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Review

Disentangling the veil line for Brazilian biodiversity: An overview from two long-term research programs reveals huge gaps in ecological data reporting

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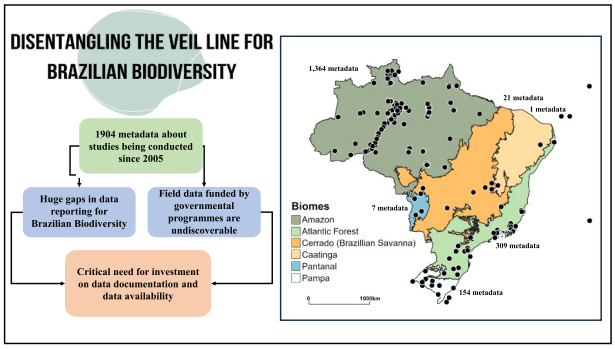
HIGHLIGHTS

- We synthesized metadata regarding field campaigns carried out in a timeline of 20 years.
- Brazilian biodiversity metadata is poorly documented.
- Most field data are undiscoverable by a broader audience.
- There are pervasive gaps regarding data documentation in the country.
- Improving data documentation will increase the number of biodiversity synthesis.

GRAPHICAL ABSTRACT



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ABSTRACT

The lack of synthesized information regarding biodiversity is a major problem among researchers, leading to a pervasive cycle where ecologists make field campaigns to collect information that already exists and yet has not been made available for a broader audience. This problem leads to long-lasting effects in public policies such as spending money multiple times to conduct similar studies in the same area. We aim to identify this knowledge gap by synthesizing information available regarding two Brazilian long-term biodiversity programs and the metadata generated by them. Using a unique dataset containing 1904 metadata, we identified patterns of metadata distribution and intensity of research conducted in Brazil, as well as where we should concentrate research efforts in the next decades. We found that the majority of metadata were about vertebrates, followed by plants, invertebrates, and fungi. Caatinga was the biome with least metadata, and that there's still a lack of information regarding all biomes in Brazil, with none of them being sufficiently sampled. We hope that these results will have implications for broader conservation and management guiding, as well as to funding allocation programs.

1. Introduction

The world is changing, probably at a rate never experienced before, as a result of human actions, and biodiversity faces unprecedented erosion (Leon et al., 2023). Understanding the existing biodiversity patterns is important, but we also need to think ahead and enhance our documentation processes to upscale information availability for present and future scientists to replicate work over time or reanalyse with improved methods. Equally important is the need to identify knowledge gaps and expand the field recording of biodiversity, especially in megadiverse sites and/or those ecosystems that are characteristically fragile and difficult to restore, as well as those considered priority areas for biological conservation. To reach this goal, it is mandatory to combine knowledge and tools from different disciplines to achieve a more robust representation of nature, and to better describe ecological patterns, processes, and even taxonomic information (Carvalho et al., 2023). In this sense, in a continental country such as Brazil, studies that synthesize information can increase our understanding of the current state-of-the-art, as well as to broader ecological questions to increase our knowledge regarding macroecological patterns.

One way to do so is to incorporate field data into repositories and databases, storing them with their respective metadata. Metadata are descriptors of datasets, usually comprising universal (e.g., creator, data collection method) and specific information (e.g., focal taxa, ecosystem and coordinates, for ecological data) on datasets that share common features and can be pooled for new analyses (Vanderbilt et al., 2022), without necessarily involving the raw spreadsheets containing field information. In the absence of standardised field spreadsheets, they can help us improve our understanding of complex systems (Alba et al., 2021).

Making data available is an important topic for improving biodiversity knowledge, and also contributes to the decision-making process. Today, most scientific journals have open-science policies and require that authors make their research data available to the scientific

community (Vanderbilt et al., 2022). Usually, biodiversity data are isolated in topic-specific and separate repositories (Waide et al., 2017). Despite billions of dollars of investment, the integration of a large number of heterogeneous biodiversity data is still incipient (Moura et al., 2015), and major areas are still underrepresented, especially in the tropics (Moura and Jetz, 2021), where data, when reported, are spread in several repositories and lack standardization, making it impossible to synthesize the ecological knowledge available. These problems lead to severe restrictions on the usage of global repositories and databases, limiting their applicability (Mugal et al., 2023), and additionally increase the cost of generating the same information in the future. It also makes biodiversity data undiscoverable and unusable for a broader audience, especially in Brazil, where scientists do not routinely store their data in repositories and databases.

