An Acad Bras Cienc (2021) 93(2): e20201604 DOI 10.1590/0001-3765202120201604
Anais da Academia Brasileira de Ciências | *Annals of the Brazilian Academy of Sciences*
Printed ISSN 0001-3765 I Online ISSN 1678-2690
www.scielo.br/aabc | www.fb.com/aabcjournal

ECOSYSTEMS

The Program for Biodiversity Research in Brazil: The role of regional networks for biodiversity knowledge, dissemination, and conservation

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Abstract: The Program for Biodiversity Research (PPBio) is an innovative program designed to integrate all biodiversity research stakeholders. Operating since 2004, it has installed long-term ecological research sites throughout Brazil and its logic has been applied in some other southern-hemisphere countries. The program supports all aspects of research necessary to understand biodiversity and the processes that affect it. There are presently 161 sampling sites (see some of them at Supplementary Appendix), most of which use a standardized methodology that allows comparisons across biomes and through time. To date, there are about 1200 publications associated with PPBio that cover topics ranging from natural history to genetics and species distributions. Most of the field data and metadata are available through PPBio web sites or DataONE. Metadata is available for researchers that intend to explore the different faces of Brazilian biodiversity spatio-temporal variation, as well as for managers intending to improve conservation strategies. The Program also fostered, directly and indirectly, local technical capacity building, and supported the training of hundreds of undergraduate and graduate students. The main challenge is maintaining the long-term funding necessary to understand biodiversity patterns and processes under pressure from global environmental changes.

Key words: Biodiversity, Long-term Ecological Research, stakeholders, knowledge production, data availability, capacity building.

INTRODUCTION

Tropical ecosystems hold more than two-thirds of the world's biodiversity (Raven 1988), maintaining ecological functions and services needed for human health and global environmental quality (Kilpatrick et al. 2017). At the same time, most tropical ecosystems are in countries with high social vulnerability and, therefore, with few resources devoted to research and practical biodiversity conservation. This situation led to concerted international attention focused on reducing natural-habitat conversion and halting global biodiversity and ecosystem-service losses by strengthening local communities. International biodiversity-conservation agreements, such as the Convention on Biological Diversity and the 2030 Agenda for Sustainable Development, require that signatory countries monitor and report their progress towards established goals. Although most of this monitoring uses ex-situ metrics (e.g., remote sensing), long-term, systematic, and standardized in-situ biodiversity-monitoring data are needed to understand long-term patterns of biodiversity change and its drivers. This approach could help to improve the assessment of progress towards biodiversity conservation agendas (Lindenmayer & Likens 2010a, Geijzendorffer et al. 2016, Proença et al. 2017, Bayraktarov et al. 2019).

In-situ biodiversity-monitoring systems have a clear connection to policy and management, and the potential to contribute substantially to reducing the research-implementation gap in conservation science (Fazey et al. 2005, Cook et al. 2010, Karam-Gemael et al. 2018), and is the best way to circumvent well-known shortfalls that prevent large-scale understanding of biodiversity (Hortal et al. 2015). With this perspective, the Program for Biodiversity Research (PPBio) was created in 2004. Linked to the Brazilian Ministry of Science, Technology, and Innovation (MCTI), the PPBio is a program that aims to expand and disseminate knowledge of Brazilian biodiversity. Hence, PPBio is a network organized into regional and local hubs in all Brazilian biomes, and its scope is to integrate academic institutions with stakeholders, researchers in regional centers, indigenous groups, non-indigenous traditional owners, farmers, foresters, fishermen, and hunters. The Program aims to foster biodiversity studies in Brazil, reduce regional inequalities in scientific research, integrate research activities, and disseminate knowledge to promote environmental management and education. PPBio did not replace existing programs and projects on biodiversity, and indeed the resources were much more limited than those of other biodiversity-research initiatives. The goal was to enhance the use of resources from various Brazilian ministries and the private sector to create scientific knowledge-production chains on biodiversity that would meet the demands of different segments of society.

In this paper, we present the history, structure and main results of the PPBio and perspectives of in-situ biodiversity monitoring. We also show how the program enables studies at different scales integrating different interfaces of the environment (e.g., biosphere and anthroposphere) and the implementation of conservation actions in some of the most biologically diverse areas of the world.

PPBIO: AN INTEGRATED BIODIVERSITY PROGRAM

Forging an integrated research network

Public concern about natural resources and environmental conservation has increased since the last century, culminating in the United Nations Conference on Environment and Development in Rio de Janeiro (Rio-92

- Earth Summit). During Rio-92, Brazil and other countries led efforts to establish goals to prevent erosion of biodiversity and associated environmental services. To advance the implementation of the goals of the Convention on Biological Diversity, the MCTI organized a series of meetings with the main actors involved with Brazilian biodiversity. These meetings revealed that the country's infrastructure for biodiversity studies was poorly dimensioned and distributed with geographical biases. After two years of discussions to determine the best form of action, the MCTI created the PPBio, which formally started in 2004 (MCTI act no. 268, 18th July, 2004).

Due to limited resources, the first PPBio research networks were established in Amazonia and the Caatinga (the semi-arid region in northeastern Brazil), where extensive gaps in biodiversity knowledge existed. Even though there were no specific resources for other biomes (sensu IBGE 2004), the experience obtained was used by the MCTI to plan activities of the Research Center in the Pantanal (CPP) and the Research Network for Sustainable Use and Conservation of the Cerrado (COMCERRADO). Despite the modest budget, the program was highly successful, and MCTI recognized its national and international influence. In 2012, a second call was made for applications of additional projects in other biomes, such as Atlantic Forest, Cerrado and Pampa.

The PPBio supported regional and local hubs. At the beginning of 2004, there were two regional hubs, one in Manaus (Instituto Nacional de Pesquisas da Amazônia) that covers western Amazonia, and the other in Belém (Museu Paraense Emílio Goeldi) responsible for research in eastern Amazonia. Within these regional groups, local hubs were established in other Amazonian states. The program had three primary components: inventories, scientific collections, and thematic projects. Inventories aim at structuring the experimental design, the choice of research areas and strategies, the establishment of sites for carrying out surveys and long-term monitoring biodiversity, and the development of sampling protocols for different biological groups. The collections component involved identifying vouchers in existing collections, surveying demands for infrastructure and institutional support, defining curatorial protocols, exchanging and sharing material, identifying knowledge gaps, and qualifying and digitizing collections. For example, the exsiccates from around 1600 plants collected in the RAPELD modules are available online at JABOT (http://rb.jbrj.gov.br). In turn, ecological data are available on DataOne (https://www.dataone.org/) and PPBio is a SiBBr data provider (https://www.sibbr.gov.br/page/provedores-de-data.html).

