



Vale & Biodiversity



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Foreword

Vale has as one of its strategic pillars incorporate sustainability into business, building economic, social and environmental legacies and mitigating the impacts of its operations. Our work continues in the pursuit of excellence in this, increasingly aligned with the global sustainability agenda, seeking to integrate and contribute to sustainable development goals. Our commitment is sealed in our mission: transform natural resources into prosperity and sustainable development.

In this context, we recognize the importance of biodiversity for our business, for people and planet. We develop initiatives aimed

at the continuous improvement of the environmental performance of our activities, applying procedures for risk analysis and management, avoidance, control, mitigation and compensation of impacts on biodiversity.

Following are some highlights of our work in Biodiversity in the past years. These initiatives reinforce our commitment and confirm that it is possible to integrate biodiversity into mining.

Alberto Ninio
Sustainability Director



Vale & Biodiversity

The largest mining company in the Americas and one of the largest in the world, Vale's purpose is transforming natural resources into prosperity and sustainable development through mining. Sustainability means working with the goal of generating an economic return for shareholders and, at the same time, adopting best practices to protect the environment and of social action.

Biodiversity and ecosystem services are essential and intrinsic themes to our business. Based on our Sustainability Policy, we are committed to:

- Know and monitor the regions in which we operate;
- Manage risks and impacts, adopting measures of avoidance, mitigation, compensation and monitoring;

- Act transparently regarding the company's practices and performance in society.

We are committed to a long-term goal of No Net Loss on biodiversity in the territories in which we operate and our actions are guided by the search for neutral impact or gains in biodiversity. The company's strategy is based on management of risks and impacts, management of important environmental attributes of the territory, and continuous improvement of performance in biodiversity, with the aid of tools aimed at risk analysis and information management, applying the hierarchy of mitigation of impacts.

In order to manage risks and impacts, Vale develops specific studies from the planning of entry into new territories to the final

design of its projects, seeking to assess areas, habitats, and sensitive species and to avoid and mitigate impacts on biodiversity. Besides, it develops researches focused on expanding knowledge about the territories in which it operates, innovation, and development of technologies that allow the increasingly sustainable use of natural resources.

Initiatives on research and management of impacts also involve the recovery of degraded areas, to recover the original habitats of the region, and the assessment and planning of recovery of essential ecosystem services. Vale also works on the compensation of impacts, investing in conservation units, planning and maintaining protected areas that are significant remnants of the biomes in which it operates. The elements resulting from

We are committed to a long-term goal of No Net Loss on biodiversity, managing risks and impacts in our activities.

these approaches, together with Research and Development (R&D) initiatives, are the basis of management of the theme at Vale.

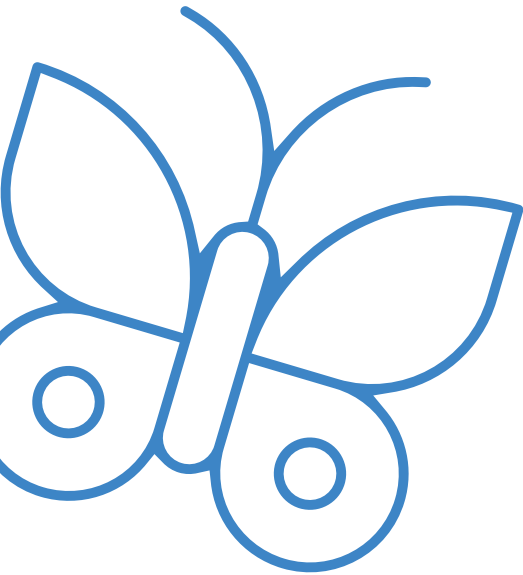
This document presents some initiatives that demonstrate the mainstreaming of biodiversity in our activities, focused on how Vale has been investing in Biodiversity for People and Planet. These initiatives are emphasized below with a brief description and strategic alignment with global goals.



Safeguarding Nature in Protected Areas

Vale Natural Reserve:

Contributing to the Conservation of a Biodiversity Hotspot



Summary of Action

Vale Natural Reserve (VNR) is one of the main protected areas maintained by Vale. It is located in Linhares, in the North region of Espírito Santo, and has approximately 23 thousand hectares that, together with the 27,000-hectare Sooretama Biological Reserve, are the largest continuous remnant of the Atlantic Forest in the Southeast tablelands of the country, especially in the Central Area of the Atlantic Forest. Acknowledged in 2008 as an Advanced Station of the Atlantic Forest Biosphere Reserve of UNESCO's Man and Biosphere Programme, it is an important area intended for conservation of flora and fauna of the biome.

Reserva Natural Vale Photo Collection





Reserva Natural Vale Photo Collection

This area plays an important role in the conservation of biodiversity, sheltering 3,000 plant species and 1.5 thousand insect morphospecies, 27 fish species, 56 amphibian species, 64 reptile species, 395 bird species and 102 mammal species, including rare, endemic and endangered species. Playing a key role in *ex situ* conservation, the Reserve has an herbarium

comprising more than 14 thousand samples of species from the Atlantic Forest. Reinforcing this role, it has one of the largest seedling nurseries in Brazil, a reference in the cultivation of species from the Atlantic Forest, with a production capacity of up to three million seedlings/year, acting in environmental recovery projects in the State. The area also has partnerships for the

“Advanced Station of the Atlantic Forest Biosphere Reserve of UNESCO’s Man and Biosphere Programme, it is an important area intended for conservation of the flora and fauna of this biome.

development of scientific researches and an area of public use that receives more than 30 thousand visitors per year. Bringing people closer to VNR through public use activities benefits the local population while raises awareness of the importance of conserving the rich biodiversity of the Atlantic Forest.

The Reserve protects about five thousand species of plants and animals from the Atlantic Forest, including more than 160 endangered species and 64 endemic species. Preserving this unique heritage and taking care of its maintenance, reducing threats that put pressure on VNR, has been Vale’s goal while maintaining the area.

Main Achievements

This year the Reserve celebrates 40 years of dedication to biodiversity conservation and research. In these 40 years, more than 241 research projects were developed, 117 new species of flora were described, environmental education projects with researchers in partnership with the Reserve, discovery and monitoring of new nests of harpy eagle, a species that is critically endangered.

Partners Involved

Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), Universidade Federal do Espírito Santo (UFES), Instituto de Botânica de São Paulo, Jardim Botânico do Rio de Janeiro, Universidade Federal do Rio de Janeiro (UFRJ), and other universities and research institutes.

Strategic Alignments

By ensuring the conservation of an area so rich in biodiversity, integrating and raising awareness of neighboring communities, VNR contributes to the environmental improvement of the biome as a whole. Besides, it stimulates the advancement of researches on ecology and the generation of a local economy, which improves people's

lives, due to the sustainable development achieved through its activities.



Further information:

Vale Natural Reserve

Marcio Santos Ferreira (marcio.santos.ferreira@vale.com)

<http://www.vale.com/brasil/pt/initiatives/environmental-social/natural-reserve>

www.vale.com/rs2017



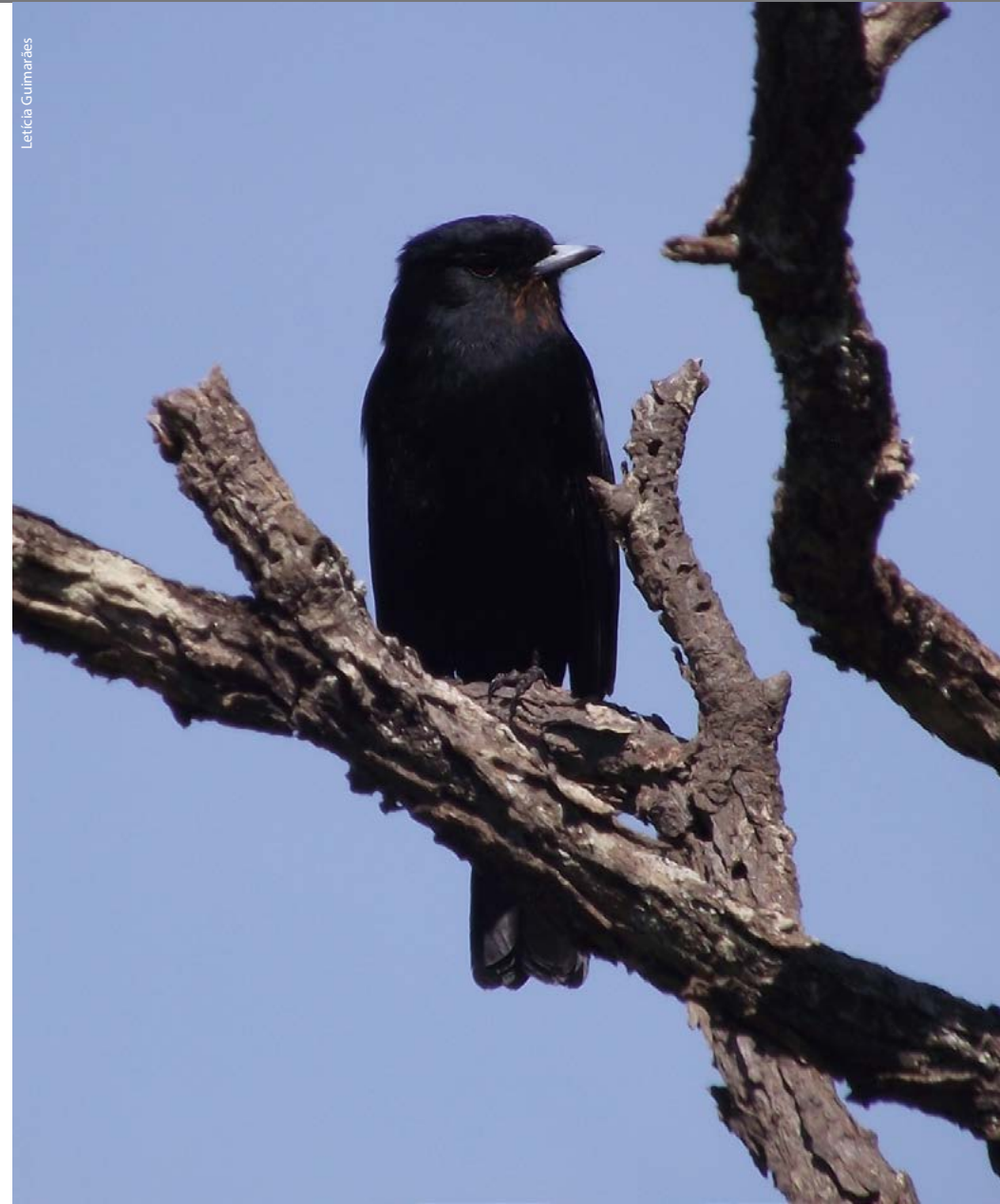
Vale's Protected Areas:

