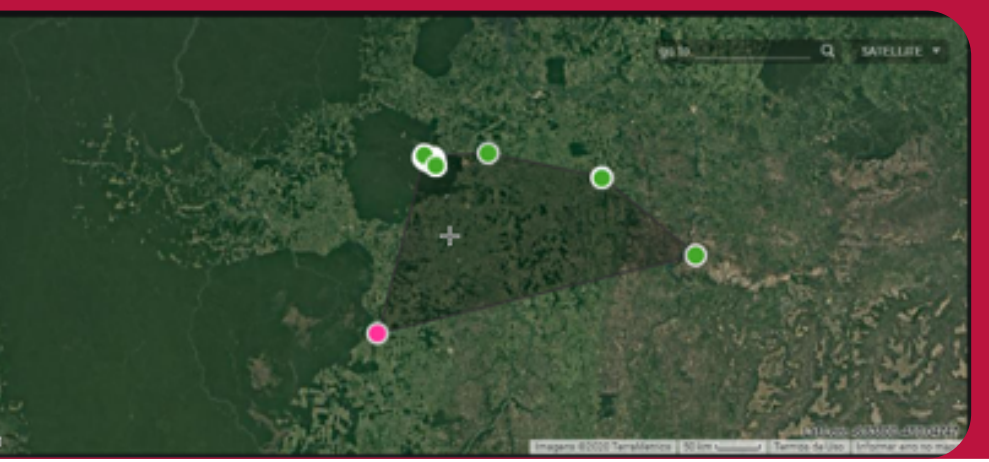


Figure 4. Updated global distribution of *Ruellia anamariae* with new records

Results

The study found 22 patches of *R. anamariae* individuals, considerately expanding its density within the area of occurrence, and demonstrating that the species is much more common than previously thought. However, the same survey method needs to be applied to other locations to effectively quantify the size of its populations.

Transplantation experiments with the species *R. anamariae* were initiated in July 2019 during the dry season, at which time 20 adult individuals were retrieved from the natural population using appropriate tools, and transplanted into wooden boxes lined with a bio-based lining to contain the substrate. Specimens were sent to the Serra Norte Nursery for monitoring. Preliminary results suggest that transplantation of adult individuals has been highly successful. However, irrigation and maintaining adequate soil moisture are essential for successful transplantation.

R. anamariae seeds were also collected in the Carajás National Forest in 2019. Plantlets produced from the seeds were cultivated at a Vale-owned seedling nursery in Miguelão (Nova Lima, Minas Gerais) to assess survival and potential for seedling production. The results from the trial indicate that *Ruellia anamariae* seeds can be used for seedling production and can be stored in seed banks for use in environmental rehabilitation. In the following stage, seedlings will be produced and larger individuals will be retrieved for introduction in protected areas in Carajás and surrounding areas.

Ruellia anamariae seeds can be used for seedling production and can be stored in seed banks for use in environmental rehabilitation

Figure 5. A flowering *R. anamariae* specimen at the nursery in Carajás

Figure 6. A flowering *R. anamariae* specimen at the nursery in Carajás

Strategic Alignment

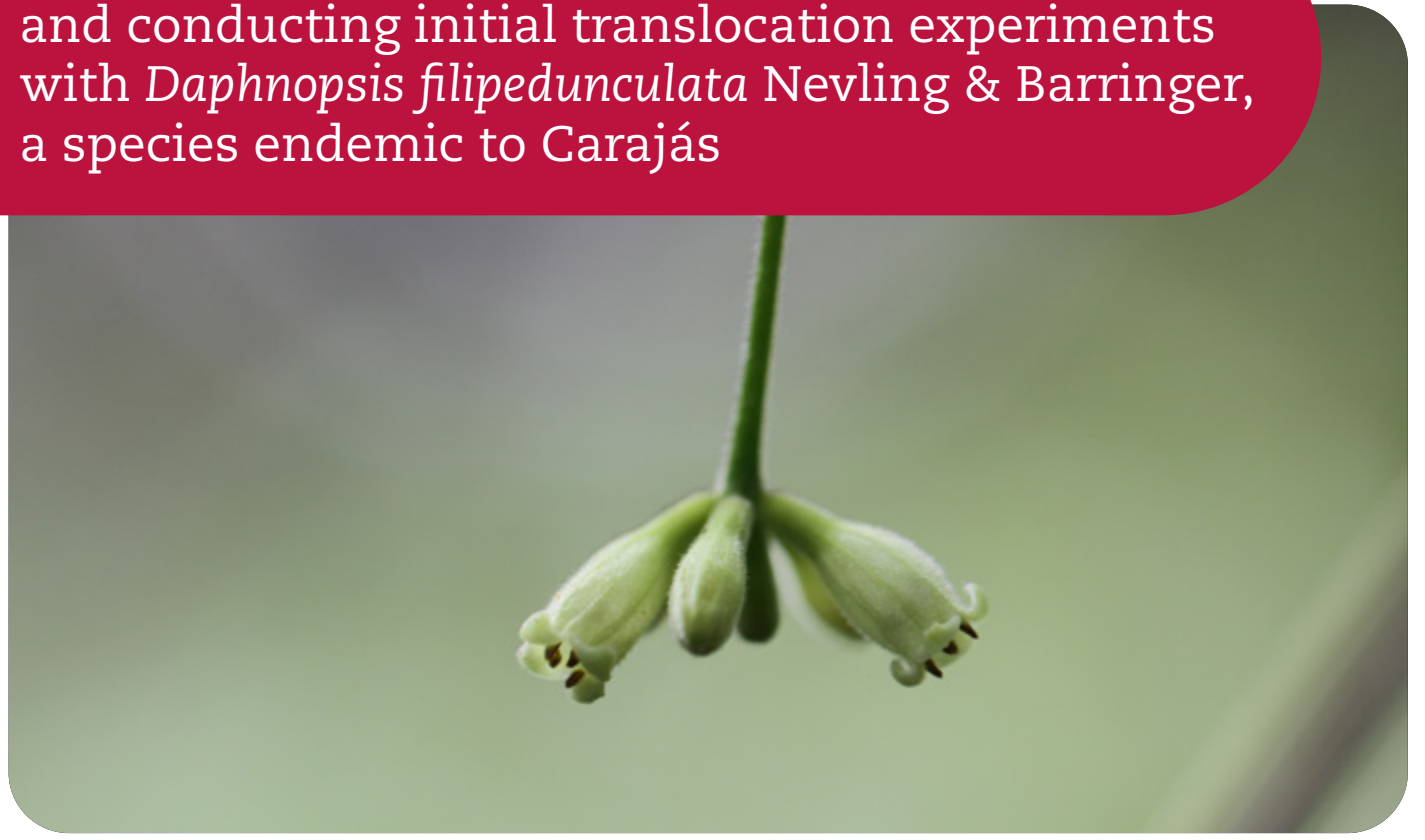
For Further Information

Mariana Wardil[1], Samir Rolim[1], Felipe Peixoto[1], Bruno Falcão[1]; Sérgio Sakawaga[1]; Marcelo Pinho[1], Fernando Santos[2], Alexandre Damasceno[2], Tais Fernandes[2], Alexandre Castilho[3], Cesar Neto[3], Marcilio Zanetti[4], Fernando Silveira[5], André Cardoso[6] (mariana.valentina@amploengenharia.com.br; fernando.gomes.santos@vale.com)

1. Amplo Engenharia Gestão de Projetos; 2. Vale, Diretoria Cadeia de Valor Ferrosos/ Gerencia de Licenciamento, Espeleologia e Estudos Ambientais; . 3. Vale, Diretoria de Ferrosos do Corredor Norte/ Gerência de Meio Ambiente; 4. Bioma Meio Ambiente; 5. Universidade Federal de Minas Gerais; 6. Sete Soluções e Tecnologia Ambiental.

Threatened & Endemic Species

Expanding known geographic distribution and conducting initial translocation experiments with *Daphnopsis filipedunculata* Nevling & Barringer, a species endemic to Carajás



Introduction

Daphnopsis filipedunculata is a small tree up to 8 m tall that is endemic to the Carajás National Forest and is described as being restricted to transition forests on the plateaus of the Serra Norte. The species was described in 1993 based on a single specimen with only male flowers that had been collected in 1982 at what was formerly a campsite and is now the N4 Mine. It was initially reported by Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis as being potentially extinct, as it was known only by its type specimen collected 40 years prior.

In 2012, botanists rediscovered the species after finding new records in the Serra Norte and, in 2017, the first female individuals were found with staminate inflorescences and fruits, with the extent of occurrence now considerably expanded in the Serra Norte. This was followed by targeted searches, ecological and phenological studies, taxonomic assessments and studies to develop cultiva-

tion and rescue methods. And the story may not yet be over, as new records may further expand the extent of occurrence far beyond its currently known boundaries.

Recent research has confirmed that *D. filipedunculata* is a rare species confined to the Carajás National Forest, occurring on plateaus N1, N2, N3, N4, N5, N6 and N7 in the Serra Norte (Watanabe et al, 2018; Giulietti et al., 2019). However, searches in Amazon and international herbaria have indicated that the species may have a wider distribution than previously thought, and may potentially have been recorded at other sites in Pará, in ombrophilous forestland (Banach), and in Guyana, in a savanna area almost 3,000 km from Carajás. The specimens were found in virtual herbaria, but still require expert validation.

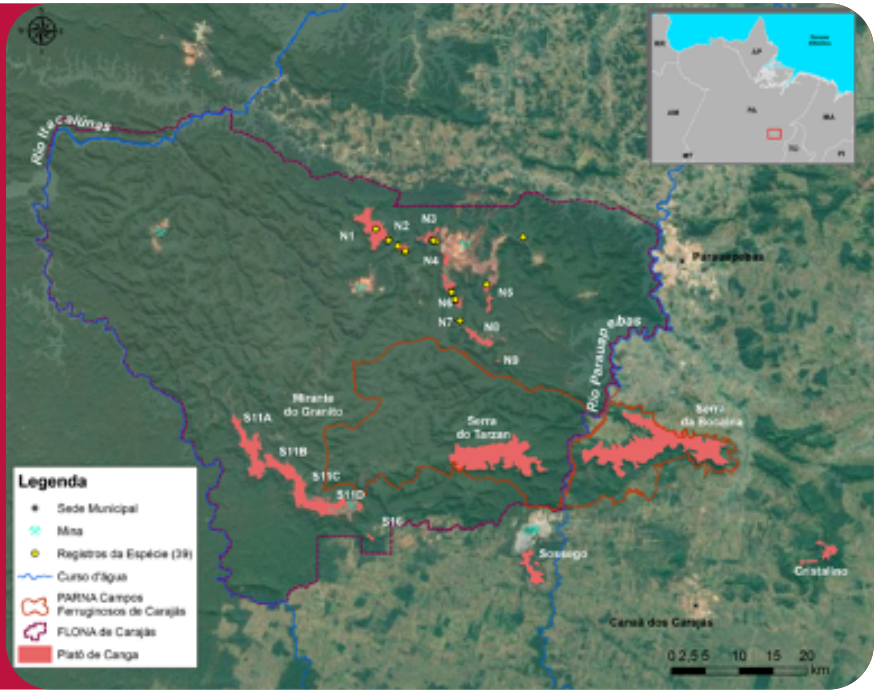


Figure 1. *Daphnopsis filipedunculata* record sites in the Carajás National Forest

Methodology

Transplantation experiments with *D. filipedunculata* were initiated in July 2019; 20 adult trees were retrieved from the population in Lagoa da Mata (N5). Each tree was transplanted into one wooden box—lined with a plant-based material—using appropriate tools to maintain the integrity of the root ball. To remove the root ball, a 20 cm deep trench was dug around the roots, and the root ball was removed using a shovel. A mixture of 70% native substrate and 30% organic compost was used to improve root development and provide organic matter. Following planting, 50% of each leaf was pruned to avoid water stress caused by uprooting trauma (Photo 5).

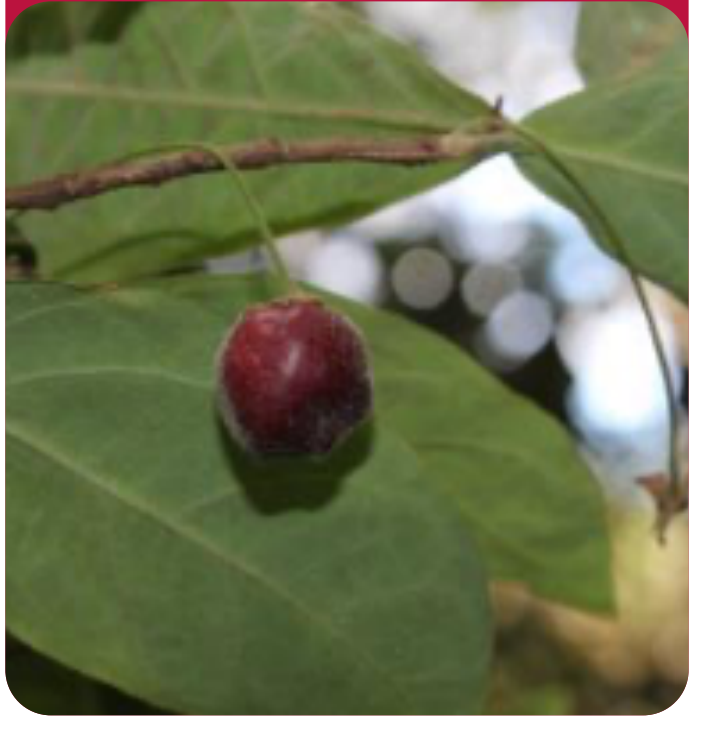
The specimens were sent to the Carajás Forest Nursery in the Serra Norte for monthly monitoring, where they were kept outdoors under 50% shade cloth.

Results

Preliminary results suggest that transplantation of adult individuals has a high potential for success; however, irrigation and maintaining adequate soil moisture are essential for successful transplantation, as non-irrigated seedlings did not survive due to water stress.

A female flower of the species *Daphnopsis filipedunculata*

A mature fruit of the species *Daphnopsis filipedunculata*



Strategic Alignment

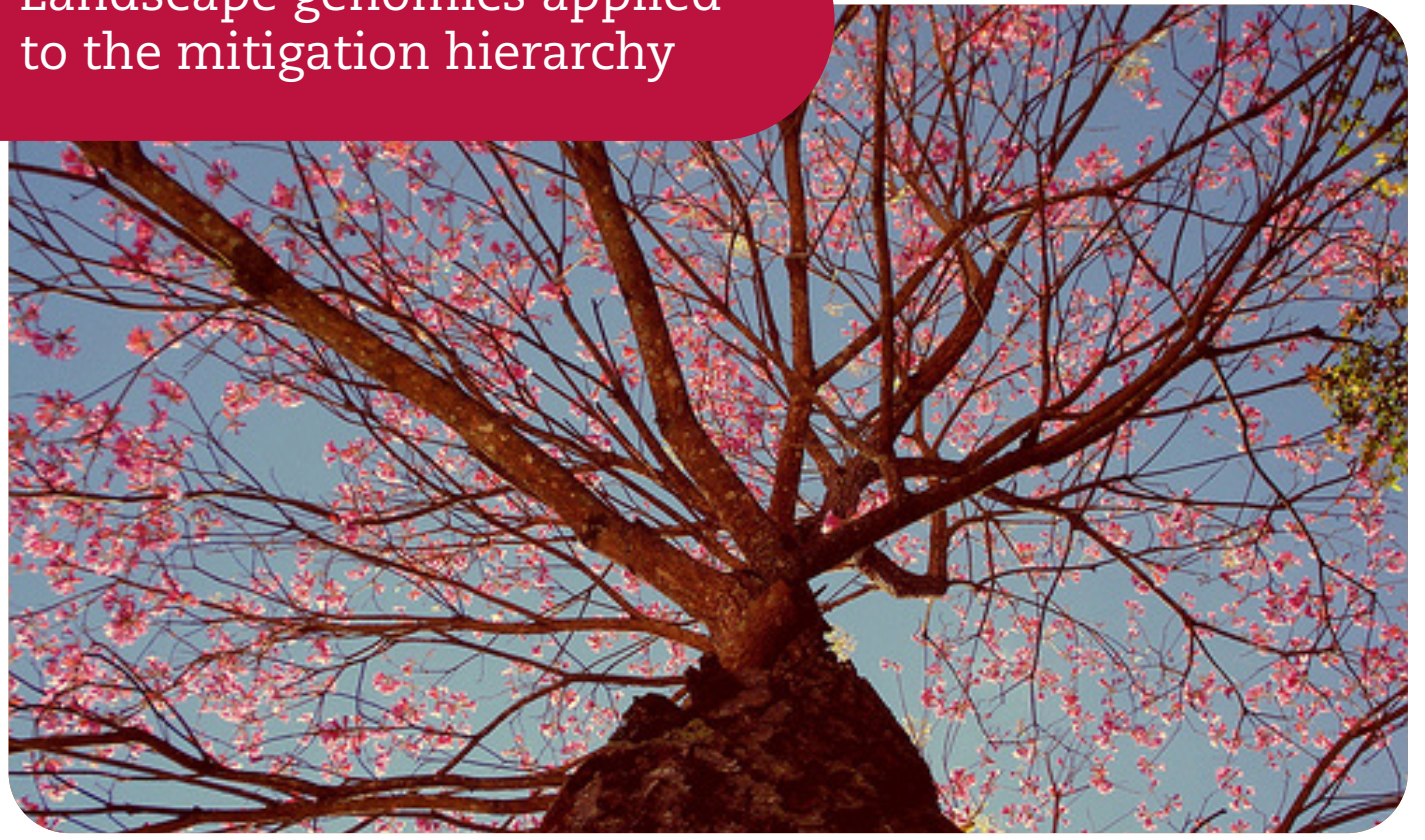
For Further Information

Mariana Wardil[1], Fernando M. G. Santos[2], Tais Fernandes[2], Alexandre Castilho[3], César Neto[3], Lourival Tyski[3], Fábia Cavalcante[3], Felipe Peixoto[1]; Bruno Falcão[1]; Felipe Pena[1], Cristiano Vidal[1], Izabella Braga[1], Sérgio Sakawaga[1]; Marcelo Pinho[1], Samir Rolim[1], André Cardoso[4], Daniela Zappi[5]; Nara Mota[5,6], Mayara Pastore[5,6]; Maurício Watanabe[5] (mariana.valentina@amploengenharia.com.br e fernando.gomes.santos@vale.com)

1. Amplo Engenharia Gestão de Projetos; 2. Vale, Gerencia de Licenciamento, Espeleologia e Estudos Ambientais, Diretoria Cadeia de Valor Ferrosos; 3. Vale, Gerência de Meio Ambiente, Diretoria de Ferrosos do Corredor Norte; 4. Sete Soluções e Tecnologia Ambiental; 5. Instituto Tecnológico Vale Desenvolvimento Sustentável; 6. Museu Paraense Emilio Goeldi

Threatened & Endemic Species

Landscape genomics applied to the mitigation hierarchy



Introduction

Landscape genomics is an interdisciplinary line of research that aims to reveal how landscape changes influence the dynamics of wild populations and their ability to survive and persist in disturbed environments. Over the past four years, a specific line of landscape genomics has been incorporated into the mitigation hierarchy framework to support the development of strategies for more sustainable exploitation of natural resources. Three projects addressing different stages of the mitigation hierarchy, which used this approach to study plants species in Carajás that are of special conservation and restoration concern, are presented below.

Strategies to prevent the extinction of the *Flor de Carajás*

Figure 1. The "Carajás Flower" (*Ipomoea cavalcantei*; photo: João Marcos Rosa

Flor de Carajás ("Carajás Flower"; *Ipomoea cavalcantei*; Figure 1), a narrowly distributed, endangered species, is a flagship species for conservation of the ferruginous cangas of Carajás. An initial study assessed the genetic health of *I. cavalcantei* compared to another plant of the same genus (*I. maurandioides*), but occurring across the continent. Unlike what was previously thought, *I. cavalcantei* had a single population with high genetic diversity, while the widespread species had multiple populations but less genetic diversity. Genetic markers potentially accounting for adaptations to environmental conditions in Amazonian savannas were also identified, which can provide inputs into future *in situ* and *ex situ* conservation programs and inform strategies to prevent extinction of the species (here).

An assessment was made of how habitat loss driven by mining has affected the genetic composition of two plant species endemic to the ferruginous cangas of Carajás (*Brasilianthus carajensis* and *Monogereion carajensis*; Fig. 2). The findings from the assessment show that losses of ferruginous canga habitats have not had any discernible genetic impact on the study species, with both species developing well in mine environments (here)

These findings indicate that some species are resilient to habit loss and can contribute to the natural regeneration of mined land. Future conservation efforts should consider species individually, as not all are equally affected by habitat loss.

Figure 2. Flowers of *Brasilianthus carajensis* (top-left; photo: Pedro Viana) and *Monogereion carajensis* (top-right; photo: Pedro Viana), and a mine in Carajás (photo: Rodolfo Jaffé)

Effective rehabilitation of mined land

Rehabilitating mined land is an integral part of offsetting environmental impacts from mining. To maximize the long-term success of mine rehabilitation, it is important to determine what species and varieties are most likely to successfully colonize and persist in disturbed sites. In this study, landscape genomics approaches were used to optimize future rehabilitation and reclamation efforts in Carajás (here). Adaptations to different soil and climate conditions were mapped for two plant species native to the ferruginous cangas of Carajás, with a view to their future use in mine rehabilitation programs (Fig. 3).

The study produced local adaptation maps showing which natural populations are more likely to survive in disturbed habitats. Plants in these areas could provide optimal parent stock for Vale's rehabilitation programs in Carajás.

Figure 3. Flowers of *Mimosa acutistipula* (top-left; photo: Pedro Viana) and *Dioclea apurensis* (top-right; photo: Daniela Zappi), and a ferruginous canga habitat in Carajás (photo: Leonardo Viana).

Strategic Alignment

For Further Information

Rodolfo Jaffé[1], Ronnie Alves[1], Cecilio Frois[1], Markus Gastauer[1], Tereza Cristina Giannini[1], Wilson Nascimento[1], Guilherme Oliveira[1], Silvio J. Ramos[1], Pedro W. Souza-Filho[1], Leonardo C. Trevelin[1], Santelmo Vasconcelos[1], Pedro L. Viana[2] (rodolfo.jaffe@itv.org)

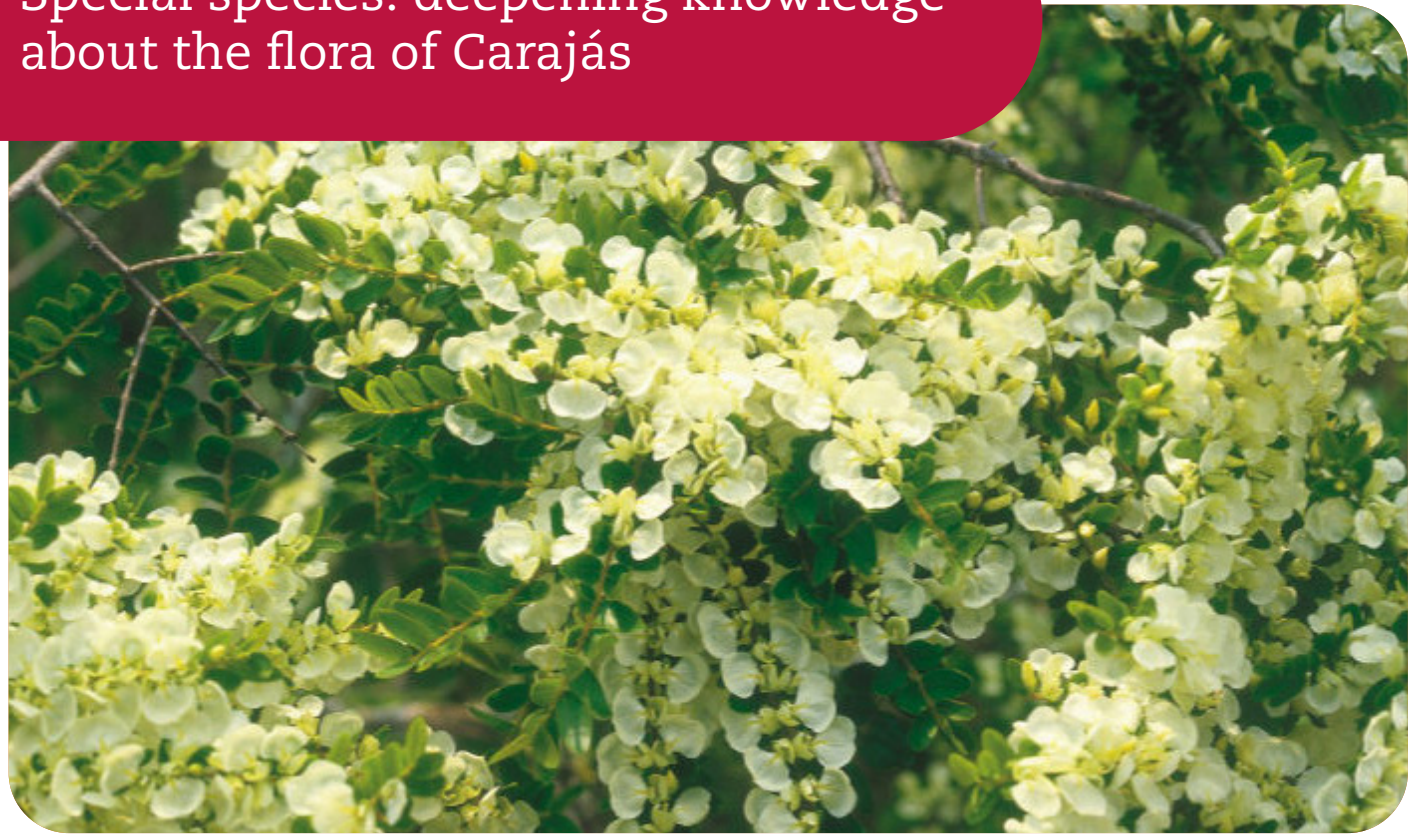
1. Instituto Tecnológico Vale; 2. Museu Paraense Emílio Goeldi

Partners

Universidade Federal do Pará, Universidade de São Paulo, Universidade do Texas e Universidade Estadual de Colorado.

Threatened & Endemic Species

Special species: deepening knowledge about the flora of Carajás



Introduction

Amazonian cangas occur on the surface of iron ore reserves and are characterized by a flora that is adapted to this unique environment, but is constantly threatened by a variety of stressors, including mining operations. A significant recent milestone in research on these flora species was the publication of "Flora of Carajás Cangas", a detailed account of 856 species of seed plants and 186 species of ferns and lycophytes occurring in canga environments.

Subsequent research has made important contributions to a better understanding of these species, providing strategic inputs into conservation initiatives for endemic species confined to ferruginous substrates. The following case studies describe research conducted in Carajás that underlines the importance of exploring new scientific frontiers and expanding knowledge about the surroundings of mine sites.

The results from these studies can be used to inform the best timing for rescue and seed collection, identify areas with range-restricted populations, quantify species rarity, and provide inputs into the rehabilitation of disturbed land through phenological studies. In this way, they can support mitigation hierarchy actions designed to prevent significant losses and the extinction of species, minimize impacts from mining, and restore habitats and populations.

Research results can be used to inform the best period for species rescue and seed collection, to identify areas with range-restricted populations, to quantify species rarity, and/or providing inputs into the rehabilitation of disturbed lands

Plants endemic to the cangas of Carajás: 38 unique species

An initial shortlist identified nearly 60 species as being potentially endemic to Carajás. In a botanical research collaboration involving several public and private institutions, a detailed taxonomic study was undertaken that narrowed the list to 38 plants that are endemic to the canga substrate in this region.

Careful mapping of each species determined whether it was restricted, to a higher or lesser degree, to a given region or characteristic environment. For example, *Ipomoea cavalcantei* has only been found to date in an area known as the Serra Norte. Another seven species are restricted to the cangas of the Carajás National Forest: *Axonopus*

Figure 1. Species endemic and restricted to the Carajás National Forest, pictured in their natural environment. (A) *Carajasia cangae* (B) *Parapiqueria cavalcantei*. Photos: Nara F. O. Mota & Pedro L. Viana.

carajasensis, *Peperomia pseudoserratirhachis*, *Paspalum carajasensis*, *Daphnopsis filipedunculata*, *Carajasia cangae*, *Parapiqueria cavalcantei* and *Isoetes cangae* (Figure 1) – (here).

These data can provide a basis for detailed conservation plans for these important species, with a particular focus on plants that, to the best of current knowledge, are found nowhere else in the world. Species distribution maps supported climate modeling studies to assess the habitats available for the species in the face of global climate change.

Revealing factors that influence the abundance of rare species in the cangas of Carajás

Rare species can have a limited range or abundance in the wild. Species rarity can be classified into different levels depending on the degree of abundance and geographical distribution. A study on several species considered rare in Brazil, and which occur in the Carajás region, determined what environmental variables have the potential to influence the density of some of the species. Around 1,000 sampling units, including transects and quadrants, were studied and a significant 30,000 specimens were documented.

Species abundance and density were influenced by climate factors such as temperature and precipitation, as well as by habitat size and altitude. Most annual and herbaceous species are negatively correlated with precipitation and habitat area; but perennial species were more abundant in environments with larger habitat area and higher temperatures. Due to the seasonal water regime, rainfall is believed to be a key factor in local abundance and population density of herbaceous and annual species in the Serra dos Carajás. Meanwhile, habitat size appears to be the primary factor affecting the density and abundance patterns of rare perennial species.

Most annual and herbaceous species are negatively correlated with precipitation and habitat area

30,000
specimens studied

The reproductive phenology of critical native species can provide important inputs for rehabilitation and conservation

Knowledge about the various aspects of canga ecosystems remains incipient, and there is currently a knowledge gap regarding the flowering and fruiting periods of the species forming associated plant communities. This information is crucial for rehabilitation efforts, as seeds are an essential ingredient of forest restoration. When data is unavailable to inform seed collection and the development of a viable seed bank, the success and planning of rehabilitation efforts can be undermined. This information is also needed in the development of protocols for the propagation and conservation of species.

Figure 2. Native species of Carajás National Forest that were monitored for phenological data: (A) *Mandevilla tenuifolia*; (B) *Lepidaploa paraensis*; (C) *Anemopaegma carajasense*; (D) *Ipomoea marabaensis*; (E) *Scleria cyperina*; (F) *Syngonanthus discretifolius*; (G) *Dioclea apurensis*; (H) *Utricularia physoceras*; (I) *Cuphea carajasensis*; (J) *Byrsonima chrysophylla*; (L) *Sporobulus multiramosus*; (M); *Borreria semiamplexicaulis* (N) *Xyris brachysepala*. Photos: Ana Carolina G. Costa & Liziane V. Vasconcelos.

In this context, several research projects have been undertaken to monitor species native to the cangas of the Carajás National Forest (Figure 2). Monitored species were either endemic, rare or potential candidates for use in rehabilitation. Since 2016, thirty-five (35) species have been monitored for a minimum of one year. During the monitoring, 10 to 30 individuals of each species were selected and evaluated monthly to determine when they develop buds, flowers, immature fruits and ripe fruits. Knowing the timing of these reproductive phases in critical species and candidates for mine rehabilitation can indicate the periods when viable seeds are more likely to be available from ripe fruit.

We found that the monitored species typically had buds and flowers, and began to develop fruit (immature fruits), during the rainy season between November and May, with average annual precipitation between 1800 and 2300 mm. Some species already had ripe fruits in this period. Ripe fruits were typically observed on the monitored species at the end of the wet season and the beginning of the dry season, which runs from June to October, with average precipitation of 10 to 350 mm per year.