The thematic component focused on integrating local demands and research, such as screening biomolecules for pharmaceutical or medicinal uses. All involved the training of human resources, strengthening regional centers, creating and supporting the development of graduate programs, and offering research opportunities for students and local researchers. With the present emphasis on integration, the Program was expanded to include other biodiversity-related activities. In 2012, PPBio aggregated two new components: data management and information, and the synthesis of knowledge promoting scientific dissemination, decision-making and the formulation of public policies. It was recognized as the National Biodiversity Monitoring Program by the MCTI, with a structured network connecting research and biodiversity agendas in all terrestrial Brazilian biomes: Amazonia, Cerrado, Atlantic Forest, Caatinga, Pantanal, and Pampa.

Core and Regional Hubs

To guarantee the functionality of biodiversity monitoring at a national scale, PPBio promoted a network of regional and local hubs that involve a consortium of local stakeholders in biodiversity in all aspects of the research. The PPBio is structured with both horizontal and vertical networks that form a biodiversity knowledge-production chain. This chain depends on many different experts, including traditional landowners, indigenous people, field biologists, geneticists, physiologists, law-enforcement and educational institutions, and private companies. The production chain involves (1) field data collection to assess distribution patterns and abundance; (2) evaluation of social relationships with biodiversity and knowledge production; (3) evaluation of the economics of production for scientific and economic chains; (4) analysis of the relations with policy and governance; and (5) market assessments for commercial solutions and products based on biodiversity and natural resources.

Today, PPBio has 161 data-collection sites in Brazil, including 63 sites in protected areas (Figure 1, Supplementary Material - Table SI). Site administration comprises nine core hubs: Western Amazonia; Eastern Amazonia; Semi-arid, South Brazilian grasslands (including sites in the Pampa and the highland grasslands in the south of the Atlantic Forest), Pantanal; two cores in the Cerrado, and two cores in the Atlantic Forest (Table SI). Hubs and sites cover a wide range of Brazilian ecosystems, including primary and secondary lowland and montane forests, savannas, grasslands, wetlands, and arid environments.

Importantly, PPBio does not usually provide funding for installing field infrastructure, and most hubs are not self-sufficient in terms of research ability and financial resources to study all aspects of biodiversity and the ecosystem processes that affect it. However, there is enormous potential for collaboration among the research groups. The infra- and scientific structure provided is recognized by state funding agencies, private companies, technicians responsible for reserves, and government agencies responsible for environmental-impact assessments. Hence, local hubs can obtain funding to integrate with other such hubs and developed regions that have more resources.

In general, the hubs are structured to (a) support the maintenance of sampling sites, (b) develop scientific strategies aimed at integrated management of interdisciplinary research, (c) use standardized methods for surveys and monitoring of biodiversity, (d) conduct studies on vegetation structure, carbon stocks, climate change, fragmentation and hydrological resources in long-term ecological sites, (e) organize studies of biodiversity and the factors that affect it at different spatial and temporal scales, (f) assist in the restructuring and modernization of biological collections, (g) contribute to the development of genetics applied to biodiversity, (h) contribute to bioprospecting associated with regional biodiversity, (i) build support for human-resources training at different levels, including local communities and researchers, (j) support database preparation, and production and integration of biodiversity data, as well as, (k) produce outreach and dissemination materials on Brazilian biodiversity.

Sampling: RAPELD and alternatives for gathering comparable biodiversity data

Long-term ecological research sites have greatly aided our understanding of ecosystem processes worldwide and many biodiversity monitoring systems have been developed in recent years (Craine et al. 2007). However, they are generally small, focus on a limited number

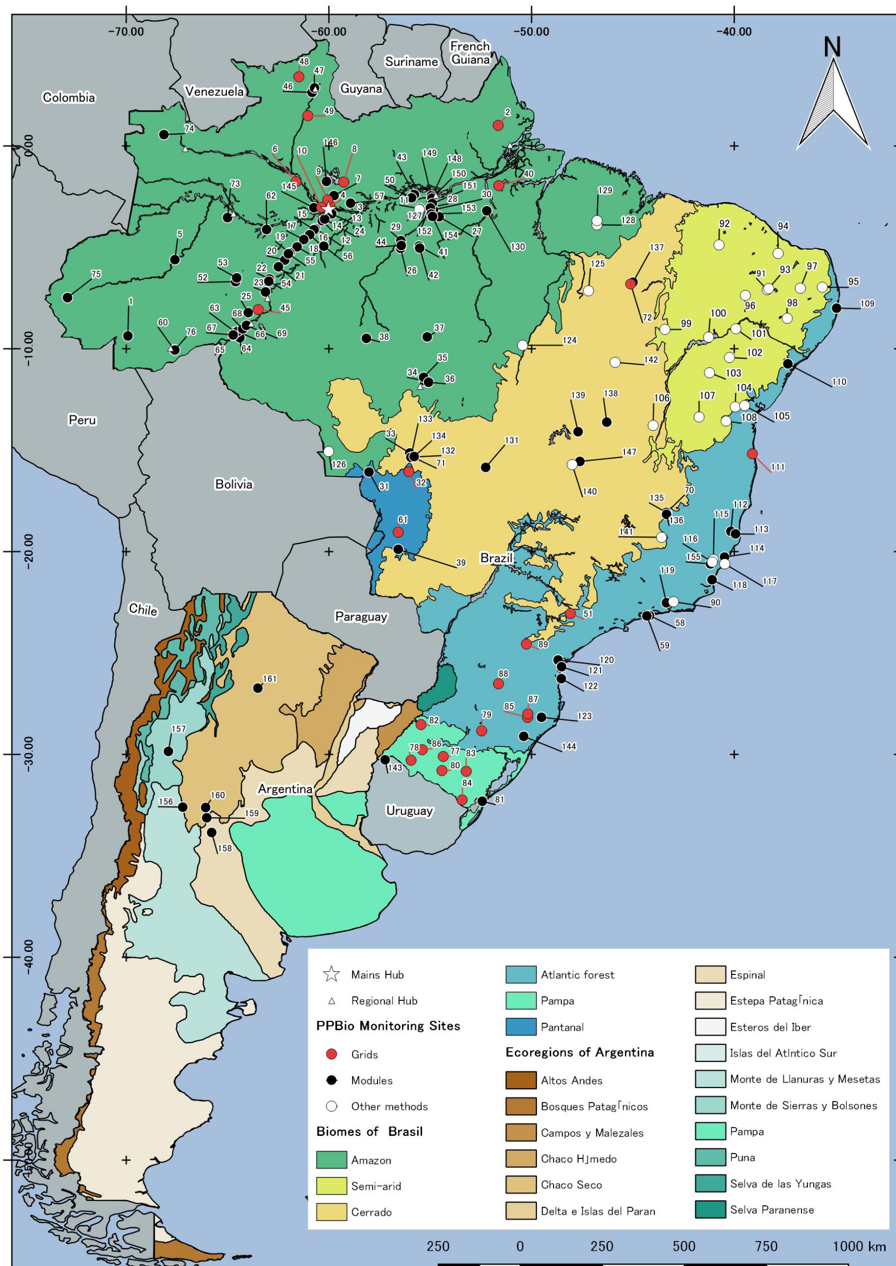

Figure 1. Sampling sites of the Brazilian and the Argentine Program for Biodiversity Research networks. See the identification and coordinates of each site in Table SI.