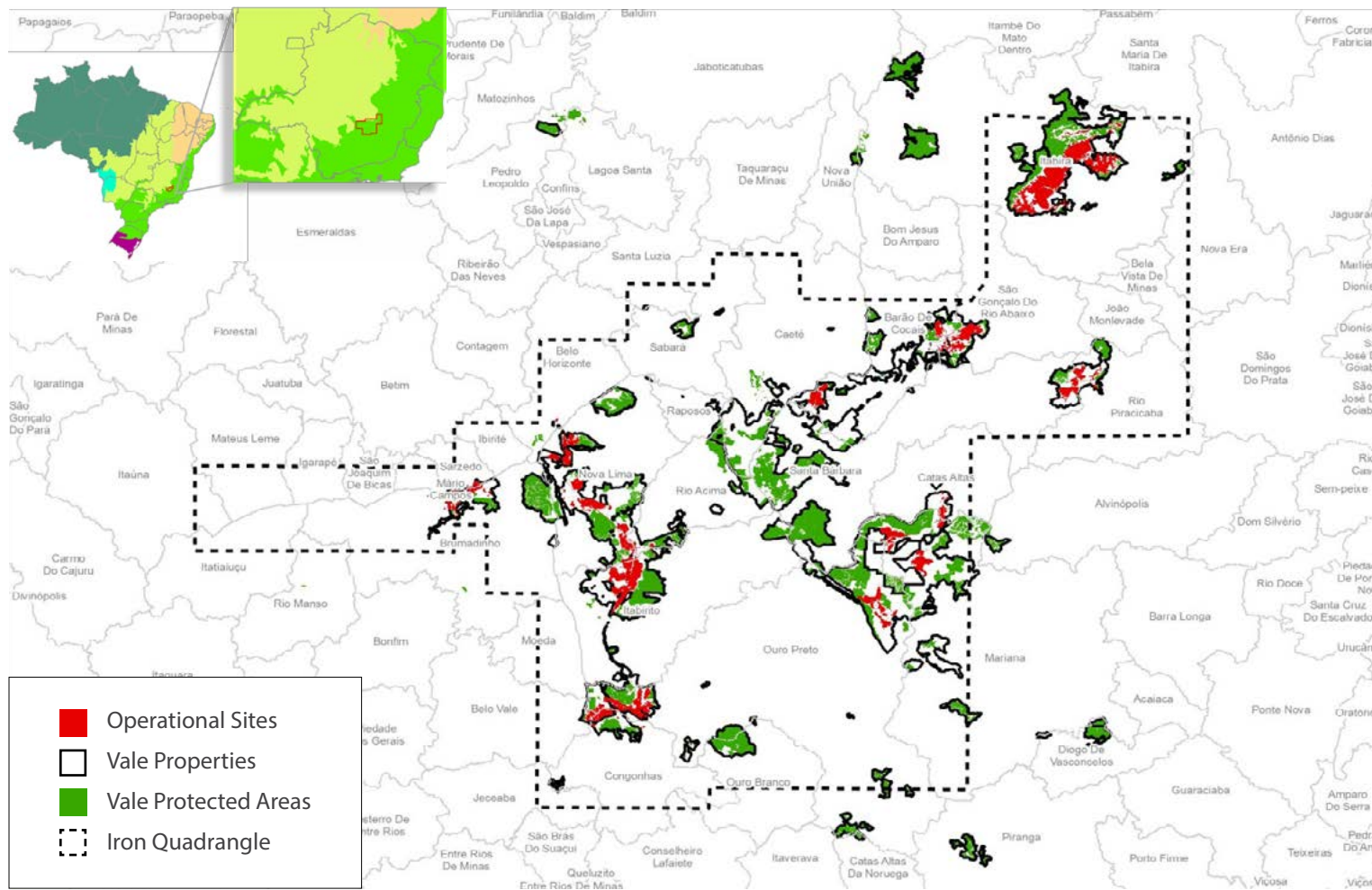
Ecological Corridors and Conservation of Endangered Species in the Quadrilátero Ferrífero – Minas Gerais / Brazil

Summary of Action

One of Vale's main initiatives to promote ecological balance and guarantee the conservation of natural resources and ecosystem services is the protection of natural areas. In total, there are 8,5 thousand km² of protected areas, approximately 5.6 times larger than the total area occupied by the company's operating units, where 92.6% of the areas are included in regions classified as wilderness areas and 7.4% in hotspots. The company owns 4.5% of the total areas it helps to protect, comprising legal reserve areas, Private Reserves of the

Letícia Guimarães





“Vale helps protect 8,5 thousand km² of protected areas, constituting remnants for the conservation of sensitive habitats and endangered and endemic species of flora and fauna.”

Natural Heritage (RPPN), and properties for conservation and future compensation. These areas are important witnesses of regional biodiversity, constituting remnants for the conservation of sensitive habitats and endangered and endemic species of flora and fauna. Together with third-party conservation units, they are important areas that support endangered and endemic species.

Main Achievements

Currently, Vale maintains RPPNs in Minas Gerais, in the region of the Quadrilátero Ferrífero, protecting more than 12,800 ha of typical formations of the Atlantic Forest and transition with the Brazilian savanna. According to data compiled in 2017, these areas play a key role in the conservation of more than 70 endangered species of flora and fauna, such as cougar (*Puma concolor*), Chaco eagle (*Urubitinga coronata*), ocelot (*Leopardus pardalis*), Brazilian sassafras (*Ocotea odorifera*), and black hawk-eagle (*Spizaetus tyrannus*).

Strategic Alignments



Further information

Environmental Management Southeast Corridor

Genilton Santos
(genilton.santos@vale.com)

Giovana Knierim
(giovana.knierim@vale.com)

www.vale.com/rs2017



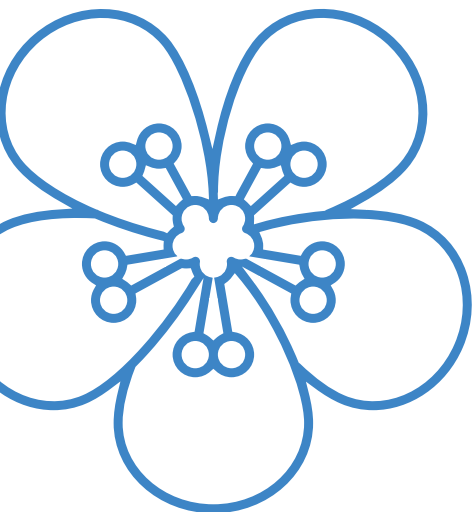
Vale Photo Collection



Vale Photo Collection

Flora Species of Interest for Conservation

in Vale's Protected Areas in Quadrilátero
Ferrífero, Minas Gerais, Brazil



Summary of Action

The Quadrilátero Ferrífero region is located in south of Serra do Espinhaço and in the central portion of Minas Gerais, presenting a complex mosaic of natural environments that occur between 800 and 2000m, structured on distinct lithotypes and geomorphological sites, colonized by Outcrops, Seasonal Semideciduous Forest, Cerrado Lato Sensu, Riparian forests and Wetlands, where key conservation plant species for conservation



Vale/ Bioma Photo Collection



Vale/Bioma Photo Collection

occur. Different forms of anthropic pressure from industrial activities – such as mining, agriculture and urban expansion – generate losses in the extent and quality of habitats. In this scenario, the protected areas are potential refuges for conservation for biodiversity conservation. Vale maintains 21 Private Reserves of Natural Heritage (RPPN) in this region, contributing for the conservation of this habitat.

In this context, since 2015 Vale has been developing studies on the flora of RPPNs, focusing on the distribution of rare, endemic and endangered species to

understanding the role of their protected areas in the conservation of these.

Main Achievements

1706 samples were obtained and registered in the BHCB Herbarium collection, and 102 families, 331 genera and 483 species were identified. 15 species were identified as endangered, 11 from the “Official National List of Endangered Species of Flora”, in effect, 14 species according to the “Red Book of the Flora of Brazil”, as well as three species according to

“Vale maintains 21 Private Reserves of Natural Heritage (RPPN) in this region, contributing for conservation of natural habitats. These areas protected 483 species of plants, 15 endangered species.

"The International Union for Conservation of Nature Red List of Threatened Species". In addition, 17 species were endemic to the Quadrilátero Ferrífero, 28 endemics to the Serra do Espinhaço, 27 endemics to the Atlantic Forest and 7 rare. Two endemic species of the Quadrilátero Ferrífero region were highlighted: *Heterocoma albida*, critically endangered, and *Eriocnema fulva*, vulnerable and rare.

These results indicate that the RPPNs sampled are playing an important role for the conservation of species of the regional native flora.