The tropics are an important source and refuge for many key species and they hold the majority of the world's biological diversity (Barlow et al., 2018). Brazilian biodiversity is estimated to include at least 13 % of the species of the world (Lewinsohn and Prado, 2005), and our current understanding of biodiversity faces two major challenges: the *Linnean* and *Wallacean* shortfalls (Bini et al., 2006). The Linnean shortfall refers to the fact that most of the existing species on the planet still need to be described, while the Wallacean shortfall can be defined as the lack of information on the limits of the geographical distribution and sampling efforts for most taxa (Hortal et al., 2015; Lomolino, 2004). The latter is particularly important in Brazil, where the investment in research and biodiversity knowledge is biased towards areas with the highest human densities, which are the most fragmented areas. These shortfalls lead to a phenomenon called "the veil line" (Magnusson et al., 2016), resulting in a geographical bias in biodiversity knowledge and investment in Brazilian research. Additionaly, it generates a concentration of publications available for biomes in more developed areas, with little investment in hyperdiverse ecosystems, such as the Amazon (Oliveira et al., 2016), or ecosystems that face human expansion and are still poorly known, such as the Cerrado and Caatinga (Santos et al., 2011). Also, it is important to highlight that, even the ecosystems that receive proportionately higher investments have huge gaps in biodiversity knowledge.

Integrating field data and metadata from multiple sources and at different spatiotemporal scales is crucial to unravel patterns and processes of biodiversity change under the ongoing environmental degradation due to deforestation, fragmentation and landscape modifications (i.e. land use and land cover change), which have been accelerated by global climate change (Bergallo et al., 2021; König et al., 2019). Most of the information on Brazilian biodiversity is outdated, and there is missing information (e.g., species lists, descriptions, geographical coordinates and ecological field data for many taxonomic groups (Hochkirch et al., 2021; Maldonado et al., 2015; Moraes et al., 2014). Furthermore, the information available for well-studied taxa (e.g., some vertebrate and plant groups (Hochkirch et al., 2021; Oliveira et al., 2016) is spread over hundreds of publications (Andrade et al., 2023), and field data are rarely available to a broader audience, which limits data usability for decision-makers and conservation policies.

Out study aims to identify the gaps in ecological metadata reporting throughout the country and to provide a call-to-action among ecologists regarding the importance of making their findings available in online repositories. Since it would be a Herculean task to gather all biodiversity data available for Brazil, our study focuses on studies conducted by the two largest public-funded research programs associated with Brazilian biodiversity: PELD (Programa de Pesquisas Ecológicas de Longa Duração – known internationally as Long Term Ecological Research – LTER) (Roque et al., 2018) and PPBio (Programa de Pesquisa em Biodiversidade – Program for Biodiversity Research) (Rosa et al., 2021). We chose these two programs because they are carried out on a national scale, involving hundreds of researchers within several institutions across different ecosystems in Brazil, and calls for their funding explicitly required that the data be made available. We used a very broad definition of data availability which considered the data to be available if metadata were provided and indicated what and where data had been collected, and by whom. Here, we compiled datasets available in online repositories, as well as unpublished metadata sent directly by the authors, that contain information from the two research programs. We synthesized this information about Brazilian biodiversity to address the following objectives:

1) To provide an overview of the fieldwork metadata conducted by PPBio and PELD.
2) Identify the patterns of metadata distribution and intensity of research conducted by PPBio and PELD across biomes and regions.
3) Investigate how metadata distribution varies within the country.
4) Provide guidance for future investment and research in Brazil, based on gaps in biodiversity sampling and data reporting.

2. Materials and methods

2.1. Database sources and compilation

Metadata collection was based on the DataOne, GBIF and iNaturalist repositories, as well as metadata for data held by individual researchers. We chose those repositories because they are popular among researchers and concentrate large volumes of metadata. Based on the scope of our study, we excluded all metadata that were not about fieldwork carried out by PELD or PPBio, as well as metadata that contained only the occurrence data without relevant ecological information (e.g., entries that didn't describe the sampling methodology and metadata with only co-occurrence information). These programs can be used as proxies to provide an overview of the state of the art regarding Brazilian biodiversity and what has been done so far. All searches in data-repositories were conducted using the following keywords: "PPBio", "Programa de Pesquisa em Biodiversidade", "The Program for Biodiversity Research", "Brazilian Biodiversity Research Programme", "PELD", "Long-Term Ecological Research Program - PELD". To search the data repositories via R program we used the DataOne package v.2.2.2 (Jones et al., 2016) and Rinat package v. 0.1.9 (Barve et al., 2022). After downloading the information, we filtered all metadata about fieldwork and merged all tables into a single database with the *dplyr* Package in R (Wickham et al., 2022).

To include all possible metadata, we invited all coordinators from PELD and PPBio, as well as researchers affiliated who work or have worked in these programs to contribute to our study sending us metadata by email.