of taxa (e.g., the CTFS 50-ha plots, Anderson-Teixeira et al. 2015), or are arbitrarily selective in the landscape features they sample (e.g., TEAM plots, Rovero & Ahumada 2017). While these initiatives are excellent for examining local processes, they generally do not provide the sort of data required by land managers or politicians (but see Forest plots 2020).

In this scenario, some hubs adopted the RAPELD system as sampling method. The RAPELD system consists of a combination of trails and permanent plots for standardized surveys and monitoring of biodiversity and ecosystem processes (Magnusson et al. 2005, Figures S1, S2). The RAPELD system grew out of the Brazilian Long-term Ecological Research Program (Costa et al. 2015) and developed within PPBio

(Magnusson et al. 2013). The impetus to develop the system grew from land managers' demands for a standardized monitoring system that was landscape-oriented, rather than taxonomy-oriented. It would provide the data required by many different biodiversity stakeholders, such as local communities, wildlife managers, foresters, farmers, managers of protected areas, catchment-management authorities, local councils, and politicians.

RAPELD attempts to meet the need for rapid surveys while providing the infrastructure necessary for long-term research. It had to be relevant to all scientists doing basic research, such as ecologists and taxonomists, and of use to local groups (e.g., local communities, protected-area managers) that need to integrate biodiversity and ecosystem processes into their daily living (Gotelli 2004). RAPELD attempts to meet the following criteria: (1) be standardized; (2) allow integrated surveys of all taxa; (3) be large enough for monitoring all elements of biodiversity and ecosystem processes; (4) be modular to allow sampling of small areas and comparisons with small samples taken over extensive areas; (5) be compatible with existing initiatives; (6) be implementable with the existing human resources; (7) make data available quickly and in a usable form to managers and other stakeholders; (8) allow long-term monitoring. Extension, grain, and taxonomic groups are defined to address specific questions, focusing on the interplay between spatial and temporal scales (Wiens 1989). The standardized methods used in RAPELD can return information at the landscape scale, so it is of use to municipal, state, and federal decision-makers and allows comparisons across biomes and ecosystems, countries, and continents. Its primary components are conventional and easily installed, and many sampling procedures can be conducted by traditional people and technicians with little experience of complicated laboratory or statistical analyses. RAPELD does not provide the questions, rather it provides spatial standardization so that questions can be answered in an integrated manner at scales relevant to land managers.

Besides Brazilian hubs and sites, the RAPELD protocols were adopted in Australia, Nepal, and Argentina. Studies started in Argentina in 2014, in collaboration with PPBio Atlantic Forest. Currently, there are six sites throughout central semi-arid Argentina (Figure 1; Table SI). They are distributed in localities with different ecological conditions, following local and regional heterogeneity. In Australia, the first RAPELD sites were established in 2007 (Hero et al. 2010). To date, five sites in Australia have RAPELD modules (Table SI), covering dry eucalypt forest, semi-arid shrubland, coastal wallum heath, lowland forest, and grasslands. The value of the RAPELD sites in Australia is apparent in the dissertations and publications on ecosystem management, monitoring, and the protection of threatened species (Lollback et al. 2017).

Besides this, some studies developed by PPBio partners have designs based on specific goals and themes, such as climate change, changes in land-use and land-cover, and disease ecology that do not use RAPELD. As with the studies that use RAPELD methodology, they are developed with goals, objectives, and specific questions to be answered, as suggested by Lindenmayer & Likens (2010b) and Gardner (2012).

Data Management

Data management is the basis of communication between data collected by researchers and society. However, most scientific data are in office drawers or not fully used by researchers (Huang & Qiao 2011). PPBio has a particular concern for sharing information to expand the results and use them at different local, regional, and national scales, or even to respond to ecological issues of international interest. Also, much of the program´s financial resources come from public funding sources, and the data is of public interest. Therefore, PPBio works with an online and public data-management system, where researchers are encouraged to deposit their field data and metadata in publicly available repositories. The Program also invests in capacity-building courses for data management. One of its executive hubs is currently the only node in South America for the international data consortium known as Data Observation Network for Earth (DataONE).

The PPBio data repositories contain data collected in the field, videos, and photos, following the principle that all collected information must be adequately documented in the form of metadata, associated with the respective set of validated data, and made available on a website with free access. The metadata present in repositories follows the EML standard (Ecological Metadata Language, http://knb.ecoinformatics.org/software/eml/; Fegraus et al. 2005), developed by the Knowledge Network for Biocomplexity (KNB, http://knb.ecoinformatics.org/index.jsp), an international network that aims to integrate data from various collection sites, laboratories and researchers. They are organized as follows: title and summary, key-words, owner, contact, associated parties, research project, use rights, geographic coverage, temporal coverage, taxonomic coverage, methods, access information, data files, and information on the attribute table.

The PPBio also works in collaboration with international consortiums, such as RAINFOR, ADTN and ForestPlots, that have developed databases for the analysis of specific questions related to vegetation structure and composition throughout the tropics.

MAIN RESULTS OF PPBIO

PPBio has evolved into the current structure, integrating more and more researchers in Brazil and other countries. The Program expanded nationwide, and similar networks were created in other countries (Australia, Nepal, and Argentina), a thermometer of the program's success. Also, human resources and capacity building are essential for the maintenance and expansion of PPBio. Many of the masters and doctors trained are now coordinators and researchers in different regional centers, reflecting the quantity and quality of scientific studies produced by the PPBio team.