Planners and Partners

Bioma Meio Ambiente LTDA

Strategic Alignments



Further information:

Ferrous Environmental Licensing Management

Ana Cristina Amoroso (ana.amoroso@vale.com)

Bioma Meio Ambiente

Lidia dos Santos (bioma.ma@biomameioambiente.com.br), Marco Otávio Dias Pivari, Júlia Andrada de Paiva, Sérgio Tomich

<http://www.vale.com/brasil/PT/aboutvale/news/Paginas/vale-lanca-livro-sobre-flora-reservas-particulares-patrimonio-natural-vale.aspx>

www.vale.com/brasil/pt/aboutvale/news/paginas/rota-das-flores-livro-apresenta-especies-do-quadrilatero-ferrifero.aspx



Vale/Bioma Photo Collection



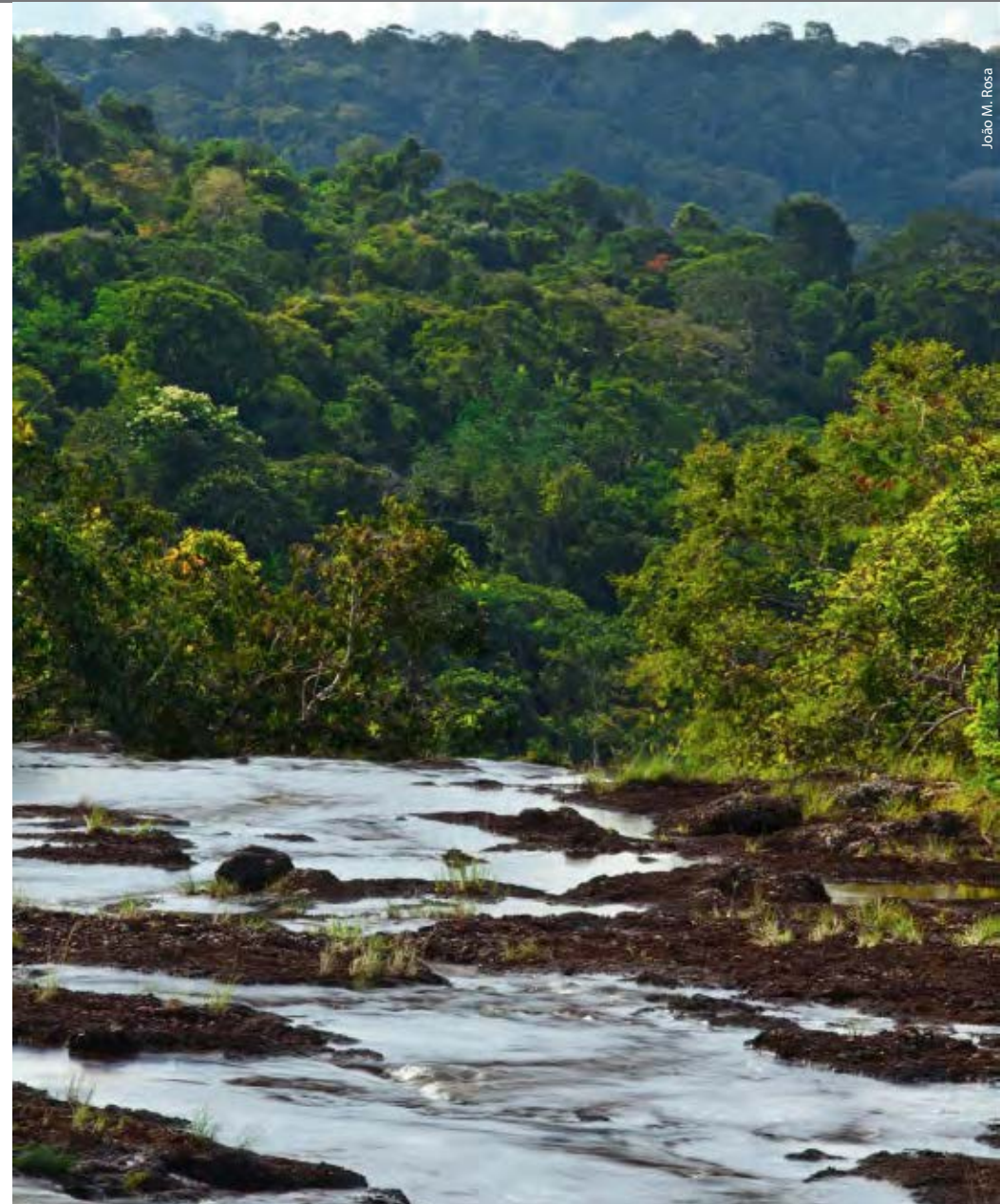
Vale/Bioma Photo Collection

The Flora of Carajás And its Special Species:

Implications for Licensing, Mitigation,
Compensation and Conservation

Summary of Action

The International Council on Mining & Metals (ICMM) good practice guidelines for mining considering that biodiversity is to be integrated to the operations and that companies must play a positive role in its protection. Between the reasons for engagement with the private sector, the Wildlife Habitat Council suggests the creation of “Positive Net Impact” through biodiversity conservation. Within this context, a public-private partnership was signed in December 2014 between the Museu Paraense Emílio Goeldi and the





João M. Rosa

Instituto Tecnológico Vale, to prepare the botanical base for mining sustainability development for the FLONA of Carajás.

Concluded in record time, the Flora of the *canga* of Carajás increased a lot the estimated number of species and

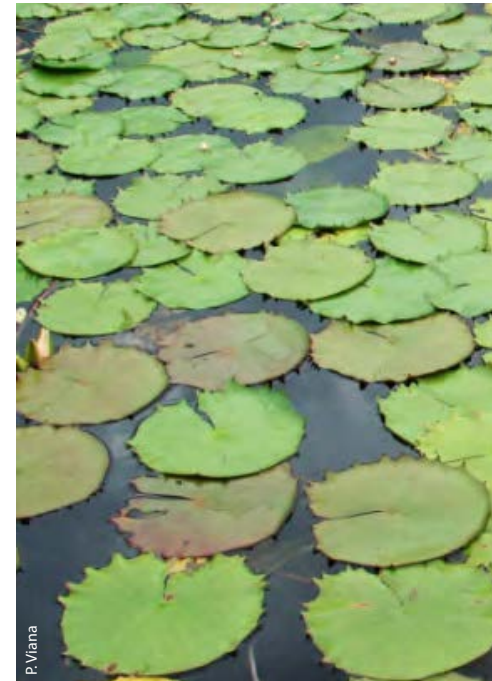
produced plant family monographs that counted with the collaboration of 140 researchers from Brazil and elsewhere in the world. The knowledge generated by this project has unfolded into advanced studies of the local biota, allowing to confirm endemism of several species, research into floral biology, rarity and the threat degree faced by *canga*'s species today.

Main Achievements

The Flora of the *canga* of the FLONA of Carajás and Parque Nacional dos Campos Ferruginosos (PNCF) recorded a total of 1094 species, treated in 163 monographs in four fascicles of *Rodriguesia* journal. The treatments included taxonomic descriptions, illustrations and species distinguish tools, such as identification keys, as well as comments regarding distribution, morphology and phenology. Collection data information was organized using distribution modelling to locate similar areas where the endemic species could be recorded. As a result of the database authenticated by the specialists, some

legal requirements were fulfilled towards threatened, endemic, rare and invasive species found within the FLONA.

A list of threatened species was prepared based on ordinance 443, consisting of 25 species (8 from the *canga*); evaluation of threatened species using the IUCN



P. Viana

“An extensive survey of all vascular plants occurring in the *cangas* from Carajás Flona, revealed that only 4% from a total of 856 seed species are endemic.





Jaborandi (*Pilocarpus microphyllus*) – the harvest of this medicinal plant is important for the local people



criteria were performed; survey of putative endemics, with 8 species endemic to the FLONA and 9 occurring also in the PNCF; a guide of invasive species that need to be managed at the S11D area; selection of promising plant species to use in recovering degraded areas (RDA); search for potential areas for compensation; public dissemination in the Landscapes

and Plants of Carajás book. The *canga* of Carajás hosts unique vegetation, differing from all other canga known from Brazil thus far; molecular studies involving landscape genetics of *Ipomoea* spp. were published and under development are *Brasilianthus* and *Monogeron*.

Partners Involved

Museu Paraense Emílio Goeldi (MPEG)

Herbário Carajás – VALE S/A (HCJS)

Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio)

Strategic Alignments



Further Information

Instituto Tecnológico Vale

Daniela Cristina Zappi
(daniela.zappi@itv.org)

Museu Paraense Emilio Goeldi

Pedro Lage Viana
(pedro.viana@museu-goeldi.br)



Flora de Carajas
– Vol. 1



Flora de Carajas
– Vol. 2



Flora de Carajas
– Vol. 3



Flora de Carajas
– Vol. 4



Landscape and
Plants of Carajas



Sustainability of
Jaborandi in the
eastern Brazilian
Amazon



Nature for People

Fundo Vale:

Sustainable Development Allied to the Conservation of Biodiversity

Summary of Action

Fundo Vale is an OSCIP (Civil Society Organization of Public Interest) created by Vale in 2009. Its mission is to promote sustainable development by inducing, connecting, or multiplying transformative solutions to societies, markets, and the environment. Throughout its 9 years of activity, it has supported 54 conservation initiatives and the sustainable use of the Amazon rainforest, investing about R\$120 million in three work programs: Strategic Monitoring, Protected Areas and Biodiversity, and Green Cities. It was acknowledged as one of the top 10 funders of actions for conservation of the



Amazon rainforest, in a study made by Moore Foundation. It works on a logic of cooperation with organizations of civil society, many of them are national and international references in sustainability, with emphasis on its reputation, presence in the field, and effective results in the Brazilian socio-environmental agenda.

Main achievements

- Contribution to the implementation and consolidation of more than 279 thousand square kilometers of Conservation Units in six states of the Amazon rainforest.
- Improvement of environmental management and implementation of protected areas in the cities of Calha Norte area, in the state of Pará, the largest continuous tropical forest on Earth. It resulted in the entry of these cities into the Green Cities Program (state of Pará) and compliance with commitments to fight against deforestation, as well as the preparation and implementation of plans for

management of extractive reserves in the region.

- Consolidation of a monitoring system in Amazon rainforest, with production and wide dissemination of information on deforestation and forest degradation

in the Biome, as a tool for transparency, decision-making, and social control of public information (SAD-3D Imazon).

- Elaboration of the country's first community protocol for fair and equitable sharing of benefits arising

from the use of biodiversity, the Bailique Community Protocol (state of Amapá), which is a model for future preparation of public policies within the scope of the Convention on Biological Diversity (CBD), with empowerment of the local community,



Rafael Araújo/Acervo Fundo Vale



Rafael Araújo/Acervo Fundo Vale



Haroldo Castro/Acervo Fundo Vale

“The experience accumulated by Fundo Vale has shown that the conservation of the Amazon rainforest and its rich biodiversity goes through a successful economy that values the maintenance of the forest.

- support to land-use planning, and strengthening of local productive chains for improvement of income. They had the first production of açaí berries with FSC certification.
- Feasibility study of reapplication of Brazilian forest monitoring methodology in pan-Amazonian regions, resulting in the creation of monitoring policies in other countries.
- It helped the expansion of the green cities model based on efficient environmental management and stimulated the Amazonian sustainable economy, resulting in the consolidation of the Green Cities Program (PMV) in the state of Pará, where Fundo Vale is still a member of the Managing Committee.
- Contribution to the development of differentiated models of management of indigenous territories in the states of Acre, Rondônia, and Mato Grosso and in the Xingu Area (state of Pará), valuing the natural resources and the sustainability of the peoples in the Amazon rainforest.
- Support to qualification for management of territories and a business vision for sociobiodiversity products in Extractive Reserves in the state of Pará, stimulating the sustainable use of natural resources and improving the income of local population. Focus on baskets of products from the forest and the creation of a traceable seal for trade (Origens Brasil), boosting the local economy and the bioma conservation.