2.2. Data processing

We carefully cleaned the data to rectify any truncated or missing information that arose after downloading the metadata from the repositories. We also excluded duplicated metadata entries, and checked and corrected the geographical coordinates. We excluded all occurrence-only metadata because they did not include information from species surveys (such as the method used in the fieldwork and geographical coordinates from the location where the study was carried out). We also excluded metadata that were not collected in Brazil. Some metadata had information regarding more than one field campaign and/or regarding more than one taxa. In those cases, we counted each field campaign and/or each different taxa entry as an individual entry. To preserve all relevant information from the original surveys, we contacted all metadata owners whenever there was missing information to clarify and correct possible errors. Since some metadata described multi-site and multispecies datasets, we contacted authors directly via e-mail to clarify the issue. We proceeded by concentrating multi-site/multispecies metadata into one entry for each site/species described in a dataset, and also considered each as a single entry/field campaign. No metadata entries in our dataset described a multi-serial (e.g. series of

field campaigns being carried for 10 years) collection. To facilitate readability and understanding, we then considered each metadata described in our study as a data point and as a single field campaign.

We gathered metadata on invertebrates, fungi, plants and vertebrates in all the Brazilian biomes, as well as in aquatic ecosystems. There was no hard limitation for the year of the beginning of the study to be included in our survey, as we included all metadata available online from PELD and PPBio (i.e. we included metadata deposited from 2000 to December 2023). We focused on this period to keep results relevant and to include all possible metadata that could be relevant for future research. We chose to focus on biome classification since public policies and funding distribution are mainly designed at the biome scale. We then compiled the following information from the remaining metadata: i) group, ii) data collection methodology, if possible, iii) when the study was carried out, iv) geographical coordinates from the sample location, v) biome, vi) which group conducted the study (i.e. PELD, PPBio or both), vii) if the metadata were about ecological studies or taxonomic studies and viii) habitat (i.e. terrestrial or aquatic). Those classifications were made by accessing information individually in each metadata package and directly contacting the data owners. We checked each coordinate individually by plotting them using QGis v.3.22.3 (QGIS Association, 2021), and proceeded to ask data owners to double checked if what was plotted corresponded to the locality of their field works.

To provide an overview of the fieldwork metadata conducted by PPBio and PELD for each biome, we built maps for each group (i.e. invertebrates, fungi, plants and vertebrates), using the package *terra* (Hijmans, 2023) in R. To identify the patterns of metadata distribution and intensity of the research conducted by PPBio and PELD across biomes and regions, we calculated an index of metadata available (number of metadata) divided by the biome extension (km^2; (IBGE, 2019)).To illustrate the distribution patterns of the metadata, we conducted a Kernel density estimation analysis on QGis v.3.22.3 (QGIS Association, 2021) with the density analysis plugin. The process of density estimation consisted of rasterizing the metadata location points' information into rasters of 5-km cell size, then smoothing the spatial patterns with a Quartic Kernel of a radius of 50 km to capture the fine-scale variation and identify the spatial concentration of metadata points, if the sampling efforts were even or distributed by chance there would be no significant concentration of the density of sampling points.