The topics and questions of publications are as heterogeneous as those of any other open network, reflecting the local research agendas and capacities. Later, these topics were integrated to answer broad questions. Until 2012, most of the publications referred to Amazonia; however, after the expansion of the network, Amazonia was proportionally less mentioned in scientific studies, with an increase in publications from other biomes and broader focuses on Brazil (Figure 2). Much of the PPBio effort directly concerns the distribution of species, but given the broad scope of the network, no taxonomic group dominates the research agenda. As biodiversity conservation is the ultimate goal of PPBio, many studies are on surveys and monitoring of populations and biological assemblages (e.g., Almeida-Gomes et al. 2015, Moreira et al. 2016, Bitar et al. 2017), natural history (e.g., Magalhães et al. 2013, Simões et al. 2019), and description and analysis of the distribution of new species (e.g., Tourinho et al. 2010 Bellini et al. 2013; Aldrete & Neto 2014), filling critical knowledge gaps in all Brazilian biomes. A preliminary evaluation of output indicated that the Amazon still accounts for 55% of publications, followed by Atlantic

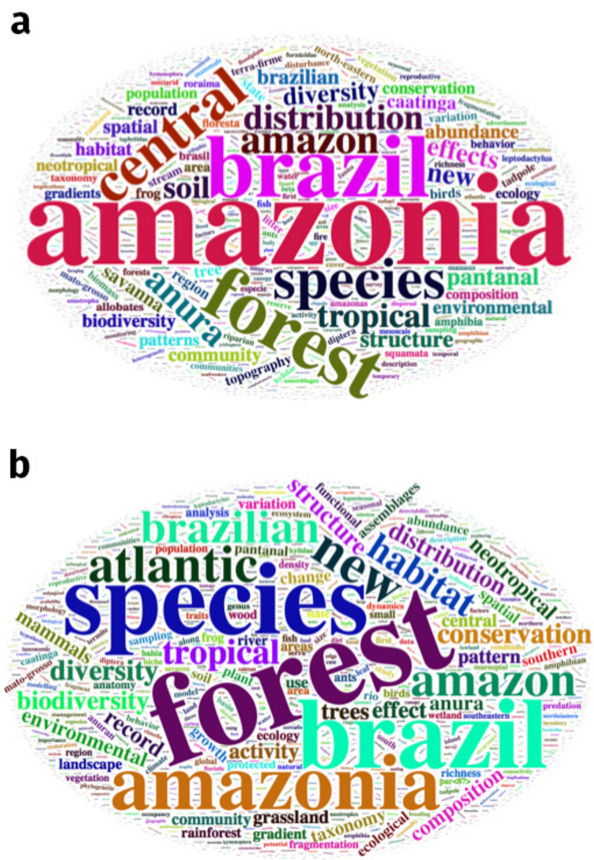

Figure 2. Word cloud using the words presented in the 1179 scientific papers titles and key-words. a) papers published to the end of 2012 and b) papers published after 2012. In both, the size of the word is proportional to its citation frequency.

Forest (17%), Caatinga (10%), Pantanal (6%), South Brazilian Grasslands (3%) and Cerrado (3%), but differences among biomes reflects to some extent biases in data reporting. Also, 2% of papers are from multiple biomes and 5% are from subjects not restricted to Brazilian biomes (e.g. methods, partnerships from Australia and Argentina, etc.). Researchers use different elements of biodiversity to test ecological hypotheses of regional and international interest. Researchers have also undertaken studies of environmental impacts of extensive infrastructure programs (Bobrowiec & Tavares 2017), fire ecology (e.g. Fadini & Lima 2012), island biogeography and metapopulation dynamics (Carvalho et al. 2008, Cintra et al. 2013), methods in ecology (Norris et al. 2014, Madalozzo et al. 2017, Fontana et al. 2018), population ecology (Brigatti et al. 2016, Ferreira et al. 2016), population genetics and phylogeography (Collevatti et al. 2014, 2015, Melo et al. 2016, Vitorino et al. 2016, 2018), genome and population genomics (Silva-Junior et al. 2018, Collevatti et al. 2019), movement ecology (Jahn et al. 2017, Brito et al. 2020), land-use effects on biodiversity (Dala-Corte et al. 2016, Palmeirim et al. 2019, Püttker et al. 2020), biological invasions (Detogne et al. 2017), data management (Pezzini et al. 2012), carbon stocks (Salimon et al. 2009, Wagner et al. 2016), human dimensions (Souza et al. 2018, Nobre et al. 2019), public policies (Dias et al. 2015), road ecology (Ferreguetti et al. 2020), landscape ecology (Crouzeilles et al. 2014, Bogoni et al. 2016), climate change (Carvalho et al. 2015, Vale et al. 2018, Lima et al. 2019), restoration ecology (Crouzeilles et al. 2015, Niemeyer et al. 2020), and systematic planning (Crouzeilles et al. 2013, Pinto et al. 2014), among others.

PPBio has produced several books about the ecology of Brazilian ecosystems and identification guides for specific groups of funga, fauna, and flora (e.g. Costa et al. 2011, Baccaro et al. 2015, Iop et al. 2016, Peixoto et al. 2016). The guides not only assist scientists in the identification of organisms, but also contribute to the dissemination of scientific information and thus to environmental education and building of scientific literacy since parts of the guides are written in easily accessible language and in some cases in the indigenous Brazilian languages (Vargas-Isla et al. 2019). The Program also published three patents (Brito et al. 2011, Nunez & Vasconcelos 2012, Nunez et al. 2014) and maintains five digital libraries (Sapoteca: anurans - https://ppbio.inpa.gov.br/sapoteca/paginainicial, Morcegoteca: bats - https://ppbio.inpa.gov.br/Morcegoteca, Fungoteca: macrofunga - https://ppbio.inpa.gov.br/fungoteca/paginainicial, Ixodoteca: ticks - https://ppbio.inpa.gov.br/Ixoditeca_Inicio, Opilioteca: harvestmen - https://ppbio.inpa.gov.br/opilioteca/paginainicial), which provide photos and species information, including vocalization, morphology, and other biological information. This material has been used widely by researchers, undergraduate and graduate students, and professors from national and international institutions.

Studies developed under the coordination of researchers linked to PPBio have 1) provided a better understanding of the distribution of species from several taxonomic groups (e.g. amphibians, reptiles, mammals, invertebrates, funga, vascular plants) present in Brazil, producing explanatory models of the variation in the distribution of populations and assemblages of these organisms in relation to biotic and abiotic variables; 2) provided bases for further studies on the dynamics of populations from different taxonomic groups, allowing for future monitoring and evaluations; 3) helped define sampling protocols with lower cost and better results, allowing quick evaluations in future studies; 4) offered necessary infrastructure to master's dissertations and doctoral theses, and trained many undergraduate students; 5) made available resources and infrastructure to identify and describe new species or larval stages of species already described; 6) helped researchers to deposit specimens of animals and plants in the Brazilian scientific collections, with the perspective to further expand the holdings of these collections; 7) fostered integrated analysis of different taxonomic groups seeking to determine ecological patterns at different spatial and temporal scales, 8) analyzed the effects of land-use change on biotic communities and abiotic factors; 9) identified threats to biodiversity and sought solutions to reduce impacts; 10) integrated different social actors, such as local communities, managers of protected areas and researchers for the expansion of knowledge and conservation of biodiversity; 11) trained and retained qualified professionals, stimulating research on biodiversity and consequently promoting scientific and technological development in the most remote regions of Brazil; and 12) identified and filled gaps in biodiversity knowledge.