- Support to the Forest Trends project of mapping more than 2,000 experiences of Payment for Environmental Services in Brazil. In addition to training sessions with indigenous people from the states of Acre and Mato Grosso for qualification in the theme, it is a benchmark for the establishment of public strategies to compensate communities for the maintenance of environmental services in indigenous lands.

The experience accumulated by Fundo Vale has shown that the conservation of the Amazon rainforest and its rich biodiversity goes through a successful economy that values the forest maintenance. Thus, the Fund redirected its strategy to focus on creating a sustainable business environment in the region, as well as financial instruments that leverage forest and low carbon chains. Elements that value the products of sociobiodiversity and bring

improvements to the living conditions of the peoples and individuals that protect the forest. To this end, it is implementing the Sustainable Business Program, which includes the creation of a platform that finances green businesses.

Partners Involved

Unesco, Recam - Rede de Capacitação da Amazônia, FIIMP - Fundações e Institutos de Impacto, Sitawi, Kaeté Investimentos, Fundação Certi, Conexsus - Conexões Sustentáveis, Fundação Mitsui Bussan do Brasil, Instituto Ventura, BID-Fomin, Fundação Avina, Saúde e Alegria, Idesam - Instituto de Desenvolvimento Sustentável da Amazônia, ISA - Instituto Socioambiental, Imaflora, IFT - Instituto Floresta Tropical, IEB - Instituto Internacional de Educação do Brasil, ICV - Instituto Centro de Vida, GTA - Grupo de Trabalho Amazônico, FVA - Fundação Vitória Amazônica, Forest Trends, ECAM - Equipe de Conservação da Amazônia, CSF - Conservation Strategy Fund, ARA - Articulação Regional Amazônica.

Strategic Alignments



Further information

Fundo Vale

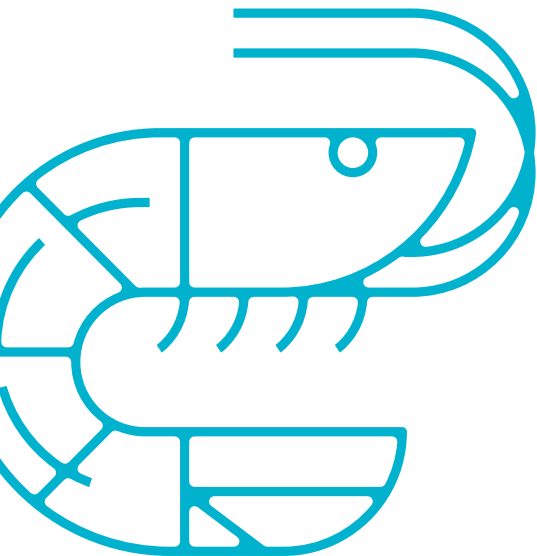
Marcia Soares (marcia.soares@vale.com)

www.fundovale.org



Sustainable Fishing

on the Amazonian Coast



Summary of Action

The inhabitants of the Amazonian coast use different ecosystems – the sea, rivers, streams, and mangroves – which are their main source of subsistence and income. In this region, Fundo Vale maintains an essential partnership with Unesco, focusing on articulation for development and strengthening of the sustainable productive chains of artisanal fishing.

The Sustainable Fishing on the Amazonian Coast project aims to improve income and quality of life to fishermen on the coast of the states of Pará, Maranhão, and Amapá, as well as ensure that the productive chain of local fishery resources is ecologically, economically, and socially sustainable.



“The Sustainable Fishing on the Amazonian Coast project aims to improve income and quality of life to fishermen.

The project supports the productive chains of swamp ghost crabs and shrimps of Amazonian, piticaia, and white types, aiming at providing small-scale artisanal

Areas of Activity of the Project



fishermen with fair access to markets and sustainable use of marine resources.

The beneficiaries of the project also include: 30 communities in 10 cities in the Amazonian Coast, benefiting almost 9 thousand families.

Main achievements

- Two diagnostic studies (Socio-cultural, economic, and environmental diagnosis and Diagnosis of value chains) with qualitative and quantitative research to

guide the lines of action of the project and to support fishing productive chains and communities.

- Workshops in all communities covered by the project to share and validate the results of the diagnoses.
- 271 workshops of youth protagonism, promoting the continuous qualification and involving about 300 young people in the 3 three states.
- 22 workshops for technical training and community strengthening, and application of low-cost social technologies that directly and indirectly benefited over 800 people, including fishermen, families, and communities.
- Articulation of institutional partnerships (44 partners including public and private sector entities, universities, educational and research institutions, NGOs, and community entities).

The diagnoses carried out by the project are intended to contribute to filling the gap of information and statistical data regarding artisanal fishing in Brazil.

Strategic Alignments



Further information

Fundo Vale

<http://www.unesco.org/brasil>

<http://unesdoc.unesco.org/images/0026/002604/260495POR.pdf>

http://bitly.com/canal_PeSCA (Youtube)



Friends of Humpback Whale:

Relationship with Communities,
Conservation, and Promotion of Local
Development



Summary of Action

The relationship with the communities in the areas where Vale operates is fundamental to the sustainability of its business. Therefore, the company invests in initiatives that contribute to social and environmental development of the locations where it operates, such the Friends of Humpback Whale Project, supported by the Department of Community Affairs of the state of Espírito Santo, an area of activity of Tubarão Unit. Vitória coast has one of





the largest concentrations of humpback whales in Brazil. However, the absence of a diagnosis of the viability of whale-watching ecotourism was an obstacle to the promotion of this local activity. In this context, the Friends of Humpback Whale Project was conceived by an “environmental team” to bring Vitoria population closer to the humpback whales using environmental and cultural education and scientific actions, as well as to influence public policies.

Main Achievements

For this purpose, vessel masters and tourism operators of the capital city were mapped, trained, and certified. A cycle of environmental education was created, covering teachers and students of the municipal network of public schools. Regarding cultural highlights, the Humpback Whale Festival was held for the first time, establishing the beginning of the sighting season. The platform Jubart. Lab was created, an unprecedented

scientific laboratory in the state that aggregates scientific data and a collection of photos and videos produced in scientific expeditions, which contents were also used for dissemination campaigns in social networks and spontaneous media (press). All the work resulted in the publication of the first diagnosis of whale watching in Espírito Santo and the production of an educational handbook. The actions involved more than 6,000 people and demonstrated the relevance of the initiative in raising awareness of the conservation of cetaceans and the marine environment, as well as a sustainable alternative for generating employment and income.

Planners and Partners

O Canal Institute, Ecomares Institute, Últimos Refugios Institute, Baleia Jubarte Institute, Vitória town hall, Federal University of Espírito Santo

Strategic Alignments



Further information:

Community Relations Management – Espírito Santo (Br)

Roberta Atherton
(roberta.atherton@vale.com)

<http://www.vale.com/brasil/pt/aboutvale/news/paginas/vale-e-amigos-da-jubarte-apresentam-resultados-de-um-ano-de-parceria-do-projeto.aspx>

www.amigosdajubarte.com

www.queroverbaleia.com



Research & Development

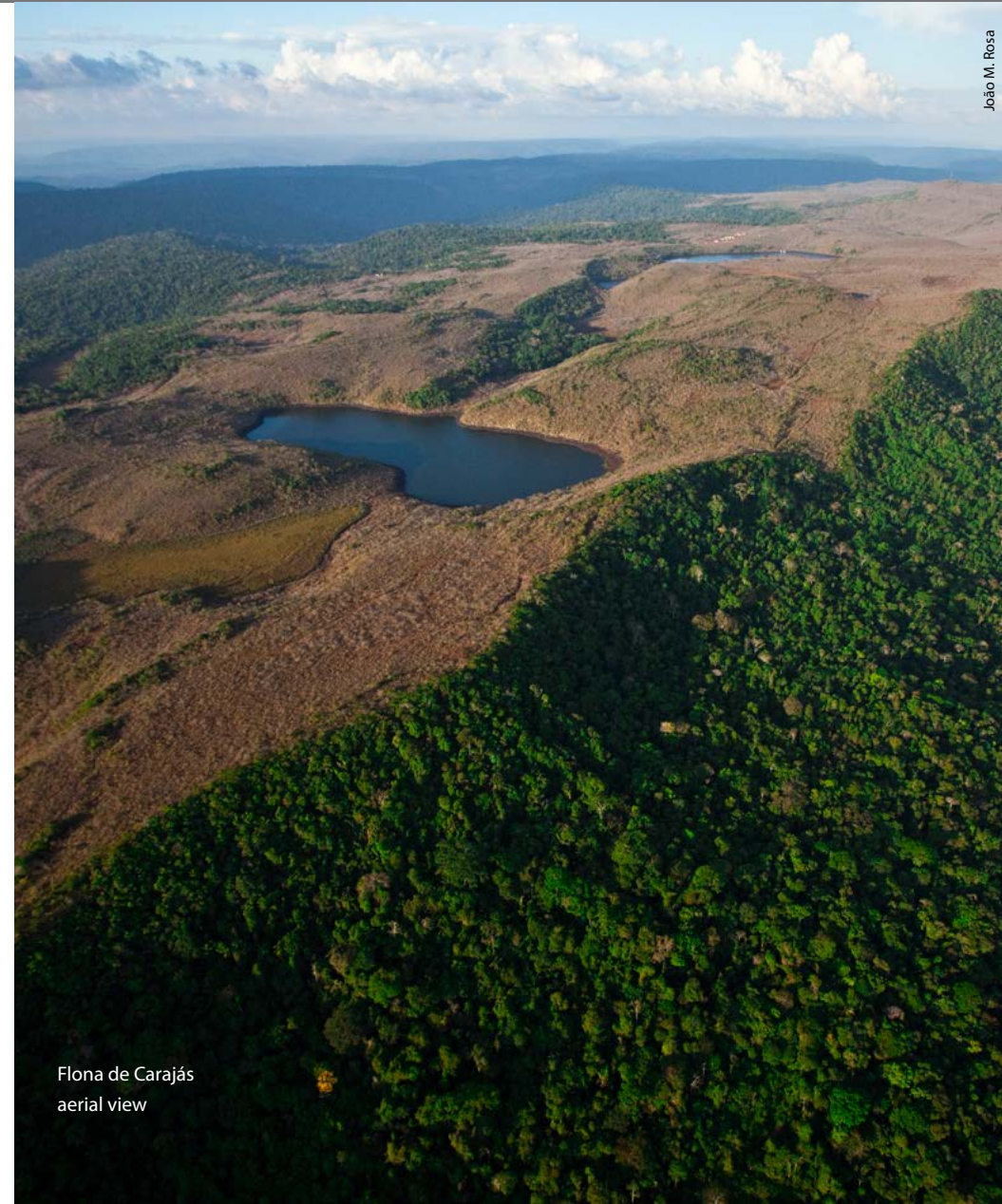
The Vale Institute of Technology (ITV):

an Initiative to Develop Research and Capacity Building in Sustainable Development