Researchers are compiling data on native species of cangas in the Carajás National Forest, including endemic, rare and rehabilitation-relevant species

Strategic Alignment

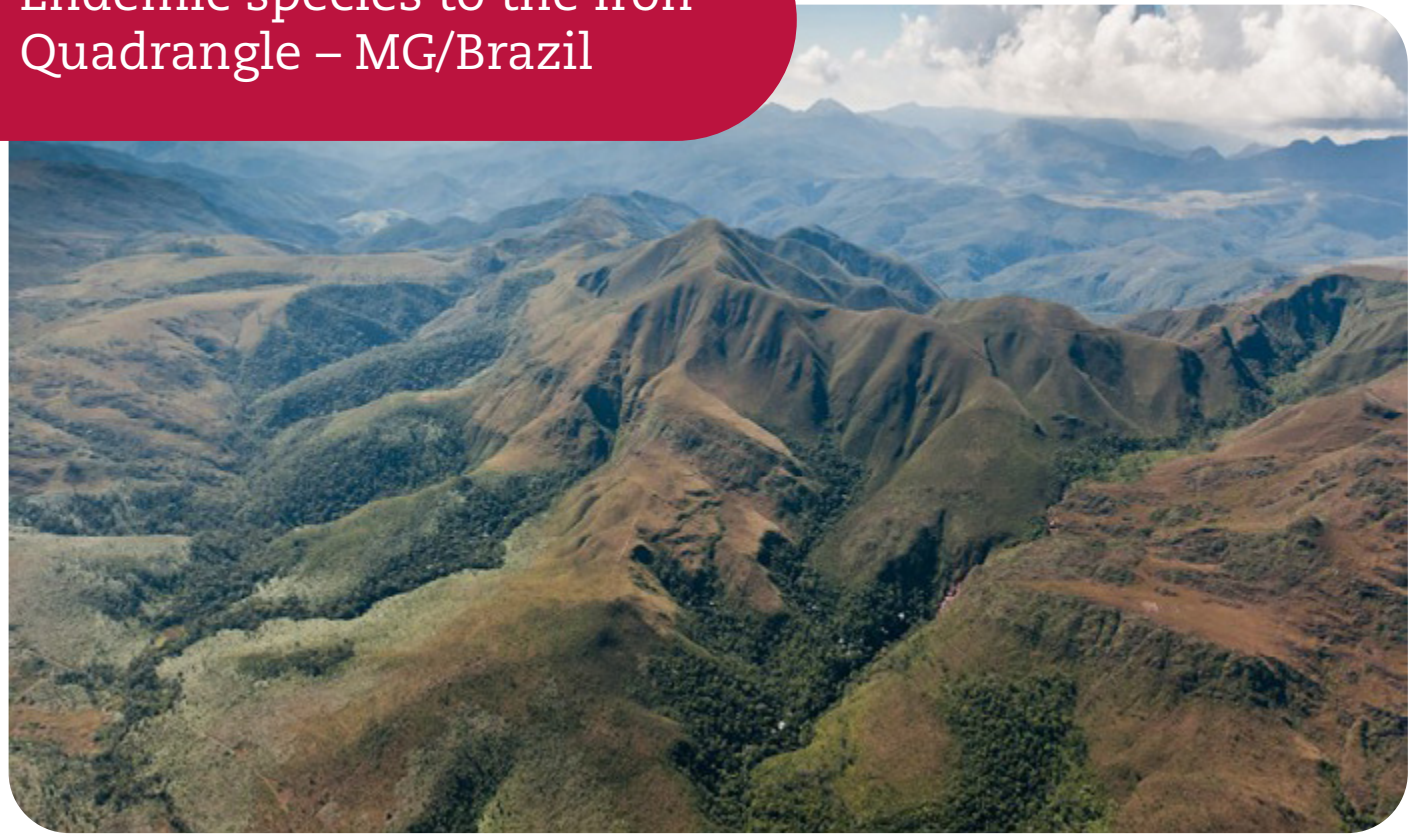
For Further Information

Maurício T. C. Watanabe[1,*], Ana Carolina G. Costa[1], Daniela C. Zappi[1], Hellen S. Lopes[1], Fernando Marino[2], Mayara Pastore[3], Nara F. O. Mota[3], Tereza C. Giannini[1], Rodolfo Jaffé[1], César C. Neto[4], Alexandre Castilho[4], Mayla Barbirato[4], Taís Fernandes[2], Pedro L. Viana[3] & Ana Maria Giulietti[5] (mauricio.watanabe@itv.org)

1. Instituto Tecnológico Vale Desenvolvimento Sustentável; 2. Vale S.A.; Gerência de Licenciamento, Espeleologia e Estudos Ambientais, Diretoria Cadeia de Valor Ferrosos; 3. Museu Paraense Emílio Goeldi; 4. Vale S.A.; Gerência de Meio Ambiente, Diretoria de Ferrosos do Corredor Norte; 5. Universidade Estadual de Feira de Santana

Threatened & Endemic Species

Endemic species to the Iron Quadrangle – MG/Brazil



Introduction

Conserving biodiversity is an obligation for signatories of international programs and protocols calling for concrete action to prevent the loss of biological diversity around the world. The Brazilian state of Minas Gerais harbors exceptional biodiversity, likely a consequence of its widely varying terrain and lithologies. Serra do Espinhaco and the Iron Quadrangle, a north-south trending mountain range, form a unique geomorphological landscape found nowhere else in the world, home to the Espinhaço Biosphere Reserve designated by UNESCO in 2005, in an area recognized for its species richness and endemism.

In addition to a diversity of geological and relief features and a wide variety of minerals—including iron, quartzite, schist, phyllite, limestone and granite formations—three Brazilian biomes are found within its boundaries, two of which are recognized as biodiversity hotspots: the Atlantic Forest (east) and the *Cerrado* (west), which are joined by the *Caatinga* to the north. Several endemic, rare and endangered plant and animal species occur in these mountainous ecosystems. Efforts to prospect for these species in protected areas, combined with specific ongoing conservation programs, have helped to improve knowledge about their ecology, supporting their *in situ* conservation, reproduction and reintroduction in disturbed areas.

Research has helped to improve knowledge about the distribution of special-concern or fragile species

Methodology

In this study, data on species endemic to the Iron Quadrangle were compiled from physical and virtual herbaria and from open-access platforms and publications. Using the MaxEnt (Maximum Entropy) algorithm and environmental variables measured at record points, predictive modeling was carried out to support field efforts. To maximize the location of species in areas that are fully protected, priority was given to protected areas in the region, where monthly surveys were undertaken to prospect for endemic species. Environmental factors such as altitude, terrain, lithotypes and the phytophysiognomy of local vegetation were analyzed, with the edaphic distribution of some species being expanded as a result.

Collected materials were identified through collaborations with experts from 15 different research institutions, mostly universities, consistent with Sustainable Development Goal 17.

Results

During the fieldwork, populations were found of six species then described in the literature as being extinct in the wild, as well as nine potentially new and undescribed species. Out of 41 species described in the literature as being endemic to the cangas of the Iron Quadrangle, 11 were confirmed to be genuinely endemic to this environment following database searches and fieldwork.

These studies have helped to improve knowledge about the distribution of special-concern species or species that are particularly vulnerable due to their restricted range. This has allowed researchers to identify and map potential parent plants from which to obtain propagules of critical

species for conservation purposes. An expanded body of knowledge about the ecology of this group of special plants supports further research on their reproduction and reintroduction in different substrates. Data about the distribution of endangered, rare or endemic species, especially in protected areas, can contribute to their *in situ* conservation and provide important inputs for analysis of their ecological behavior. In addition, information about species distribution and survival on different types of substrates can be useful in developing protocols for reproduction and rehabilitation of mined land.

Strategic Alignment

For Further Information

Ana Cristina Amoroso[1]; Ana Maria Giulietti[2]; Lídia Maria dos Santos[3]; Mauricio Watanabe[4] (ana.amoroso@vale.com)

1. Vale, Diretoria de Cadeia de Valor de Ferrosos/ Gerencia de Licenciamento Ambiental; 2. Universidade Estadual de Feira de Santana; 3. Bioma Meio Ambiente; 4. Instituto Tecnológico Vale Desenvolvimento Sustentável

Partners

Rede de Taxonomistas Parceiros: Instituto de Botânica de São Paulo, Instituto Tecnológico Vale, Museu Paraense Emílio Goeldi, Universidade de Brasília, Universidade de São Paulo, Universidade Estadual de Santa Cruz, Universidade Estadual do Oeste do Paraná, Universidade Federal de Goiás, Universidade Federal de Juiz de Fora, Universidade Federal de Minas Gerais, Universidade Federal de Ouro Preto, Universidade Federal de Santa Catarina, Universidade Federal de São João del-Rei, Universidade Federal de Uberlândia, Universidade Federal do Espírito Santo.

Data about the distribution of endangered, rare or endemic species can contribute to their *in situ* conservation

Threatened & Endemic Species

Friends of the Humpback Whale: from cetaceans monitoring to sustainable tourism

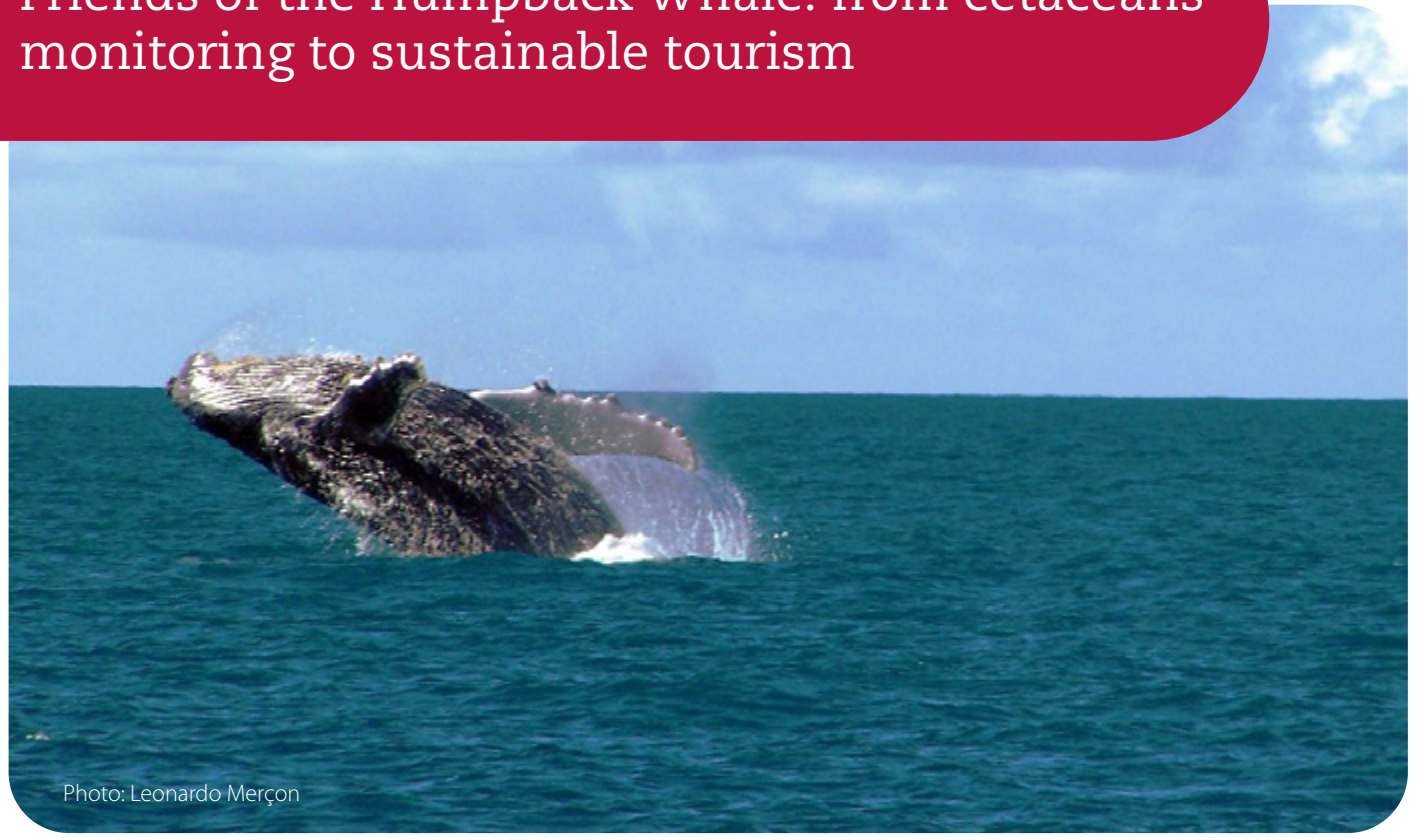


Photo: Leonardo Merçon

Introduction

Since 2016, Vale has worked in partnership with the Amigos da Jubarte ("Friends of the Humpback Whale") project to monitor humpback whales (*Megaptera novaeangliae*) off the coast of Espírito Santo. The initiative, created by Instituto O Canal in partnership with Instituto Últimos Refúgios, aims to improve methodological tools for long-term whale monitoring on the continental shelf of Greater Vitória, in order to provide a baseline for assessing potential impacts from port and shipping activities on these animals, and to inform measures to preserve whale populations in this marine ecosystem.

The study area is restricted to the continental shelf of Greater Vitória, bounded by a polygon with the following coordinates: UTM WGS84 - 349049 E / 7712588 S; 385581 E / 7691744 S; 377387 E / 7776650 S; 415484 E / 7762393 S, up to an isobath of 200m. The monitoring envelope covers an area of approximately 3,319 Km^2.

Methodology

Data is collected through monthly sighting surveys conducted throughout the breeding season. Efforts are concentrated in the period from the second fortnight of May to and including the first fortnight of November, when researchers cover the entire sampling area in three days aboard whale watch boats. Data is collected along linear transects, including information such as occurrence, density, abundance, behavior, bioacoustic data and anthropic activities. In addition to the traditional method of distance sampling, unmanned aerial vehicles (UAVs) are used to obtain photographs and video footage for an image database and for analysis of ecological aspects such as site fidelity patterns, residence, interactions, individual movements and other population parameters.

Alongside this scientific front, called Jubarte.Lab, other initiatives are ongoing that contribute to science outreach, awareness and engagement of direct and third-party employees and communities, and that promote sustainable whale-watching tourism by engaging and training actors in the local tourism value chain.

Vessel masters and travel agencies offering whale watching tours also receive training. The goal is to provide theoretical and practical training to actors in Espírito Santo's ecotourism industry in order to promote good practices in sustainable whale watching tourism in Greater Vitória, and to strengthen this activity as an important source of livelihoods and income in the area.

Photo: Leonardo Merçon

Vessel masters and travel agencies offering whale watching tours receive training to promote sustainable tourism in the area and improve livelihoods and income

Results

In the six most recent monitoring surveys in 2019, 470 cetaceans were sighted along a distance of 900 nautical miles. Sightings during the 2019 season included 3 cetacean species: one sighting of *Stenella frontalis*, four sightings of *Tursiops truncatus* and 271 sightings of *Megaptera novaeangliae*. Another 193 individuals were sighted but could not be identified to the species level: 182 baleen whales (Mysticeti) and 11 toothed whales (Odontoceti). A total of 218.6 minutes of acoustic recordings were captured. In 65% of recordings, humpback whale calls and whistles of odontocete species were recorded at six stations. No cetacean collisions with vessels were reported throughout the survey period. Whale monitoring and integrated data analysis since 2014 have shown that the continental shelf off Greater Vitória is an established migratory route and calving habitat for humpback whales, harboring around 240 individuals simultaneously during the breeding season.

Amigos da Jubarte organized 41 awareness-raising activities in 2019, including an initiative at the State Environment Institute (IEMA) that was attended by 3,000 people, among them direct and third-party employees and residents in the Vitória metropolitan area. The initiative was covered in the local and international media, and generated around 29,000 interactions in a single campaign on Vale's social media accounts. Since inception, the local community has recognized the project as an important environmental initiative supporting sustainable development in the region.

Photo: Leonardo Merçon

470 cetaceans
sighted along 900 nautical miles

Whale monitoring since 2014 has shown that the continental shelf off Greater Vitória is an established migratory route for humpback whales

Photos: Leonardo Merçon and Felipe de Moraes

Strategic Alignment

For Further Information

Andressa Azevedo[1], Brunella Pianna Veronez[2], Edmilson Junior[2]; Agnaldo Martins[3,4]; Thiago Ferrari[3,5]; Leonardo Merçon[3,5]; Jonathas Barreto[3]; Sandro Firmino[5] (andressa.azevedo@vale.com; brunella.veronez@vale.com; edmilson.junior@vale.com)

1. Diretoria de Sustentabilidade e Investimento Social/ Gerência de Sustentabilidade ES / Coordenação de Relações com Comunidades ES e EFVM; 2. Diretoria de Pelotização e Manganês/ Gerência de Meio Ambiente e Pelotização; 3. Jubarte.Lab; 4. Universidade Federal do Espírito Santo; 5. Projeto Amigos da Jubarte - www.queroverbaleia.com

Threatened & Endemic Species

Bioindicator monitoring program: seahorses and Guiana dolphins

Introduction

A Bioindicator Monitoring Program, using seahorses as a bioindicator of rocky-reef health and Guiana dolphins as a bioindicator of water column health, was launched in 2015 in a partnership between Vale and ISBio. Sepetiba Bay is classified as an area of extremely high biological importance and priority in the National Strategic Plan for Protected Areas (PNAP), established during the World Summit on Sustainable Development (2002), in the Strategic Plan for the United Nations Convention on Biological Diversity (2004), and in National Environment Conferences (2003 and 2005). In addition to helping to detect operational failures at ports and associated structures, bioindicator monitoring provides a better understanding of species ecology and conservation in the environment.

Both seahorses and Guiana dolphins are at the top of the food chain within their habitats. Seahorses are benthic predatory—primarily carnivorous—animals that live in rocky shore habitats. They are a highly sedentary species and are at the top of the food chain of phytal ecosystems. The Guiana dolphin, in turn, is a pelagic, restricted-range dolphin species with a resident population in Sepetiba Bay. It is also at the top of its habitat's food chain.

In addition to being indicative of environmental health, both species are also considered to be endangered. In this context, the purpose of this program is to monitor populations of longsnout seahorses (*Hippocampus reidi*) and Guiana dolphins (*Sotalia guianensis*) in Sepetiba Bay, evaluating population estimates, structural aspects, their interactions with Vale's structures, and other parameters. A second goal of the program is to disseminate knowledge about these species to society to promote their conservation.

Methodology

Guiana dolphins are monitored across 20 monitoring sectors covering the entire Sepetiba Bay area

Bioindicator monitoring is being conducted in Sepetiba Bay (043º 30'W/44º. 10'W and 22º 50'S/23º 05'S), with seahorse monitoring confined to the area surrounding Vale's Guaíba Island Port Terminal (TIG) operations, including rocky shore habitats along the Tapera, Raposa and Aguada beaches, in the northern portion of the island. Guiana dolphins are being monitored throughout the entire Sepetiba Bay area, which has been divided into 20 discrete monitoring sectors.

Monthly seahorse monitoring is conducted along continuous 20m x 4m transects. Individuals found along the transects are identified in terms of species, sex and individual size for identification of juveniles and adults. Their behavior and the habitat they are recorded in are also documented.

Guiana dolphins are monitored from a watch boat that covers all monitoring sectors in Baía de Sepetiba once per month. All sighted individuals are documented by photographs and video footage captured by an overhead UAV. After recording individuals, their dorsal fins are sketched and input into the DARWIN 2.22 software system to estimate the likelihood of resighting.

Educational activities about both species are conducted at Vale's port terminals, at primary and secondary schools and at events in the Mangaratiba community.

Results

To date, 171 diving surveys have been conducted in the monitoring areas, totaling around 350 hours underwater. During the course of the program, 2,315 seahorses of the species *Hippocampus reidi* have been sighted. Of this total, 1,013 were males and 965 were females—a sex ratio that is typical of this species—and 337 were juveniles, suggesting that Guaíba Island serves as a breeding ground for this species, especially from November to January and from July to September. Resting behavior accounted for 97% of sightings, which is expected for this species.

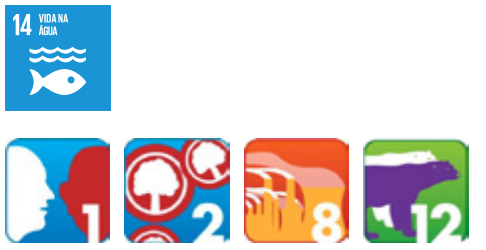
2,315
longsnout seahorse
individuals sighted

The habitats most used for anchoring are *Sargassum vulgare* algae and turf algae. All population parameters indicated a healthy environment—Guaíba Island is known to be a hotspot for seahorses, home to the world's largest population of longsnout seahorses.

A total of 57 sighting surveys were also conducted for Guiana dolphins, *Sotalia guianensis*, totaling 457 hours of observation and 9,120 km sailed. The highest abundance of dolphins was found at the entrance channel to Sepetiba Bay, at 100.03 individuals, while the lowest values of average abundance were recorded in areas further into the bay, at 0.13 individuals. The sectors with highest abundance values are closer to Guaíba Island, where breeding and feeding behaviors were also observed, demonstrating the importance of this area for the Guiana dolphin. The estimated population of Guiana dolphins in Sepetiba Bay is close to 350 individuals, but is likely to be seasonally variant, as individuals previously sighted in Sepetiba Bay have been subsequently recorded feeding and mating in Ilha Grande Bay, confirming that the habitat range of this population extends beyond Sepetiba Bay.

During the first three years of the program, 156 internal and external awareness-raising initiatives were organized, including visits to schools, visits hosted at Fazenda Marinha da Vale, inclusion activities for disabled people, and training programs such as *Jovem Cientista* ("Young Scientist") and *Condutores Marinhos* ("Sea Pilots"). In all, 2,052 people were directly benefited, representing 5% of the population surrounding the TIG. Local community outreach activities have helped to change perceptions about the environment and provide a better understanding about sustainable development.

Strategic Alignment



For Further Information

Natalie Villar Freret Meurer[1], Bruno Corrêa Meurer[1], Vitor Libanio[2]; Vitor Saboya[2] (nataliefreret@yahoo.com.br; vitor.saboya@vale.com)

1. ISBio Soluções e Serviços Ambientais/ Universidade Santa Úrsula; 2. Vale, Gerencia de Sustentabilidade RJ, MS e BA.

Local community outreach

Ongoing actions for the future we want

Rehabilitation & Restoration

Rehabilitation & Restoration

The Vale Nature Reserve nursery: genetic conservation of endemic and threatened Atlantic Forest species

Introduction

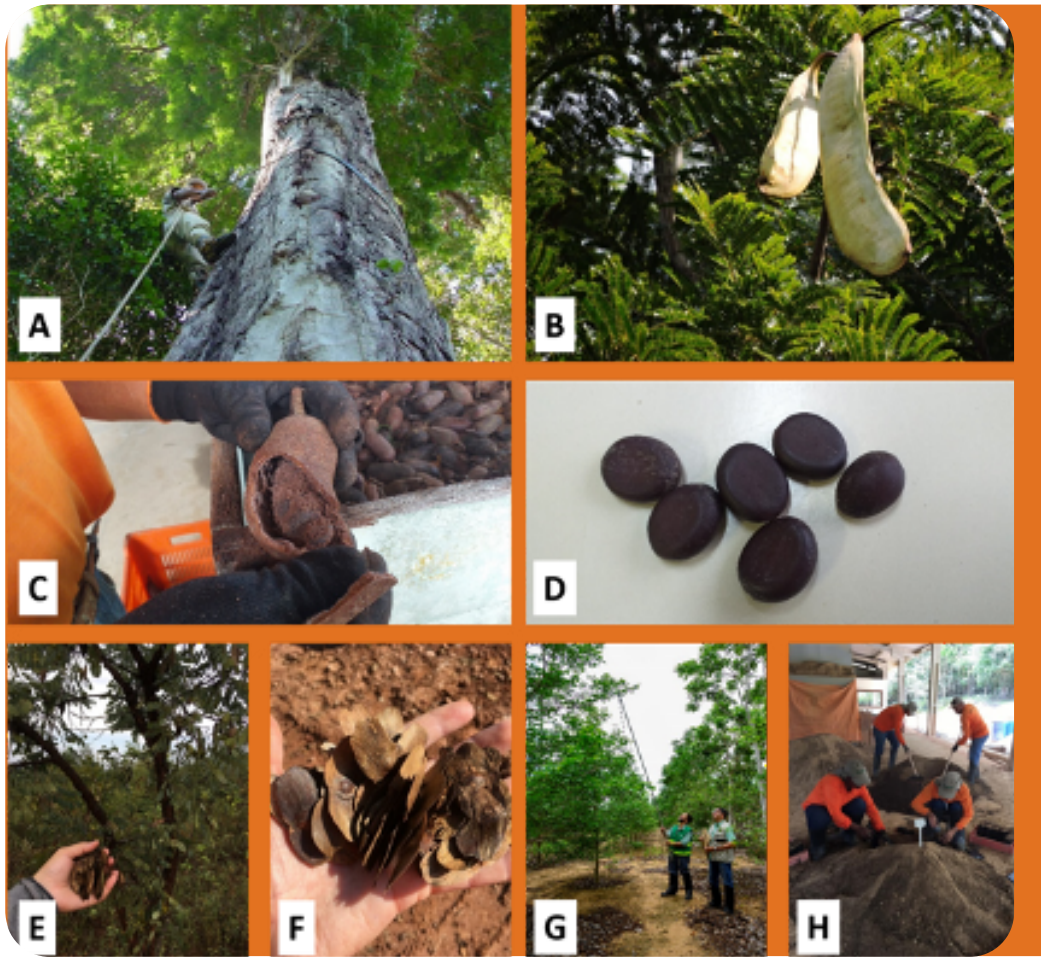
Forest fragmentation and degradation are currently occurring at a global scale, and have long occurred in Brazil's Atlantic Forest, inevitably leading to loss of biodiversity, local climate change and depletion of ecosystem services. In this context, the establishment of protected areas for conservation of biodiversity and the development of strategies to achieve this objective, are of paramount importance. These strategies include, for example, the creation of native seedling nurseries to support conservation of threatened species, providing important stocks of flora diversity for use in restoration of Atlantic Forest lands.

The Vale Nature Reserve (RNV, *Reserva Natural Vale*) preserve more than 23,000 ha of Atlantic Forest formations in Linhares (ES/Brazil), and has a tree nursery established in the early 1970s that has since supported restoration and reintroduction of species across a variety

of Brazilian biomes. With a current production rate of 2 million seedlings per year and a maximum production capacity of 3 million seedlings per year, the nursery has the expertise and capabilities to produce up to 800 different species concurrently (currently producing an average of 200 species).

One of the nursery's objectives is to support conservation of Atlantic Forest genetic heritage, with a primary focus on threatened species, especially *Dinizia jueirana-facao* (jueirana-facão), a critically endangered (CR) species (Figure 1a, b); *Handroanthus arianeae* (ipê-preto) and *Plinia spiritosantensis* (jabuticaba-roxa), designated as vulnerable (VU) species; and *Handroanthus riodocensis* (ipê-amarelo), designated as a critically endangered (CR) species.

The Vale Nature Reserve preserve more than 23,000 hectares of Atlantic Forest formations in Linhares (ES/Brazil)



Dinizia jueirana-facao (jueirana-facão), a critically endangered species (CR) (A, B); mapping parents and collecting seeds (C, D), monitoring phenology (E, F, G) and processing and planting seeds (H)

Methodology

To produce seeds of the above mentioned species, potential parent specimens were identified and assessed, and the best parents selected (Figure 1c, d). The reproductive phenology of individuals was then monitored to determine the optimal period for harvesting fruits and seeds (Figure 1e, f, g). Following harvesting, the fruit and seeds were transported to the nursery for extraction and processing. The seeds were then transferred to bags containing clay, sand, coffee chaff and mineral fertilizer (Figure 1h). Lastly, seedlings were produced for use in restoration initiatives and environmental awareness campaigns in areas surrounding the RNV and in nearby municipalities.

Results

In the period 2016-2019, a total of 4,333 seedlings of the threatened species listed above were produced, including 2,499 of the species *Handroanthus riodocensis* (average production time: 5-6 months); 12 of the species *Plinia spiritosantensis* (average production time: same as above); 1,520 of the species *Plinia spiritosantensis* (average production time: 7-12 months); and 302 of the species ***D****inizia jueirana-facao* (average production time: 6 months), for use in restoration and environmental awareness initiatives (Figure 2a, b, c, d, e).

These initiatives support the reintroduction of these species in their original biomes and can, in the long term, help to reestablish populations and even generate a positive change in the face of threats. In addition to forest restoration initiatives, seedlings have also been used for urban tree planting and environmental awareness campaigns. These campaigns help communities to feel they are a part of the species conservation process, which can be a first step in sparking environmental awareness.


Photo: Geovane Siqueira

4,333
seedlings
of threatened tree species producedde extinção foram produzidas

Strategic Alignment

For Further Information

Guilherme Felitto, Débora Mendonça, Ernesto Sakai, Jonacir Souza, Márcio Ferreira; Tiago Godinho (guilherme.felitto@vale.com).

Diretoria de Sustentabilidade e Investimento Social/Gerência Executiva de Gestão Ambiental/ Reserva Natural Vale.

Seedlings for restoration and environmental awareness initiatives

Rehabilitation & Restoration

Effectiveness of direct seeding for forest restoration

Introduction

On top of protecting Atlantic Forest remnants and producing seedlings, the Vale Nature Reserve (RNV) also engages in research on restoration and ecology to assess, advance and support more efficient methods of rehabilitating disturbed sites.

The use of direct seeding—a technique that uses an assortment of seeds (known in Brazil as *muvucas*) containing a large diversity of species of different ecological groups (ISA 2009)—can greatly facilitate forest establishment and restoration in difficult-to-access locations. One of the main drawbacks of the use of this method, however, is the high cost of purchasing large quantities of seeds and the low germination and survival rates that have been observed in the field for many species.

Methodologies

In this study we revisited an experimental direct-seeded forest restoration area established at the RNV in May 2013 to evaluate the long-term effectiveness of the process 16 years after establishment. In the experiment, 29 species were used for seeding, with a total seed density of 394,555 seeds/ha. After 16 years, all individuals with a circumference at breast height (CBH) ≥ 15 cm and a height H ≥ 30 cm were assessed and classified using the Angiosperm Phylogeny Group classification (APG IV, 2016). Species were also classified by successional category and their phytosociological parameters were calculated.

Results

A total of 106 individuals, 5 botanical families and 16 different species were found, suggesting a low species survival rate 16 years after establishment (34.5%). A low diversity index was observed (H'= 1.91) compared to values found in surrounding protected areas (H'= 4.87). Importance value and coverage were highest for the species *Joannesia princeps* (42.4% and 53.1%) and *Spondias venulosa* (22.3% and 24.2%), respectively, indicating that, despite the passage of time, the area is still in early stages of restoration, with a dominance of pioneering species.

In conclusion, while the area was found to be in the process of regeneration, frequent monitoring would have been important to maximize the process, which could perhaps have been at a more advanced stage had other restoration methods been combined with direct seeding (enrichment planting, nucleation, topsoil transfer).

Strategic Alignment

For Further Information

Diego Balestrin[1] (diego.balestrin@vale.com); Guilherme Felitto[1]; Jonacir de Souza[1]; Sebastião Venâncio Martins[2].

1. Vale, Diretoria de Sustentabilidade e Investimento Social/Gerência Executiva de Gestão Ambiental/ Reserva Natural Vale; 2. Universidade Federal de Viçosa (UFV)/ Laboratório de Restauração Florestal.