RESEARCH AND SOCIETY

PPBio has worked with local communities in the generation of bioproducts, such as extraction and marketing of oils and edible mushrooms in the Amazon. The program works to transfer knowledge to society through talks, lectures and workshops offered in communities close to the sampling areas, training of community members to collect biological data and monitor, radio and television interviews (national and international networks) and official channels, projects of environmental education, video production, and interactions with elementary-school students.

In addition to the strong involvement of PPBio with local communities, the projects developed have influenced public policies. Inspired by PPBio, government agencies, such as IBAMA (Brazilian Institute of the Environment and Renewable Natural Resources), the federal environmental licensing body, and the Brazilian Forest Service, have adopted standardized biodiversity monitoring systems. The EU BON and GEO BON consortia have used PPBio experience in the development of biodiversity monitoring and biological-data management. Also, through bioprospecting, there is the possibility of obtaining products from plant species to increase local communities' incomes. The program also contributed to the Brazilian

Biodiversity Information System (SiBBr) designed by the MCTI to meet the needs for storage and availability of data by all Brazilian researchers working with biodiversity.

The PPBio experience has shown that it is possible to integrate many stakeholders into biodiversity decisions, even when they are not from the academic world. The PPBio does not work alone in these actions as many researchers collaborate in initiatives focused on the conservation and use of biodiversity, such as the Brazilian Platform for Biodiversity and Ecosystem Services (BPEBS).

NEXT STEPS

Despite the many advances since its creation, PPBio faces social, legal, and political restrictions (Magnusson et al. 2018). One of the greatest challenges for maintaining long-term monitoring programs is the lack of guaranteed funding, which has consequences not only for scientific research and biodiversity knowledge but also for conservation (Fernandes et al. 2017; Overbeck et al. 2018). The network and capacity-building activities presently rely on short-term funds raised by individual researchers. Therefore, PPBio requires a strategic funding plan explicitly destined for its maintenance and maintenance of the data it generates. With financial support guaranteed, researchers would be able to focus on major ecological questions, such as the scientific basis for the conservation of the high social and biological diversity typical of tropical and subtropical environments.

Brazil and other signatory countries are far from reaching the 20 targets of the five strategic objectives of the Aichi Goals. Brazil´s failure to meet the goals was due to setbacks in environmental protection that started in the years before the COVID-19 crisis, and that intensified during the pandemic, such as the dismantling of environmental agencies, weakening of environmental legislation, the dismantling of surveillance, among others activities. The PPBio will have to intensify studies of biodiversity to evaluate the impacts caused by environmental deregulation, strengthen local communities through training, and further increase integration by making more data readily available. The program, with its country-wide extent, can contribute to solving many environmental problems. The current site network already allows for the detection of human impacts at different spatial scales. Monitoring data obtained in natural environments can serve as a baseline for the ecological restoration of degraded ecosystems, one of the most important fields for conservation today. Increased extension of the network into anthropogenic landscapes offers the potential to assess and better understand the effects of human land use on biodiversity and ecosystem services, which can then guide conservation and restoration planning. In doing so, it seems promising to include standardized procedures of ecosystem-process analyses (Leidinger et al. 2017) and link ecosystem functioning to biodiversity across Brazil's varied ecosystems.

Among the challenges and future actions, the PPBio network needs to strengthen and consolidate actions by the regional hubs, especially those created recently or in regions with less financial resources. Their consolidation will allow higher permeability of actions at the state and regional levels, allowing sustainable development and reducing social inequities in Brazil. Training human resources (e.g., undergraduates, graduate students, local communities), consolidating and producing new partnerships are the strategies that need to be adopted in the regional hubs.

Scientific activity should be collaborative and science education is essential so that all citizens can participate in decision making. For this reason, PPBio must seek scientific training that allows all the people involved to participate in relevant discussions and social-interest decisions. These are significant challenges for large hyperdiverse countries, such as Brazil, with marked social inequalities, and only an extensive and active network can overcome those barriers.

Acknowledgments

The Biodiversity Research Program (PPBio) of the Brazilian Ministry of Science, Technology, Innovation, and Communication (MCTI) created the opportunity for integrated networks, and many funding agencies, such as Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Fundações Estaduais de Amparo à Pesquisa (FAPs) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) financed specific studies.

REFERENCES

ALDRETE ANG & NETO AMDS. 2014. Two new species of *Lachesilla* in species groups *riegeli* and *forcepeta* (Psocodea, 'Psocoptera', Lachesillidae), from the state of Bahia, Brazil. Rev Bra Entomol 58: 7-10.

ALMEIDA-GOMES M, ROCHA CFD & VIEIRA MV. 2015. Anuran community composition along two large rivers in a tropical disturbed landscape. Zoologia 32(1): 9-13.

ANDERSON-TEIXEIRA KJ ET AL. 2015. CTFS-Forest GEO: a worldwide network monitoring forests in an era of global change. Glob Change Biol 21(2): 528-549.

BACCARO FB, FEITOSA R, FERNANDEZ F, FERNANDES IO, IZZO T, SOUZA JL & SOLAR R. 2015. Guia para os gêneros de formigas do Brasil. Manaus: Editora INPA, 388 p.

BAYRAKTAROV E, EHMKE G, O'CONNOR J, BURNS EL, NGUYEN HA, MCRAE L, POSSINGHAM HP & LINDENMAYER DB. 2019. Do big unstructured biodiversity data mean more knowledge? Front Ecol Evol 6: 239.

BELLINI P, DI CLAUDIO M, NESI P & RAUCH N. 2013. Taxonomy and review of big data solutions navigation. Big Data Computing. In: Akerkar R (Ed), Big data computing, CRC Press, p. 1-31.

BITAR YOC, TUOMISTO H, PINHEIRO LPC, JUEN L & SANTOS-COSTA MC. 2017. Species turnover in Amazonian frogs: low predictability and large differences among forests. Biotropica 49: 695-705.

BOBROWIEC PED & TAVARES VDC. 2017. Establishing baseline biodiversity data prior to hydroelectric dam construction to monitoring impacts to bats in the Brazilian Amazon. Plos One 12(9): e0183036.

BOGONI JA ET AL. 2016. Contributions of the mammal community, habitat structure, and spatial distance to dung beetle community structure. Biodivers Conserv 25(9): 1661-1675.