Background

Back in 2009, Vale created the Instituto Tecnológico Vale (ITV) with the mission of developing and organize knowledge towards responsible use of natural resources. In Belém, Pará State, Brazil, this scientific research institute generates knowledge in relevant topics for the maintenance of biological diversity and its interactions with economic and social aspects. As well as research, ITV is involved in capacity building through



Flona de Carajás
aerial view

its professional masters course entitled “Sustainable use of Natural Resources in Tropical Regions”, which aims to widen the competency of students in relevant themes for the sustainable development of the Amazon region.

The ITV has a team of around 100 researchers that act in the development of knowledge and solutions for the challenge of sustainable use of natural resources in the mining sector. The priority study themes are biodiversity, impacts of global change on biodiversity, environmental services, hydric resources, socio-economy, land occupation and use of soil, climate change, landscape genomics, amongst others. An extensive network of partners (science and technology institutes and universities) strengthens the role of ITV to produce highly renowned scientific research in its main areas. The knowledge and innovation generated by the institute are made available for the public as scientific publications in indexed, specialized journals.

One important axis of the work at ITV is to map biodiversity and its role in the ecosystem

services. The studies concentrate on flora and fauna of the areas of canga of the Floresta Nacional de Carajás, regions with rock dwelling vegetation in the middle of the Amazon forest. The molecular understanding of these species is used for quick identification and understanding of their functionality within the ecosystem. The identification of both plants and animal species increasingly uses DNA barcoding and genomic studies. Evolutionary mechanisms and the genetic diversity of the species and the study of soil micro-organisms as an important part of the environment are carried out through metagenomics and the isolation of species with interesting functions.

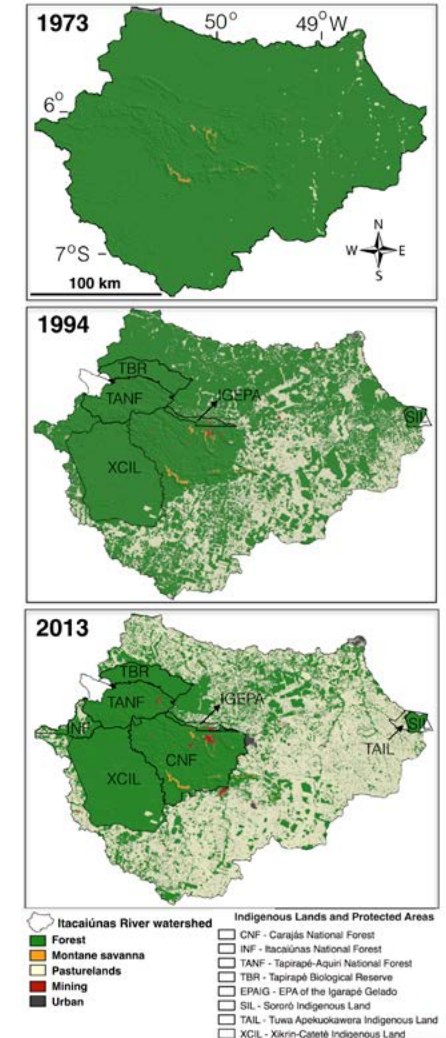
The ITV represents an innovative example of how mining can employ efforts to reduce the biodiversity knowledge gap in the Amazon region, a model to be applied elsewhere. Improving the multidisciplinary research on the local ecosystem functions and their services, it is possible to plan strategies for the natural resources use and conservation under the principles established by ICMN.

Main Achievements

ITV research, with a multidisciplinary approach is working to mainstream biodiversity and ecosystem services in mining activities, to provide scientific support for the Vale decisions related to one of their main goals, the life comes in first place.

The Institute is located in Para state and focusing research in Carajás National Forest, that can be partially used for mining activities and protection. The mining operation occurs in outcrop areas with a typical vegetation called iron canga. The research has many approaches applied to canga vegetation, fauna and ecosystem services. To highlight the impact of mining in nature use and conservation a careful study was done to compare the land coverage in last four decades, through satellite imagery. Half of the forests were converted in pastures. The preserved areas are found either within indigenous land or in parks and reserves.

Change in land cover and use maps for the Itacaiúnas river basin (Souza- Filho et al., 2016).



“ITV works to create options for the future through scientific research and development of technologies to expand Vale’s knowledge and business frontiers in a sustainable manner

Selected biodiversity cases are presented below. At this stage, in last four years a complete Flora of the Cangas in Carajas was done and published, ecosystem services related to biodiversity studied focusing pollinators and seed dispersals, the landscape analyzed to design and evaluated the best solutions for new corridors to connect natural areas in next future. Databases and niche modeling were essential tools used to evaluating the current distribution of animal and plants studied and their distribution under several scenarios under climate change. The caves were studied and our knowledge on their importance increased a lot with a collaborative research among several Vale branches and other partnerships.

A remarkable achievement was the use of genetic tools to evaluate populations and

communities. A large bank of DNA barcode was formed and applications are already resulting in good publications.

As a research and development private institution regarding to improve the sustainability of the mining activities, ITV also takes care of regional environmental and sustainability educational legacy. With the support of the master course that focuses mining activities and the drives of change that comes with this activity, also has a commitment to the scientific support for restoration. Our goal for this legacy concerning mainstreaming biodiversity is to work with local research and educational institutions, to improve knowledge with this partnership that will allow us to establish together the priorities for research in mining and biodiversity. We also consider the applications

of biodiversity knowledge in local communities, to improve their standard of life mainly at the next generations, for a sustainable future.

Strategic Alignments



Further information:

Vale Institute of Technology

josiane.martins@itv.org

sandoval.carneiro@vale.com

www.itv.org

DNA Barcodes and Genomics:

the Basis for Licensing and Conservation of Biodiversity

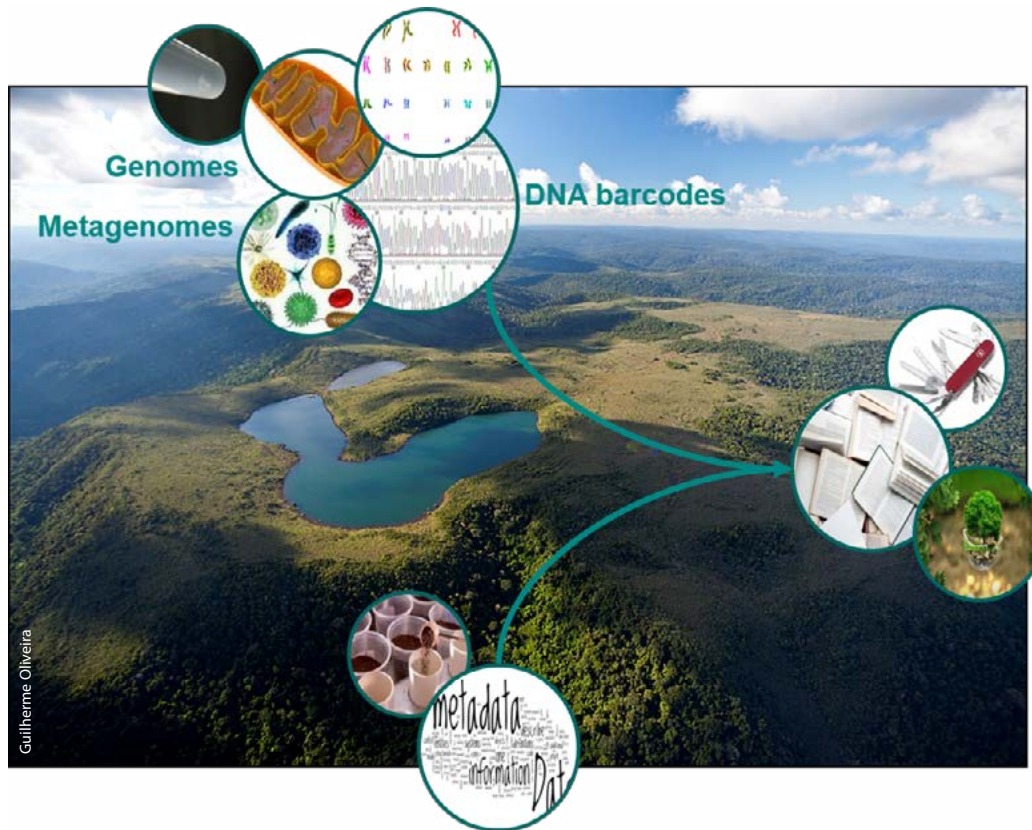
Summary of Action

Biodiversity assessment of species is usually based on their specific morphological characteristics. Conventional taxonomy, however, requires highly trained specialists to conduct a meticulous and time-consuming analysis, resulting in increased time and financial costs. Molecular tools can be used to aid in species characterization.

DNA barcodes are a short DNA sequence that has been implemented for species identification. The creation of a reference library for the flora of the ferruginous



DNA samples are collected in the wild from plants of known provenance and with voucher specimens deposited in the Herbarium at the Museu Paraense Emílio Goeldi



fields of the Carajás region, and for cave invertebrates, provides the opportunity for the deployment of molecular tools to assess and monitor the biodiversity in the region. The DNA barcode encapsulates

the taxonomist knowledge and provides a digital platform for species identification. Chloroplast and nuclear markers were used for the plant reference database and a mitochondrial marker for invertebrates.