Rehabilitation & Restoration

The Hu'u Project nursery: seed collection and seedling production for forest restoration in Sumbawa, Indonesia

Introduction

The Hu'u Project is a gold and copper mine operated by a Vale joint venture in Indonesia, PT. Sumbawa Timur Mining (STM). The project is located on the island of Sumbawa and is administratively located in the Dompu and Bima Regencies, in the province of Nusa Tenggara Barat (NTB), Indonesia (Figure 1).

A protected forest covers most of the Hu'u project site, approximately 73% of its total area. A commercial forest covers 19%, with only 8% of the area unforested. This means that approximately 92% of the project area is covered by forest vegetation.

Forest protection is an ongoing challenge for companies operating in forested areas, whether in mining or in any other activity. While the Hu'u project is still in the planning phase, Vale is required under the Contract of Work (CoW) to protect, recover and rehabilitate the entire area which could potentially be affected by its operations.

Methodology

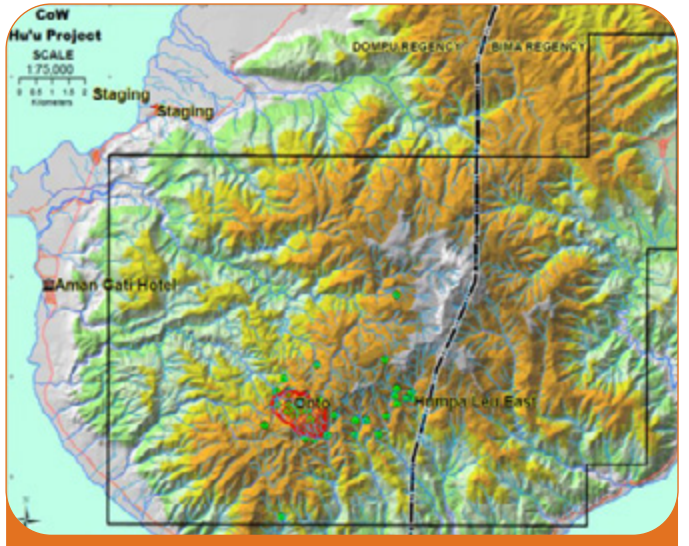


Figure 1 - Hu'u Project Area

CLASSIFICATION	AREA (HECTARES)
Protected Forest	14,070
Commercial Forest	3,628
Other uses (non-forest)	1,562
TOTAL	**19,260**

Vale has made an effort to minimize and mitigate impacts on forest habitats, even though in this case the impacts affect relatively small areas other than the area where its operations are located. In line with best practice, Vale has also invested in education programs and actively encouraged communities to contribute to forest protection, both by inviting participation in volunteering programs and by creating business opportunities, such as tree nurseries and tree replanting programs.

Seeds of endemic and local pioneering species are routinely collected and prepared for planting. Plants are also salvaged from areas that are cleared, and then cultivated at the nursery for use in rehabilitation and revegetation.

Rehabilitation activities are conducted in full compliance with Indonesian regulations, and in accordance with the following basic rules:

Minimize land clearing and waste piles to the area strictly needed to meet operational requirements;

Store the top soil properly when clearing an area to prevent loss of the fertile layer of the soil to erosion;

Select seeds and prepare seedlings using appropriate methods (as recommended in training and advice provided by the Bogor Agricultural Institute - IPB) and, for those plants for which established methods are not available, develop plant-specific methods to support rehabilitation activities;

Conduct remediation, rehabilitation and revegetation work with a focus on restoring the area's baseline functions;

Monitor the rehabilitation area regularly to assess the need for and conduct periodic maintenance and repairs as necessary, ensuring optimal plant growth;

Work with local team members to ensure knowledge is passed on.

Results

The Hu'u nursery is set within the environment where the seedlings will be planted, i.e. within the forest in the project area. This helps the seedlings to better adapt after planting, and minimizes the risk of loss or under-development of seedlings used in the rehabilitation process in the area.

Special priority is given to rescue and collecting seeds from endemic and endangered species, which are then cultivated at the nursery for subsequent planting at rehabilitation sites, ensuring that populations of these species are maintained.

The primary types of plants that are kept and developed at the nursery are the following:

LOCAL NAME	INDONESIAN NAME	SCIENTIFIC NAME
Sancari	Jabon	*Anthocephalus cadamba*
Rondu	Bungur	*Lagerstroemia speciosa*
Sengon	Sengon	*Paraserianthes Falcataria L*
Kamonca	Meranti Kuning	*Shorea Dipterocarpus*
Anggo Doro	Kersen Hutan	*Muntingia calabura L*
Due	Beringin	*Ficus benjamina*
Kawaba	Waru Hutan	*Vernonia arborea*
Bara	Randu	*Ceiba pentandra*
Foo Doro	Mangga Hutan	*Mangifera foetida*
Heci	Kenari	*Canarium asperum*
Ipil	Merbau	*Intsia bijuga*
Monggo Doro	Meranti Merah	*Shorea leprosula*

The approach taken to disseminate knowledge about seedling cultivation and planting, proper soil management, and the different techniques involved in forest protection, was to hire local people to be part of the team, and this has been a good experience for both sides.

Figure 2. A nursery within the forest in the Hu'u project area

Since the nursery project began in 2014, it has supported the rehabilitation of 61 sites with a total area of approximately 6.10 hectares, producing approximately 3,500 to 4,500 seedlings per year. A total of 9,268 seedlings have been planted, including perennial trees and fast-growing plants, and another 10,000 seedlings are ready to be used for the next rehabilitation program.

Figure 3. An example of a research site, shaft VHD 024, which is undergoing rehabilitation

Strategic Alignment

For Further Information

Abdul Hamid[2], Arizal Ardyansyah[1], Giselle Chissini[1], Razky Akbar[2] (giselle.chissini@vale.com; razky.akbar@vale.com; abdul.hamid[1]@vale.com; arizal.ardyansyah@vale.com)

1. Vale Base Metals/ Legal, Corporative affairs & Sustainability/ Environmental; 2. Vale Base Metals/ Legal, Corporative affairs & Sustainability/ Forestry

Rehabilitation & Restoration

Restoration with *Bertholletia excelsa* Bonpl. and other threatened species near protected areas in Carajás is enhancing natural resource sustainability in the region

Introduction

The Brazil nut tree (*Bertholletia excelsa* Bonpl.) is an emergent tree species found in upland ("***terra firme***") ombrophilous forests in the Amazon Basin. It tends to have an uneven distribution throughout its range, from commonly to rarely occurring, often forming clusters known locally as ***castanhais***. This emblematic species is well suited for reforestation of disturbed and/or deforested sites due to its high rates of seedling survival, environmental ruggedness (tolerant to disturbed sites and resistant to prolonged droughts), and satisfactory performance under high-sunlight irradiation.

Methodology

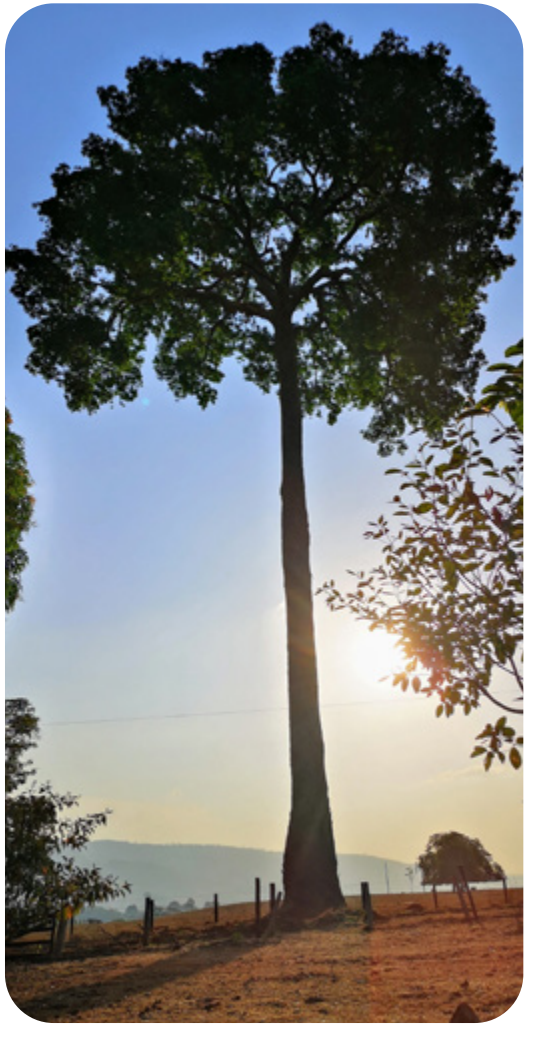
Vale and several institutional partners have established Brazil nut tree (*Bertholletia excelsa* Bonpl.) populations in several areas in Carajás, and these and other initiatives as part of a project to plant Brazil nut trees and rehabilitate disturbed sites in the Carajás Mosaic (SALOBO METAIS S.A. / ICMBIO) have had successful conservation results for this and other vulnerable species in the region.

The site used for threatened species offsets has an area of 254.23 hectares

Results

The site used for threatened species offsets covers an area of 254.23 ha, with 289 ha remaining to be planted by 2025. The site was previously an area of pastureland populated by several grass species, and has been under rehabilitation for more than 5 years. Brazil nut (C) trees are spaced 12 m apart and heliophile tree species 4 m apart in full sun. In total, 625 seedlings are being planted per hectare, including 69 Brazil nut (C) and 556 heliophile (H) species. Seedlings are planted using hydrogel to increase water availability, and mineral and organic fertilizers to provide the nutrients needed for vigorous growth. Invasive species management is also a constant at restoration sites.

State Law no. 6 895 (August 1, 2006) establishes that, if Brazil nut trees are felled, those responsible are re-



quired to immediately plant triple the number of trees that were felled. As of 2020, 15,721 Brazil nut seedlings had been planted, *positively contributing to the conservation of the species while helping to build a positive agenda for a range of stakeholders*. Another 22,835 individuals of 13 threatened species have been planted, while 116,733 seedlings of essential forest species have helped to increase ground cover, create new micro-habitats, attract wildlife, deposit organic matter and cycle nutrients in the soil, as well as increasing diversity in offset planting sites and restoring important ecosystem services for the region.

Start of planting in 2016
Source: Florestas Engenharia.

Four years later
Source: Florestas Engenharia, 2020.

Strategic Alignment

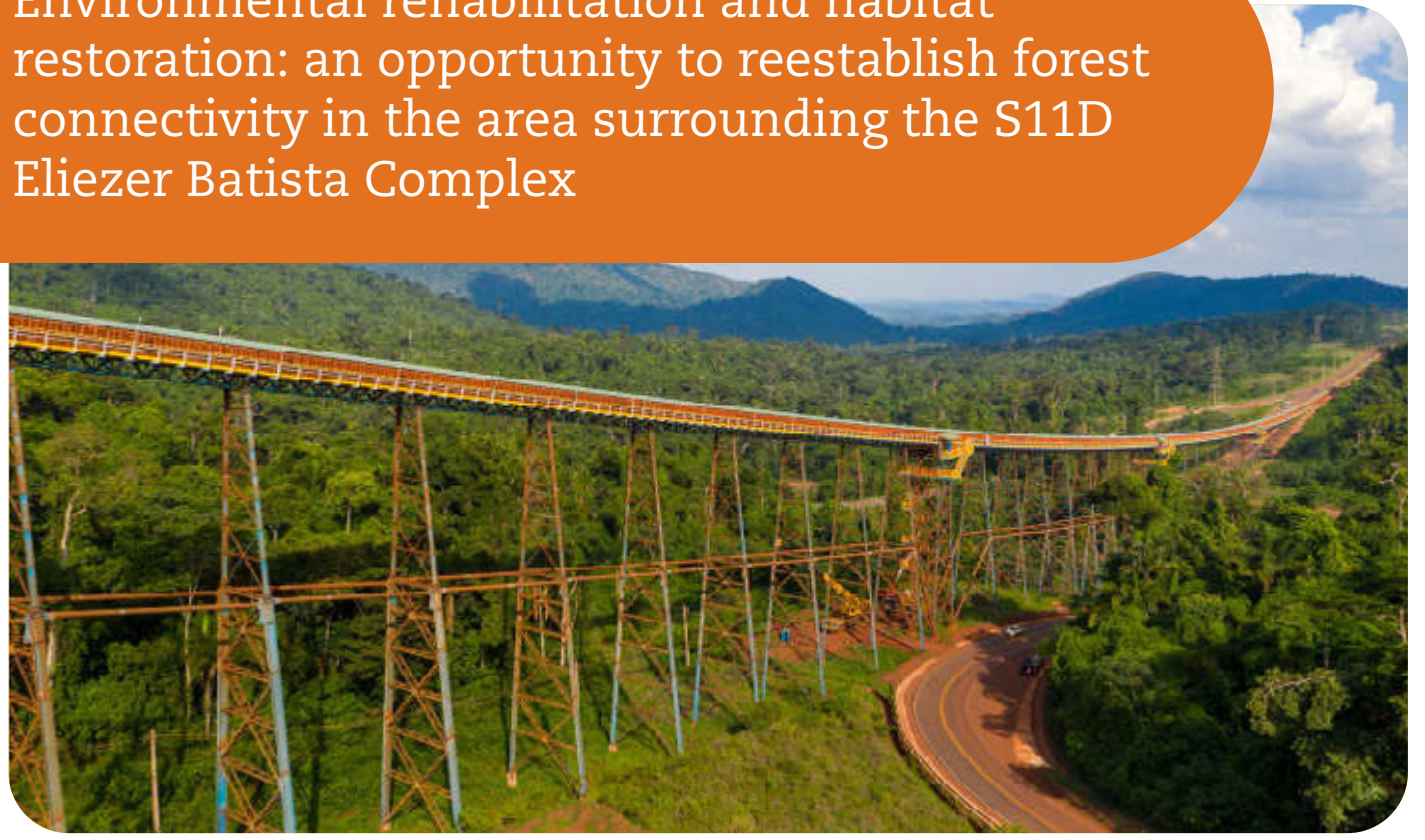
For Further Information

Schweyka Stanley Holanda de Oliveira[1], Khrisna Raphaela Moraes da Silva[2], Bruna Evelly da Silva Costa[2], Vitória Caroline Ribeiro de Morais[1], Arnaldo Silva Santos[1], Iara Alves Moreira[1], Leonardo Castro[1], Marcelo Aiub de Mello[2], Henrique Cesar Marquesini[1], Sergio Melo Franco do Amaral Machado[1], Silvio Junio Ramos[3] (schweyka.holanda@vale.com; raphaela.florestas@gmail.com; silvio.ramos@itv.org).

1. Gerência Meio Ambiente Metais Básicos Atlântico Sul; 2. Florestas Engenharia; 3. Instituto Tecnológico Vale Desenvolvimento Sustentável.

Rehabilitation & Restoration

Environmental rehabilitation and habitat restoration: an opportunity to reestablish forest connectivity in the area surrounding the S11D Eliezer Batista Complex



Introduction

The S11D Eliezer Batista Complex has a total area of 2,745.72 hectares. The mine site is partly located within the Carajás National Forest, a Sustainable Use protected areas. The National Forest is bounded by other protected areas, together forming an area known as the Carajás Mosaic. These protected areas contain the most important native forest remnants in the southeast of Pará State, and are part of the South Amazon Ecological Corridor, a priority area for biodiversity conservation. The region is encircled by anthropogenic landscapes created by an advancing agricultural frontier, vast smallholder settlements, timber and artesanal mining activities.

Rehabilitating anthropically disturbed areas to restore natural habitats in this region and expand and reestablish native forest cover can serve to offset impacts from the mine project that could not be avoided and/or mitigated, while also supporting the reestablishment of wildlife populations and forest connectivity through the formation of ecological corridors.

6,491 hectares
of forest restoration area

Methodology

The primary procedures used in the forest restoration process included site protection with fencing to prevent access by cattle, creation and maintenance of fire breaks, promoting natural regeneration by creating patches of trees to attract dispersers, and forest enrichment by planting seedlings, transplanting seedlings from the soil seed bank, direct seeding and natural regeneration. More than 500,000 seedlings of different native forest species with high floristic diversity have been planted in reforestation projects. These areas have been systematically monitored in the field over the years to collect data and assess performance.

500,000 seedlings of different native forest species have been planted

Results

Habitat rehabilitation activities surrounding the S11D Eliezer Batista Complex work on two complementary fronts: reestablishing forest connectivity by creating ecological corridors in the mine's area of influence, and restoring supplementary forest patches on purchased properties in the immediate vicinity of the mine site, which also form a part of the ecological corridors.

The first front is part of an environmental offsets program required under the environmental license for the mine and under Federal Decree 5 975/2006, in which land is being purchased to offset the disturbance of the natural environment caused by mining. As part of this program, ecological corridors are being established in the area surrounding the S11D Complex through forest restoration on Vale-owned properties, and educational initiatives are promoting forest restoration on surrounding third-party properties.

The objective of the program is to, within 10 years, rehabilitate 100% of the selected areas within the mine's direct and indirect area of influence, equal to the amount of area that

A significant contribution to maintaining regional biodiversity and establishing wildlife connectivity

has been disturbed by mine development (2,745.72ha). Currently, 4,860.48 hectares of disturbed land around the S11D mine and plant footprint are undergoing forest restoration, more than the legal requirement. Of these, 3,853 hectares have nearby parent forests that improve resilience, and are in an advanced stage of natural regeneration. In addition, 1,007.48 ha have undergone interventions to optimize the restoration process (480.25 ha as offsets for the S11D mine, 336.87ha of legal protected areas (called permanet preservation area, APP in Brazil legal freamwork) as offsets for the Serra Norte project, and 190.36 ha as offsets for the Salobo project).

On the second front, other areas in addition to the recovery/restoration areas within the program above have been selected, especially land previously used for cattle farming, then at varying stages of regeneration in terms of vegetation cover. Activities on this front were based not only on prior experience from previous projects, but also on the principles of resilience and ecological succession, including promotion of natural regeneration and management of invasive species. On the second front, 1,631 ha of area are currently under restoration.

The two fronts combined form a total of 6,491 ha of forest habitats under restoration in the last 4 years, a significant contribution to maintaining regional biodiversity and establishing wildlife and forest connectivity through ecological corridors.

Strategic Alignment

For Further Information

Ricardo Campelo Costa[1] (ricardo.campelo@vale.com); Salim Jordy Filho[2] (salim.jordy@vale.com); André Cardoso[3]; Cesar de Sá Carvalho Neto[1]; José Camilo Araújo[1], Lourival Tyski[1]; Luiz Felipe Campos[2]; Marcelo Gomes da Silva[2]; Mario Luis Oliveira[1].

1. Diretoria Corredor Norte / Gerência de Meio Ambiente Rel Inst Soc Econ Com.; 2. Diretoria de Sustentabilidade e Investimento Social/ Gerência de Recuperação de Áreas Degradadas e Fechamento de Mina; 3. Sete Soluções e Tecnologia Ambiental.

Rehabilitation & Restoration

Corridors connecting protected areas in Carajás

Photo: João Marcos Rosa

Introduction

Loss of habitat has long threatened biodiversity in tropical forests, and anthropogenic climate change now poses a new threat to species. Although protected areas have been established, there remains an urgent global need to increase connectivity between them to support the conservation of forest species and help them cope with land-use and climate change.

In this context, the purpose of this study was to identify potential ecological corridors to connect the protected areas (PAs) in Carajás ("Carajás PAs") to other protected areas west and north. These corridors are designed to facilitate the migration of species to find adequate habitats, addressing at once the fragmentation caused by deforestation and the climate change predicted to occur in the future (year 2050).

Methodology

Data was compiled from the literature on the potential impacts of climate change on three important wildlife groups in Carajás: bats (Costa et al. 2018), birds (Miranda et al. 2019), and bees (Giannini et al. 2020). As pollinators and seed dispersers, these groups play an essential role in their interaction with plant species. The potential movement of species between forest fragments was therefore incorporated in our climate change models.

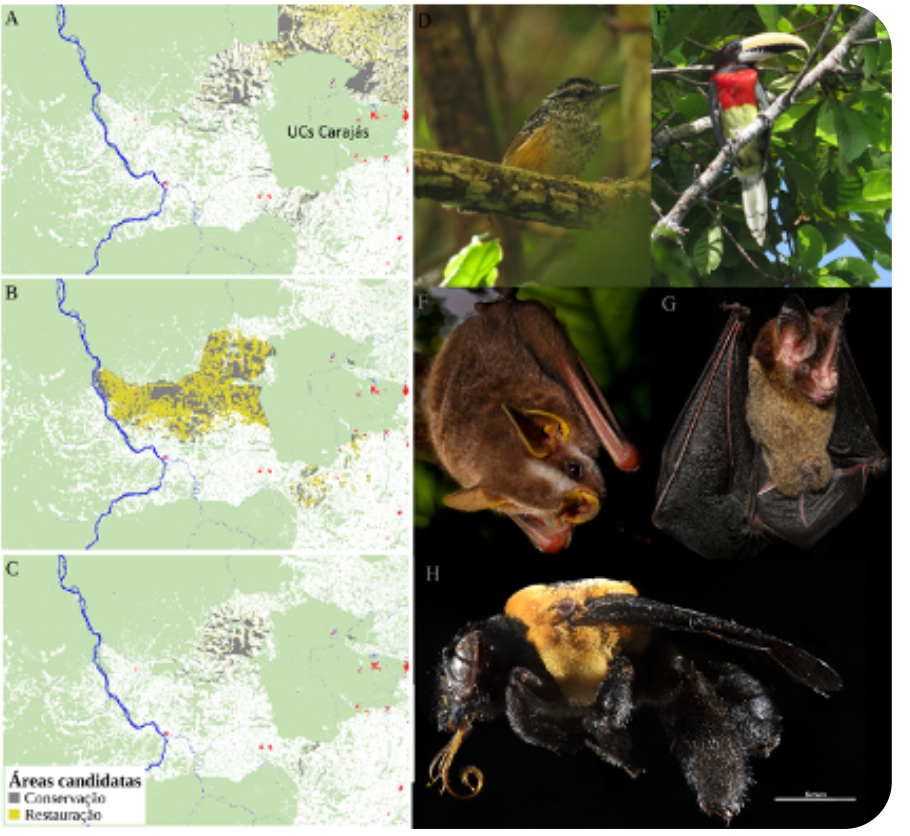
Forest fires were reduced in 2020 following the introduction of agroforestry systems

Results

The modeling results (Figure 1) show that, if only potential movement through forest remnant fragments is considered, potential corridor areas are largely located north of the study area (trending toward the Parakanã indigenous reserve). This changes when species stability and adaptation to climate are taken into account based on future climate change projections, with the best corridors now trending west (toward the Terra do Meio protected area). Areas overlapped by both approaches measure a total of 135,171ha. Roughly over 117,000 ha have forest cover; the remaining 18,000 ha are deforested and can be considered a priority for restoration actions. The best suited areas for implementation of corridors are the ones modeled as described above, which can also support the selection of areas for offsets.

Forest restoration initiatives are already in progress to improve connectivity among Carajás PAs, largely through the establishment of agroforestry systems. These initiatives began in 2012 and were expanded to a larger area in 2017, with approximately 45,000 seedlings and 54 ha of agroforestry systems established as part of a project in partnership between ICMBio and Vale (Salobo Metais S.A).

Agroforestry systems attempt to replicate the multi-storied structure of a native forest in order to benefit from synergies between crop and forest plants, while supporting both subsistence and livelihoods. These systems have been implemented using crops such as maize, beans, cassava, sweet potatoes, bananas, papayas, açai, cocoa, andiroba, Brazil nuts and copaiba. In addition to playing an important restoration role by protecting biodiversity, mitigating climate change and increasing connectivity, agroforestry initiatives help provide livelihoods for local communities. As another benefit, in 2020 a survey found that forest fire outbreaks had been reduced following implementation of agroforestry systems. The survey was conducted using heat map data from the Brazilian Institute for Space Research (INPE) for 2010, 2012, 2014, 2016, 2018 and 2020 in the municipalities of São Félix do Xingu, Parauapebas and Marabá. The data was then drilled down to the areas where agroforestry systems have been implemented, and areas with a fire risk greater than zero were counted. The number of heat spots in the region as mapped by the INPE had decreased 400%, suggesting that agroforestry can be useful in preventing forest fires and consequent deforestation.



Areas selected to increase connectivity among Carajás PAs based on A) habitat permeability (presence of forest fragments); B) projected climate change impacts in 2050 on 603 bird, bat and bee species occurring in Carajás; C) the two criteria above combined. Examples of species used in the modeling: D) *Hypocnemis striata* and E) *Pteroglossus bitorquatus* (Photos: L. Miranda); F) *Dermanura gnoma* and G) *Gardnerycteris crenulatum* (Photo: L. Trevelin); H) *Centris denudans* (Photo: F. Trancoso).

Strategic Alignment

For Further Information

Tereza Cristina Giannini[1,2], Leonardo Miranda[3], Leandro Reverberi Tambosi[4], Wilian França Costa[5], Rafael Cabral Borges[1,2], Leonardo C. Trevelin[1], Rodolfo Jaffé[1], Antonio Mauro Saraiva[6], Vera Lucia Imperatriz-Fonseca[6], Schweyka Holanda[7], Vitória Caroline Ribeiro de Morais[7], Sergio Melo Franco do Amaral Machado[7] (tereza.giannini@itv.org).

1. Instituto Tecnológico Vale; 2. Universidade Federal do Pará; 3. Museu Paraense Emilio Goeldi; 4. Universidade Federal do ABC; 5. Universidade Mackenzie; 6. Universidade de São Paulo; 7. Vale, Diretoria de Operações de Metais Básicos Atlântico Sul/ Gerência Meio Ambiente.

Rehabilitation & Restoration

DNA metabarcoding provides insight into insect succession and vertebrate diversity during rehabilitation of mined land

Photo: Christina Lynggaard

Introduction

The mitigation hierarchy calls for action to be taken to avoid, minimize, remediate an offset impacts from human activities, such as mining. These actions include remediating or rehabilitating disturbed sites. Monitoring areas under remediation and rehabilitation is important in assessing the success of these initiatives.

Although vegetation structure is most commonly used as an indicator of the rehabilitation status of an ecosystem, animal communities can also provide good indicators, as resident wildlife can reflect changes in ecosystems.

Arthropods, for example, are abundant and highly diverse, especially in tropical forests. And while they are easy to collect in large quantities, using traps set in monitored areas over the space of a few days, their identification based on morphology requires in-depth taxonomic knowledge. Unlike arthropods, however, vertebrates can be readily identified morphologically, but they are difficult to monitor, as they are often shy or limited in abundance.

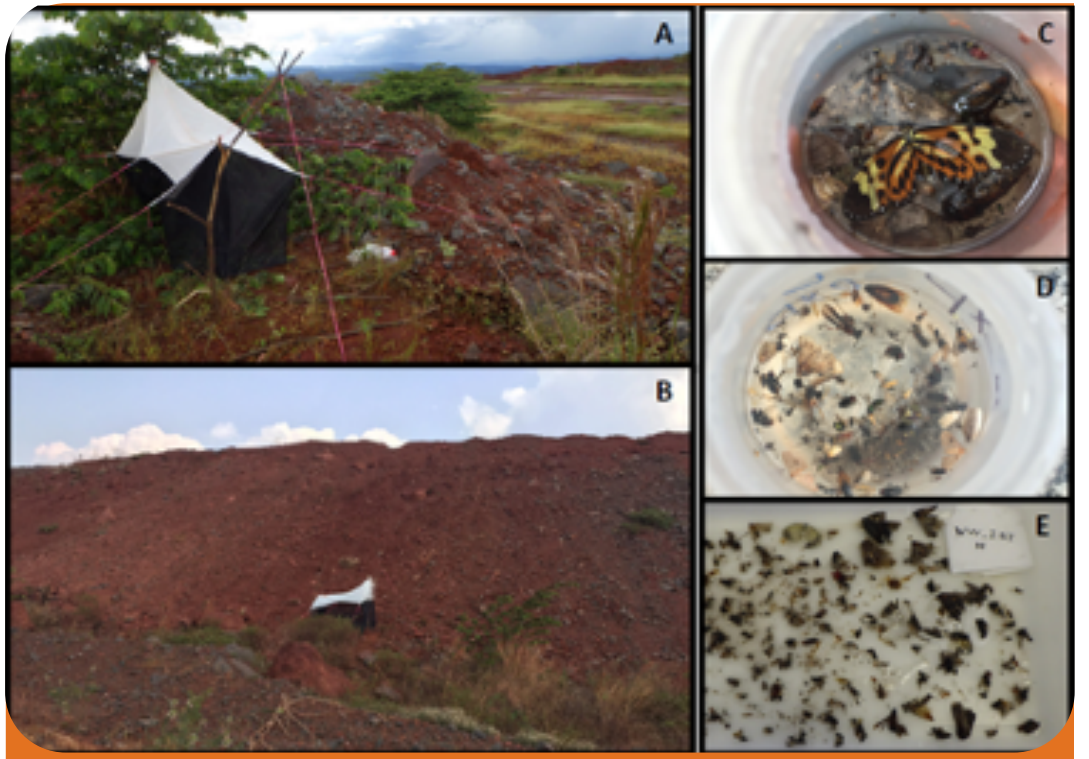
DNA metabarcoding can provide information about vertebrates based on arthropod samples

Methodology

Molecular methods, such as DNA metabarcoding, facilitate identification and monitoring of these animals by enabling detection of multiple species at a large temporal and spatial scale, based on the DNA present in environmental samples (soil, water, sediment and feces) or composite tissue samples (plants or animals). The technique is based on mass sequencing of specific regions of DNA to generate barcodes that can then be compared with those contained in reference databases for species identification. In theory, this method enables identification of all organisms present in a bulk environmental sample in a single sequencing run, in an efficient and cost effective process. Due to its ease of application, the DNA metabarcoding approach has been widely used for monitoring arthropods, as it enables rapid identification of all species present in an environmental sample. This method can also be used to derive information about vertebrates based on arthropod samples. This is possible because arthropods—such as sand flies, bot flies, mosquitoes and ticks—feed on vertebrates, whose DNA then accumulates in their guts. Arthropods collected in studies can be used to analyze the DNA of these invertebrates (iDNA) as well as to identify any vertebrates they may have had contact with. This allows both groups to be monitored in the areas of interest.

In a scientific collaboration between the University of Copenhagen (KU) and the Vale Institute of Technology, arthropod samples were collected during the dry and wet season using Malaise traps set at waste pile sites at varying stages of environmental rehabilitation in the N4-N5 sites, within the Carajás National Forest.

These sites had been rehabilitated by spraying a mixture of seeds, fertilizer and mulch directly onto the soil with a hose, a process known as hydroseeding. The mixture contained seeds of fast-growing groundcover species as well as a variety of native species to initiate natural succession and ensure ecosystem services would be reinstated over time. The traps were set on pile slopes at different stages of environmental rehabilitation: bare



Traps set in areas under environmental rehabilitation (A, B), captured arthropods (C, D) and arthropods being sorted (E)

Samples were collected from waste pile sites at varying stages of environmental recovery, as well as in canga and forest areas

unvegetated soils; areas at initial stages of rehabilitation up to three years after seeding; areas at intermediate stages of rehabilitation, four to five years after seeding; and areas at advanced stages of rehabilitation, six to seven years after seeding. For benchmarking purposes, samples were also collected from undisturbed ecosystems such as cangas and forests in the region.

Because the biodiversity that could be expected in the samples was unknown, a non-destructive DNA extraction protocol was used. In this protocol, arthropods are morphologically preserved so that future studies can catalog the sampled specimen, potentially leading to the description of new species. DNA metabarcoding allowed specific regions of vertebrate and invertebrate genomes to be evaluated based on bulk samples, using group-specific molecular markers.