BRIGATTI E, VIEIRA MV, KAJIN M, ALMEIDA PJAL, MENEZES MA & CERQUEIRA R. 2016. Detecting and modelling delayed density-dependence in abundance time series of a small mammal (*Didelphis aurita*). Sci Rep 6: 19553.

BRITO TO, SOUZA JLP, FONSECA CRV & QUIRINO MG. 2011. Grampo de Sutura. Brazil. Patente: Privilégio de Inovação. Número do registro: WO/2012/088575, data de depósito: 29/12/2011, título: "Grampo de Sutura", Instituição de registro: WIPO - World Intellectual Property Organization.

BRITO ES, RODRIGUES EAS, FERRÃO M, FERREIRA VL, TOMAS WM & STRÜSSMANN C. 2020. *Acanthochelys macrocephala* (Big-headed Pantanal Swamp Turtle). Population and movement. Herpetol Rev 51: 104-105.

CARVALHO JR EAR, LIMA AP, MAGNUSSON WE & ALBERNAZ ALKM. 2008. Long-term effect of forest fragmentation on the Amazonian gekkonid lizards, *Coleodactylus amazonicus* and *Gonatodes humeralis*. Austral Ecol 33: 723-729.

CARVALHO BM, RANGEL EF, READY PD & VALE MM. 2015. Ecological niche modelling predicts southward expansion of *Lutzomyia* (*Nyssomyia*) *flaviscutellata* (Diptera: Psychodidae: Phlebotominae), vector of *Leishmania* (*Leishmania*) *amazonensis* in South America, under climate change. Plos One 10: e0143282-21.

CINTRA R, MAGNUSSON WE & ALBERNAZ A. 2013. Spatial and temporal changes in bird assemblages in forest fragments in an eastern Amazonian savannah. Ecol Evol 3(10): 3249-3262.

COLLEVATTI RG, TELLES MPC, LIMA JS, GOUVEIA FO & SOARES TN. 2014. Contrasting spatial genetic structure in *Annona crassiflora* populations from fragmented and pristine savannas. Plant Syst Evol: 10.1007/s00606-014-0997-9.

COLLEVATTI RG, TERRIBILE LC, DINIZ-FILHO JAF & LIMA-RIBEIRO MS. 2015. Multi-model inference in comparative phylogeography: an integrative approach based on multiple lines of evidence. Front Genet 6: 31.

COLLEVATTI RG, NOVAES E, SILVA-JUNIOR OB, VIEIRA LD, LIMA-RIBEIRO MS & GRATTAPAGLIA D. 2019 A genome-wide scan shows evidence for local adaptation in a widespread keystone Neotropical forest tree. Heredity 123: 117-137.

COOK CN, HOCKINGS M & CARTER RW. 2010. Conservation in the dark? The information used to support management decisions. Front Ecol Environ 8: 181-188.

COSTA FV ET AL. 2015. Synthesis of the first 10 years of long-term ecological research in Amazonian Forest ecosystem - implications for conservation and management. Nat Conserv 13: 3-14.

COSTA FRC, ESPINELLI FP & FIGUEIREDO FOG. 2011. Guia de Zingiberales dos sítios PPBio na Amazônia Ocidental Brazileira. Manaus: Attema Design Editorial Ltda.

COSTA FRC & MAGNUSSON WE. 2010. The Need for Large-Scale, Integrated Studies of Biodiversity the Experience of the Program for Biodiversity Research in Brazilian Amazonia. Nat Conserv 8: 3-12.

CRAINE JM, BATTERSBY J, ELMORE AJ & JONES AW. 2007. Building EDENs: The rise of environmentally distributed ecological networks. BioScience 57(1): 45-54.

CROUZEILLES R, LORINI ML & GRELLE CEV. 2013. The importance of using sustainable use protected areas for functional connectivity. Biol Conserv 159: 450-457

CROUZEILLES R, PREVEDELLO JA, FIGUEIREDO MSL, LORINI ML & GRELLE CEV. 2014. The effects of the number, size and isolation of patches along a gradient of native vegetation cover: how can we increment habitat availability? Landsc Ecol 29: 479-489.

CROUZEILLES R, BEYER HL, MILLS M, GRELLE CEV & POSSINGHAM HP. 2015 Incorporating habitat availability into systematic planning for restoration: a species-specific approach for Atlantic Forest mammals. Divers Distrib 21: 1-11.

DALA-CORTE RB, GIAM X, OLDEN JD, BECKER FG, GUIMARÃES TF & MELO AS. 2016. Revealing the pathways by which agricultural land-use affects stream fish communities in Southern Brazilian Grasslands. Freshw Biol 61: 1921-1934.

DETOGNE N, FERREGUETTI AC, MELLO JHF, SANTANA MC, DIAS AC, MOTA NC, GONÇALVES AEC, SOUZA CP & BERGALLO HG. 2017. Spatial distribution of buffy-tufted-ear (*Callithrix aurita*) and invasive marmosets (*Callithrix* spp.) in a tropical rainforest reserve in southeastern Brazil. Am J Primatol 79(12): e22718.

DIAS LFO, DIAS DV & MAGNUSSON WE. 2015. Influence of environmental governance on deforestation in municipalities of the Brazilian Amazon. PloS One 10(7): 10.1371/journal.pone.0131425.

FADINI RF & LIMA AP. 2012. Fire and host abundance as determinants of the distribution of three congener and sympatric mistletoes in an Amazonian Savanna. Biotropica 44(1): 27-34.

FAZEY I, FAZEY JA & FAZEY DM. 2005. Learning more effectively from experience. Ecol Soc 10(2): 1-22.

FEGRAUS EH, ANDELMAN S, JONES MB & SCHILDHAUER M. 2005. Maximizing the value of ecological data with structured metadata: an introduction to Ecological Metadata Language (EML) and principles for metadata creation. Bull Ecol Soc Am 86(3): 158-168.

FERNANDES GW ET AL. 2017. Dismantling Brazil's science threatens global biodiversity heritage. Perspect Ecol Conser 15(3): 239-243.

FERREGUETTI AC. GRACIANO JM, LUPPI AP, PEREIRA-RIBEIRO J, ROCHA CFD & BERGALLO HG. 2020. Roadkill of medium to large mammals along a Brazilian road (BR-262) in Southeastern Brazil: spatial distribution and seasonal variation. Stud Neotrop Fauna 1-10.

FERREIRA MS, VIEIRA MV, CERQUEIRA R & DICKMAN CR. 2016. Seasonal dynamics with compensatory effects regulate populations of tropical forest marsupials: a 16-year study. Oecologia 182: 1095-1106.

FONTANA CS, CHIARINI E, MENEZES LS, ANDRETTI CB & OVERBECK GE. 2018. Bird surveys in grasslands: do different count methods present distinct results? Revista Brasileira de Ornitologia 26: 116-122.