“Molecular technologies advance biodiversity monitoring to the digital age: the use of DNA evidence for species identification and environment assessment

For challenging resolution species more in-depth genomic level information is produced. Accessory genomes (chloroplast for plants and mitochondria for invertebrates) provide more analytical power and have been utilized to determine species boundaries and evaluate the genetic profile of species. Considerably richer nuclear genome level data provide additional information.

The current production pipeline generates DNA barcodes for all specimens,

chloroplast or mitochondrial data for those that require higher resolution and nuclear genome-level information for selected species. Further developments include the use of environmental DNA (eDNA) coupled with deep DNA sequencing for biodiversity assessment using the local substrate (i.e. soil) instead of sampling the species directly. The deployment of the next generation of technologies will significantly lower costs and increase the speed of the process.

Main Achievements

To date over 10,000 DNA barcodes were produced for approximately 5,000 specimens. All plant and most invertebrate specimens have museum vouchers. The Carajás ferruginous fields region is the only flora in Brazil that has been fully characterized by DNA barcodes. A complete computational pipeline for real-time DNA barcodes production has been deployed. DNA sequence information, along with specimen data, are regularly uploaded to ITVBioBase that provides instant and automated analysis of the results. The information is routinely shared with public DNA databases. Several species have been resolved using accessory and nuclear genome data. eDNA has been tested and is currently being validated as an alternative and supporting methodology for conventional to morphology-based taxonomy.

Partners Involved

Museu Paraense Emílio Goeldi

Strategic Alignments



Further information

Instituto Tecnológico Vale

Guilherme Oliveira
(guilherme.oliveira@itv.org)



Climate Change:

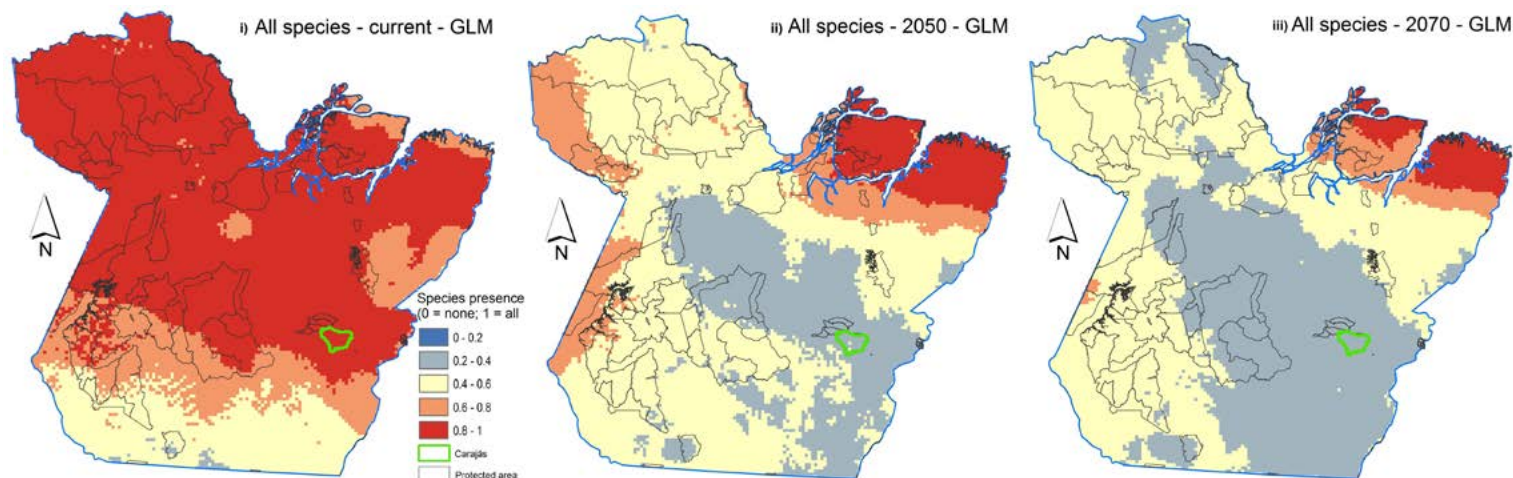
Potencial Impact in Ecosystem Services Providers in Carajás (Eastern Amazon)

Summary of Action

Anthropogenic climate change is one of the main current threats to biodiversity, because rainfall regimes and temperatures (the main determinants of species distribution) have changed at a much faster rate than species can adapt. In this context, certain species deserve to be highlighted because, due to their different dietary habits, they perform different functions in nature, acting as pollinators (nectarivores), seed dispersers (frugivores) and pest controllers (insectivores). The effects of climatic changes on the distribution of bats, birds and bees occurring in the Carajás National Forest



Sturnira lilium
E. Geoffroy



The potential impact of climate change was estimated on three main groups of ecosystem service providers (pollination and seed dispersal) in Carajás: bats, birds and bees. The maps above show the potential occurrence of bat species in the current scenario (i), 2050 (ii) and (iii) 2070. Areas with warmer colors (red) are suitable areas for most species. (Costa, W.F. et al., 2017)

(Eastern Amazonia, southeastern Pará state) were examined. A total of 590 birds, 210 bees and 80 bats were analyzed. We considered the projections for different future scenarios to answer: (i) Which species are most sensitive to climate change and may not find suitable areas in Carajás in the future? (ii) What are the priority areas in the state of Pará that protect the largest number of species from climate change?

Main Achievements

Bats and frugivorous birds (seed dispersers) will be the potentially most affected, as well as bees of small and large size. Potentially more suitable areas are located in the north and west of Pará and are under varying degrees of conservation, from well preserved protected areas to areas degraded by different anthropogenic impacts, especially agriculture and livestock. Potentially, Carajás will be a place that is not suitable climatically for bees and bats,

protecting a few species in the future. However, for birds, it will be an essential place, protecting many species. Next steps consist of analyzing the flora species. This work emphasizes that the location of species protection areas needs to be analyzed in conjunction with the potential effect of climate change to ensure that areas that act as climate refuges for species in the future are protected. Besides it can guide compensation projects, indicating priority areas to protect species from ongoing climate change.

Partners Involved

Escola Politécnica da Universidade de São Paulo

Strategic Alignments



Further information

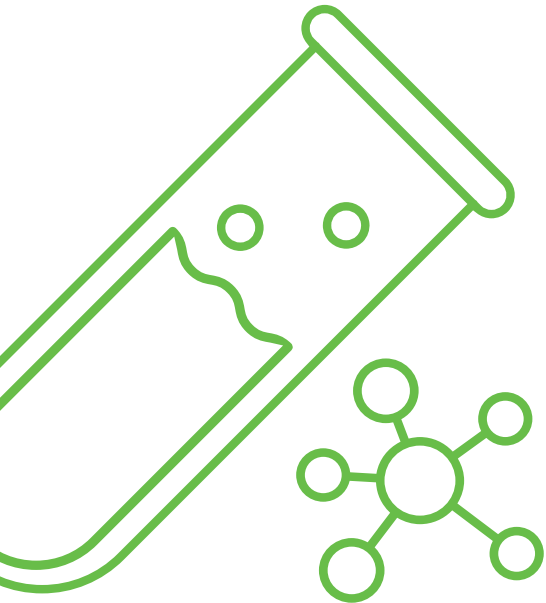
Instituto Tecnológico Vale

Tereza Cristina Giannini
(tereza.giannini@itv.org)

Antonio Mauro Saraiva
(saraiva@usp.br)

Evolutionary Genetics

for Conservation Management



Summary of Action

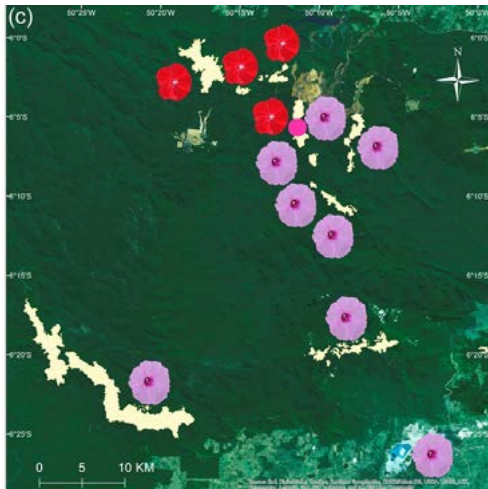
The process of natural selection acts on standing phenotypic variation in the species, increasing their Darwinian fitness in environments that evolve in space and time. The survival of species by adaptation to changing environments critically depends on phenotypic variation that can be generated by mutations and interspecies hybridization both in plants, animals and microorganisms. Natural selection in combination with establishments of reproductive barriers results in the origin of new species, the process of speciation. Thus, (i) to lower species extinction rates; and (ii) conserve species evolving ability under climate change, the overarching goal of our research is to incorporate principles of evolutionary



The narrow endemic Flor-de-Carajás (*Ipomoea cavalcantei*) is being studied from the point of view of its genetics

“Nothing in Biology Makes Sense Except in the Light of Evolution”

Theodosius Dobzhansky



Distribution of *Ipomoea cavalcantei* (red flower) and *I. marabaensis* (blue flower) in Carajás canga



CANGA Evolution in Action. What should be found, identified, preserved and understood?

theory into biodiversity conservation management. Our focus species is a morning glory *Ipomoea cavalcantei*, known as flor de Carajás. The species is a narrow endemic that populates canga savannah islands, collectively measuring 20 square kilometers in Floresta Nacional de Carajás, Pará, and a critically endangered in Carajás. To develop conservation strategies, we address such questions as: what is a role of *Ipomoea cavalcantei* in canga ecosystems; what are the mechanisms that prevent the spreading of the species to other cangas; what are the sources of phenotypic variation and can we prioritize observed traits concerning to the future species evolutionary success; how to apply this knowledge to preserve *Ipomoea cavalcantei*?

Main Achievements

Our research showed that *I. cavalcantei* is self-incompatible, i.e. allogamous, species that depends on interactions with pollinators for

its reproduction. The species produces large amounts of nectar to reward pollinators, between 30-80 μL per flower, one of the largest of all Brazilian plant. We show that this nectar store supports numerous species of animals, amongst which hummingbirds, honey bees, solitary bees are most likely pollinators of the species. *I. cavalcantei* readily hybridizes with a closely related *I. marabaensis* in nature. Furthermore, the interspecies hybrids are fertile, produce both viable progeny and, rather unexpectedly, functional pollen. Molecular studies of nuclear genome strongly suggest that interspecies hybridization makes a significant contribution to the generation of variation in flower shape and color, and leaf morphology in Carajás morning glories, thus increasing species plasticity and adaptability to environmental changes. We propose that evolutionary significant molecular variation is more relevant to the conservation management; is easier to measure, offering more economically viable ecosystem monitoring solutions.