Results

As expected, most collected arthropods could not be identified to the species level due to the unavailability of genetic references in public databases (85-91% of sequences per sample). Despite this limitation, the results revealed seasonal effects on arthropod communities and that areas at advanced stages of rehabilitation tend to have greater diversity than areas at intermediate or initial stages, at least in the dry season. Waste piles with bare, unvegetated soil had the least diversity in both seasons. Arthropod communities found on waste piles six to seven years after revegetation showed an ecological succession trending toward the reference forests, but not to cangas.

From the same samples, information was derived on the vertebrates living in the area. DNA from amphibians (frogs, such as *Physalaemus cuvieri*) and mammals (bats (*Molossus molossus, Artibeus* sp.), South American tapirs (*Tapirus terrestris*), howler monkeys (*Alouatta* sp.), and tamarins (*Saguinus* sp. and rodents)) was detected in the samples. This maximized the information obtained from the same remotely collected bulk samples, and demonstrated how technology can be harnessed to monitor the rehabilitation of disturbed sites and to achieve a better understanding of ecosystem functioning.

Technology has proven to be highly useful in monitoring the rehabilitation of disturbed sites

Strategic Alignment

For Further Information

Christina Lynggaard[1], Gisele Nunes[2], Santelmo Vasconcelos[2], Guilherme Oliveira[2], Markus Gastauer[2] (markus.gastauer@itv.org).

1. Universidade de Copenhagen; 2. Instituto Tecnológico Vale.

Rehabilitation & Restoration

Environmental quality monitoring used to quantify contributions from rehabilitation to the mitigation hierarchy

Introduction

Reforested mine sites contain a variety of native herbaceous (including grass), liana, shrub and tree species.

The mitigation hierarchy framework and its four pillars—avoid, minimize, remediate and offset environmental impacts—are designed to ensure that economic development is reconciled with protection of natural resources. However, for the framework to be effective in managing natural resources, it is important that contributions within each pillar are quantified.

Rehabilitation of disturbed sites, one of the primary strategies in remediating environmental impacts caused by mining, aims to restore both physical features as well as biodiversity and ecosystem services to their

original state (Gastauer et al. 2018). The more successful the rehabilitation efforts, the lesser the residual impacts remaining to be offset. In this context, researchers and environmental teams from Vale have worked to develop methodologies for quantifying the environmental status of rehabilitated sites (Figure 1).

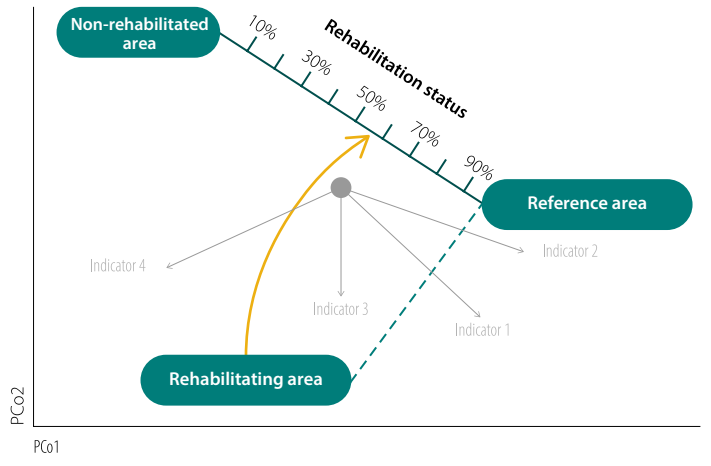


Figure 1. Illustration of the method of quantifying environmental rehabilitation status (environmental quality) on mined land. The rehabilitation status denotes, as a percentage, the extent to which the rehabilitating site approximates the target site (reference area). To measure this percentage, monitored areas are ordered using multivariate analysis based on environmental indicators (Indicators 1-4). The distance from the rehabilitating site to the target site (dashed line) is then related to the distance from the non-rehabilitated area to the target (bold, scaled line), as represented by the orange arrow

Methodology

To measure rehabilitation progress, important ecosystem features and functions were monitored at different sites. The parameters analyzed included information about vegetation structure (degree of coverage or number of trees), diversity and composition of vegetation and fauna communities (number and abundance of native species), and selected ecological processes (functional diversity, enzyme activity in the soil, etc.).

To gather this information, soil, vegetation and fauna samples were collected from sites at different stages of rehabilitation in the Urucum iron ore mines in Mato Grosso do Sul (Figure 2); on waste piles in the Serra de Carajás, Pará, northern Brazil; and at decommissioned sandstone quarries in the Serra de Carajás (Figure 3).

At each of these three sites, areas of bare soil, areas at varying stages of rehabilitation (2-3 years for

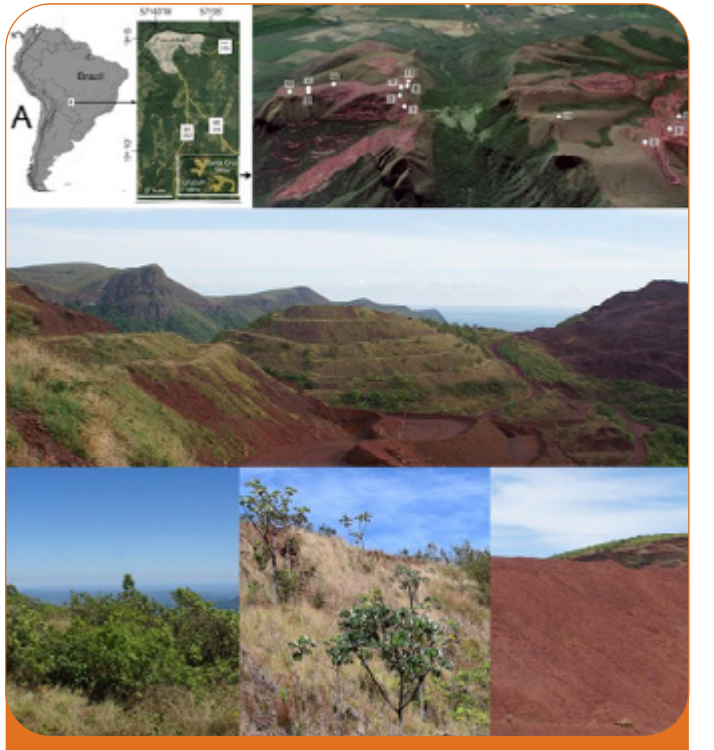


Figure 2. Locations of monitored rehabilitation sites at Urucum, in Corumbá, Mato Grosso do Sul (A). The general landscape (B) comprises open savanna formations on the hilltops and forest formations on the slopes, rehabilitating sites (*the slopes shown left and center in the image*) and non-revegetated mine sites (*the slopes on the right*). C-E show details of the region's characteristic grasslands and tree and shrub savannas (rehabilitation targets, sites 1, 9, 10 in (B), rehabilitating sites (2, 4, 6, 7, 8, 12, 13) and nonrevegetated slopes (other sites)

Corumbá, 1-7 years for the waste piles and 1-12 years for the sandstone quarries) and reference areas covered by undisturbed natural vegetation were sampled. Nonrevegetated (disturbed) areas and areas covered by natural vegetation, or rehabilitation targets, were sampled to assess environmental progress or trajectories during the course of rehabilitation (Vickers, Gillespie, and Gravina 2012). Rehabilitation targets and strategies differed across the three case studies. At the Urucum mines, located in the *Pantanal* wetlands in midwestern Brazil, the rehabilitation targets are the cangas in the region, ranging from grassland to tree-and-shrub savanna (Figure 2). To initiate the mine rehabilitation process, seeds and seedlings of more than 100 native herbaceous (including grass), liana, shrub and tree species are taken to the field.

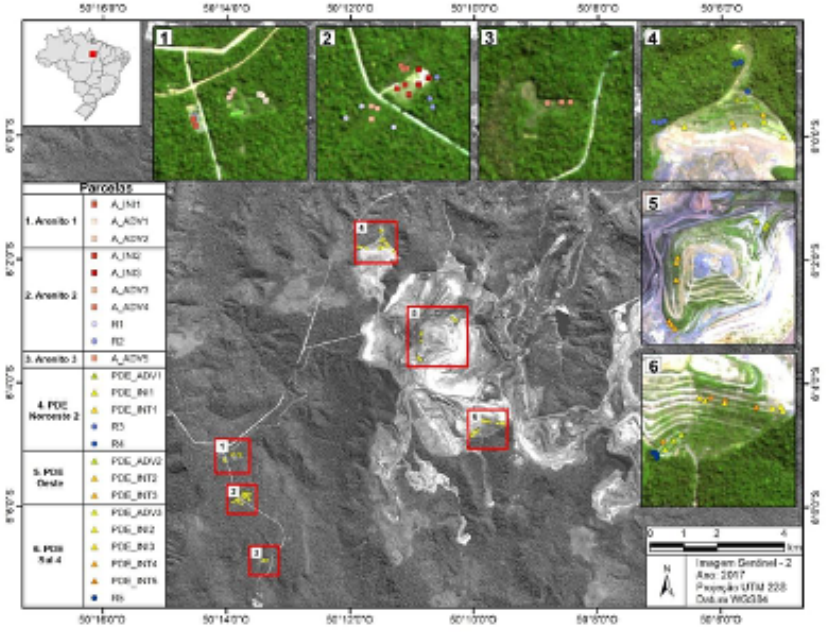


Figure 3. Locations of monitored areas in the Serra de Carajás; sites 1-3 are sandstone quarries, and sites 4-6 are waste piles

In the Serras de Carajás, set within the Amazon biome, where vast forests dominate the landscape, mining operations require large volumes of topsoil and overburden or waste rock to be removed and deposited in piles up to 60 m high. To rehabilitate these sites, a seed mixture is sprayed onto the piles in a process known as hydroseeding. The mixture contains seeds of fast-growing groundcover species as well as a variety of native species to initiate natural succession and ensure ecosystem services will be reinstated over time. The sandstone quarries in this region were rehabilitated by placing topsoil and planting seedlings of tree species.

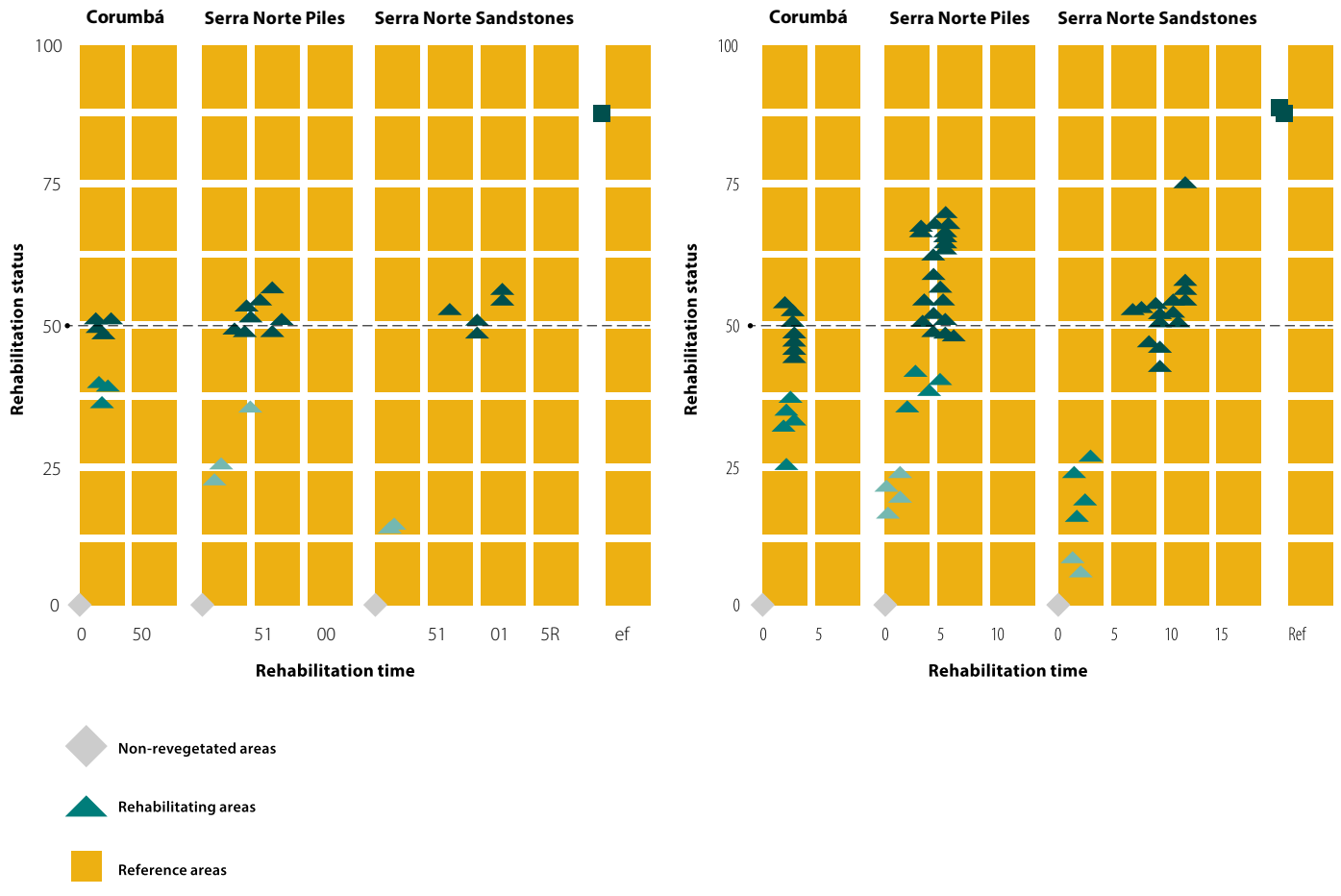
Based on the monitored soil and vegetation parameters, the rehabilitation status of the three sites was ordered using multivariate analysis to spatialize environmental differences. The rehabilitation status (i.e. the distance between rehabilitating sites and the reference/target sites, in relation to the distance between nonrevegetated areas and the reference sites) was then determined to quantify environmental improvement to date at the rehabilitating sites.

Results

Surveys across the three sites showed that rehabilitation activities have successfully reinstated much of the pre-mining diversity, structure and ecological processes. In Corumbá, after three years of regeneration, the rehabilitation status is now at 50% of the values for the target areas (Figure 4). In Carajás, the environmental status of rehabilitating waste piles improved over time to 53% after seven years, while the sandstone quarries improved to 60% after 12 years (Figure 4). Rehabilitation of savanna formations in Corumbá will likely require less time to achieve a rehabilitation status of 50% than Amazon forests.

Estimation of rehabilitation status showed no bias toward individual variables (Gastauer et al. 2019; 2020). Specifically, statistical testing confirmed that a sufficient number of environmental parameters was considered to estimate rehabilitation status reliably (Gastauer et

Figure 4. Environmental status improvement with rehabilitation time at different monitored sites



The proposed environmental monitoring approach was shown to be effective in quantifying the quality of rehabilitating sites

Figure 5. The rehabilitating chronosequence on the Northwest II waste pile in the Serra Norte, Carajás

al. 2019; 2020). In addition, the inclusion of different modeled variables representing ecosystem properties or functions that had not yet been measured in the field—such as abundance or diversity of specific taxonomic groups—changed the rehabilitation status only marginally (Gastauer et al. In Prep.), further confirming the reliability of the figures presented.

Monitoring rehabilitation success can provide assurance that biodiversity, structure, functionality and ecological processes at disturbed sites have been reinstated, although longer periods may be required to restore all ecosystem properties. As successional processes in these areas continue, rehabilitating sites are expected to further approximate the rehabilitation targets over time. Rehabilitation to more than 50% of target environmental quality in only one decade highlights the importance of mine rehabilitation activities to effectively mitigate mining impacts. The environmental monitoring approach developed in this study was shown to be effective in quantifying environmental quality at rehabilitating sites and ensuring that the objective of No Net Loss is being achieved in the company's operations.

Strategic Alignment

For Further Information

Markus Gastauer[1], Cecílio Frois Caldeira[1], Silvio Junio Ramos[1], Rodolfo Jaffé[1], Leonardo Trevelin[1], Delmo Fonseca Silva[2], Renan Rodrigues Coelho[2], Sergio Souza Junior[2], Felipe Tadashi Asao Coelho[3], Pedro Walfir1, Rosilene Rodrigues Silva[3], Túlio Márcio Nascimento dos Santos[3], Valdenir Vaz Filho[3], Leonardo Neves[2] (markus.gastauer@itv.org).

1. Instituto Tecnológico Vale; 2. Diretoria do Corredor Norte/Gerência de Meio Ambiente Rel. Inst. Socioe. Com.; 3. Diretoria Corredor Sul/Gerência de S&S Meio Ambiente e Serviços Corumbá.

Rehabilitation & Restoration

Propagation and growth of native species for mineland rehabilitation

Introduction

The need to reconcile human activities with sustainable use of natural resources is increasingly urgent. Rehabilitating disturbed land, conserving native vegetation and maintaining ecosystem services are a fundamental part of achieving this.

The Carajás National Forest contains formations ranging from evergreen to deciduous forests, as well as patches of savanna vegetation that occur on plateaus covered by ferruginous outcrops. This vegetation forms a rich mosaic of predominantly open vegetation directly associated with the rocky substrate, known as ferruginous cangas (Viana et al 2016). Limited information is available about

the canga and forest species in Carajás, especially information on seed characteristics, germination and other factors that can influence the successful establishment of these species at rehabilitation sites. Research on native species is therefore important to inform seedling production, biodiversity management and the development of strategies for rehabilitation of mined land in the region. The Vale Institute of Technology (ITV) is conducting several studies on the propagation and cultivation of native plant species, and developing protocols to improve seed germination and the cultivation of native species on mined land.

Research on native species is important to inform seedling production, biodiversity management and the development of strategies for mineland rehabilitation

Methodology

Seeds of several species native to the cangas and forests of Carajás were assessed through purity tests, biometrics, x-ray imaging, germination tests, assessments on overcoming dormancy, and assessments of tolerance to desiccation and storage. Growth studies are also being carried out with these native species, with different fertilization treatments on substrates replicating the mine sites to be rehabilitated.

Results

Our research revealed that for several native species, seed dormancy needs to be overcome before seeds are planted in nurseries or directly at rehabilitation sites through hydroseeding. For most species, scarification with fine grit sandpaper proved to be an efficient method to increase both the germination rate and the germination speed index (GSI), enabling fast and homogeneous germination while also making these species more competitive when taken to the field—as well as facilitating seedling production at nurseries.

Findings regarding seed size (Figure 1) for Fabaceae species from the cangas and forests of Carajás show that larger seeds from forest species have better germination performance than the smaller seeds commonly found in canga species, suggesting greater attention is required in collecting seeds from canga species for use in revegetation. Study results also

suggest that long-term storage reduces germination for some species. Thus, overcoming dormancy and limiting storage time can improve native species' germination yields in revegetation activities.

In relation to the propagation and growth of native grass species in Carajás (*Paspalum cinerascens* and *Axonopus longispicus*), both species were observed to have good potential for vegetative propagation using separated tillers (Figure 2), making them well suited for use in rehabilitation of disturbed sites. The study also showed that nitrogen fertilization led to increased tillering in both species, as well as a higher capacity for carbon fixation and, consequently, accumulation of biomass in *Paspalum cinerascens*.

A study comparing species of the genus *Crotalaria*, including a non-native species that is widely used in revegetation of mined land in Brazil (*Crotalaria spectabilis*) and another species native to the cangas of Carajás (*Crotalaria maypurensis*), found that mineral and organic fertilizers improved growth in both species on mined land in Carajás (Figure 3).

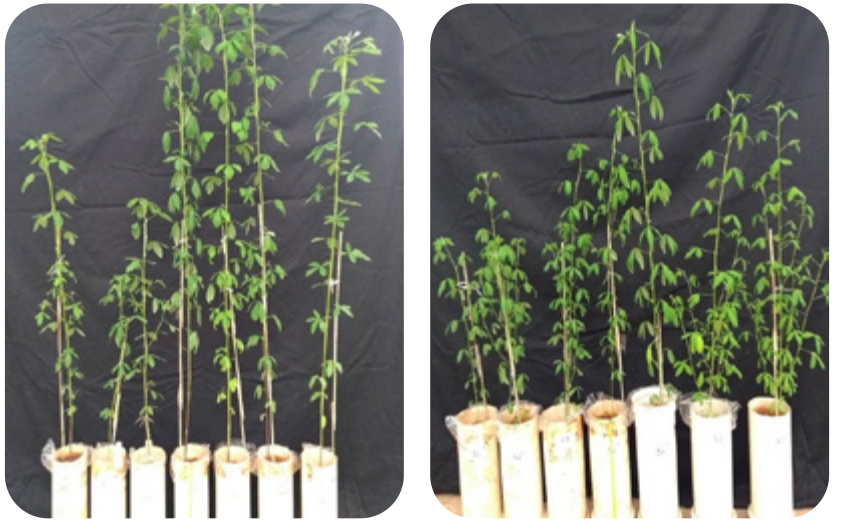
This study also showed that the species have significant differences regarding nitrogen metabolism in leaf tissues. While *C. maypurensis* tends to have a higher concentration of nitrate in its leaves, *C. spectabilis* has nitrogen primarily

Figure 1. Seeds of eight Fabaceae species

Figure 2. *Paspalum cinerasens* growing in substrates from mined land in Carajás

Native *Crotalaria* species' rapid growth and abundant seeds make them well suited for revegetation activities

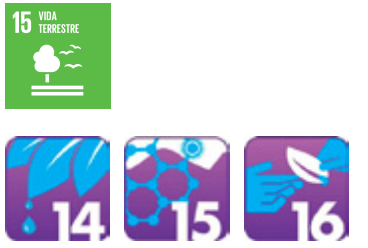
in the form of ammonia, which would explain why native species are slower-growing than non-native species, as more energy is spent on metabolizing nitrate in plant tissues. Although the native Crotalaria species grows slower than its commercial counterpart, its use in the revegetation of mined land in Carajás should still be considered, as this species produces a substantial amount of seeds and exhibits rapid growth in mined substrates, while helping to meet the legal requirement to use native species.



Crotalaria maypurensis *Crotalaria spectabilis*

Figure 3. Comparative growth of a commercial Crotalaria species (*Crotalaria spectabilis*) and native species (*Crotalaria maypurensis*) in mine soil containing organic and mineral fertilizers

Strategic Alignment



For Further Information

Silvio Junio Ramos[1], Cecílio Caldeira[1], Markus Gastauer[1], Rafael Silva Guedes[1], Hemelyn Soares das Chagas[2], Renan Coelho[3], Mário Luís Oliveira[3], Pedro Walfir Souza-Filho[1] (silvio.ramos@itv.org).

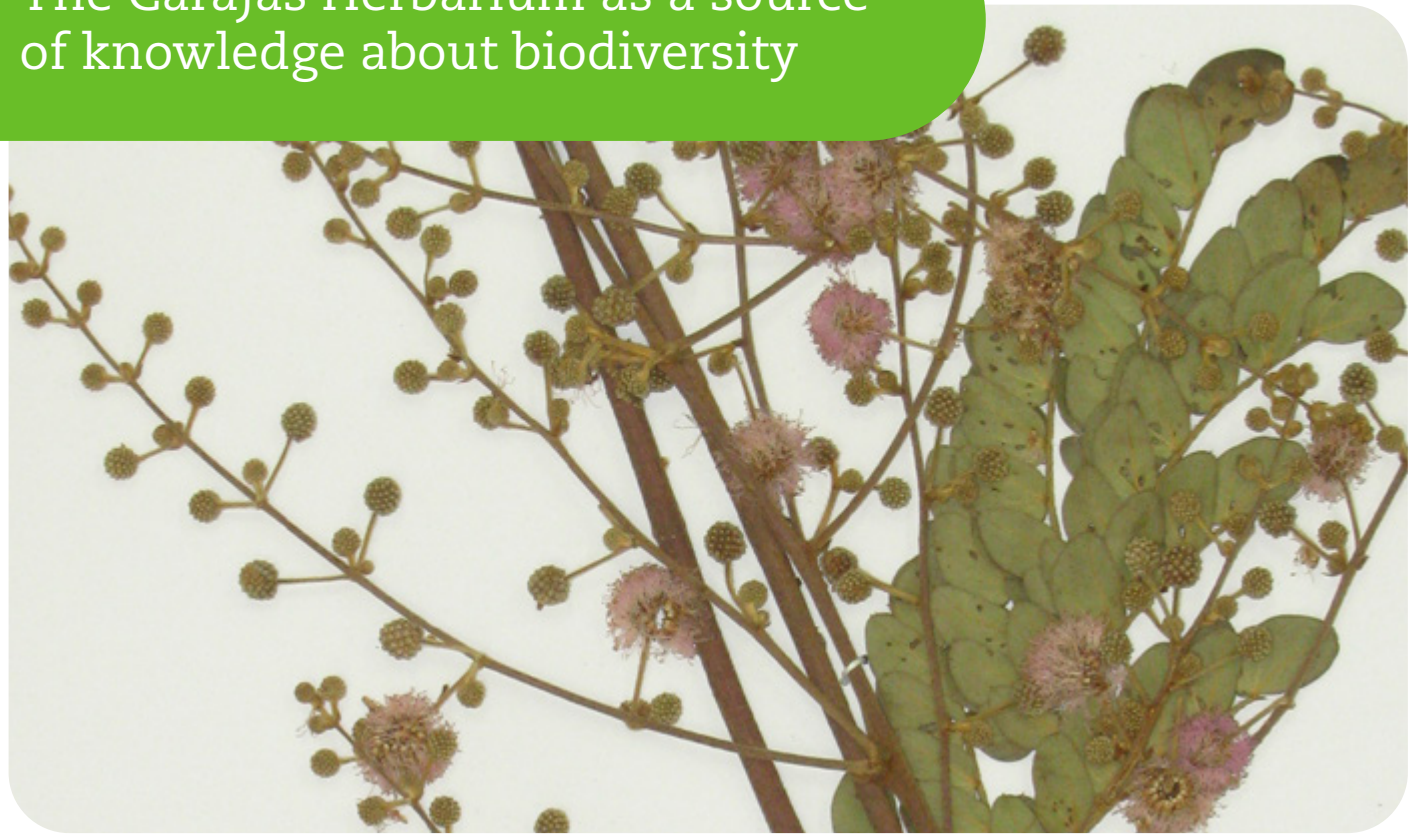
1. Instituto Tecnológico Vale – Desenvolvimento Sustentável; 2. Universidade Federal Rural da Amazônia; 3. Diretoria do Corredor Norte/ Gerencia Meio Ambiente.

Ongoing actions for the future we want

Ex Situ Conservation

Ex Situ Conservation

The Carajás Herbarium as a source of knowledge about biodiversity



Introduction

Botanical research in Carajás, in the southeast of Pará State, Brazil, began in 1969 as part of the *"Grande Carajás"* mineral exploration program. During that period, all collected botanical specimens were sent to the herbarium at Museu Paraense Emilio Goeldi (MG). The Carajás Herbarium was later created in 1987, and in 2007 a major effort was undertaken to collect materials from across the Carajás region and deposit them in the herbarium, which by then had been registered as part of the Brazilian Herbarium Network, under the code HCJS. In 2016 the collection was indexed in the *Index Herbariorum*, a directory managed by the New York Botanical Garden.

With an emphasis on species linked to the Carajás region, HCJS provides an important record of the floristic diversity of the region, with an especially large collection of species found in ferruginous canga. The collection provides an account of the present and past occurrence of a variety of species, and a record of their distribution.

The Carajás Herbarium is located at the Vale Zoobotanical Park in Carajás, in an air-conditioned and well-equipped room at the Visitor Center. The collection currently contains more than 7100 exsiccates across 170 botanical families, including a large number—146 families—of angiosperms; 23 families of pteridophytes, and the only genus of gymnosperms found in the region, Gnetum, of the family Gnetaceae. Among the angiosperm specimens, 11 families account for more than 50% of the collection: Leguminosae 13.62%, Rubiaceae 6.93%, Poaceae 5.91%, Melastomataceae 4.63%, Cyperaceae 3.78%, Orchidaceae 3.1%, Asteraceae 3.02% Myrtaceae 2.99%, Convolvulaceae 2.78%, Euphorbiaceae 2.26%, and Bignoniaceae 2.06%.

In addition to the inestimable value of the information it provides on plants in the collection, the herbarium has made positive contributions by: helping to close knowledge gaps relating to the occurrence and distribution of species; training plant scientists who work in a range of activities at Vale; and building closer links with the academic community through direct interaction with researchers and students from different institutions, providing data and materials for research. Several partners and other actors have played an important role in building the collection, including the Rio de Janeiro Botanical Garden, Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), Museu Paraense Emilio Goeldi and the Vale Institute of Technology.

The facilities and collections at the Carajás Herbarium

Strategic Alignment

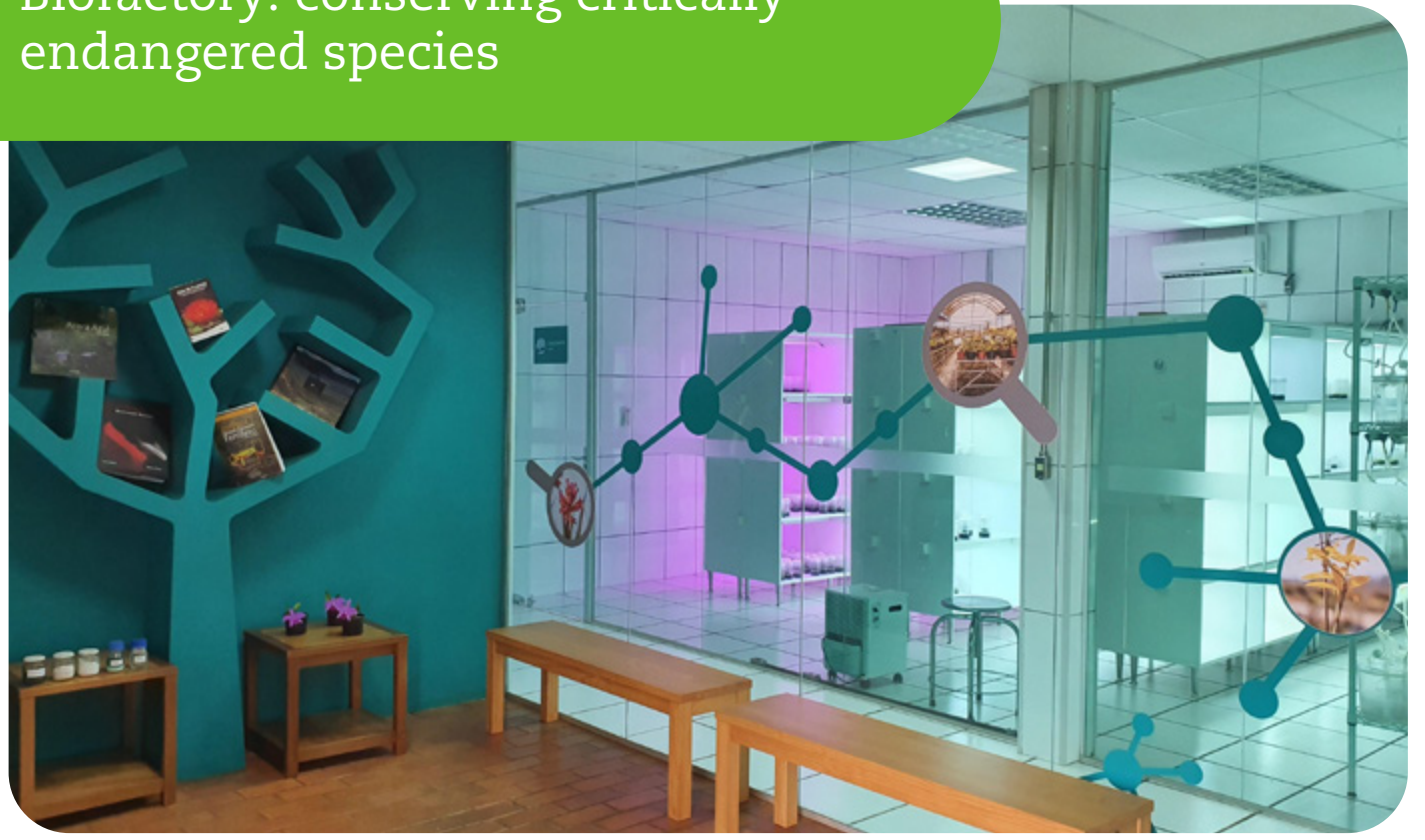
For Further Information

Lourival Tyski[1], Tarcisio Rodrigues[1], Delmo Fonseca[1], Edivaldo Araujo[1], André Cardoso[2] (lourival.tyski@vale.com).