FOREST PLOTS. 2020. https://www.forestplots.net/pt. Accessed in October 1st, 2020.

GARDNER T. 2012. Monitoring Forest Biodiversity. London: The Earthscan Forest Library, Routledge Publisher, 388 p.

GEIJZENDORFFER IR ET AL. 2016. Bridging the gap between biodiversity data and policy reporting needs: An Essential Biodiversity Variables perspective. J Appl Ecol 53(5): 1341-1350.

GOTELLI NJ. 2004. A taxonomic wish–list for community ecology. Philos Trans R Soc Lond B Biol Sci 359(1444): 585-597.

HERO J-M, CASTLEY JG, MALONE M, LAWSON B & MAGNUSSON WE. 2010. Long-term ecological research in Australia: innovative approaches for future benefits. Aust Zool 35: 216-228.

HORTAL J, BELLO F, DINIZ-FILHO JAF, LEWINSOHN TM, LOBO JM & LADLE RJ. 2015. Seven shortfalls that beset large-scale knowledge of biodiversity. Annu Rev Ecol Evol S 46: 523-549.

HUANG X & QIAO G. 2011. Biodiversity databases should gain support from journals. Trends Ecol Evol 26: 377-378.

IBGE. 2004. Mapa de biomas do Brasil. Escala 1:5.000.000. Rio de Janeiro: IBGE, 2004. https://www.ibge.gov.br/geociencias/informacoes-ambientais/15842-biomas.html?edicao=16060&t=downloads. Accessed in 25th September 2020.

IOP S, SANTOS TG & CECHIN S. 2016. Anfíbios anuros dos Campos Sulinos: espécies com ocorrência nas áreas campestres do Pampa e da Mata Atlântica. Porto Alegre: UFRGS, 22 p.

JAHN AE, BEJARANO V, CUETO VR, DI GIACOMO AS & FONTANA CS. 2017. Movement ecology research to advance conservation of South America's grassland migratory birds. Perspect Ecol Conserv 15: 209-215.

KARAM-GEMAEL M, LOYOLA R, PENHA J & IZZO T. 2018. Poor alignment of priorities between scientists and policymakers highlights the need for evidence-informed conservation in Brazil. Perspect Ecol Conserv 16(3): 125-132.

KILPATRICK AM, SALKELD DJ, TITCOMB G & HAHN MB. 2017. Conservation of biodiversity as a strategy for improving human health and well-being. Philos Trans R Soc Lond B Biol Sci 372(1722): 20160131.

LEIDINGER JLG ET AL. 2017. Historical and recent land use affects ecosystem functions in subtropical grasslands in Brazil. Ecosphere 8(12): e02032.

LIMA AA, RIBEIRO MC, GRELLE CEV & PINTO MP. 2019. Impacts of climate changes on spatio-temporal diversity patterns of Atlantic Forest primates. Perspect Ecol Conserv 17: 50-56.

LINDENMAYER DB & LIKENS GE. 2010a. The science and application of ecological monitoring. Biol Conserv143(6): 1317-1328.

LINDENMAYER DB & LIKENS GE. 2010b. Effective Ecological Monitoring. Collingwood: Csiro Publishing, 184 p.

LOLLBACK GW, CASTLEY JG, MOSSAZ A & HERO J-M. 2017. Fine scale changes in spatial habitat use by a low-density koala population in an isolated peri-urban forest remnant. Aust Mammal 40(1): 84-92.

MADALOZZO B, SANTOS TG, SANTOS MB, BOTH C & CECHIN S. 2017. Biodiversity assessment: selecting sampling techniques to access anuran diversity in grassland ecosystems. Wildl Res 44: 78-91.

MAGALHÃES FM, GARDA AA, AMADO TF & SÁ RO. 2013. The tadpole of *Leptodactylus caatingae* Heyer & Juncá, 2003 (Anura: Leptodactylidae): external morphology, internal anatomy, and natural history. South Am J Herpetol 8: 203-210.

MAGNUSSON WE, LIMA AP, LUIZÃO R, LUIZÃO F, COSTA FRC, CASTILHO CV & KINUPP VF. 2005. RAPELD: a modification of the Gentry method for biodiversity surveys in long-term ecological research sites. Biota Neotrop 5: 1-6.

MAGNUSSON WE ET AL. 2013. Biodiversity and integrated environmental monitoring. Manaus: Áttema Editorial.

MAGNUSSON WE ET AL. 2018. Effects of Brazil's Political Crisis on the Science Needed for Biodiversity Conservation. Front Ecol Evol 6: 1-5

MOREIRA LFB, SOLINO-CARVALHO LA, STRÜSSMANN C & SILVEIRA RML. 2016. Effects of exotic pastures on tadpole assemblages in Pantanal floodplains: assessing changes in species composition. Amphibia-Reptilia 37: 179-190.

NIEMEYER J, BARROS FSM, SILVA DS, CROUZEILLES R & VALE MM. 2020. Planning forest restoration within private land holdings with conservation co-benefits at the landscape scale. Sci Total Environ 717: 135262.

NOBRE HSMF, AZEVEDO MS, MATOS NB, MANZATTO ÂG, ROMÃO NF, AIZZO JRS & SAMPAIO AF. 2019. Avaliação da atividade antimicrobiana de extrato, frações e óleo essencial da *P. obliquum* Ruiz e Pavon - Esec Cuniã, Porto Velho, Rondônia. South Am J Bas Educ Tech Technol 6(1): 48-66.

NORRIS D, FORTIN M & MAGNUSSON WE. 2014. Towards monitoring biodiversity in Amazonian forests: how regular samples capture meso-scale altitudinal variation in 25 km2 plots. Plos One 9: e106150.

NUNEZ CV & VASCONCELOS MC. 2012. Novo Alcaloide Antitumoral de Duroia macrophylla. Patente: Privilégio de Inovação. Número do registro: PI10201203380, data de depósito, 31(12), 2012.

NUNEZ CV, MARTINS D, RAMOS DF & SILVA PEA. 2014. Uso de composto, método ex-vivo, processo e extrato purificado. 2014, Brazil. Patente: Privilégio de Inovação. Número do registro: BR1020140308636, data de depósito: 09/12/2014, Instituição de registro: INPI - Instituto Nacional da Propriedade Industrial.

OVERBECK GE, BERGALLO HG, GRELLE CEV, AKAMA A, BRAVO F, COLLI GR, MAGNUSSON WE, TOMAS WM & FERNANDES GW. 2018. Global Biodiversity Threatened by Science Budget Cuts in Brazil. BioScience 68(1): 11-12.