Partners Involved

Museu Paraense Emílio Goeldi (MPEG).

Strategic Alignment



Further information

Instituto Tecnológico Vale

Elena Babiitchouk
(elena.babiitchouk@itv.org)

Departamento de Ferrosos Corredor Norte, Gerência de Meio Ambiente

Alexandre Castilho
(alexandre.castilho@vale.com)

Babiychuk, E. et al. 2017. Natural history of the narrow endemics *Ipomoea cavalcantei* and *I. marabaensis* from Amazon Canga savannahs. Scientific Reports 7: 7493, DOI:10.1038/s41598-017-07398-z

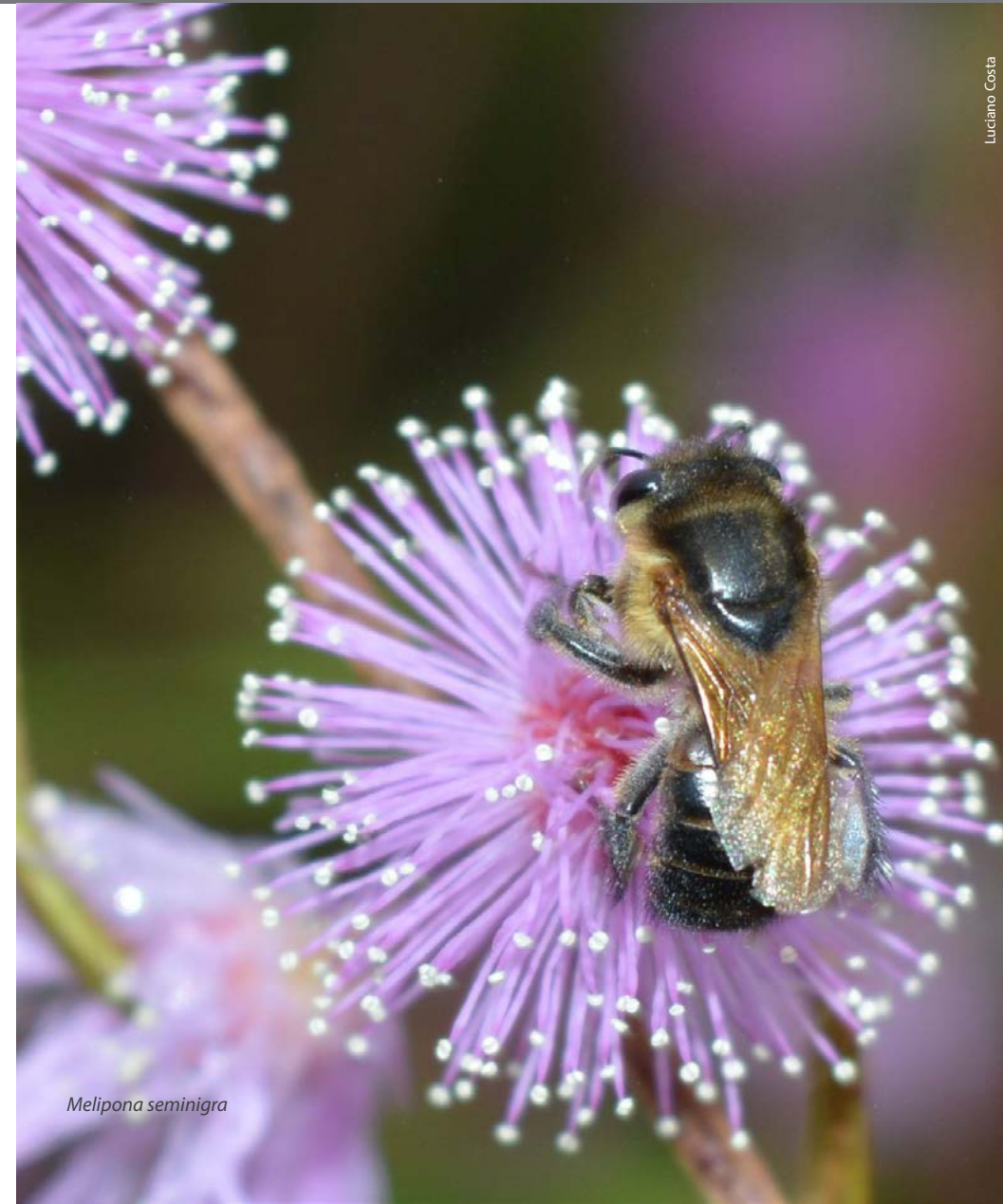
Native Bees of Carajás:

Diversity, Biomonitoring and Income Support for Local Population



Summary of Actions

The Amazon is very rich in species of native bees, still little studied. However, these bees are vital for the maintenance of the forest, through the pollination of most of the plants of economic importance, such as açai, brazil nuts, guaraná, cupaçu, and others. To date 215 bee species were collected and identified in Carajás. Some of these species of social bees, the stingless bees, also known as Meliponini, produce a delicious honey that has great utility as a remedy and as an exceptional food, a sugary natural source. Most canga plants have bees as their primary pollinators. The value of this service was estimated



Melipona seminigra

using INVEST, for Serra da Bocaina. Some species have the potential already valued as important pollinators, and also a great ability to explore a wide area in the environment in which they live.

Main Achievements

The work with Carajás bees involved annual surveys of flowers visited, interaction networks between bees and canga plants, analysis of the food collected by bees to identify the floral resource used by them as a food source, analysis of the geographical distribution of bees and the impact of climatic changes on this distribution in the future, the use of bees as environmental monitoring with identification of radio frequency labels, more accurate assessment of the flight range of some species and the study of the possibilities of breeding these bees in large scale for use in agriculture and in communities for income support. With the list of species of bees that occur in Carajás in hand and the map of their geographical distribution it was possible to prioritize future activities and separate the best options to initiate a process of income generation for communities and other entrepreneurial initiatives, based on the knowledge accumulated in these years.

As relevant results we have the biomonitoring with RFID tags in the native bees of Carajás (*Melipona fasciculata* and *Melipona seminigra*), arranged in apiaries, which evidenced the high capacity to monitor the environment in distances never before suggested (10,000 m for *M. fasciculata*) and return to the nest, where the nectar of the flowers sampled by the bees and the collected pollen are stored. Beekeepers have managed these species of bees in the vicinity of Carajás, so a training project in meliponiculture and selection of quality and sanity of their nests will be implanted soon. Several meliponiculture projects have been implemented in Brazil, but a model with support for conducting business, developing the production chain and sanitation certification does not yet exist.

Partners Involved

Departamento de Ferrosos Corredor Norte,
Gerência de Meio Ambiente
Embrapa

“Animal pollination plays a vital role as a regulating ecosystem service in nature and in food production

Strategic Alignments



Further information:

Instituto Tecnológico Vale

Vera Lucia Imperatriz Fonseca
(vera.fonseca@itv.org)

Luciano Costa
(luciano.costa@itv.org)

Departamento de Ferrosos Corredor Norte, Gerência de Meio Ambiente

Alexandre Castilho
(alexandre.castilho@vale.com)



Valuation of Pollination Services in Protected Areas:

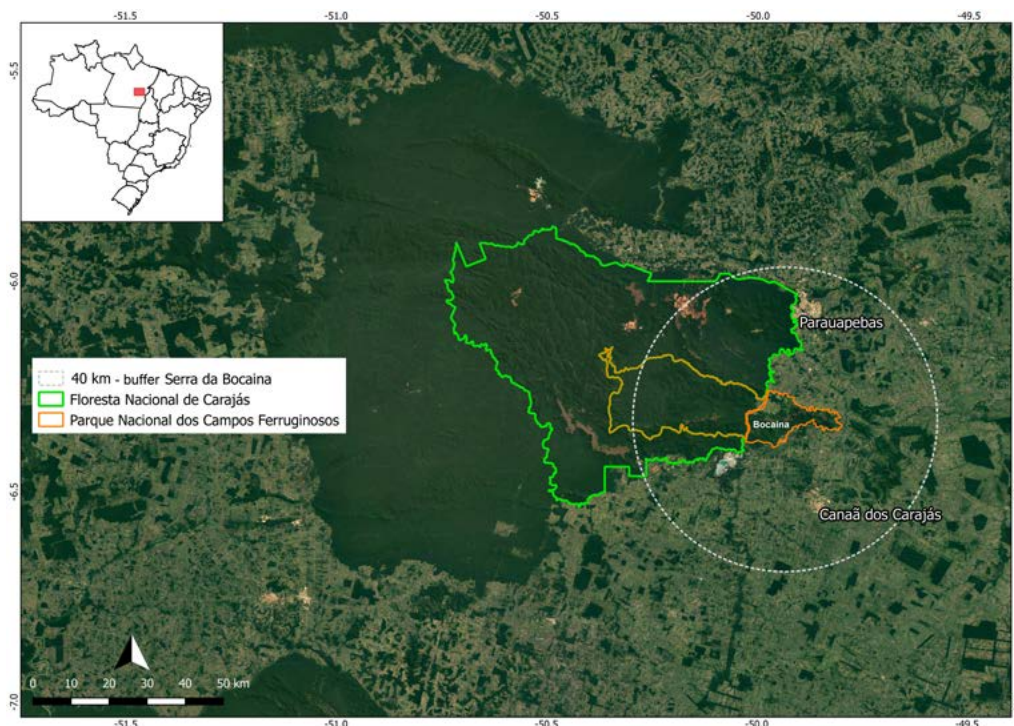
the Case of Bocaina and Jambreiro Nature Reserves in Brazil

Summary of Action

The valuation of ecosystem services is an important strategy for decision makers given the growing need to reconcile biodiversity with conservation measures. To analyze the pollination services in two protected areas (PAs), two valuation methodologies, one monetary and one non-monetary, were combined. The PAs are located in the Brazilian north (Serra da Bocaina in the National Park of Campos



Brazil nut flowers need pollination by large bees to produce fruits



The value of the pollination service was estimated in agricultural areas located around two protected areas. This figure shows the buffer zone of 40km around the Serra da Bocaina, part of the Parque Nacional dos Campos Ferruginosos (Pará, Eastern Amazon, Brazil). This protected area is a compensation for mining occurring inside the Floresta Nacional de Carajás. (Tereza Cristina Giannini)

Ferruginosos Park, Pará) and southeast (Natural Reserves of Mata do Jambreiro, Minas Gerais), in forested areas, respectively in the Amazon and Atlantic Forest biomes. For the monetary valuation a methodology

was used that considers the contribution of pollination in the crops produced in the PA vicinities. For the non-monetary valuation, the software InVEST (Integrated Valuation of Environmental Services and Tradeoffs) was

used, which considers the spatial context of the occurrence of pollinators, the plants visited by them and the places available for nesting.