1. Vale, Diretoria Corredor Norte, Gerência de Meio Ambiente Rel. Inst. Soc. Econ. Com.; 2. Sete Soluções e Tecnologia Ambiental.

Ex Situ Conservation

Biofactory: conserving critically endangered species



Introduction

Vale operates in areas of high biodiversity value where, alongside efforts to reduce and manage impacts from its operations, the company implements a range of strategies to rehabilitate disturbed land and restore habitats and populations, with a focus on conserving biodiversity.

In 2015 Vale launched a Biofactory at the Ferrous Metals Technology Center in Nova Lima, a city in the Iron Quadrangle in Minas Gerais, southeastern Brazil, where the Atlantic Forest transitions into *Cerrado* savannas. The facility has capabilities to multiply plant species using biotechnology, and for *in vitro* reproduction of native flora species. Initially focusing on the reproduction of threatened and rare species, and species endemic to ferruginous cangas—these being directly impacted by Vale's operations—the facility now produces several other rare species found in Atlantic Forest and *Cerrado* formations.

Methodology

The plant reproduction process begins in the field. Specimens identified in the field are used as parent stock to collect seeds, and individuals are also retrieved as part of flora rescue programs. Salvaged plants are sent to the nursery and collected seeds are taken to the laboratory. After the seeds are disinfested, they are inoculated and transferred to a growth room that recreates ideal nutritional, temperature and lighting conditions for plantlet development.

After this processes, the plants are transferred to greenhouses, where they continue to develop under controlled conditions that are closer to conditions in the wild. The last stage is acclimatization, in which the plants are kept in an environment more closely approximating the natural conditions of their habitat before they are reintroduced at the final planting site.

Results

Under the ideal conditions created in the lab, a single seed pod can turn into hundreds or even thousands of individuals. These are then grown in greenhouses and, after acclimatization under conditions approximating their natural habitat, are reintroduced in the wild. The species produced are used in rehabilitating mine sites or restoring habitats, and are monitored to ensure the different species, individuals and populations have been successfully established.

One example is *Cattleya milleri*, an orchid species endemic to the Iron Quadrangle in Minas Gerais. This species occurs on ironstone outcrops known as ferruginous cangas, at altitudes ranging from 800 to 1500 meters, including mine sites. Pressures on their habitats, and

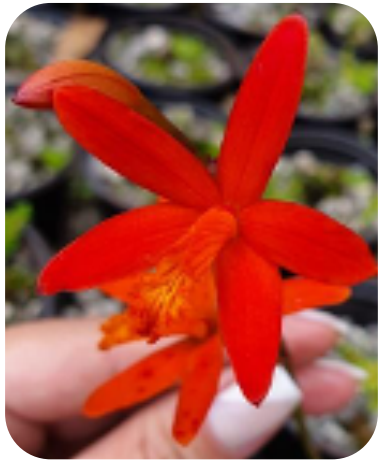
their small red flowers, which are prized by collectors, have made populations of this species increasingly rare in their habitats, to a point where they are now considered critically endangered in Brazil.

Under natural conditions, *Cattleya milleri* can produce as many as 10,000 seeds from each fertilized flower. However, seed germination rates in the wild are extremely low, as the seeds have no nutritional reserve and need ideal conditions to develop—including an optimal balance of moisture, light and nutrients.

Under ideal conditions at the Biofactory lab, approximately 18,000 *Cattleya milleri* seedlings have been produced to date, and around 3,000 individuals have been reintroduced in nature at offset sites, helping to restore habitats and reestablish populations. The seedlings have been monitored *in loco* for approximately 2 years, exhibiting satisfactory growth and low mortality rates.

This is one example of how the Biofactory has contributed to restoring populations and habitats, and to conserving species.

Seedlings have been monitored *in loco* for approximately 2 years, showing strong growth and low mortality



A *Cattleya milleri* orchid

Cattleya milleri seedlings

Seedlings undergoing acclimatization

Strategic Alignment

For Further Information

Leilane Gomes; Genilton Santos (leilane.gomes@vale.com; genilton.santos@vale.com).

Diretoria do Corredor Sul/Gerência de Meio Ambiente do Corredor Sul.

Ex Situ Conservation

Minimizing impacts – rescue and conserving bee species

Introduction

Developing mines or mine expansions requires areas of native vegetation to be cleared, directly and indirectly affecting the area's flora and fauna. One way to mitigate impacts is to implement programs to rescue wildlife during clearing operations. Rescuing native beehives is among the measures taken to mitigate impacts in our South Corridor iron ore operations in the Iron Quadrangle in Minas Gerais.

In 2016, Vale created a beekeeping facility at the Ferrous Metals Technology Center in Nova Lima, where rescued colonies are multiplied for subsequent reintroduction.

Methodology

The multiplication and reintroduction process begins in the field, where colonies found in areas being cleared are rescued by a specialized team and taken to the beekeeping facility. Colonies are then transferred to an INPA-standard box using the Novy approach. These colonies are kept under controlled nutrition and temperature conditions to increase colony vigor before they are multiplied for introduction into native habitats surrounding offset and rehabilitation sites.

Colonies in a temperature-controlled environment

Results

The beekeeping facility currently houses a total of 20 colonies of seven honey bee species: Mandaçaia (*Melipona quadrifasciata anthidioides*), Jataí (*Plebeia remota*), Mandaguari preta (*Scaptotrigona postica*), Mandaguari amarela (*Scaptotrigona xanthotricha*), Irai (*Nannotrigona testaceicornis*), Arapoa (*Trigona spinepes*), Mirim Guaçu (*Plebeia remota*). The colonies are currently being developed and strengthened.

The beekeeping facility also provides an important tool for environmental education, helping to disseminate the knowledge that has been gathered and raise awareness about the importance of bees. Since 2016, the facility has received approximately 2930 visitors, who have learned about the importance of bees for conserving biodiversity and strengthening essential ecosystem services.

Multiplying indigenous bee colonies and reintroducing them in the environment will help to conserve these species and restore ecosystem services that are essential for the environment, for human well-being and for business.

Strategic Alignment

For Further Information

José Marangon; Genilton Santos (jose.marangon@vale.com; genilton.santos@vale.com)

Diretoria Corredor Sul/Gerência de Meio Ambiente Corredor Sul.

A colony prepared for multiplication

Ex Situ Conservation

A roadmap for *ex situ* conservation of seeds endemic species of the ferruginous cangas

Introduction

Ex situ conservation has been increasingly advocated as an important avenue for maintaining biodiversity at a global and regional scale, consistent with the objectives of the Convention on Biological Diversity and the Aichi Goals. *Ex situ* conservation is relatively inexpensive, requires little space, and species can be conserved for hundreds of years, protecting them from natural and man-made disasters that could result in the extinction of species in the wild.

This research project developed a database on seed collection, viability and storage conditions for species found in ferruginous cangas, which harbor a highly specialized flora with high levels of endemism.

Methodology

In Pará, seeds from 53 species were collected from the Carajás National Forest, the Campos Ferruginosos National Park and from surrounding mountain ranges, including the Serra da Bocaina, Cristalino, Serra de Campos and Serra Arqueada. Another seven species were collected in the Iron Quadrangle in Minas Gerais. To enhance genetic diversity, seeds were collected from as many individuals as possible without compromising the viability of populations in the field. Outwardly healthy seeds were tested with tetrazolium to assess the viability of embryos.

Depending on availability, seeds were stored from 29 species endemic to Carajás to determine the ideal storage conditions for germination. Seeds were stored at room temperature for 24 months in sealed ziploc bags or in falcon tubes, wrapped in aluminum foil. Ambient air temperature was controlled and, after storage, the seeds were used in germination experiments at optimal temperature and under the same experimental conditions as for the fresh seeds.

Results

Of the total seeds collected, 28 (46.5%) are considered endemic, including 22 species endemic to ferruginous cangas in Carajás (Giulietti et al 2019), 2 species endemic to ferruginous cangas and granite outcrops in Serra de Carajás, 2 species newly described for the region of Carajás, and 2 species endemic to ironstone outcrops in Minas Gerais. Six of the species (10%) are threatened, including the critically endangered *Monogereion carajensis* and *Mimosa skinneri* var. *carajarum*, and the endangered *Ipomoea cavalcantei*, *Hypolytrum paraense*, *Axonopus carajasensis* and *Pilocarpus microphyllus* (Figure 1).

46.5% of species in the study are considered endemic, and 10% are threatened

Figure 1. Species endemic to Carajás, classified by degree of threat. *Mimosa skinneri* var. *carajarum* (A) and *Monogereion carajensis* (B), critically endangered; and *Pilocarpus microphyllus* (C), *Hypolytrum paraense* (D), *Axonopus carajasensis* (E) and *Ipomoea cavalcantei* (F), endangered

Baseline viability varied across taxa, from 5.8% for Utricularia subulata to 99.3% for Vellozia glauca, averaging 65.3%. Four species (*Utricularia neottioides, U. physoceras, U. subulata and Sobralia liliastrum*) had viability values lower than 30%, indicating poor suitability for *ex situ* conservation, and the need to develop other strategies, such as translocation of individuals. For 31 species, mid-range values were recorded (33.3 to 69.7% viability), indicating suitability for *ex situ* conservation, but also suggesting the need to collect parent individuals producing high-quality seeds. The 25 remaining species (41.6%) had viability values higher than 70%, indicating high suitability for *ex situ* conservation.

For the 29 species that were kept in storage for 24 months, 22 species (75.8%) experienced significant losses during germination after storage, indicating that the species are intolerant to extended periods of storage at room temperature and must be used as quickly as possible after collection. For seven species (24.2%) there were no significant differences in germination rates between seeds used after storage or fresh, showing that these species are tolerant to extended storage and can be used in conservation programs without loss of viability.

In 2017, four endemic and threatened species (*Mimosa skinneri* var. *carajarum*, *Monogereion carajensis*, *Axonopus carajasensis* and *Ipomoea maurandioides*) were deposited in an *ex situ* seed bank at the Rio de Janeiro Botanical Garden. Further seed collection is planned for continued germination experiments to develop protocols for all vascular species endemic to ferruginous cangas, as well as for deposits at EMBRAPA Genetic Resources and Biotechnology for long-term conservation.

Further seed collection is planned for continued germination experiments to develop protocols for all vascular endemic species of ferruginous cangas, as well as for deposits at EMBRAPA Genetic Resources and Biotechnology

Strategic Alignment

For Further Information

Marcilio Zanetti[1], Rúbio Moraes[1], Lidia Maria dos Santos[1]; Fernando Santos[2], Alexandre Damasceno[2], Tais Fernandes[2], Alexandre Castilho[3], Cesar Neto[3], Mariana Wardil[4], Samir Rolim[4], Fernando Silveira[5] (zanettimarcilio@gmail.com; fernando.gomes.santos@vale.com).

1. Bioma Meio Ambiente; 2. Vale, Diretoria Cadeia de Valor Ferrosos/Gerencia de Licenciamento, Espeleologia e Estudos Ambientais; 3. Vale, Diretoria de Ferrosos do Corredor Norte/Gerência de Meio Ambiente; 4. Amplo Engenharia Gestão de Projetos; 5. Universidade Federal de Minas Gerais.

Ongoing actions for the future we want

In Situ Conservation

In Situ Conservation

Vale Eco Center Malaysia: social investment and biodiversity conservation

Introduction

Launched in October 2015, and managed by Vale Malaysia Minerals (VMM), the Vale Eco Center (VEC) is a social investment initiative inspired by the company's commitment and values. The Eco Center provides a gateway to the 290 ha Teluk Rubiah forest preserved by Vale, one of the rare biodiversity-rich coastal forests in Malaysia. The center is aimed to serve as an educational platform for local community members and the public at large to discover and appreciate biodiversity in the Teluk Rubiah forest.

The preserved forest area forms a green belt around the company's operations as a natural buffer along the coastal area around the perimeter of the iron ore distribution center. It also provides a natural way to mitigate visual pollution and protect the operations.

Results

In 2014, Vale and the Malaysian Nature Society (MNS) undertook an expedition with 55 researchers from local universities and MNS. During the expedition, an abundance of biodiversity was identified in the forest, such as:

More than 100 plant species
typical to lowland dipterocarp forests

125 bird species
including the Great Hornbill

28 dragonfly species

An abundance
of small mammals including 3 primate species
and many more

And many other marine species

Community activities available at the Center include education camps, guided walks, hands-on experiments and experiences, birdwatching, butterfly and insect studies, ecological activities, firefly walks, and coast and river monitoring. There are three main forest trails available at the center (Main Trail, Coastal Trail and Waterfall Trail), where visitors can learn about the environment while immersed in the forest.

The Center was designed to harmonize with the surrounding natural landscape. It nests a traditional Malay house named "Rumah Ibu", which houses mainly a reception area, exhibition hall, a meeting area, and a pantry. The building features environmental friendly design principles, such as minimizing the use of energy. In-built skylight roofing allows natural light into the Center while using natural air ventilation. It was also designed to contain rainwater which is then recycled for general cleaning or watering plants.

Strategic Alignment

For Further Information

Rabani Ashaari, Mohd Hazlan Ghazali, Gayathri Indran (Gayathri.Indran@vale.com)

Vale Malaysia Minerals/Meio Ambiente

The building followed ecological design principles, for example, to minimize the use of energy

In Situ Conservation

Biodiversity in a protected area at the Moatize mine in Tete, Mozambique

Introduction

Vale has established a protected area within its mine concession area at the Moatize coal mine in Mozambique called the Environmental Protection Area. The 1600 ha protected area is a voluntary initiative that aims to support conservation of biodiversity in the Tete area, as well as preserving cultural heritage and raising environmental awareness among the public. Creating a private nature reserve delivers on the company's commitment under its Sustainability Policy to leave an environmental legacy in the regions where it operates.

The study aimed to expand knowledge about protected fauna and flora species in the area

It was in this spirit that, in a partnership with Golder Moçambique, Vale conducted a study on the diversity of terrestrial flora and fauna in a protected area in the district of Moatize, in the province of Tete. The study aimed to: expand knowledge about protected fauna and flora species in the area; assess specific conservation value; and describe the ecological characteristics of the study area, and its context within the surrounding landscape.

Methodology

The study consisted of a desktop assessment to screen biodiversity characteristics, and a field survey for subsequent data analysis. To identify and characterize specific and important species and habitats in the study area, a landscape screening approach was used in accordance with the screening recommendations in the International Financial Corporation's (IFC) Performance Standard 6 (PS6), identifying the occurrence of critical or priority habitats and species for conservation.

Results

The protected area is characterized by five types of vegetation: open forest dominated by *Combretum* spp., open savanna, riparian vegetation, scrubland, and cropland. This vegetation is home to 50 species of insects identified to date, across eleven orders (Bladodea, Mantodea, Plecoptera, Hemiptera, Orthoptera, Phasmatodea, Hemiptera, Coleoptera, Diptera, Leptoptera and Hymenoptera). Five species of reptiles and 49 species of birds were also recorded, the most

50 insects
species identified

common being the southern red bishop (*Euplectes orix*), the southern masked weaver (*Ploceus velatus*), the emerald-spotted wood dove (*Turtur chalcospilos*), the ring-necked dove (*Streptopelia capicola*), the grey-backed camaroptera (*Camaroptera brevicaudata*), the common bulbul (*Pycnonotus barbatus*), the laughing dove (*Streptopelia senegalensis*), the white-crested helmetshrike (*Prionops plumatus*) and the sombre greenbul (*Andropadus importunus*).

This study informed action plans for restoring habitats, review of documented species, and raising awareness in surrounding communities

Two species endemic to southern Africa were identified in the study area: the pale batis (*Batis soror*) and the white-bellied sunbird (*Cinnyris talatala*). Three bird species in the study area are on the list of migratory species—the Egyptian goose (*Alopochen aegyptiacus*), the African paradise flycatcher (*Terpsiphone viridis*) and the white-faced whistling duck (*Dendrocygna viduata*)—and therefore benefit from international cooperation to ensure the stability of their populations.

This study, and the findings from further surveys and other projects that are ongoing in the area, will inform action plans for restoring habitats, maintaining populations of documented species, and raising awareness in surrounding communities.

Strategic Alignment

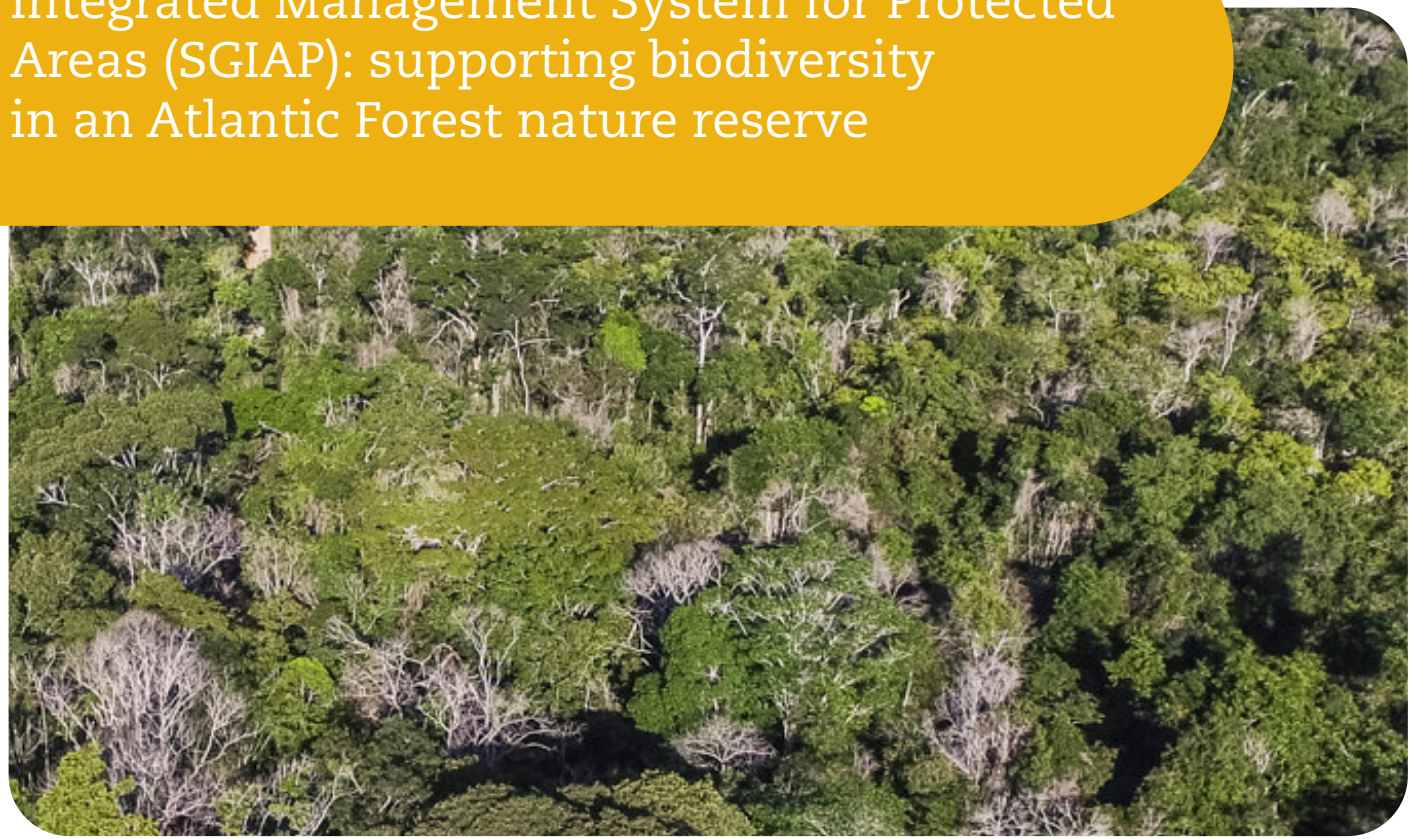
For Further Information

[1]Alves Sandramo (alves.sandramo@vale.com), [1]Geralda Lopes, [1]Paulo Bueno, Simplicio Chivambo[2].

1. Vale, Diretoria de Operações de Carvão/ Gerência de Meio Ambiente; 2. Golder Associates Moçambique

In Situ Conservation

Integrated Management System for Protected Areas (SGIAP): supporting biodiversity in an Atlantic Forest nature reserve



Introduction

Protected areas are an important tool for biodiversity conservation. The Vale Nature Reserve (RNV, Reserva Natural Vale), for example, preserves 23,000 ha of uniquely pristine Atlantic Forest remnants in Linhares, Espírito Santo, southeastern Brazil. Being connected to the Sooretama Biological Reserve (REBIO), the two together form a single block of continuous protected forest, covering an area of 50.000 ha. The area, which was listed by UNESCO in 1999 as a World Heritage Site, is one of the 14 centers of high diversity and endemism in Brazil.

Despite their importance and intensive conservation efforts, these areas continue to be threatened by environmental crimes, and require a structured and efficient management system to address these challenges.

Methodology

In this context, an Integrated Management System for Protected Areas (SGIAP) was developed and approved by Vale S/A to organize and integrate important information and data for use in the management of these areas. The system has an Ecosystem Protection module for documenting and investigating poaching, arson and other incidents involving environmental crimes (Figure 1).

Environmental crimes occurring within the RNV or REBIO reserve are reported by a 26-strong ecosystem protection team of Vale and third-party employees. The team patrols the reserve's roads, fire breaks and forest trails on a daily basis, and scans the reserve using drones, to find evidence of poaching.

The team also works with the Environmental Police to detain poachers and carry out joint operations. After completing surveillance activities for the day, any incidents are documented in the SGIAP system.

To ensure information is precisely documented, incidents can be classified into different types and further details can be provided, such as the geographical coordinates where the incident occurred, whether any plants or wildlife were seized, whether any equipment was seized, the evidence found and whether the animal was alive or dead. The number of the police report, the name of the offender and photos of the operation can also be entered in the system.

The team monitors the areas with the support of drones daily, and makes an active search for traces of hunting on roads and firebreaks, inside the forest.

For fire incidents, information is entered on the probable cause, a description and geographic coordinates of the site, the vegetation affected, the crew that was dispatched, the agencies assisting in the fire response, the equipment used in the operation, and attachments and photographs. Other types of incidents, such as rescued pets, property damage and theft, can also be recorded. This information can be used to generate a range of trend reports, from frequently hunted species to total weekly incident counts, graphs and maps.

Diversa	14/02/2021 15:36	Ação Preventiva	Entorno Rebio Sooretama	Estrada do Areial
Diversa	14/02/2021 13:35	Ação Preventiva	Entorno Rebio Sooretama	Barra do Rio Água Limpa
Diversa	13/02/2021 19:05	Ação Preventiva	Entorno RNV	Estrada Santa Terezinha
Diversa	13/02/2021 17:40	Ação Preventiva	Entorno RNV	Córrego João Pedro
Diversa	13/02/2021 15:25	Ação Preventiva	Reserva das Imbiribas	Reserva das Imbiribas
Diversa	13/02/2021 10:00	Ação Preventiva	Entorno RNV	Canto Grande
Caça	12/02/2021 14:45	Caça	ReBio Sooretama	Córrego Quirino
Caça	12/02/2021 10:30	Caça	ReBio Sooretama	Córrego Quirino
Caça	06/02/2021 15:50	Caça	Entorno Rebio Sooretama	Córrego São João do Estivado (Zona de amortecimento da REBIO)
Incêndio	06/02/2021 11:15		Entorno Rebio Sooretama	Rio Barra Seca (Zona de Amortecimento da REBIO)
Diversa	03/02/2021 19:00	Recolhimento de Animais	Entorno Rebio Sooretama	Córrego Palmito
Caça	02/02/2021 15:35	Caça	Entorno RNV	Córrego Rancho Alto
Diversa	02/02/2021 14:15	Outros	RNV / Reserva Natural Vale	Reserva Natural Vale

Figure 1. SGIAP Ecosystem Protection Module

Results

In the period from July 1999 to May 2020, a total of 2,467 environmental crime incidents were reported on the reserves, including 2,107 poaching incidents—26% (549) on the RNV reserve and 5% (112) in surrounding areas. The remaining 63% (1,321) of incidents were on the REBIO reserve and 5% (126) in surrounding areas. A total of 177 poaching reports were made in which the animals or plants were seized, some of which are on the endangered species list, including four South American tapirs (*Tapirus terrestris*), 23 red-billed curassows (*Crax blumenbachii*), one white-lipped peccary (*Tayassu pecari*), five broad-snouted caimans (*Caiman latirostris*), 11 solitary tinamous (*Tinamus solitarius*), and one red-browed amazon (*Amazona rhodocorytha*), among other animals. The most frequently seized specimens included 471 kg of fish, 208 guariroba (*Syagrus oleracea*) palm hearts, 10 seven-banded armadillos (*Dasypus septemcinctus*), 73

Figure 2. Poaching (A, B) and fire (C, D) incidents

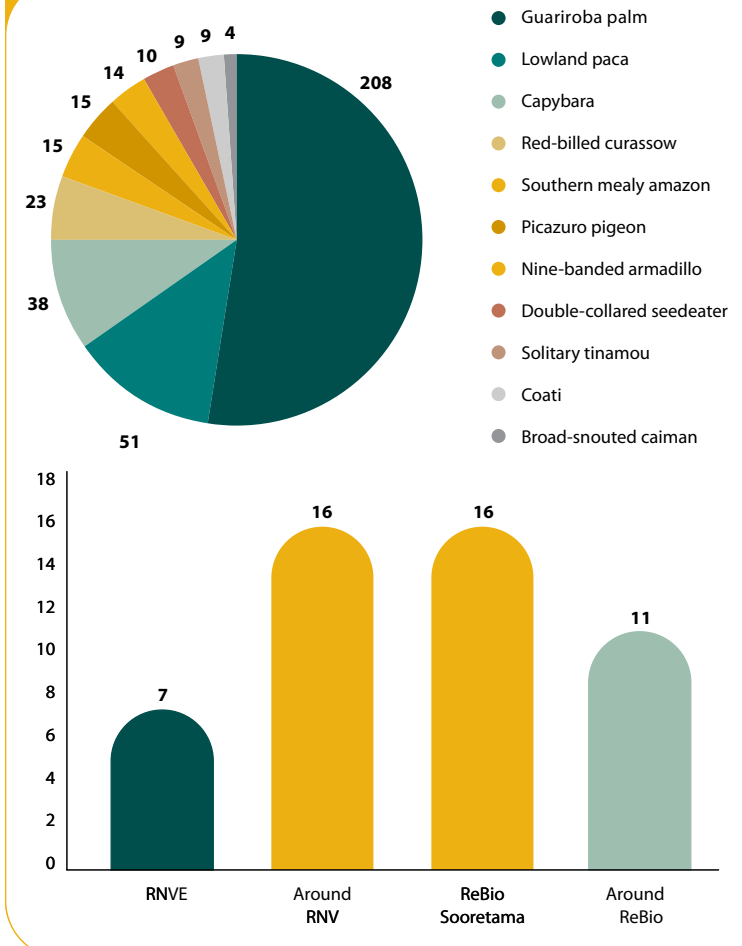



Photo: Gustavo Magnago

Information management and more targeted initiatives have helped to contain and reduce incidents, and to maintain species populations

lowland pacas (*Cuniculus paca*) and 39 capybaras (*Hydrochoerus hydrochaeris*). Since 2000, a total of 53 fire or incipient fire incidents have been reported, including 7 on the RNV reserve and 19 in surrounding areas. On the REBIO reserve, 16 fire incidents have been reported on the reserve and 11 in surrounding areas (Figure 2).

The figures above were all compiled from reports generated using the SGIAP platform, which provides a traceable and transparent system for managing information. Based on these reports, the ecosystem protection team is instructed on priority areas for surveillance, and strategies are developed to prevent and combat environmental crimes. System reports also inform awareness initiatives in communities, environmental education initiatives through programs implemented at the reserve (the Environmental Education Program and the *Eu Pesquisador* project), and door-to-door outreach in neighborhoods surrounding the reserve.

These initiatives aim to reduce environmental crime rates over time, which is crucially important to maintaining and reestablishing populations of threatened species. The system can also be used as a model for managing other protected areas, helping managers and teams to develop more effective strategies for tackling environmental crimes and making data-informed decisions.

Strategic Alignment

For Further Information

Jackeceli Falqueto Rizzo; Débora Mendonça; Mariana Senna; Sayonara Induzzi Cometti; Márcio Ferreira (jackeceli.falqueto@vale.com)

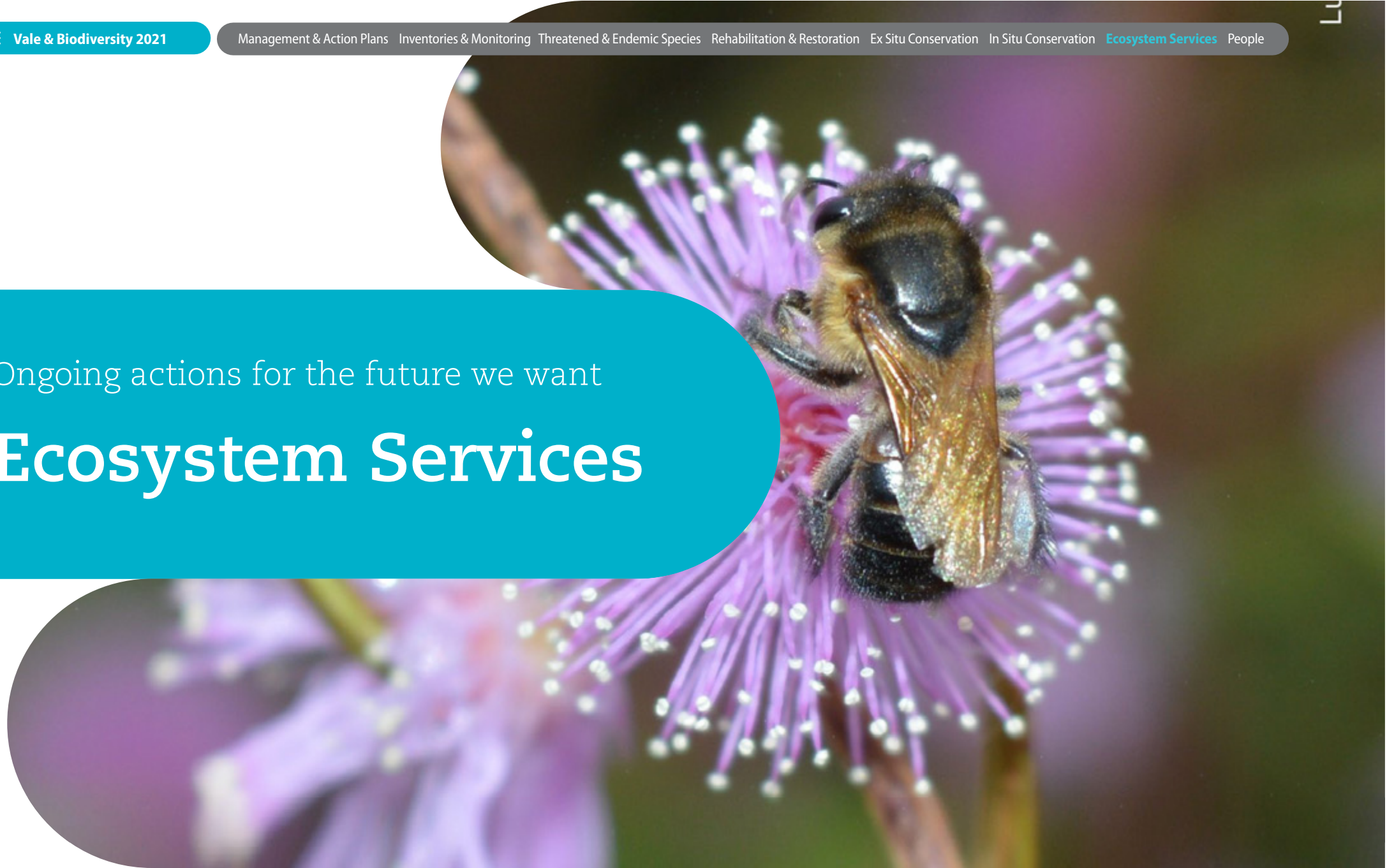
Diretoria de Sustentabilidade e Responsabilidade Social/ Gerência Executiva de Gestão Ambiental/ Reserva Natural Vale

Partners

Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio); Polícia Ambiental; Polícia Militar.