PALMEIRIM AF, FIGUEIREDO MSL, GRELLE CEV, CARBONE C & VIEIRA MV. 2019. When does habitat fragmentation matter? A biome-wide analysis of small mammals in the Atlantic Forest. J Beiogeogr 46(12): 2811-2825.

PEIXOTO AL, LUZ JRP & BRITO MA. 2016. Conhecendo a biodiversidade. Brasília: MCTIC/CNPq/PPBio, 191 p.

PEZZINI FF ET AL. 2012. The Brazilian Program for Biodiversity Research (PPBio) Information System. Biodivers Ecol 4: 265-274.

PINTO MP, SILVA JUNIOR JSE, ALMEIDA A & GRELLE CEV. 2014. Multi-Scales Analysis of Primate Diversity and Protected Areas at a Megadiverse Region. Plos One 9: e105205.

PROENÇA V ET AL. 2017. Global biodiversity monitoring: from data sources to essential biodiversity variables. Biol Conserv 213: 256-263.

PÜTTKER T ET AL. 2020. Indirect effects of habitat loss via habitat fragmentation: A cross-taxa analysis of forest-dependent species. Biol Conserv 241: 108368.

RAVEN PH. 1988. Our diminishing tropical forests. Biodiversity 15: 119-122.

ROVERO F & AHUMADA J. 2017. The Tropical Ecology, Assessment and Monitoring (TEAM) Network: An early warning system for tropical rain forests. Sci Total Environ 574: 914-923.

SALIMON CI, WADT PGS & DE SOUZA ALVES S. 2009. Decrease in carbon stocks in an oxisol due to land use and cover change in southwestern Amazon. Rev Ambient Água 4(2): 57-65.

SILVA-JUNIOR OB, GRATTAPAGLIA D, NOVAES E & COLLEVATTI RG. 2018. Design and evaluation of a sequence capture system for genome-wide SNP genotyping in highly heterozygous plant genomes: a case study with a keystone Neotropical hardwood tree genome. DNA Research 25: 535-545.

SIMÕES VJLP, LEITE MLDMV, IZIDRO JLPS, JÚNIOR GDNA & TEIXEIRA VI. 2019. Carbon assimilation in forage plants. Appl Res & Agrotec 12(1): 125-134.

SOUZA AO, CHAVES MPSR, BARBOSA RI & CLEMENT CR. 2018. Local ecological knowledge concerning the invasion of Amerindian lands in the northern Brazilian Amazon by *Acacia mangium* (Willd.). J Ethnobiol Ethnomed 14: 33.

TOURINHO AL, MAN-HUNG NFL & BONALDO AB. 2010. A new species of *Ricinulei* of the genus *Cryptocellus* Westwood (Arachnida) from northern Brazil. Zootaxa 2684: 63-68.

VALE MM, SOUZA TV, ALVES MAS & CROUZEILLES R. 2018. Planning protected areas network that are relevant today and under future climate change is possible: the case of Atlantic Forest endemic birds. PeerJ 6: e4689.

VARGAS-ISLA R, CABRAL TS, OLIVEIRA JJS & ISHIKAWA NK. 2019. Guia para coleta de cogumelos. Dihti Bʉhkʉ serã a'tiro weya ni masiõripũri. Manaus: Editora INPA.

VITORINO LC, LIMA-RIBEIRO MS, TERRIBILE LC & COLLEVATTI RG. 2018. Demographical expansion of *Handroanthus ochraceus* in the Cerrado during the Quaternary: implications for the genetic diversity of Neotropical trees. Biol J Linn Soc 123(3): 561-577.

VITORINO LC, LIMA-RIBEIRO MS, TERRIBILE LC & COLLEVATTI RG. 2016. Demographical history and palaeodistribution modelling show range shift towards Amazon Basin for a Neotropical tree species in the LGM. BMC Evolutionary Biology 16: 213.

WAGNER FH ET AL. 2016. Climate seasonality limits leaf carbon assimilation and wood productivity in tropical forests. Biogeosciences 13: 2537.

WIENS JA. 1989. Spatial scaling in ecology. Funct Ecol 3: 385-397.

SUPPLEMENTARY MATERIAL

Table SI. **Location of sites of the Brazilian Program for Biodiversity Research network.**
Supplementary Appendix.
Figure S1. **Example of a RAPELD grid in the Ecological Station of Cuniã, Amazon.**
Figure S2. **Example of a RAPELD module in Mato Grosso state, Amazon.**

How to cite
CLARISSA ROSA ET AL. 2021. The Program for Biodiversity Research in Brazil: The role of regional networks for biodiversity knowledge, dissemination, and conservation. An Acad Bras Cienc 93: e20201604. DOI 10.1590/0001-3765202120201604.

Manuscript received on October 13, 2020;
accepted for publication on January 11, 2021

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Silva, Thiago Junqueira Izzo, Amanda Frederico Mortati, Leandro Lacerda Giacomin, Thaís Elias Almeida, Thiago André, Maria Aurea Pinheiro de Almeida Silveira, Antônio Laffayete Pires da Silveira, Mariluce Rezende Messias, Marcia C. M. Marques, Andre Andrian Padial, Renato Marques, Youszef O. C. Bitar, Marcos Silveira, Elder Ferreira Morato, Rubiani de Cássia Pagotto, Christine Strussmann, Ricardo Bomfim Machado, Ludmilla Moura de Souza Aguiar, Geraldo Wilson Fernandes, Yumi Oki, Samuel Novais, Guilherme Braga Ferreira, Flávia Rodrigues Barbosa, Ana C. Ochoa, Antonio Mangione, Ailin Gatica, M. Celina Carrizo, Lucía Martinez Retta, Laura E. Jofré, Luciana L. Castillo, Andrea M. Neme, Carla Rueda, José Julio de Toledo, Carlos Eduardo Viveiros Grelle, Mariana Vale, Marcus Vinicius Vieira, Rui Cerqueira, Fernando Pereira de Mendonça, Quêzia Leandro de Moura Guerreiro, Aureo Banhos, Jean-Marc Hero, Rodrigo Koblitz, Rosane Garcia Collevatti, Luís Fábio Silveira, Heraldo L. Vasconcelos, Cecília Rodrigues Vieira, Guarino Rinaldi Colli, Sonia Zanini Cechin, Tiago Gomes dos Santos, Carla S. Fontana, João A. Jarenkow, and Luiz R. Malabarba, Marta Rueda, Publio A. Araujo, Lucas Palomo, Marta C. Iturre: helped to organize local information from each hub of PPBio and wrote the article. Emílio Manabu Higashikawa: organized spatial data to build Figure 1 and wrote the paper. Helena G. Bergallo and William E. Magnusson: planned the main idea of the article and wrote the article.