Main Achievements

For Serra da Bocaina, the monetary value of the pollination services for agriculture in the surrounding municipalities executed by bee species was estimated at approximately US\$3.6 million for the year 2016. For Mata do Jambreiro, it was equivalent to US\$ 1 million for the same year. Non-monetary valuation has emphasized the areas around PAs, especially agricultural ones, that can benefit from the presence of pollinators. Thus, both methodologies integrate the diversity of bees and the composition of the natural vegetation of the APs with the characteristics of the surrounding landscape, including the agricultural production of the neighboring municipalities. Such an approach demonstrates that the scale, resolution, and land use of PAs and their surroundings influence outcomes, which has a direct implication on decision making. Although the studies with the theme presented here are scarce, this

work demonstrates where the efforts can be concentrated for future propositions of valuation of pollination services and strategies of management and conservation.

Partners Involved

Environmental Licensing and Speleology Vale

Strategic Alignments



Further information

Instituto Tecnológico Vale

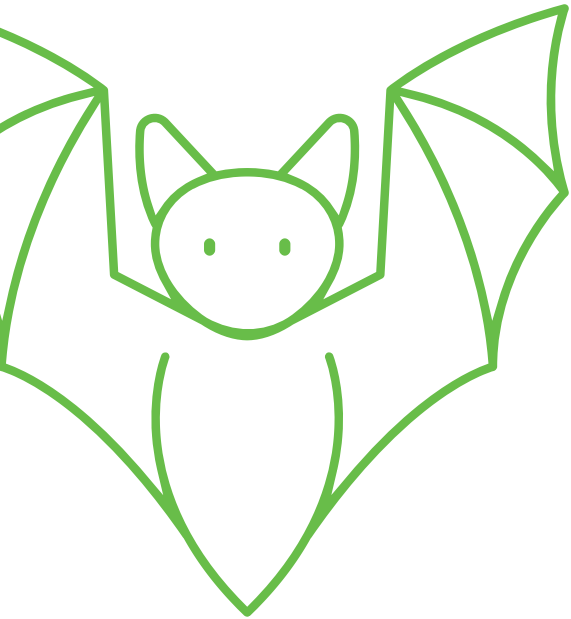
Tereza Cristina Giannini
(tereza.giannini@itv.org)

Ferrous Environmental Licensing Management

Sergio Dias

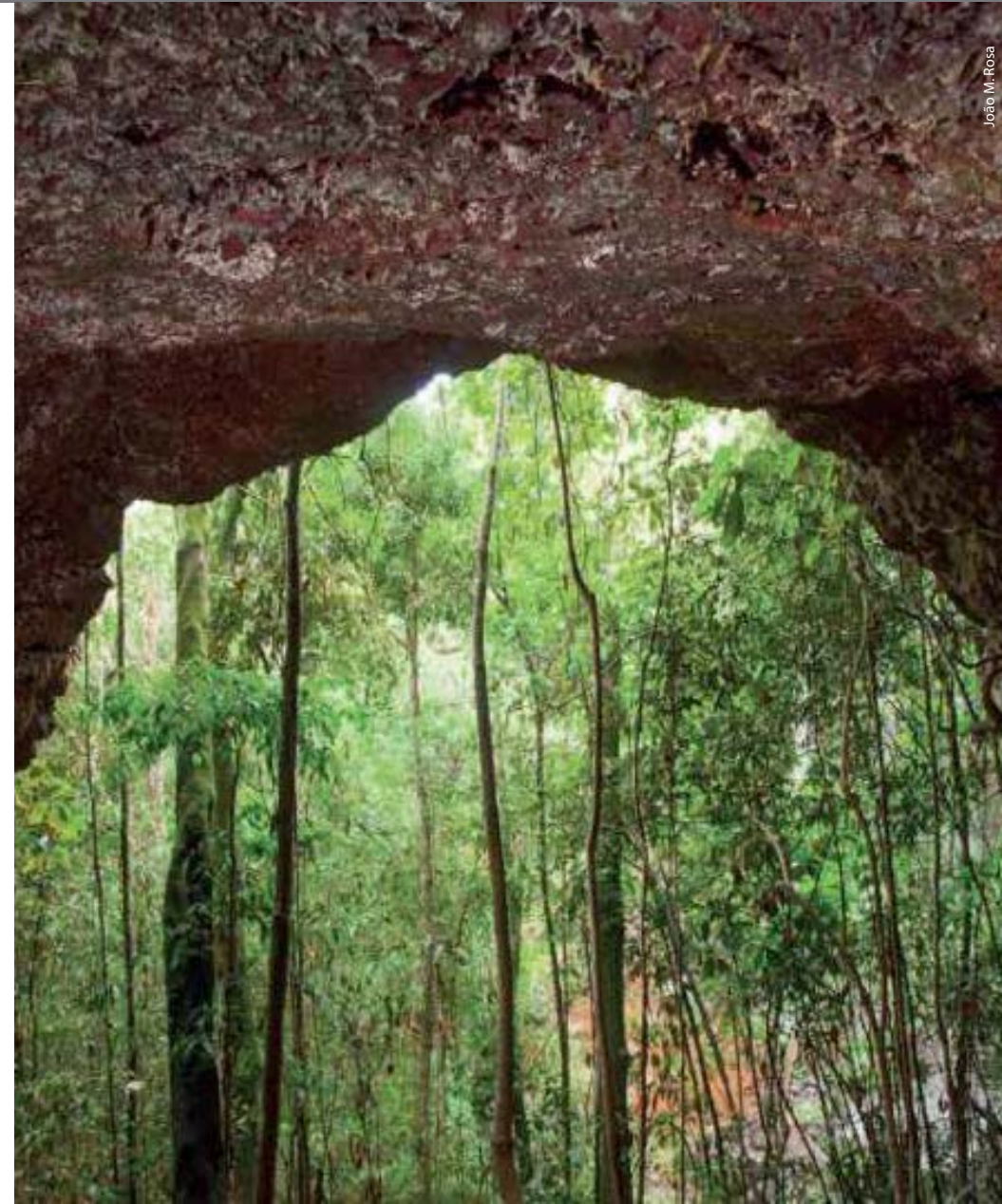
Reconciling Mining

with the Conservation of Cave Biodiversity



Summary of Action

Caves pose significant challenges for mining projects, since they harbor many endemic and threatened species, and must therefore be protected. While the licensing process is long, complicated and cumbersome, the criteria used to assign caves into conservation relevance categories are often subjective, with relevance being mainly determined by the presence of obligate cave dwellers (troglobites) and their presumed rarity. However, the rarity of these troglobitic species is questionable, as most remain unidentified to the species level and their habitats and distribution ranges are poorly known. Using data from



844 iron caves retrieved from different speleology reports for the Carajás region (South-Eastern Amazon, Brazil), one of the world's largest deposits of high-grade iron ore, one of our research projects (Jaffé et al. 2016) assessed the influence of different cave characteristics on cave biodiversity indicators (species richness, presence of troglobites, presence of rare , and presence of resident bat populations), and then examined how the current relevance classification scheme ranks caves with different biodiversity indicators.

A later initiative (Jaffé et al. 2018) then employed data from comprehensive and curated lists of troglobitic taxa occurring in 473 iron caves from Carajás, to assess the influence of cave characteristics and the surrounding landscape on troglobitic communities and quantify how different landscape features influence the connectivity between caves. Finally, innovative DNA-barcoding tools were used to help identify plant species contributing biomass to iron caves, as roots are known to be key predictors of cave biodiversity.

Main Achievements

These studies reveal the critical importance of habitat amount, guano, water, lithology, geomorphology, and elevation in shaping iron cave troglobitic communities. Species composition, species richness, phylogenetic diversity, and the occurrence of troglobites showed spatial autocorrelation, suggesting some level of underground connectivity. They also show that by prioritizing the conservation of rare troglobites, the current relevance classification scheme is undermining overall cave biodiversity and leaving ecologically important caves unprotected. The proposed alternative relevance ranking scheme could help simplify the assessment process, and channel more resources to the adequate protection of overall cave biodiversity. More generally, this body of research sheds important light onto one of the most overlooked terrestrial ecosystems, and highlights the need to shift conservation efforts from individual caves to subterranean habitats as a whole.

Partners Involved

Environmental Licensing and Speleology Vale

xavier.prous@vale.com

Vale Institute Technology

rodolfo.jaffé@itv.org

Strategic Alignments



Further information

Ramalho AJ, Zappi DC, Nunes GL, Watanabe MT, Vasconcelos S, Dias MC, Jaffé R, Prous X, Giannini TC, Oliveira GC, Giulietti AM (2018) Blind testing: DNA barcoding sheds light upon the identity of plant fragments as a subsidy for cave conservation. *Front. Plant Sci.* | doi: [10.3389/fpls.2018.01052](https://doi.org/10.3389/fpls.2018.01052)

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Credits

Alberto Ninio

Sustainability Director

Gleuza Jesué

Executive Manager of Environmental Management

Patrícia Daros

Biodiversity and Environmental Recovery Manager

Richardson Costa Faria

Recovery of Degraded Areas and Mine Closure Manager

José Oswaldo Siqueira

Scientific Director - Vale Institute of Technology Sustainable Development

Vera Lucia Imperatriz Fonseca

Senior Researcher, Head of Biodiversity and Ecosystem Services

Organization

Letícia Souza Lima Guimarães
(Biodiversity and Environmental Recovery)

Vera Lucia Imperatriz Fonseca
(Vale Institute of Technology)

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