Ongoing actions for the future we want

Ecosystem Services



Ecosystem Services

Ecosystem services and habitat restoration: estimating biomass carbon stock and shadow price for rehabilitating sites at the S11D Eliezer Batista iron ore mine

Introduction

Forests contain around 80% of terrestrial biodiversity and annually provide US$ 75-100 billion in ecosystem services and goods. Halting the loss and degradation of natural systems and promoting their restoration have the potential to contribute over 1/3 of the total climate change mitigation scientists say is required by 2030. In this context, initiatives as part of Vale's Forest Connectivity Program—which aims to rehabilitate pastureland purchased in areas surrounding the S11D iron ore mine, near the southern boundary of the Carajás National Forest, in Canaã dos Carajás, Pará, Northern Brazil—can not only contribute to restoring and conserving biodiversity, but can also reinstate and improve ecosystem services at both a local and regional scale.

Methodology

Biomass carbon stock was assessed using dendrometric data collected in 2018 in the 4th assessment and monitoring survey in part of the areas under passive restoration (i.e. where natural regeneration has been most significant and mediated by isolation and protection measures), covering a total area of 1,678.02 ha. The permanent plot approach was used to assess the brush and tree component of this area. Plots measuring 10x10 m /10x20 m were distributed at 25 m intervals along transects randomly distributed throughout the target area. Within each plot, sub-plots measuring 5x5 m were marked to assess natural regeneration. A total of 12 transects and 116 plots were marked in the field. Within each plot, records were taken of all plants/individuals with a circumference at breast height (CBH, measured at a height of 130 cm) equal to or greater than 31.41 cm (equivalent to a diameter at breast height (DBH) of 10 cm) and a total height greater than 1.5 m.

116 plots
marked in the field

Estimation of volume, and consequently of carbon stock, was based on the aboveground biomass contained in the tree component of areas under natural regeneration. Volume equations were applied to the available data. These equations were obtained by fitting normal non-linear models to volume data for the stems and branches, including bark, of secondary vegetation, as outlined in CETEC (1995). This approach was developed for secondary perennial or semi-deciduous vegetation at different stages of natural regeneration, created by the felling or burning of primary formations.

Estimation of volume, and consequently of carbon stock, was based on the aboveground biomass contained in the tree component of areas under natural regeneration

This is the case of the pastureland under regeneration near the S11D mine, which is characterized as a mosaic of secondary formations at different stages of succession, but predominantly mid-stage formations with evidence of disturbance, based on the results from phytosociological analysis. To convert the estimated volume into biomass, the basic mean tree wood density was arbitrated to be 0.44 g/cm^3, and a factor of 0.45 was used to calculate the quantity of carbon in the biomass. To convert the biomass carbon into CO2e, the ratio of the specific mass of CO2 to the specific mass of element C was used as a factor.

Results

Based on the total estimated mean wood volume of 63.54 m^3/ha for pastureland under natural regeneration near the S11D mine, the total average quantities of C and CO2 were calculated to be respectively 12.58 t/ha and 46.17 t/ha. For a total monitored area of 1,678.02 ha under regeneration, carbon stocks were estimated to be 21.1 ktC and 77.5 ktCO2e. The table below shows the results from applying the same estimation procedure to dendrometric data collected in 2016 during the 3rd assessment and monitoring survey, in order to compare and estimate differences or variance in C and Co2e stock (sequestration) from one monitoring survey to the other.

As a result of the pastureland rehabilitation process, average sequestration of 0.55 tC/ha and 2.03 tCO2e/ha, and total sequestration of 927 tC and 3,402 tCO2e, were recorded in the period from late 2016 (3rd monitoring survey) to early 2018 (4th monitoring survey). Assuming a shadow price of US$ 10.00/tCO2e, the biomass carbon stock in rehabilitating areas is estimated to be worth US$ 775,000.

Biomass carbon stock in rehabilitating areas is estimated to be worth US$ 775,000

ATTRIBUTE	3rd SURVEY	4th SURVEY	DIFFERENCE / VARIANCE
Average VOB (m^3/ha)	60.75	63.54	2.79
VOB (m^3)	101,939.72	106,621.39	4,681.68
tCO/ha	12.03	12.58	0.55
tCO_2/ha	44.14	46.17	2.03
Total tCO	20,184.06	21,111.04	926.97
Total tCO_2	74,075.51	77,477.50	3,401.99

VOB: volume over bark: tC: metric tons of carbon; tCO2: metric tons of carbon dioxide.

Strategic Alignment

For Further information

Luiz Felipe Campos[1], Mário Luis Oliveira[2], José Camilo Araújo[2], Ricardo Campelo Costa[2] (luiz.felipe.campos@vale.com).

1. Diretoria de Sustentabilidade e Investimento Social/Gerência Executiva de Gestão Ambiental;
2. Diretoria Corredor Norte/Gerência de Meio Ambiente Rel. Inst. Soc. Com.

Ecosystem Services

Estimating and pricing biomass carbon stock in the Mata do Jambreiro Private Natural Heritage Reserve in Nova Lima, Minas Gerais

Introduction

Since Brazil was first colonized five centuries ago, its Atlantic Forest has undergone successive cycles of deforestation and changes in land use. Today, little more than 12% of its original cover remains. The Atlantic Forest is the fifth most threatened biome on the planet and one of the richest in endemic species worldwide. Much of its remnants are on private land, which underlines the importance of biodiversity conservation on private properties to supplement government efforts and incentives. This led to the introduction in Brazil of Private Natural Heritage Reserves (RPPNs), a category of Private Sustainable Use Conservation Units, which are essential for establishing ecological corridors, improving functional connectivity and ultimately structuring metapopulations and maintaining populations of threatened species.

In this context, and in applying the mitigation hierarchy framework to project feasibility assessments, the establishment of RPPNs to protect critical biodiversity features identified in environmental impact assessments can be a way to ensure project feasibility by reconciling production and conservation, thereby reducing risks both to biodiversity and to prospective projects. RPPNs also play an important role in providing ecosystem services, including climate regulation, maintaining water quality and quantities, pollination and biological control, as well as cultural services including recreation, education and research. Finally, by protecting part of the land in which they are established, they help to prevent CO2 emissions from deforestation and degradation, in addition to as providing other ecosystem services.

The Mata do Jambreiro RPPN is predominantly composed of seasonal semi-deciduous forests, followed by transitions into higher altitude *Cerrado* formations

Methodology

To put a value on an important part of these services, the biomass carbon stock contained in Vale's Mata do Jambreiro RPPN—an area of approximately 912 ha in the municipality of Nova Lima, Minas Gerais—was estimated and priced. The reserve is located in the Iron Quadrangle, in the center-southeast portion of Minas Gerais State, and specifically in the southern portion of the Serra do Curral.

Although set within the Atlantic Forest biome, the Mata do Jambreiro RPPN is at a transition between two important global biodiversity hotspots—or regions that have a high degree of diversity and endemism and are highly threatened. Forest vegetation occurs more frequently in encased valleys and on steep and rugged slopes, while *cerrado* vegetation occurs more commonly in areas with flatter and gentler relief, and along drainage divides, with the type of vegetation also strongly influenced by altitude and soil, as well as climate.

The reserve is predominantly composed of seasonal semi-deciduous forests, followed by transitions into higher altitude *Cerrado* formations (*cerrado*, wooded savanna, and tree and shrub savanna), as well as transitions into an open vegetation habitat known as *candeial.* Approximately 90.93% (829.29 ha) of the area is occupied by forest cover and 9.07% (82.71 ha) by non-forest cover.

Biomass carbon stock was estimated and priced using dendrometric data from floristic and phytosociological studies conducted on the reserve in 2019 by Amplo. Data were obtained by marking 14 sampling plots, each measuring 10x50, and measuring the circumference at breast height (CBH, measured at 130 cm from the ground) and total height of all trees within the plots having a diameter equal to or greater than 5 cm. Wood volume was estimated using a volume equation obtained by fitting normal non-linear models to volume-over-bark data for secondary vegetation, as outlined in CETEC (1995). The estimated average volume for the Mata do Jambreiro RPPN was 262.72 (±32.89)

m^3/ha, with a 12.52% sampling error and a 90% confidence level. The Reliable Minimum Estimate (RME) was calculated to be 237.65 m^3/ha. Total volume of forest cover on the reserve was estimated to be 217,868.47 m^3 (RME = 197,078.63 m^3). To convert the estimated volume into biomass, the basic mean tree wood density was arbitrated to be 0.445 g/cm^3, and a factor of 0.47 was used to calculate the quantity of carbon in the biomass. To convert the biomass carbon into CO2e, the ratio of the specific mass of CO2 to the specific mass of element C was used as a factor.

Finally, to price the carbon stock contained in the forest cover on the reserve, an internally defined shadow price of US$ 10.00/tCO2e was used. Using this method, the carbon stock on the Mata do Jambreiro reserve was valued at approximately US$ 1.5 million.

PARAMETERS	PER UNIT OF FOREST COVER				TOTAL AREA OF FOREST COVER		
	Lower CL	Mean	Upper CL	RME	Mean	Upper CL	RME
Total wood volume c/c	m^3/ha	m^3/ha	m^3/ha	m^3/ha	m^3	m^3	m^3
	229.83	262.72	295.60	237.65	217,868	245,142	197,079
Wood biomass	tms/ha	tms/ha	tms/ha	tms/ha	tms	tms	tms
	102.27	116.91	131.54	105.75	96,951	109,088	87,700
C stock of wood biomass	tC/ha	tC/ha	tC/ha	tC/ha	tC	tC	tC
	48.07	54.95	61.83	49.70	45,567	51,271	41,219
$CO2e_2$e stock	tCO2e/ha	tCO2e/ha	tCO2e/ha	tCO2e/ha	tCO2e	tCO2e	tCO2e
	176.25	201.47	226.69	182.25	167,080	187,995	151,136

US$ 1.5 million

in biomass carbon stock on the reserve

Strategic Alignment

13 AÇÃO CONTRA A MUDANÇA GLOBAL DO CLIMA

15 VIDA TERRESTRE

For Further information

Luiz Felipe Campos (luiz.felipe.campos@vale.com)

Diretoria de Sustentabilidade e Investimento Social/ Gerência Executiva de Gestão Ambiental.

Ecosystem Services

Restoring interaction between plants, pollinators and seed dispersers

Photo: Luciano Costa

Introduction

Interactions are critical for the survival of species and their habitats. One of the most important interactions between fauna and flora species is pollination, in which certain animals directly contribute to the reproductive success of flowering plants by helping them produce fruits and seeds and maintain genetic diversity. This interaction is also essential in providing food for animal populations that consume fruits and seeds. An equally important interaction is seed dispersal, which is primarily mediated by birds, bats and other frugivorous animals. These two types of interactions are central to ecosystem functioning and maintaining biodiversity.

Mineland rehabilitation success can be enhanced by pollinator and seed disperser activity, and therefore plant species providing a food source for these animals should be prioritized in the rehabilitation program. The goal in planting these species is to accelerate regeneration by reinstating and restructuring lost interactions. In addition, when they are attracted to these plants at rehabilitation sites, pollinators and dispersers bring genetic material (gametes and seeds) from other areas, helping to maintain and increase the genetic diversity of populations, even in areas that are still relatively inhospitable. The presence of pollinators and seed dispersers can therefore accelerate regeneration of rehabilitating sites to conditions approximating those of reference sites, i.e. mature and healthy natural environments.

A seed dispersal study used molecular methods to identify food resources ingested by birds

Methodology

At ITV, studies were conducted on the animal-plant interactions involved in pollination and seed dispersal. In the pollination study, we investigated the diversity of interactions between plants and pollination (Figure 1) - (Borges et al. 2019). This study compared areas under post-mining rehabilitation with areas containing pristine forests to identify plant and pollinator species that can contribute to reinstating ecological interactions. We used metrics indicating which species have the largest number of partners, as these can contribute most effectively to reestablishing interactions. We also identified which species are best suited for breeding and reintroduction at rehabilitation sites.

Birds were captured using mist nets, identified, stored in cotton handling bags until defecating, and then released at the capture site (Figure 1). The seeds present in the feces are currently under analysis. A comparison of the birds present in the different areas provided information on taxonomic and functional diversity. The seed dispersal study (Awade et al. 2019) is using molecular methods (DNA metabarcoding) to identify food resources ingested by birds at post-mining rehabilitation sites and in primary forests (control) in Carajás.

Figure 1.
Two examples of birds captured at rehabilitation sites: *Ceratopipra rubrocapilla* and *Cyanoloxia rothschildii* (photos: L. Miranda). Examples of bees of the family Halictidae and the tribe Meliponini (genus *Trigona* sp) on flowers at rehabilitated sand quarries (photos: T.C. Giannini)

Results

In the bee study, diversity of interactions was greatest in forest areas and in areas at initial stages of rehabilitation, but was not significantly different in other sampled areas. Ten plant species were selected for investigation at rehabilitation sites, due to their ability to attract the pollinator species *Aparisthmium cordatum, Bixa orellana, Byrsonima stipulacea, Lophanthera lactescens, Miconia alata, Senegalia multipinnata, Senna alata, Senna latifolia, Stigmaphyllon paraense, and Vernonanthura brasiliana*. Ten priority bee species were selected for the study, and an assessment is currently being conducted on the potential use of artificial nests to serve as shelters for these species.

Monitoring bee populations at rehabilitation sites is important to inform interventions where populations are absent or in decline. Because they help to maintain pollination services and can improve success in rehabilitation efforts, these key plant and bee species need to be prioritized in rehabilitation programs.

In relation to bird species and their taxonomic diversity, the rehabilitation sites were shown to be approaching conditions in the control areas, suggesting a successful trajectory toward rehabilitation. This was not true, however, for functional diversity, with significant discrepancies observed between the study areas. This indicates that areas under rehabilitation have not yet recovered the functionality observed at control sites, although it is possible that they are converging toward the control areas, albeit at a slower pace. Five species of frugivorous birds were found across all stages of recovery: *Ceratopipra rubrocapilla* (red-headed manakin), *Cyanoloxia rothschildii* (Amazonian grosbeak), *Geotrygon montana* (ruddy quail-dove), *Mionectes macconnelli* (McConnell's flycatcher) and *Turdus albicollis* (white-necked thrush). Because the species are present in areas at all stages of rehabilitation, they can move between these areas and significantly contribute to seed dispersal.

The findings from this research demonstrate the importance of ecosystem services, i.e. the role that nature can play in enhancing the success of rehabilitation efforts. Bees and birds are important groups for conservation, and the species described in this study are key to maintaining pollination and seed dispersal services. Initiatives to prioritize and protect them are therefore essential.

Five species of frugivorous birds were found across all stages of recovery

Strategic Alignment

For Further information

Tereza Cristina Giannini[1,2], Rafael Cabral Borges[1,2], Leonardo Miranda[3,1], Michele Molina[1], Markus Gastauer[1], Cecilio Frois Caldeira Jr[1], José Eustáquio dos Santos Júnior[4], Lourival Tisky[5], Delmo Silva[5], Renan Coelho[5], Sergio Souza Jr.[5] (tereza.giannini@itv.org).

1. Instituto Tecnológico Vale; 2. Universidade Federal do Pará; 3. Museu Paraense Emílio Goeldi; 4. Universidade Federal de Minas Gerais; 5. Diretoria Corredor Norte/Gerência Meio Ambiente.

Ecosystem Services

Pollinators and crop production in Vale's area of influence and in agroforestry systems

Introduction

Animal pollination is an important example of an ecosystem service that has a direct bearing on food security, as it increases both the yields and the quality of fruits and seeds. Understanding the important role that pollinators play, and prioritizing conservation of pollination services, are two important ways of guaranteeing global food security in the long term.

Our study covered three dimensions: pollination, food production, and social and economic development in the areas where Vale operates:

1) We estimated the value of pollination services for commercial agriculture in the state of Para;

2) We prepared a list of trees that have edible fruits consumed by traditional Amazon communities for subsistence, and their potential pollinators;

3) We evaluated the role of pollination in agroforestry systems, especially those on the Vale Nature Reserve (RNV, Linhares, ES).

Methodology

To assess the value of pollination services for commercial agriculture in the state of Pará, we asked the following key questions (Borges et al. 2020): a) What is the economic value of crop production and pollination service in Pará? and b) Which municipalities are most dependent on pollination services considering local economies?

For our analysis of the species consumed by traditional communities in the Amazon forest (Paz et al. 2021): a) we built a list of edible plant species; b) we determined the pollinators of each species; c) and we performed a review of the scientific literature, searching for their pollinator/visitors.

36 different crops are grown in Pará

Results

We found 36 crops produced in Pará, of which 20 (55%) are dependent on pollinators. In 2016, total crop production value in the state was US$ 2.95 billion, and total pollination service value (PSV) was US$ 983.2 million, or 33% of total crop production value in Pará (Figure 1).

The crops with highest PSV were açai palm (US$ 635.6 million), cocoa (US$ 187.6 million), soybeans (US$ 98.4 million), and watermelons (US$ 26.1 million), which accounted for 96% of total PSV. Two municipalities (Medicilândia and Igarapé Miri) had more than 50% of their Gross Domestic Product (GDP) based on pollination services. We also found low crop diversity in municipalities in Pará, suggesting agricultural vulnerability.

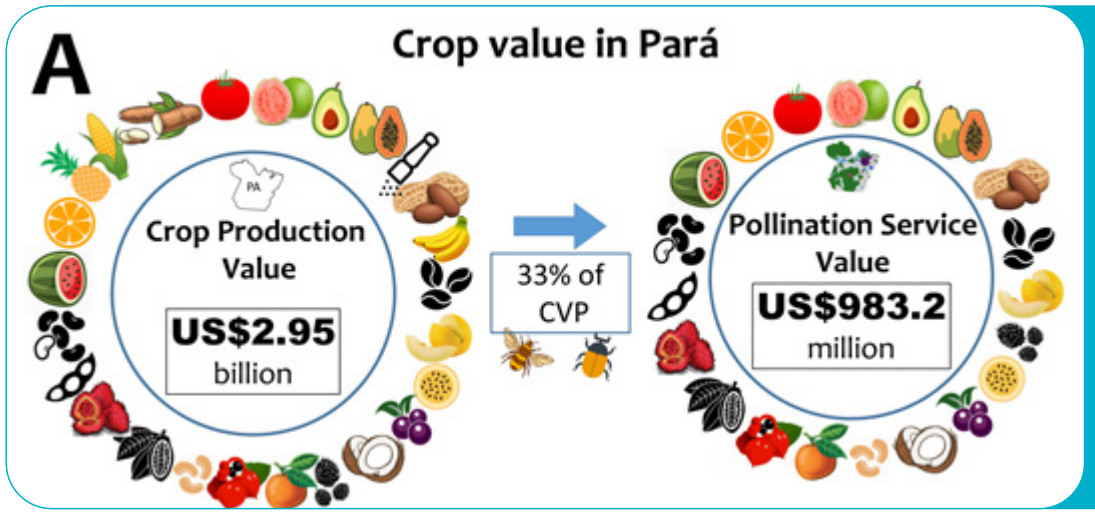


Figure 1. Annual economic value of crop production and pollination service in Pará (year 2017) (prepared by R. C. Borges)

Our findings show that agriculture associated with pollinator-friendly cropping practices is urgent for ensuring food security and supporting sustainable development for the state. The research has also provided important data for decision-making on crop production and information on the role of biodiversity in agriculture. It is important to consider that pollinator conservation is reliant on forest conservation, as pollinators require standing forests as nesting grounds and alternative sources of food during periods when crops are not blossoming. Conservation of forests surrounding cropland is therefore important for agricultural production, especially for those crops that are highly dependent on pollinators.

Conservation of forests surrounding cropland is important for agricultural production, especially for crops that are highly dependent on pollinators

In our assessment of plants consumed by traditional Amazon communities, a total of 188 plants were identified and listed (Figure 2). An assessment of floral morphology showed that the most common pollinators for these species are bees (101 of the plant species analyzed) and beetles (26 species). We also found 238 pollinators quoted for 52 (28%) plant species in previous publications, of which 124 are bees (52%). The species list produced can inform potential options for crop diversification in Amazon states, and can make an important contribution to rural livelihoods and research in agrobiodiversity. As shown above, this potential is still underexplored in Pará, and future investments in crop diversification can help to enhance social and environmental sustainability. Agroforestry systems have been implemented at the RNV and in other areas where Vale operates (Figure 3), and their interaction with pollinators is an important focus of

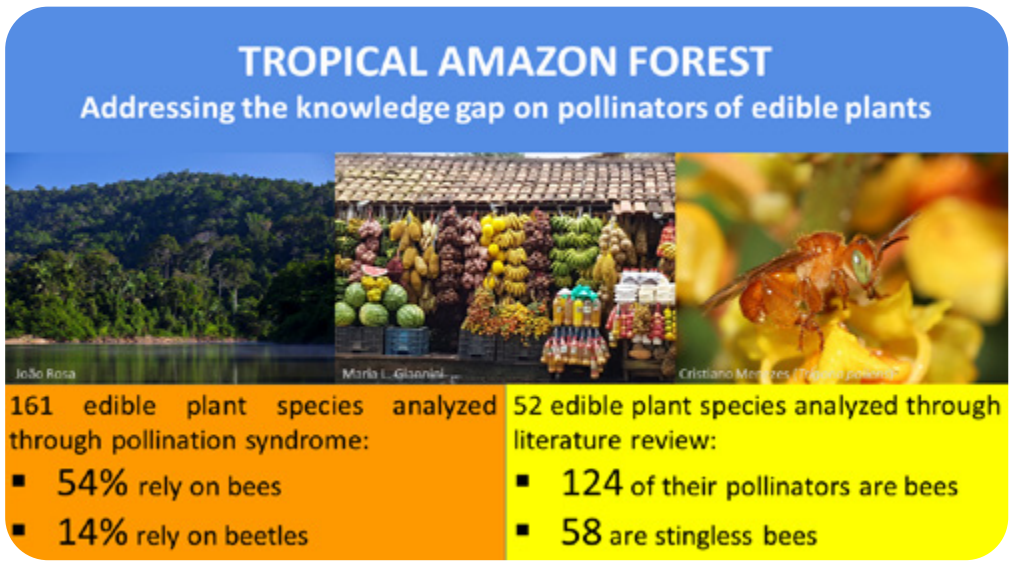


Figure 2. Summary of findings on the knowledge gap about pollinators of fruit species consumed by traditional Amazon communities (prepared by T.C.Giannini)

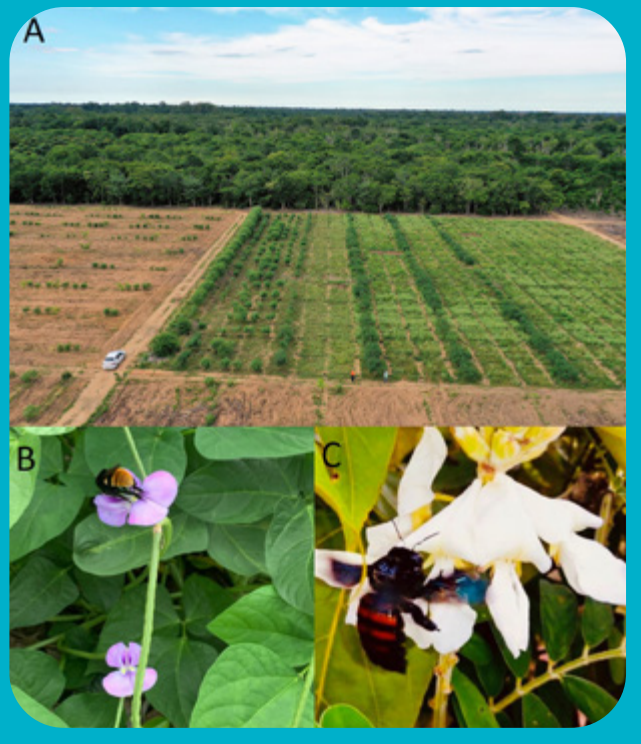


Figure 3. A) An agroforestry system on the Vale Nature Reserve (photo: M. Senna); B) An *Eulaema* sp. bee on a cowpea flower (*Vigna unguiculata*) and C) A *Xylocopa frontalis* bee on a Vogel tephrosia flower (*Tephrosia vogelii*) (photos: B.M. Marchiori)

research. Two plants used as green manure (pigeon peas and Vogel tephrosia) have been used in eight hectares at the RNV. Both are visited by solitary bees of the genera *Xylocopa* and *Eulaema*. The area is also home to several other bee species, including bees of the genus *Centris*, which are important for pollinating acerola cherries. Another potential opportunity involves integration of agroforestry systems with native beekeeping. Agroforestry production and food security can be enhanced by pollination services provided by bees, as well as by the production of honey. In addition, beekeeping can provide a valuable source of supplementary income for smallholders.

In agroforestry systems, pollination services through integrated native beekeeping can enhance yields and food security

Strategic Alignment

For Further information

Tereza Cristina Giannini[1,2] (tereza.giannini@itv.org), Rafael Borges[1,2], Fabricia Paz[1,3,] (fabricia.spaz@gmail.com) Juliana Galaschi[1], Luciano Costa[1], Bia Makiyama Marchiori[4] (bia.marchiori@vale.com), Debora Melo Furtado de Mendonça[4]

1. Instituto Tecnológico Vale; 2. Universidade Federal do Pará; 3. Universidade do Estado do Pará; 4. Diretoria de Sustentabilidade e Investimento Social/Gerência Executiva de Gestão Ambiental/ Reserva Natural Vale.

Ecosystem Services

Native beekeeping and meliponiculture around the Carajás National Forest in the Amazon

Introduction

Native stingless bees form a diverse group of social insects that play an important role in the pollination of wild and crop plants. They are also kept commercially to produce honey, propolis and other bee products. At the Native Bee Biofactory in Carajás, colonies of different stingless bee species rescued from areas cleared for mining provide a source of livelihood for local communities and help to conserve biodiversity. From rescued parent colonies, important pollinator and honey species are multiplied at large scale, in a process that connects bees, communities and conservation by creating colonies of native species for beekeeping in municipalities neighboring the Carajás National Forest.

The Biofactory is structured to multiply bee nests safely and efficiently, and to evaluate and select species for

different applications in the region, including honey production, assisted pollination and restoration of ecosystem services at mine rehabilitation sites. Rescuing fauna also helps to mitigate impacts from mining.

The Biofactory facilities are distributed across two separate sites, both in Carajás: the Forest Nursery and the Vale Zoobotanical Park (PZV), where three separate locations are available for establishing bee colonies, with a capacity for approximately 100 colonies. The PZV has a laboratory for *in vitro* queen-rearing, producing new colonies and preparing supplementary food. The facilities currently house 28 parent colonies of seven species (Figure 1), including three species that are important for developing bee stock and related research: uruçu-boca-de-renda (*Melipona seminigra*), canudo preta (*Scaptotrigona postica*) and canudo amarela (*Scaptotrigona xanthotricha*).

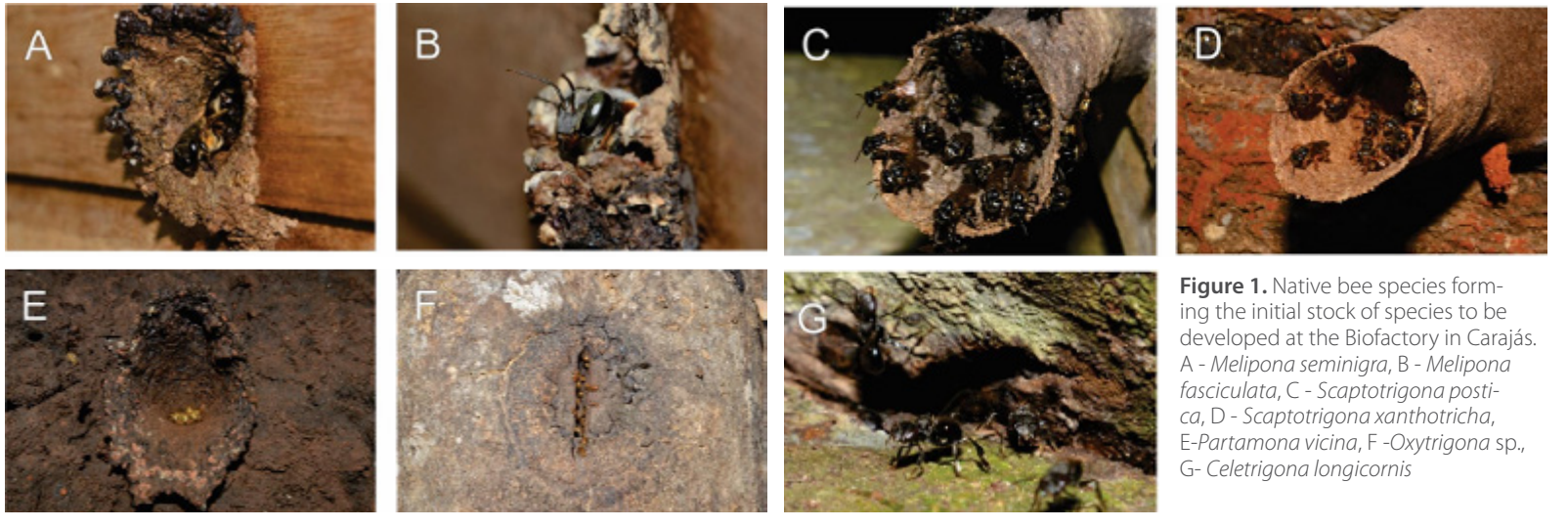


Figure 1. Native bee species forming the initial stock of species to be developed at the Biofactory in Carajás. A - *Melipona seminigra*, B - *Melipona fasciculata*, C - *Scaptotrigona postica*, D - *Scaptotrigona xanthotricha*, E-*Partamona vicina*, F -*Oxytrigona* sp., G- *Celetrigona longicornis*

The Biofactory is structured to multiply bee nests safely and efficiently

Methodology

To support fauna rescuing operations, a guide has been developed to help identify bee species. The manual, titled "Photographic Guide on Identifying Stingless Bees for rescuing" (here) contains photographs of 41 species occurring in the region, depicting worker bees at the entrances to their nests. Clearing activities are also monitored, and training is provided to rescuing teams, including both theoretical and hands-on training.

To learn more about the stingless bee species that are most commonly kept in the area surrounding the Carajás National Forest, and about the challenges involved in beekeeping, we interviewed 20 stingless beekeepers in three municipalities surrounding the Carajás National Forest (Figure 2). Three were women and 17 were men, aged 31 to 85 and averaging 54. They each had an average of 16 stingless bee colonies, with some properties having as many as 52 colonies of different species.

Figure 2. Location of stingless beekeepers interviewed near the Carajás National Forest.

To support fauna rescuingoperations, a guide has been developed to help identify bee species

Results

Interviewed beekeepers said their primary motivation for beekeeping was producing and selling honey. Many, however, cited additional reasons, saying they got into the trade as a way to preserve bee species and the environment, out of a love of bees, as a hobby, and out of curiosity about the insects. These responses show that beekeeping, from the perspective of beekeepers, is not only a livelihood but also a source of personal fulfillment and (environmental) education, and is recognized as improving their quality of life.

The species kept by interviewed beekeepers include: *Melipona seminigra, Melipona fasciculata, Melipona flavolineata, Melipona amazonica, Scaptotrigona postica, Scaptotrigona polysticta, Frieseomelitta* spp., *Plebeia* spp., *Nannotrigona punctata* and *Tetragonisca angustula*. The most commonly kept species was *Melipona seminigra*, which beekeepers said was due to it being commonly found in the region and easy to manage. As a result, most beekeepers' colonies are of this bee species.

Beekeepers reported that the biggest challenge in native beekeeping is obtaining new colonies. There are limited colonies available for sale, and beekeepers have little knowledge about methods of hiving swarms in the wild. The Biofactory aims to fill this gap as a way of supporting stingless beekeeping in the region.

The Biofactory produces bee colonies as a way of supporting stingless beekeeping in the region

Strategic Alignment

For Further information

Juliana Stephanie Galaschi-Teixeira[1] (juliana.teixeira@itv.org), Luciano Costa[1] (costa.luciano@itv.org), Jamille Costa Veiga[1] (jamille.veiga@pq.itv.org), Tereza Cristina Giannini[1] (tereza.giannini@itv.org), Fabia Cavalcante[3] (fabia.cavalcante@vale.com), Sérgio Souza Junior[3] (sergio.souza.junior@vale.com).

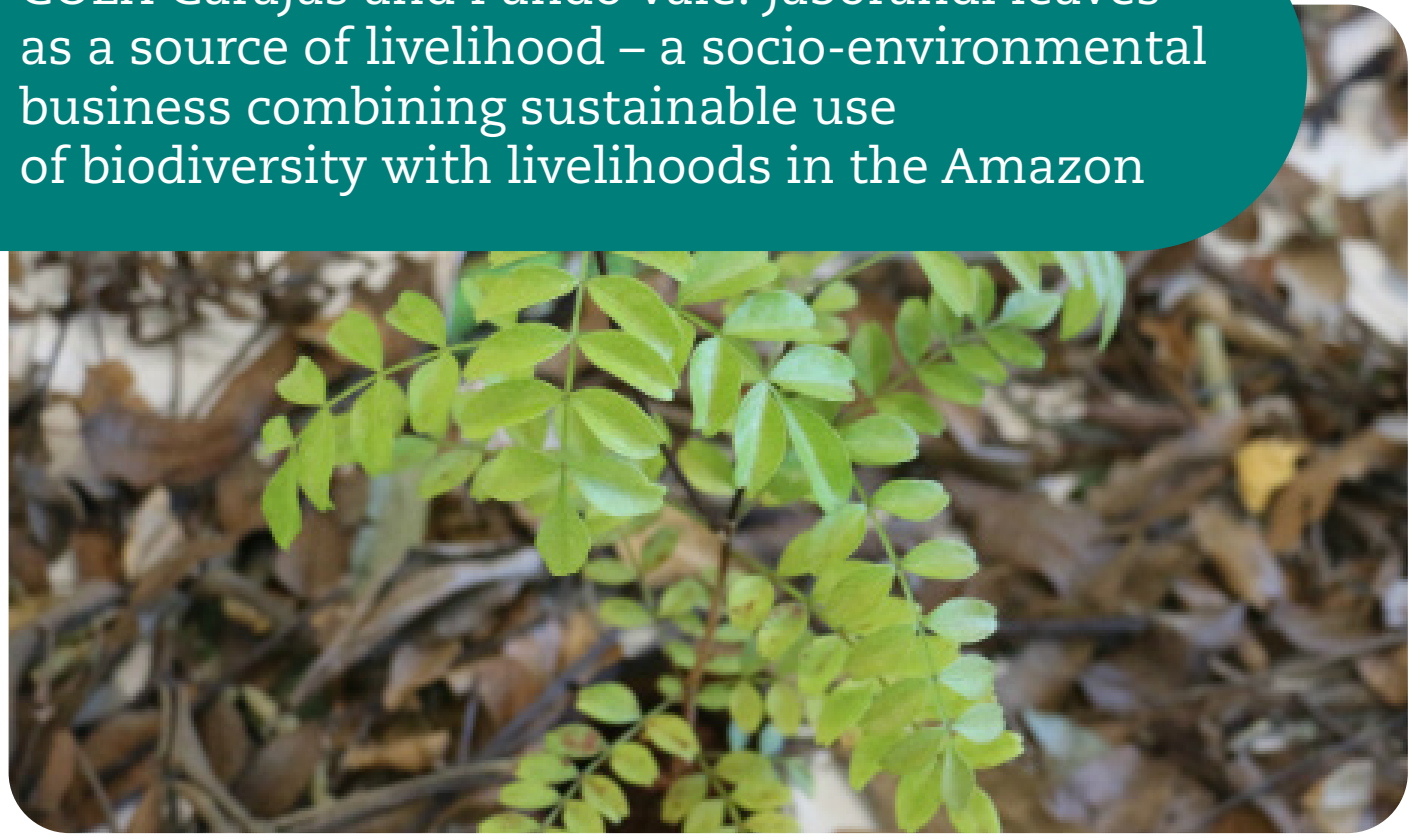
1. Instituto Tecnológico Vale. 2. Universidade Federal do Pará. 3. Gerência de Meio Ambiente Ferrosos Norte.

Ongoing actions for the future we want

People & Partnerships

People & Partnerships

COEX Carajás and Fundo Vale: jaborandi leaves as a source of livelihood – a socio-environmental business combining sustainable use of biodiversity with livelihoods in the Amazon



Introduction

The Carajás National Forest Collector Cooperative (COEX Carajás), in the municipality of Parauapebas (Pará, Brazil), was founded in 2006 to organize harvesters active in the region since the 1980s. Members derive their primary livelihood from harvesting and selling leaves from the jaborandi, a threatened species that is used to produce medicines for glaucoma and cancer by extracting pilocarpine nitrate and hydrochloride from plant's dry leaves.

The Cooperative sells the raw material without processing, as well as seeds from 350 other native species for land rehabilitation and habitat restoration activities. It is today the only local collector cooperative that supports environmental conservation and has been authorized by ICMBio, the federal agency responsible for managing the reserve, to sustainably collect jaborandi leaves within the National Forest. This approach supports conservation of Amazon forest species, provides a source of livelihood for local communities, reduces deforestation rates, and helps to prevent losses of native species.

Methodology

COEX Carajás is led by young Ana Paula Nascimento, the only woman in the cooperative. She explains that collecting jaborandi leaves is a seasonal activity, and that the species is spread across remote areas of the National Forest. This requires collectors to spend between 30 and 40 days deep in the forest each season. Like all small businesses, the cooperative has weaknesses in its management, capacity building, logistics, marketing and market access, and has a need for a sound financial management and business strategy.

COEX Carajás was selected in the 2019-2020 call for project proposals within the Fundo Vale PPA Acceleration Program

Fundo Vale was created 10 years ago as a voluntary initiative to invest in critical biomes. Its mission is to strengthen businesses making a positive social and environmental impact and to provide funding for projects that create value from standing forests, support forest restoration and advance sustainable land use, especially as part of low-carbon value chains.

Among the initiatives that Fundo Vale supports is the PPA (Partnership for the Amazon) Acceleration Program, which in the last two years has selected 15 socio-environmental startups to receive a package of benefits to strengthen their business, in addition to financial investment. In the 2019-2020 call for proposals, COEX Carajás was among the successful candidates.

Through the PPA program, the cooperative has received expert mentoring to help solve key issues within the business, as well as access to funding from Fundo Vale, USAID and the crowdlending platform Sitawi. These loans have been used toward training cooperative members, identifying parent plants, and purchasing collection equipment to expand the business.

Jaborandi leaf collectors spend 30 to 40 days deep in the forest during harvest season

Results

As the cooperative's largest customer, Vale signed an agreement to purchase seeds for the Carajás Nursery over the next three years. In addition, the Vale Institute of Technology has a dedicated line of research that is working to expand scientific knowledge about the species.

145 hectares
rehabilitated with jaborandi seeds

350 seed
species sold

39 families
benefited

COEX Carajás had previously been benefited by an acceleration program offered by ISES (Instituto de Socioeconomia Solidária), a Vale Foundation partner, and its selection to the PPA program reflected the maturity the business had reached, to the point where it was ready to expand into other regions of Brazil.

Significant results to date include:

Rehabilitation of approximately 145 hectares of land with jaborandi seeds collected and supplied by the cooperative for Vale's reforestation projects.

350 seed species sold per year, all registered with the Brazilian Seed and Seedlings Registry (RENASEM) and inspected by an expert, supporting conservation of local biodiversity.

An added source of monthly income for 39 collectors and their families.

More than 30 metric tons of dry native jaborandi leaves sold in 2019, in a process that uses biodiversity sustainably, demonstrating the potential of bioeconomics to support Amazon conservation.

Strategic Alignments

For Further Information

Márcia Soares (marcia.soares@vale.com).

Diretoria de Sustentabilidade e Investimento Social/ Gerência de Conhecimento e Empreendedorismo de Impacto; Fundo Vale.

People & Partnerships

Collecting and supplying seeds for seedling production, mineland rehabilitation and species conservation

Foto: Arquivos Fundo Vale

Introduction

The Carajás Forest Nursery is a Vale initiative that contributes to biodiversity conservation in Carajás, while also playing a social role by sourcing most of the seeds for the Nursery directly from the Carajás National Forest Collector Cooperative (COEX), providing a source of livelihood and supporting the development of cooperative members and their families.

Under an agreement with Vale, cooperative members supplement their primary occupation of harvesting jaborandi leaves by collecting native seeds for seedling production at the Carajás Forest Nursery as part of species conservation, mineland rehabilitation and habitat restoration programs.

Methodology

Species are selected and minimum quantities are specified in advance by the nursery team. Collected seeds are largely from species endemic to Pará, as well as species required on demand, such as when environmental license requirements specify certain endangered species for restoration. When they arrive at the nursery, the seeds have already been weighed and labeled with the date and site where they were collected. The nursery team checks the seeds for proper taxonomic identification, quality, weight and processing before receipt (Figure 1). Seeds are paid for per kilo, with prices varying depending on importance, size, collection effort, processing requirements and other criteria.

Results

In 2019 the nursery purchased from the cooperative a total of 4,035 kg of seeds of more than 207 native species—a highly diverse assortment. Seed orders from the cooperative rose substantially by 2,699 kg or 302% from the previous year, reflecting added demand for seeds and species for use in mine land revegetation.

Of the total amount, the cooperative supplied 479.5 kg of seeds from 11 species listed on official threatened species lists, including the vulnerable (VU) species *Bertholletia excelsa*, *Mezilaurus itauba*, *Ocotea tabacifolia*, *Swietenia macrophylla* (IUCN, MMA and COEMA), *Apuleia leiocarpa*, *Hymenaea parvifolia*, *Virola surinamensis* (IUCN and MMA), *Cedrella fissilis* (MMA), *Mimosa acutistipula* and *Protium heptaphyllum* (COEMA), and the endangered (EN) species *Pilocarpus microphyllus* (IUCN, MMA and COEMA) and *Ocotea tabacifolia* (IUCN and MMA).

In addition to purchasing seeds from the cooperative, Vale also provides training in partnership with organizations such as the East Amazon chapter of the Brazilian Agricultural Research Corporation (EMBRAPA) and the Federal Rural University of Amazônia, helping cooperative members to acquire new skills and incorporate new technologies in collecting species native to Carajás and the Amazon.

Diversifying the business into seed collection has also been a way to supplement income earned from harvesting jaborandi leaves, helping to improve the livelihoods of families living near the Carajás National Forest.

Strategic Alignments

For Further Information

Jenaldo Carvalho[1] Lourival Tyski[1], Delmo Fonseca[1], Jerffesson Dutra[2], Alexandre F. Castilho[1], Giselly Mota da Silva[2], André Luiz de Rezende Cardoso[2] (jenaldo.carvalho@vale.com).

[1]Diretoria Corredor Norte/Gerência de Meio ambiente e Relações Institucional Socioeconomia e Comunicação; [2]Sete Soluções e Tecnologia Ambiental.

People & Partnerships

Research applied to conservation and local livelihoods from sustainable harvesting in the Carajás National Forest

Foto: Cecílio Caldeira

Introduction

Although society is aware of the harmful effects of environmental degradation on biodiversity, and has undertaken commitments to use natural resources efficiently and to produce goods and services sustainably (SDG 12 and 15, United Nations), widespread exploitation without adequate environmental management and severe devastation are still observed in different ecosystems around the world. The damages are even greater where commercially high-value native species are involved, such as the jaborandi (*Pilocarpus microphyllus*) (Fig. 1), the world's only source of pilocarpine, an alkaloid extracted from the leaves and used to treat diseases such as glaucoma and xerostomia (Abreu et al., 2011).

Figure 1. Jaborandi (*Pilocarpus microphyllus*) plants at different stages of growth and reproduction: (a) an adult plant approximately 2.5 m tall; (b) a seedling growing in the forest understory; (c) flowers; (d) fruits; and (e) seeds collected after fruit dehiscence. Source: Caldeira et al. 2017

The plant, which occurs in Pará, Maranhão and Piauí (Pirani, 2015), is an important source of livelihood for families of collectors and harvesters, such as those described in in the previous case studies. However, historical deforestation in the region where the plant occurs, coupled with rising demand for pilocarpine, has led to widespread and mismanaged harvesting, a decline in natural populations, and local extinctions (Grabher, 2015), placing the species on the list of threatened flora (Martinelli and Moraes, 2013).

The Carajás National Forest contains one of the largest reserves of *P. microphyllus*, thanks to its preserved forest cover and despite the intensive deforestation that is occurring around its boundaries (Souza-Filho et al., 2016).

Research efforts have included surveys with support from harvesters to map the occurrence of jaborandi plants in the Carajás National Forest, and a study on genetic diversity

Methodology

Research efforts began with a survey to map out the areas where jaborandi occurs naturally in the Carajás National Forest. The survey relied on empirical knowledge about harvesting locations provided by members of the COEX Carajás harvesters' cooperative, who were trained on data acquisition. Because jaborandi plants grow in the forest understory, plant clusters were mapped by using meander walks and plotting points until forming polygons.

The geographic coordinates were then used to prepare maps showing the locations and sizes of plant clusters. Data was collected in two phases: 199 clusters (5,539 hectares) were mapped in the first phase in known harvest areas, and 133 clusters (1,516 hectares) were found in areas that had been previously explored, but without any recently recorded occurrence (Fig. 2). These areas can now be harvested sustainably, as an added source of livelihood for harvesters in the region.

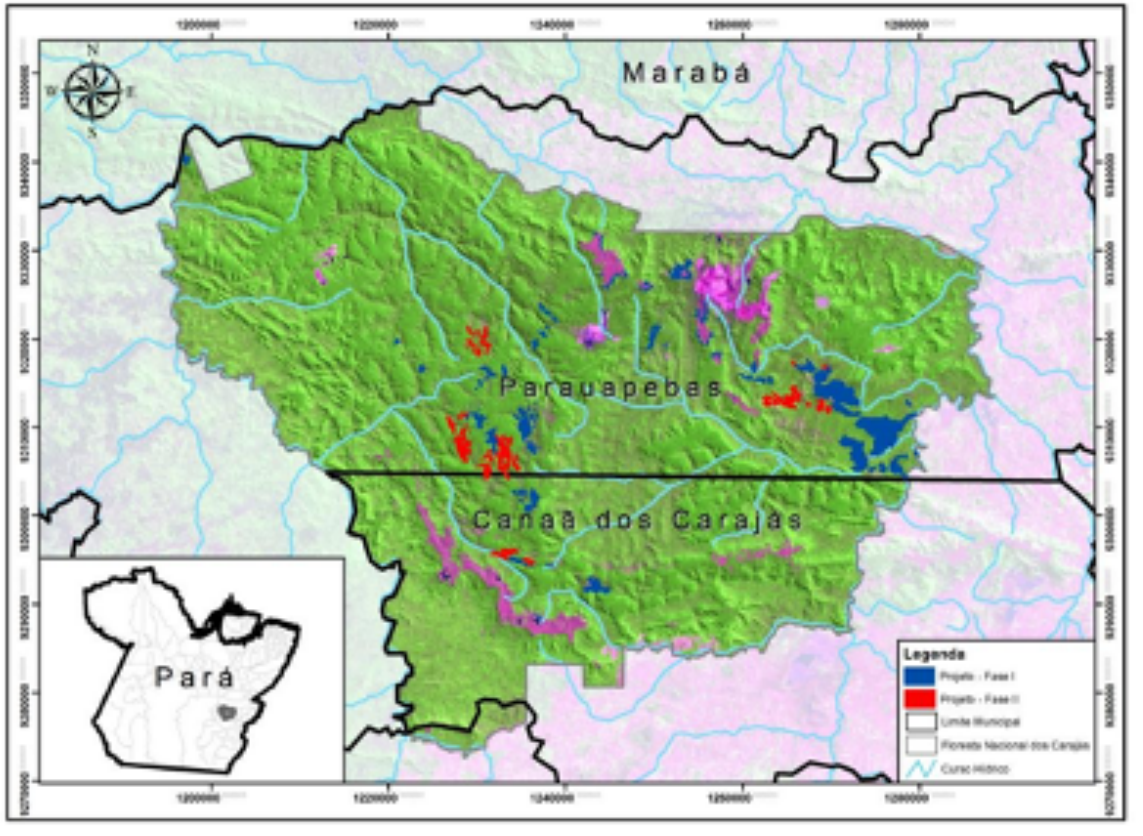


Figure 2. Jaborandi (*Pilocarpus microphyllus*) plant clusters in the Carajás National Forest (blue patches were mapped in the 1st phase, and red patches in the 2nd phase)

Results

During the mapping survey, leaf and nearby soil samples were collected to select parents with a high content of pilocarpine, as well as to identify variables associated with pilocarpine synthesis. Five plants (out of 91 analyzed) had a foliar pilocarpine content higher than 2%, a very high value compared to the previously estimated typical average of 1% (Costa, 2012). Another 16 plants were identified with pilocarpine content values from 1.5 to 2.0 %, for a total of 21 georeferenced plants at different locations in the Carajás National Forest, which can now be used as parent plants for future propagation.

The two plants identified with a pilocarpine content of virtually zero were useful to gain insight into the synthesis of this compound. To this end, we built models with the now-available data on nutrient concentrations in the leaves and soil to predict variables affecting pilocarpine

content. The model with the highest predictive accuracy, using the Akaike information criterion (AIC), suggests that higher pilocarpine content is associated with a higher concentration of N and Mg in the leaves and Fe in the soil, and a lower concentration of phosphorus in the leaves and sulfur in the soil. In addition to informing the selection of parent plants, these data can provide important inputs for sustainable use of *P. microphyllus*. Ongoing studies using machine learning are incorporating new environmental variables as well as genetic markers from approximately 300 jaborandi plants to identify genes associated with high pilocarpine content.

In one study, data on the genetic diversity and structure of plant populations, which are important in developing conservation and sustainable use plans, were derived from representative samples collected from mapped clusters. The study used thousands of Single Nucleotide Polymorphism (SNP) markers to assess a representation of the genome. After filtering the data, three genetic clustering approaches consistently indicated the formation of four genetic populations in the Carajás National Forest (Fig. 3). Designated here as A, B, C and D, these populations are spatially separate, and have high diversity values within populations and reduced gene flow

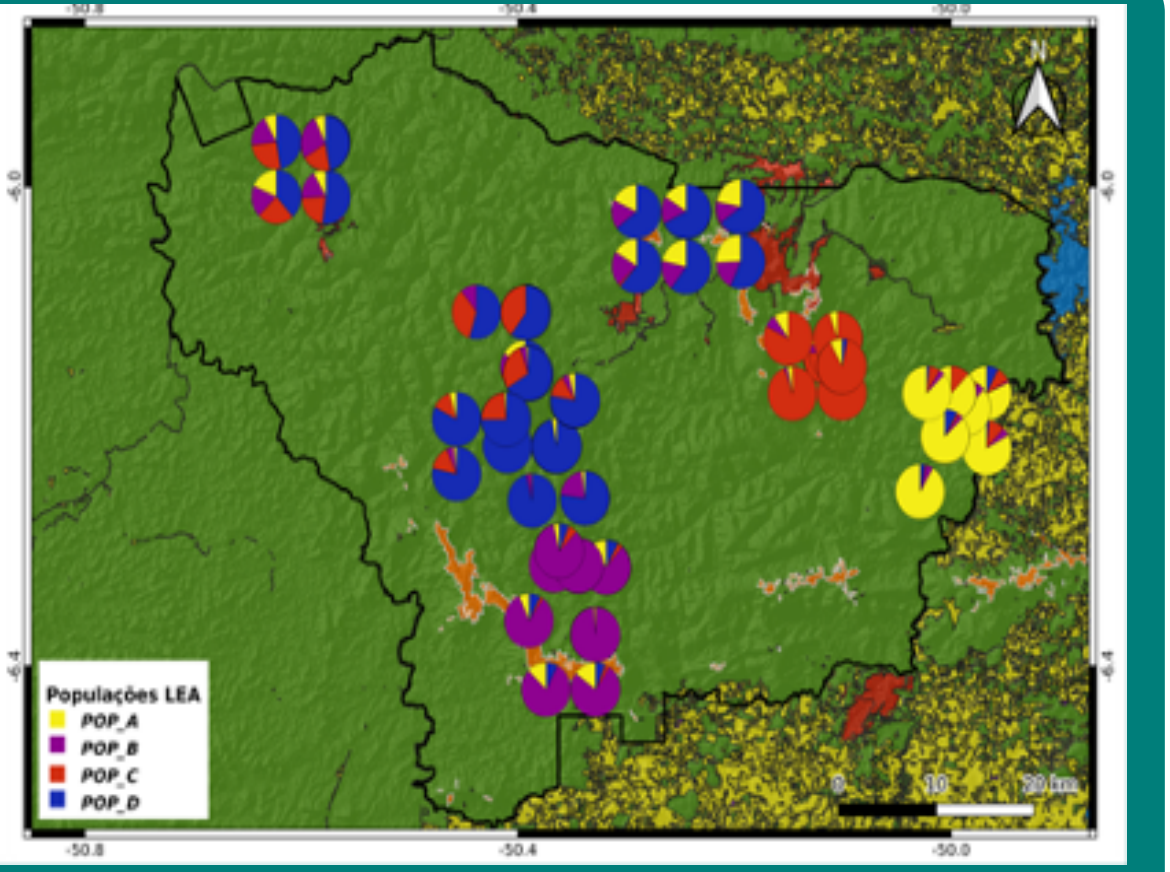


Figure 3. Discriminant Analysis of Principal Components (DAPC) indicating the formation of four subgroups of *P. microphyllus*

across populations, potentially explained by the short flight ranges of their pollinators—bees and flies.

To ensure this genetic diversity is maintained, we established an Active Germplasm Bank (AGB) at the Carajás National Forest. Because jaborandi seeds lose viability during storage, the AGB has to maintain a group of living plants representing the diversity of each population. Plants are selected for propagation based on the genetic diversity and structure of their source populations, as well as information on species reproduction (Hoban et al., 2020).

In this first approximation, maintaining plants propagated from 60 parent plants from each of the four populations would preserve at least 95% of existing genetic diversity, and would be sufficient to prevent inbreeding.

Collaborations have played a key role in generating and applying new knowledge

These analyses are now being refined to include other measures of genetic diversity, such as adaptive variance. To prevent significant losses during germination and the death of individuals before they reach reproductive age, we began collecting seeds from an additional 80 individuals per population. If necessary, future expeditions will be planned to collect seeds and expand the jaborandi AGB at the Carajás National Forest.

The collaborations that have been established play a key role in generating and, more importantly, applying knowledge in a way that benefits society by conserving a threatened species of Brazilian flora; laying out a roadmap for sustainable management of his natural resource; and supporting livelihoods across the value chain, from leaf harvesting through processing. Research going forward will assess the physiology and nutritional aspects of *P. microphyllus,* and methods of planting seedlings from selected parent plants at rehabilitation sites, where they can be managed to maximize production of plant material and pilocarpine.

Strategic Alignments

For Further Information

Cecilio F. Caldeira[1], (cecilio.caldeira@itv.org) Silvio Ramos[1], Markus Gastauer[1], Waleria Monteiro[1], Jeronymo Dalapicolla[1], Rodolfo Jaffé[1], Gracialda Ferreira[2], Jayne Nobrega[3], Renan Coelho[4], Jenaldo Carvalho[4], Pedro Walfir[1]

[1]Instituto Tecnológico Vale Desenvolvimento Sustentável (ITV); Universidade Federal Rural da Amazônia (UFRA); [3]COEX Carajás; [4]Diretoria Corredor Norte/ Gerência de Meio ambiente, Relações Institucional Socioeconomia e Comunicação.

Partners

COEX Carajás, Vale, Fundo Vale, ITV-DS, Fundação Vale, Usaid (Agência de Cooperação dos EUA), Idesam (Instituto de Desenvolvimento Sustentável da Amazônia), Sitawi Finanças do Bem, ISES (Instituto de Socioeconomia Solidária), UFRA.

People & Partnerships

Education and partnerships for sustainable development

Introduction

Specialized education and strategic collaborations are important enablers of research and development at the Vale Institute of Technology - Sustainable Development (ITV-DS). There, new talents are trained to work at the company and elsewhere ITV's master's degree program and through doctoral, post-doctoral and technological development programs. Education scholarships and research fellowships to researchers with technical backgrounds, in line with UN Sustainable Development Goal 4.

In addition to training young talents, ITV-DS establishes strategic collaborations with institutions in Brazil and internationally to build technological capabilities internally and create opportunities for researchers and students to share experience. Researcher training and collaborations are essential levers in research programs supporting the SDGs and addressing ESG (Environmental, Social and Governance) gaps identified by the company. Through these initiatives,

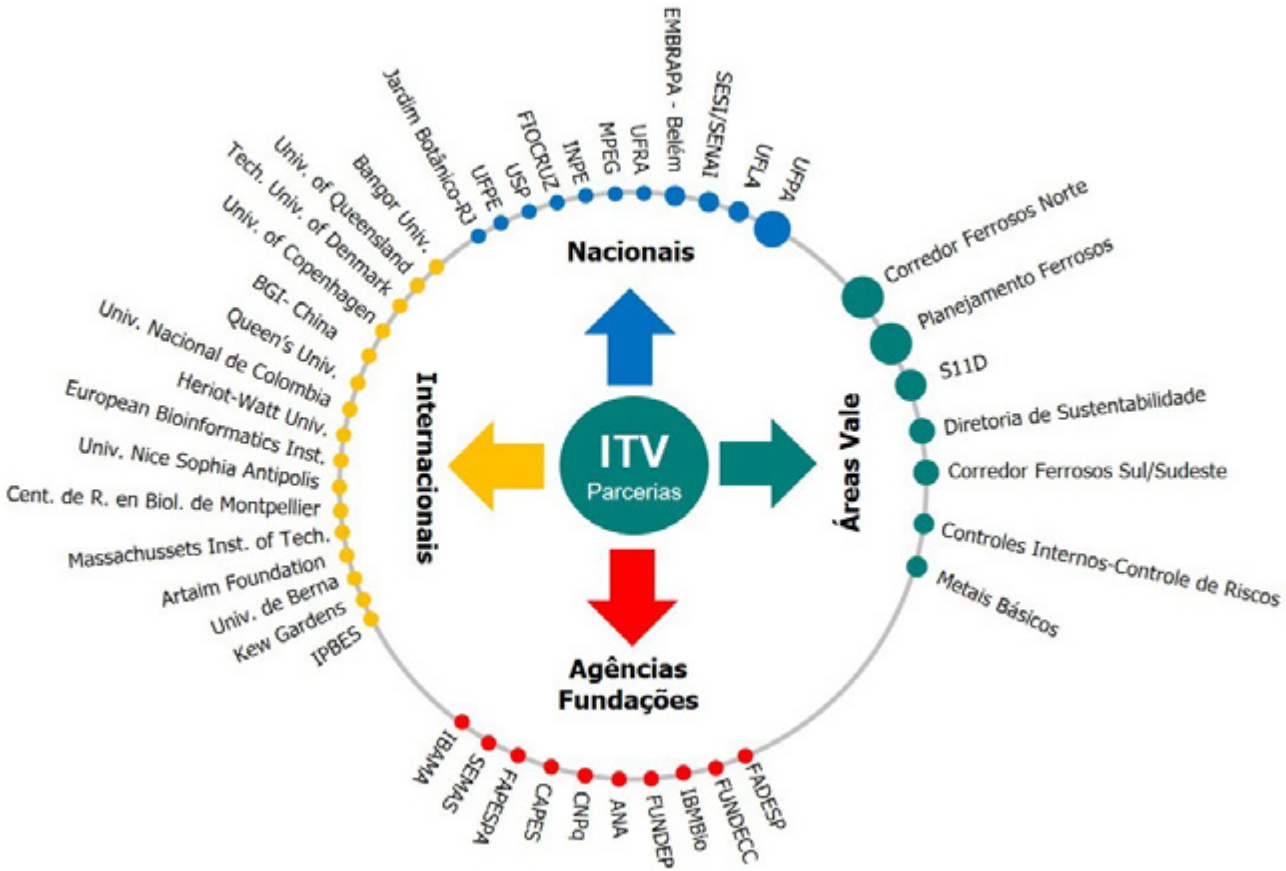
ITV is actively contributing to science dissemination, outreach and scientific training, all of which support SDG 17.

ITV's graduate program provides master's scholarships awarded preferentially to students living in the state of Pará on topics related to the SDGs. The program annually selects 20 students and awards up to 10 scholarships. The master's program at ITV is free and is attended by both Vale employees and members of the community. To date, 98 master's dissertations have been defended, including 41 by employees. The selection process for 2020 received 254 applications, and 60 students are currently enrolled. The research fellowship program is broader in scope. Approximately 50 fellowships are offered—ranging from junior researcher to post-doctoral fellowships—to researchers working on projects at ITV. In 2021, a total of 90 fellowships will be offered.

Research at ITV is interdisciplinary, exploring topics related to Amazon biodiversity, water monitoring in strategic river basins, landscape ecology, sustainable use of biodiversity as a local source of livelihoods, socio-economic studies, mineland rehabilitation and forest restoration, among other topics.

Our network of collaborators and partners provides a broad pool of skills and supports the development of capabilities, enhancing research and development perfor-

Figure 1: ITV-DS's most important institutional partners.



mance in fields that are important for reducing regional disparities. ITV-DS establishes cross-sector collaborations that leverage and share knowledge, expertise, technology and funding for research. The research network enables collaboration both among researchers and with other institutions. Among partner institutions are important local, cross-state, government and international institutions. ITV-DS also collaborates closely with other departments within the company. Its most important research partners are summarized in Figure 1.

Scientific collaboration across institutions, and especially across borders, enhances the research process and leads to higher-impact research and papers. In the last 9 years, a total of 518 peer-reviewed papers have been published (Figure 2).

This research has been developed through an extensive collaboration network currently comprising 106 institutions. At the national level, ITV collaborates most with institutions in the states of Minas Gerais (22 institutions) and São Paulo (21 institutions). We also collaborate extensively with institutions in Pará (10 institutions) (Figure 3).

One of the most emblematic research projects at ITV-DS, a study titled *Flora das cangas da Serra dos Carajás* ("Flora of Carajás Cangas"), was a collaboration with Museu Paraense

518 peer-reviewed papers published in the last nine years

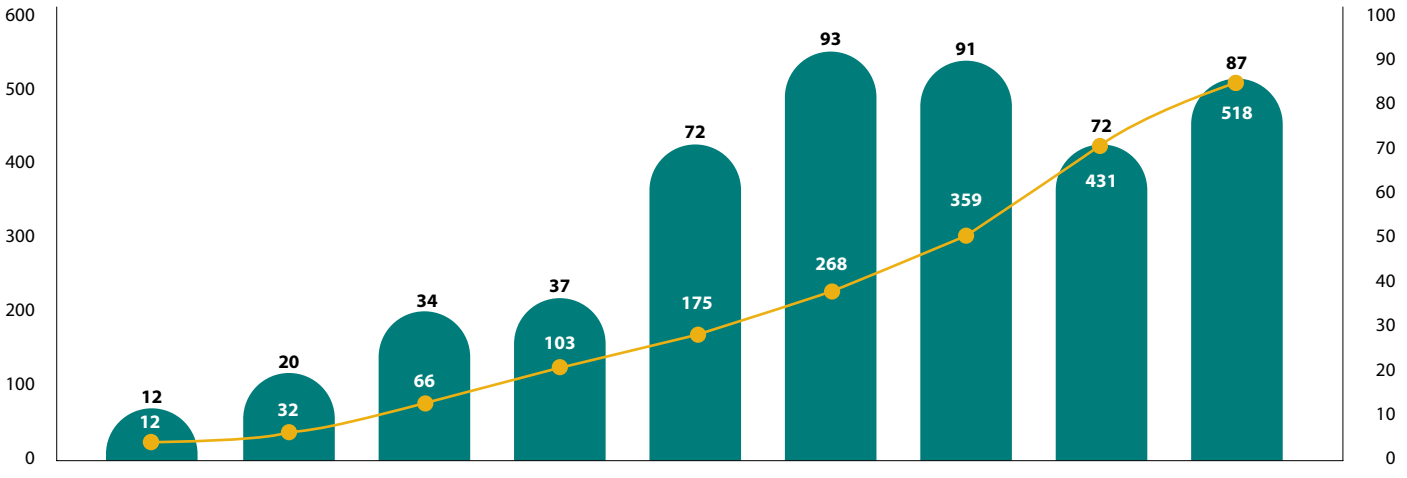


Figure 2. Number of papers published by ITV-DS between 2012 and 2020 (July), annual (bar) and all-time (line).

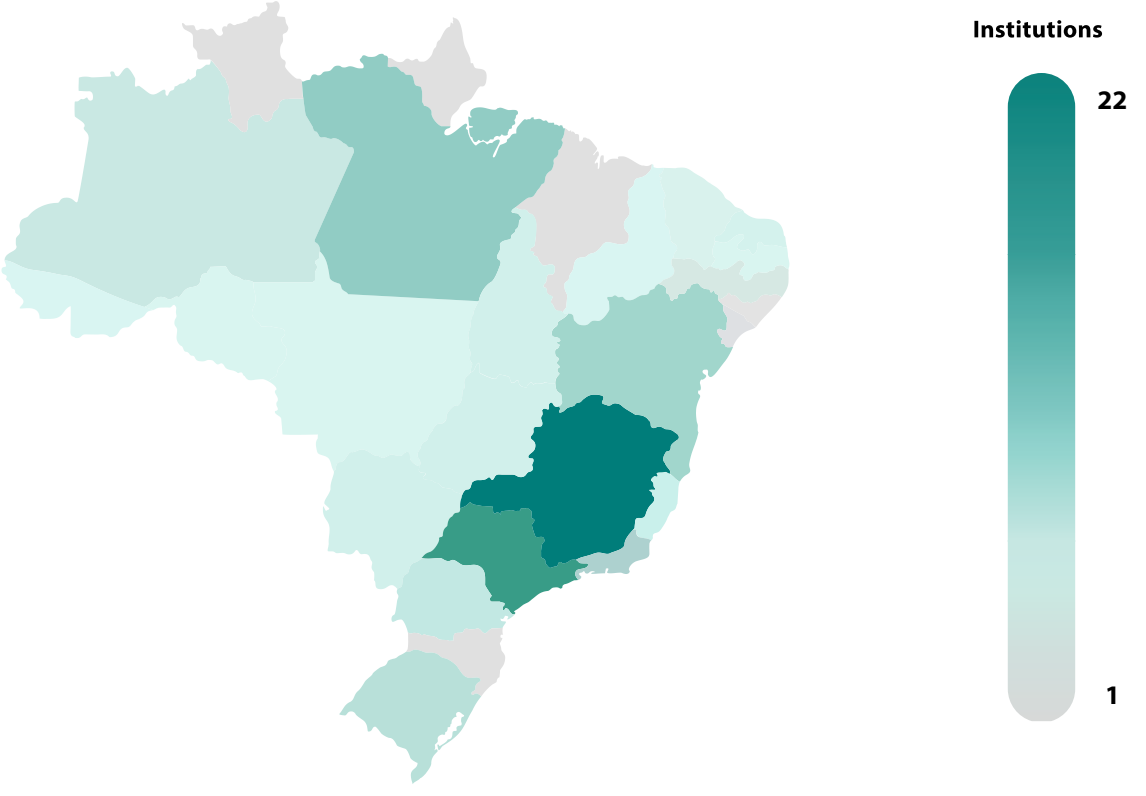
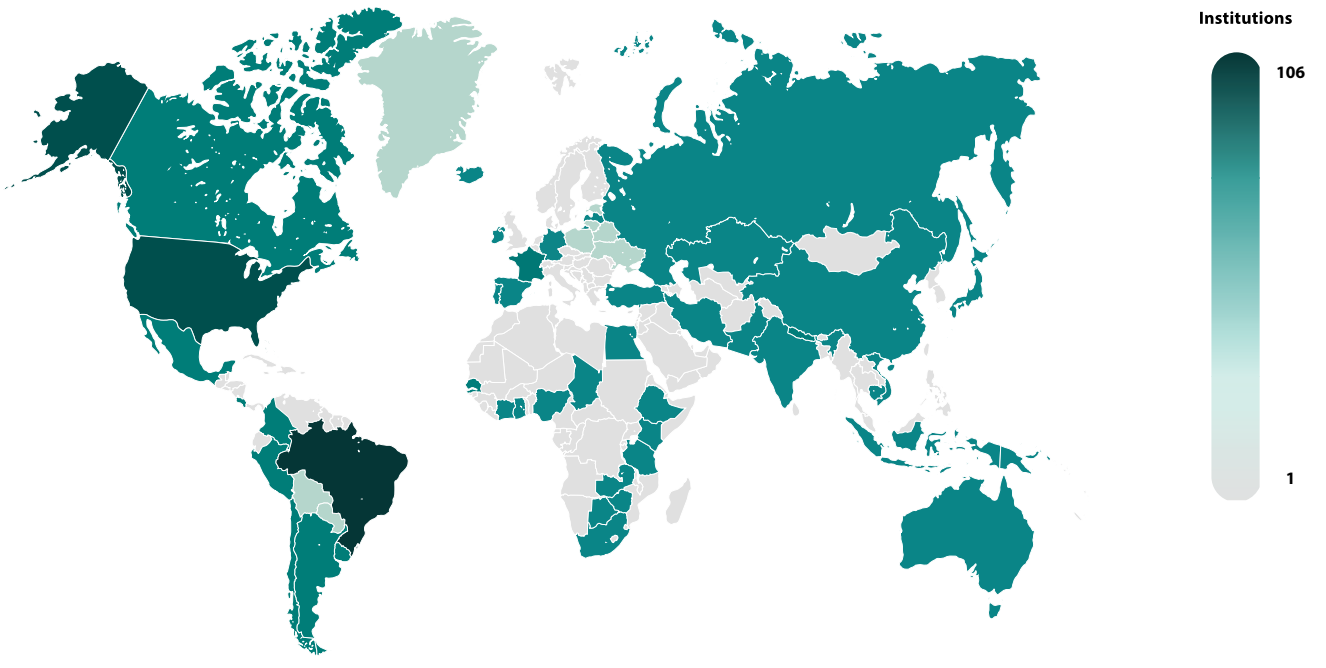


Figure 3: Intensity of collaborations with institutions in Brazil. The darker the hue, the larger the number of institutions collaborating with ITV-DS on research papers in each state.

Emilio Goeldi and botanists at several Brazilian and international institutions. The research was reported in four issues of the journal *Rodriguésia,* published by the Rio de Janeiro Botanical Garden. The species that were researched as part of this project represent 15% of all the flora then known to occur in the state of Pará. ITV-DS has also collaborated broadly with international research institutions, as illustrated in Figure 4. Outside Brazil, ITV-DS has collaborated most extensively with institutions in the US (63 institutions), followed by France (27 institutions), England (19 institutions), Australia (18 institutions) and Germany (17 institutions) (Figure 4). Research collaborations are also established with several countries in Africa, South America and Asia, but with a fewer number of institutions.

In Brazil, ITV collaborates most with institutions in Minas Gerais and São Paulo, but also extensively with institutions in Pará

Figure 4: Intensity of collaborations with international institutions. The darker the hue, the larger the number of institutions collaborating with ITV-DS on research papers in each country.



Research and development are an important lever for regional development, as noted in several of the SDGs. With an emphasis on social and environmental research, ITV-DS has been actively engaged in training human resources and in national and international collaborations to achieve the sustainable development goals.

Strategic Alignments

For Further Information

Josiane Martins; Guilherme Oliveira (guilherme.oliveira@itv.org).

Diretoria de Sustentabilidade e Investimento Social/ Gerência Executiva de Investimento Social Cultura e Inovação/ Instituto Tecnológico Vale.

For further information

Abreu, I.N., Choi, Y.H., Sawaya, A.C.H.F., Eberlin, M.N., Mazzafera, P., Verpoorte, R., 2011. Metabolic alterations in different developmental stages of Pilocarpus microphyllus. Planta Med. 77, 293–300. https://doi.org/10.1055/s-0030-1250314

Andersen, K., Bird, K. L., Rasmussen, M., Haile, J., Breuning-Madsen, H., Kjaer, K. H., Willerslev, E. Metabarcoding of'dirt' DNAfrom soil reflects vertebrate biodiversity. Molecular Ecology, v.21, p.1966–1979, 2012.

Andrino, C. O. et al. Iron islands in the Amazon: investigating the floristic network of canga outcrops. Phytoke-ys (no prelo).

Awade, M.; Miranda, L.; Molina, M.; Giannini, T.C. Recuperação de áreas degradadas na FLONA de Carajás com base na diversidade taxonômica e funcional de aves. Relatório de Pesquisa ITV. DOI: 10.29223/PROD.TEC.ITV.DS.2019.24.Awade. 2019.

Borges, R.C.; Brito, R.M.; Imperatriz-Fonseca, V.L.; Giannini, T.C. The value of crop production and pollination services in the Eastern Amazon. Neotropical Entomology v.49, p. 545–56. 2020. https://doi.org/10.1007/s13744-020-00791-w

Borges, R.C.; Santos Júnior, J.E.; Tyski, L.; Silva, D.F.; Giannini, T.C. Selecionando espécies para recuperação de interações planta-polinizador na Amazônia Oriental. Relatório de Pesquisa ITV. DOI: 10.29223/PROD.TEC.ITV.DS.2019.32. Borges. 2019.

Caldeira, C.F., Abranches, C.B., Gastauer, M., Ramos, S.J., Guimarães, J.T.F., Pereira, J.B.S., Siqueira, J.O., 2019. Spo-reling regeneration and ex situ growth of Isoëtes cangae (Isoetaceae): Initial steps towards the conservation of a rare Amazonian quillwort. Aquat. Bot. 152, 51–58. https://doi.org/10.1016/j.aquabot.2018.10.001

Costa, F.G., 2012. Os folheiros do jaborandi: organização, parcerias e seu lugar no extrativismo Amazônico (Thesis). University of Para, Belém/PA.

Costa, W.F.; Ribeiro, M.; Saraiva, A.M.; Imperatriz-Fonseca, V.L.; Giannini, T.C. Bat diversity in Carajás National Fo-rest (Eastern Amazon) and potential impacts on ecosystem services under climate change. Biological Conser-vation v. 218, p. 200–210. 2018. https://doi.org/10.1016/j.biocon.2017.12.034

De Paula A, Soares JJ (2011). Estrutura horizontal de um trecho de floresta ombrófila densa das terras baixas na Reserva Biológica de Sooretama, Linhares, ES. Floresta, v. 41, n.2, pp.321-334.

Derhé, M. A., H. Murphy, G. Monteith, and R. Menéndez. (2016). Measuring the success of reforestation for res-tor-

ing biodiversity and ecosystem functioning. J. Appl. Ecol. 53, 1714–1724.

Devecchi, M. F. et al. Beyond forests in the Amazon: biogeography and floristic relationships of the Amazonian savannas. Bot. J. Linn. Soc. 193, 478–503 (2020).

FAO. (1993). Ex situ storage of seeds, pollen and in vitro cultures of perennial woody plant species. Rome: FAO, 83 (forestry paper, 113).

Felitto, G.; Lozano, E. D.; Canestraro, B. K. & Kersten, R. A. 2017. Riqueza, composição e estrutura da comunidade arbustivo-regenerante em diferentes estágios sucessionais de uma Floresta Subtropical do Brasil. Hoehnea, 44(4): 490-504.

Fonseca-da-Silva, T. L. et al. Plant species on Amazonian canga habitats of Serra Arqueada: the contribution of an isolated outcrop to the floristic knowledge of the Carajás region, Pará, Brazil. Braz. J. Bot. 43, 315–330 (2020).

Gastauer, Markus, Cecílio Frois Caldeira, Silvio Junio Ramos, Delmo Fonseca Silva, and Jose- oswaldo Siqueira. 2019. "Active Rehabilitation of Amazonian Sand Mines Converges Soils, Plant Communities and Environmental Status to Their Predisturbance Levels." Land Degradation & Development, October. https://doi.org/10.1002/ldr.3475.

Gastauer, Markus, Cecílio Frois Caldeira, Sílvio Junio Ramos, Leonardo Carreira Trevelin, Rodolfo Jaffé, Guilher-me Oliveira, Mabel Patricia Ortiz Vera, et al. 2020. "Integrating Environmental Variables by Multivariate Ordina-tion Enables the Reliable Estimation of Mineland Rehabilitation Status." Journal of Environmental Manage-ment 256 (February): 109894.

Gastauer, Markus, Pedro Walfir Martins Souza Filho, Silvio Junio Ramos, Cecilio Frois Caldeira, Joyce Reis Silva, Jose Oswaldo Siqueira, and Antonio Eduardo Furtini Neto. 2018. "Mine Land Rehabilitation in Brazil: Goals and Techniques in the Context of Legal Requirements." Ambio, April. https://doi.org/10.1007/s13280-018-1053-8.

Gastauer, Markus, Silvio Ramos, Cecílio Caldeira, Leonardo Trevelin, Rodolfo Jaffé, Guilherme Oliveira, Mabel Vera, et al. 2019. "Integrating Environmental Variables by Multivariate Ordination Enables the Reliable Estima-tion of Mineland Rehabilitation Status," September. https://doi.org/10.20944/preprints201909.0206.v1.

Giannini T. C. et al. Selecting plant species for practical restoration of degraded lands using a multiple-trait approach. Austral Ecol. 42: 510–521 (2016).

Giannini, T.C.; Costa, W.F.; Borges, R.C.; Miranda, L.; Costa, C.P.W.; Saraiva, A.M.; Imperatriz-Fonseca, V.L. Climate change in the Eastern Amazon: crop-pollinator and occurrence-restricted bees are potentially more affected. Regional Environmental Change v. 20, p. 1-12. 2020. https://doi.org/10.1007/s10113-020-01611-y

Giulietti, A. M., Giannini, T. C., Mota, N. F., Watanabe, M. T., Viana, P. L., Pastore, M., ... & Pereira, J. B. (2019). Edaphic endemism in the Amazon: vascular plants of the canga of Carajás, Brazil. The Botanical Review, 85(4), 357-383.

Giulietti, A.M.; et al. 2019. Edaphic Endemism in the Amazon: Vascular Plants of the canga of Carajás, Brazil. The Botanical Review, 24: 357 – 383.

Grabher, C., 2015. A governança e a sustentabilidade do extrativismo do jaborandi na Amazônia e transição para o Cerrado e a Caatinga (PhD Thesis). University of Porto Alegre.

Hebert, P. D., Ratnasingham, S., & de Waard, J. R. Barcoding ani- mal life: Cytochrome c oxidase subunit 1 di-vergences among closely related species. Proceedings of the Royal Society of London B: Biological Sciences, 270, S96–S99, 2003.

Hoban, S., Callicrate, T., Clark, J., Deans, S., Dosmann, M., Fant, J., Gailing, O., Havens, K., Hipp, A.L., Kadav, P., Kramer, A.T., Lobdell, M., Magellan, T., Meerow, A.W., Meyer, A., Pooler, M., Sanchez, V., Spence, E., Thompson, P., Toppila, R., Walsh, S., Westwood, M., Wood, J., Griffith, M.P., 2020. Taxonomic similarity does not predict ne-cessary sample

size for ex situ conservation: a comparison among five genera. Proc. R. Soc. B Biol. Sci. 287, 20200102. https://doi.org/10.1098/rspb.2020.0102

Kelly, R. P. et al. Genetic and manual survey methods yield different and complementary views of an ecosys-tem. Front Mar Sci 3, 283, 2017.

Lima, de R. A.; Mori, D. P.; Pitta, G.; Melito, M. O.; Bello, C.; Magnago, L. F. & Prado, P.I. 2015. How much do we know about the endangered Atlantic Forest? Reviewing nearly 70 years of information on tree community surveys. Biodiversity and Conservation, 24: 2135-2148.

Lynggaard, C, Nielsen, M, Santos- Bay, L, Gastauer, M, Oliveira, G, Bohmann, K. Vertebrate diversity revealed by metabarcoding of bulk arthropod samples from tropical forests. Environmental DNA, 1: 329– 341, 2019.

Lynggaard, C., D. W. Yu, G. Oliveira, C. F. Caldeira, S. J. Ramos, M. R. Ellegaard, M. T. P. Gilbert, M. Gastauer and K. Bohmann. DNA-based arthropod diversity assessment in Amazonian iron mine lands show ecological succes-sion towards undisturbed reference sites. Frontiers in Ecology and Evolution (submitted).

Lynggaard, C., M. Nielsen, L. Santos- Bay, M. Gastauer, G. Oliveira, and K. Bohmann. (2019). "Vertebrate Diversity Revealed by Metabarcoding of Bulk Arthropod Samples from Tropical Forests." Environmental DNA. 1(4): 329–41.

Merritt D. J., Kingsley, W., Dixon, K. W. Restoration Seed Banks— A Matter of Scale. Science 332: 424–425 (2011)

Miranda, L.S.; Imperatriz-Fonseca, V.L.; Giannini, T.C. Climate change impact on ecosystem functions provided by birds in southeastern Amazonia. PLoS ONE v. 14, p. e0215229. 2019. https://doi.org/10.1371/journal.pone.0215229

Moraes, B. C. et al.Variação espacial e temporal da precipitação no estado do Pará. Acta Amaz 35:207–214 (2005)

Mota, N. F. de O. et al. Amazon canga: the unique vegetation of Carajás revealed by the list of seed plants. Ro-driguésia 69, 1435–1487 (2018).

Mota, N. F. de O. et al. Amazon canga: the unique vegetation of Carajás revealed by the list of seed plants. Ro-driguésia 69, 1435–1487 (2018).

Mota, N.F.O. & Giulietti, A.M., 2016. Flora das cangas da Serra dos Carajás, Pará, Brasil: Thymelaeaceae. Rodri-guésia, 67(5):1481–1484.

Nevling L.I.J. & Barringer, K. 1993. A new species of Daphnopsis (Thymelaeaceae) from Brazil. Brittonia, 45: 335–336.

Nunes, G.L., Oliveira, R.R.M., Guimarães, J.T.F., Giulietti, A.M., Caldeira, C., Vasconcelos, S., Pires, E., Dias, M., Wa-ta-nabe, M., Pereira, J., Jaffé, R., Bandeira, C.H.M.M., Carvalho-Filho, N., da Silva, E.F., Rodrigues, T.M., dos Santos, F.M.G., Fernandes, T., Castilho, A., Souza-Filho, P.W.M., Imperatriz-Fonseca, V., Siqueira, J.O., Alves, R., Oliveira, G., 2018. Quillworts from the Amazon: A multidisciplinary populational study on Isoetes serracarajensis and Isoetes cangae. PLOS ONE 13, e0201417. https://doi.org/10.1371/journal.pone.0201417

Pavlik, B.M. 1996. Defining and measuring success. Restoring diversity: strategies for the reintroduction of en-dangered plants, 6:127–155.

Paz, F.S.; Pinto, C.E.; Brito, R.M.; Imperatriz-Fonseca, V.L.; Giannini, T.C. Edible plant species in the Amazon Forest rely mostly on bees and beetles as pollinators. Journal of Economic Entomology, 2021. https://doi.org/10.1093/jee/toaa284

Pereira, J.B. de S., Salino, A., Arruda, A., Stutzel, T., 2016. Two New Species of Isoetes (Isoetaceae) from northern Brazil. Phytotaxa 272, 141–148. https://doi.org/10.11646/phytotaxa.272.2.5

Pompanon F, Deagle BE, Symondson WOC et al. Who is eating what: diet assessment using next generation sequencing. Molecular Ecology, 21, 1931–1950, 2012.

Ramos, SJ, Caldeira CF, Gastauer M, Costa DLP, Furtini Neto AE, Souza FBM, Souza-Filho PWM, Siqueira JO (2019)

Native leguminous plants for mineland revegetation in the eastern Amazon: seed characteristics and germination. New Forests, 50:859-872. https://link.springer.com/article/10.1007/s11056-019-09704-1

Reis, A.S.; Gil, A.S.B.; Kameyama, C. 2017a. Flora das cangas da Serra dos Carajás, Pará, Brasil: Acanthaceae. Ro-driguesia, 68: 887–903.

Reis, A.S.; Gil, A.S.B.; Kameyama, C. 2017b. Ruellia anamariae, a new species of Acanthaceae from northern Brazil. Acanthaceae. Phytotaxa, 327 (3): 276–282.

Ribeiro, R.A., Giannini, T. C., Gastauer, M., Awade, M., Siqueira, J.O. 2018. Topsoil application during the rehabili-tation of a manganses tailing dam increases plant taxonomic, phylogenetic and functional diversity. Journal of Environmental Management 227, 386-394.

Rolim SG, Jesus RM, Nascimento HEM (2007). Restauração experimental de uma pastagem na mata atlântica através de semeadura direta. In: Ecossistemas Costeiros do Espírito Santo. Menezes, L. F. T.; Fábio Ribeiro Pires, Oberdan José Pereira, Publisher: EDUFES, pp.269-290.

Ruppert, Krista M., Richard J Kline, and Md Saydur Rahman. Past, present, and future perspectives of environ-mental DNA (eDNA) metabarcoding: A systematic review in methods, monitoring, and applications of global eDNA. Global ecology and conservation 17: e00547, 2019.

Schmidt PA, Bálint M, Greshake B, Bandow C, Römbke J, et al. Illumina metabarcoding of a soil fungal community. Soil Biol Biochem 65:128–132, 2013.

Silveira, A. L.; Ribeiro, L. S. V. B.; Dornas, T. T. e Fernandes, T. N. 2020a. Novos registros de Sphaenorhynchus canga (Amphibia, Anura, Hylidae) no Quadrilátero Ferrífero em Minas Gerais, Sudeste do Brasil. Neotropical Biology and Conservation, 15(1): 19-28.

Silveira, A. L.; Ribeiro, L. S. V. B.; Dornas, T. T. e Fernandes, T. N. 2010b. Distribuição geográfica de Scinax crospe-dospilus (Anura, Hylidae), incluindo novos registros na Mata Atlântica de Minas Gerais (Brasil). Revista Brasileira de Zoociências, 21(1): 1-19.

Silveira, A. L.; Ribeiro, L. S. V. B.; Dornas, T. T. e Fernandes, T. N. 2019a. Taxonomic identity of Adelophryne (Anu-ra, Eleutherodactylidae) populations in the Atlantic Forest in Minas Gerais, Brazil. Herpetology Notes, 12: 311-3117.

Silveira, A. L.; Ribeiro, L. S. V. B.; Dornas, T. T. e Fernandes, T. N. 2019b. Novos registros geográficos, variação morfológica e notas de história natural de Scinax tripui (Amphibia, Anura, Hylidae) na Mata Atlântica de Minas Gerais (Brasil). Revista Brasileira de Zoociências, 20(2): 1-23.

Silveira, A. L.; Ribeiro, L. S. V. B.; Dornas, T. T. e Fernandes, T. N. 2018a. Primeiro registro de Leptodactylus cu-preus (Anura, Leptodactylidae) no Quadrilátero Ferrífero em Minas Gerais, Brasil. Revista Brasileira de Biociên-cias, 16(2): 47-52.

Silveira, A. L.; Ribeiro, L. S. V. B.; Dornas, T. T. e Fernandes, T. N. 2018b. New records of Dispas albifrons (Serpen-tes, Dipsadidae) in the Atlantic Forest of Minas Gerais, Brazil, with morphological data. Herpetology Notes, 11: 809-815.

Silveira, A. L.; Ribeiro, L. S. V. B.; Fernandes, T. N. e Dornas, T. T. 2019c. Anfíbios do Quadrilátero Ferrífero (Minas Gerais): atualização do conhecimento, lista comentada e guia fotográfico. Belo Horizonte, Editora Rupestre. 448 pp. ISBN: 978-65-80945-00-9.

Silveira, F. A. O., Teixido, A. L., Zanetti, M., Pádua, J. G., Andrade, A. C. S. de, & Costa, M. L. N. da. (2018). Ex situ conservation of threatened plants in Brazil: a strategic plan to achieve Target 8 of the Global Strategy for Plant Conservation. Rodriguésia, 69(4), 1547–1555.

Souza-Filho, P.W.M., de Souza, E.B., Silva Júnior, R.O., Nascimento, W.R., Versiani de Mendonça, B.R., Guima-rães, J.T.F., Dall'Agnol, R., Siqueira, J.O., 2016. Four decades of land-cover, land-use and hydroclimatology changes in the Itacaiúnas River watershed, southeastern Amazon. J.

Environ. Manage. 167, 175–184. https://doi.org/10.1016/j.jenvman.2015.11.039

Taberlet, P., E. Coissac, and F. Pompanon. (2012). Towards Next-generation Biodiversity Assessment Using DNA metabarcoding. Molecular Ecology. 21(8): 2045-50.

Viana PL, Mota NFO, Gil ASB, Salino A, Zappi DC, Harley RM, Ilkiu-Borges AL, Secco RS, Almeida TE, Watanabe MTC, Santos JUM, Trovó M, Maurity C, Giulietti AM (2016) Flora das cangas da Serra dos Carajás, Pará, Brasil: história, área de estudos e metodologia. Rodriguésia, 67:1107-1124.

Viana, P. L. et al. Flora of the cangas of the Serra dos Carajás, Pará, Brazil: history, study area and methodology. Rodriguésia 67, 1107–1124 (2016).

Viana, P. L. et al. Flora of the cangas of the Serra dos Carajás, Pará, Brazil: history, study area and methodology. Rodriguésia 67, 1107–1124 (2016).

Viana, P. L., Mota, N. F. O., Gil, A. S. B., Salino, A., Zappi, D. C., Harley, R. M., Ilkiu-Borges, A. L., Secco, R. S., Almeida, T. E., Watanabe, M. T. C., Santos, J. U. M., Trovó, M., Maurity, C., Giulietti, A. M. (2016). Flora das cangas da Serra dos Carajás, Pará, Brasil: história, área de estudos e metodologia. Rodriguésia, 67(5), 1107-1124.

Viana, P. L., Mota, N. F. O., Gil, A. S. B., Salino, A., Zappi, D. C., Harley, R. M., Ilkiu-Borges, A. L., Secco, R. S., Almeida, T. E., Watanabe, M. T. C., Santos, J. U. M., Trovó, M., Maurity, C., Giulietti, A. M. (2016). Flora das cangas da Serra dos Carajás, Pará, Brasil: história, área de estudos e metodologia. Rodriguésia, 67(5), 1107-1124.

Wardil, M.V.; et al. 2017. Primeiro registro de indivíduos femininos de Daphnopsis filipedunculata Nevling & Barringer (Thymeliaceae) e ampliação da distribuição geográfica da espécie endêmica na Floresta Nacional de Carajás, Pará, Brasil. Anais do 68º Congresso Nacional de Botânica, RJ.

Watanabe, M.T.C.; Mota, N.F.O.; Pastore, M.; Santos, F.M.G.; Zappi, D.C. 2018. Completing the jigsaw: the first record of the female plant of Daphnopsis filipedunculata (Thymelaeaceae), an endemic species from the Bra-zilian Amazon. Phytokeys, 109: 93–101.

Wyse, S. V., Dickie, J. B., & Willis, K. J. (2018). Seed banking not an option for many threatened plants. Nature Plants, 4(11), 848–850.

Yoccoz, N., Brathen, K., Gielly, L., Haile, J., Edwards, M., Gostar, T., Pompanon, F. DNA from soil mirrors plant ta-xonomic andgrowth form diversity. Molecular Ecology, v.21, p. 3647–3655, 2012.

Zappi, D. C. et al. Plotting a future for Amazonian canga vegetation in a campo rupestre context. PLOS ONE 14, e0219753 (2019).

Zappi, D. C. et al. Plotting a future for Amazonian canga vegetation in a campo rupestre context. PLOS ONE 14, e0219753 (2019).

Credits

Luiz Eduardo Osorio
Executive Officer, Institutional Affairs, Communications & Sustainability

Hugo Barreto
Head of Sustainability & Social Investment

Bruno Ferraz
Executive Manager, Environmental Management

Vitor Cabral
Manager, Biodiversity & Parks

Richardson Costa Faria
Manager, Mine Closure & Rehabilitation

Organization

Letícia Souza Lima Guimarães
Mine Closure & Rehabilitation

Tereza Cristina Giannini
Vale Institute of Technology/Biodiversity & Ecosystem Services

Technical Assessment Committee

Fernando Marino Gomes dos Santos
Environmental Research

Letícia Souza Lima Guimarães
Mine Closure & Rehabilitation

Luiz Felipe Campos
Mine Closure & Rehabilitation

Taís Fernandes
Environmental Licensing, Value Chain and Speleology Studies, Ferrous Metals

Tereza Cristina Giannini
Vale Institute of Technology/Biodiversity & Ecosystem Services

Rodolfo Jaffe
Vale Institute of Technology

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