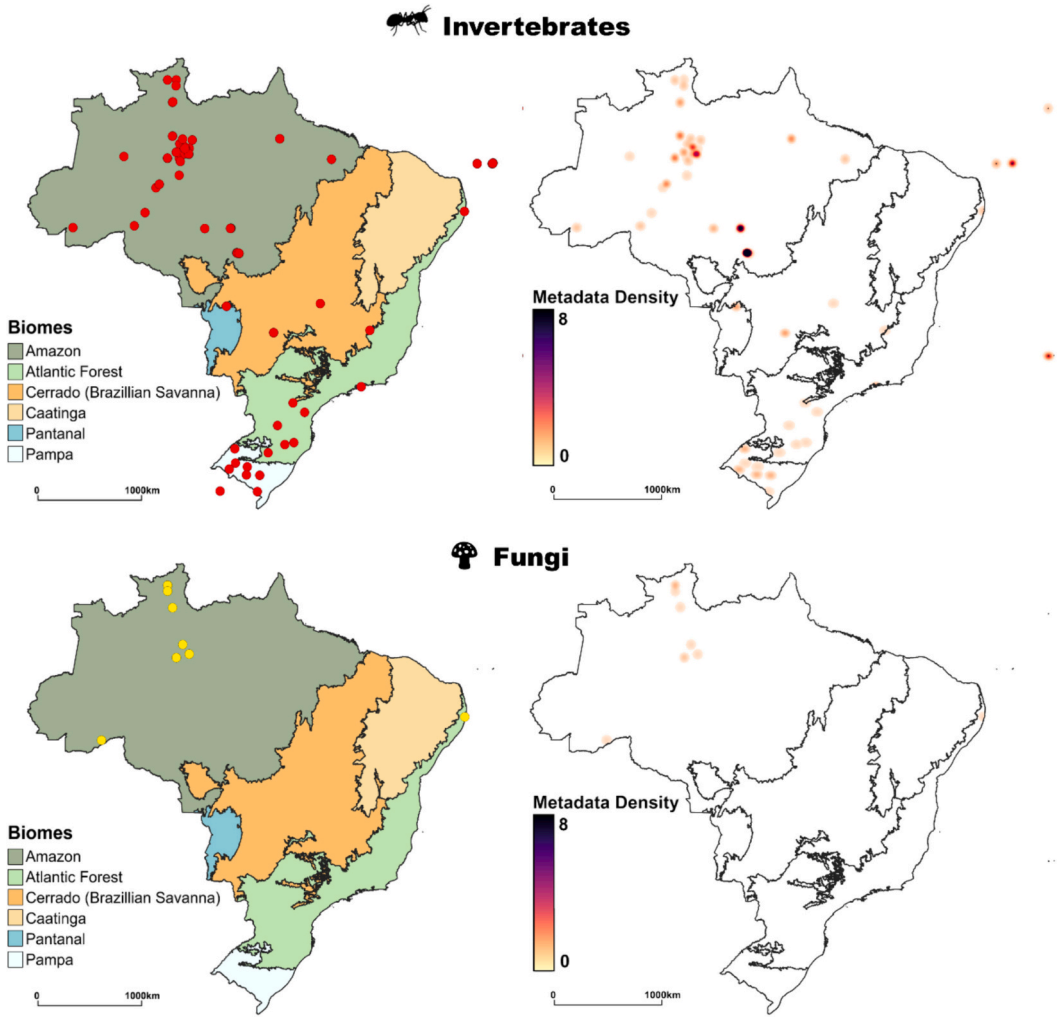

Fig. 1. Geographic locations of the metadata about studies conducted by the programs Long-Term Ecological Research (PELD) and Program for Biodiversity Research (PPBio) available in online repositories or sent directly by the data owners. The left side maps represent invertebrates (top left, in red) and Fungi (bottom left, in yellow) metadata distribution represented by circles distributed in the biome where the original study was conducted. The right-side maps represent metadata density for invertebrates (top) and fungi (bottom), calculated using a raster image of Brazil's geographical limits with a 5 km cell size and kernel density estimation with a 50 km radius, representing the concentration of metadata (darker pixels represent higher local densities). Points outside the limits of the country represent studies conducted in marine environments.

3. Results

3.1. General results

We found 1904 metadata about studies conducted by the two programs (Fig. 1). The majority of the metadata were about studies funded exclusively by PPBio (1686), while 63 metadata were exclusively funded by PELD and 155 metadata had mixed funding (overlap funding from PELD and PPBio). Most of the metadata were about ecological studies (1309) and the minority were about taxonomic studies (592). Three metadata lacked enough information to be classified regarding ecological or taxonomic studies. The majority of the metadata (50.89 %) were sent to us directly by the authors and are not available in online repositories, while 49.10 % of the metadata were available online. We directly contacted 46 coordinators from PELD and 326 researchers from PPBio to request owners' permission to use their metadata, and only 11 and 25 replied, respectively. PELD currently has 34 active sites distributed in Brazil (Brito et al., 2020), and we found metadata about studies conducted in 18 sites, while for PPBio we found metadata about studies conducted in 97 of the 155 active sites reported by (Rosa et al., 2021).

3.2. Taxa sampled by PPBio and PELD

The majority of metadata were about vertebrates (1083), followed by plants (563), invertebrates (247) and fungi (11; Figs. 1 and 2). Within these groups, the majority of the metadata (Table 1) were from studies about other vertebrates (475), followed by woody plants (376), non-flying mammals (370) and terrestrial invertebrates (209). The metadata for 48 studies had missing information that made them impossible to classify in any category regarding the organisms sampled.

3.3. Distribution of the Brazilian biodiversity metadata

Most of the studies were conducted in the States of Para (488), Mato Grosso (321), Amazonas (201), and Rio Grande do Sul (192). The Brazilian federative units with the least metadata were Goias (5), Distrito Federal (4), and Maranhão (4).

The biome with the highest number of metadata deposited was the Amazon (1364), followed by the Atlantic Forest (309), Pampa (154), Cerrado (21), Pantanal (7), and Caatinga (1) (Figs. 1 and 2). The index of metadata per biome extension was higher for the Pampa (0.0008), with lower densities in Amazonia (0.0003), Atlantic Forest (0.0002), Pantanal (0.00004), Cerrado (0.000001) and Caatinga (0.0000001;

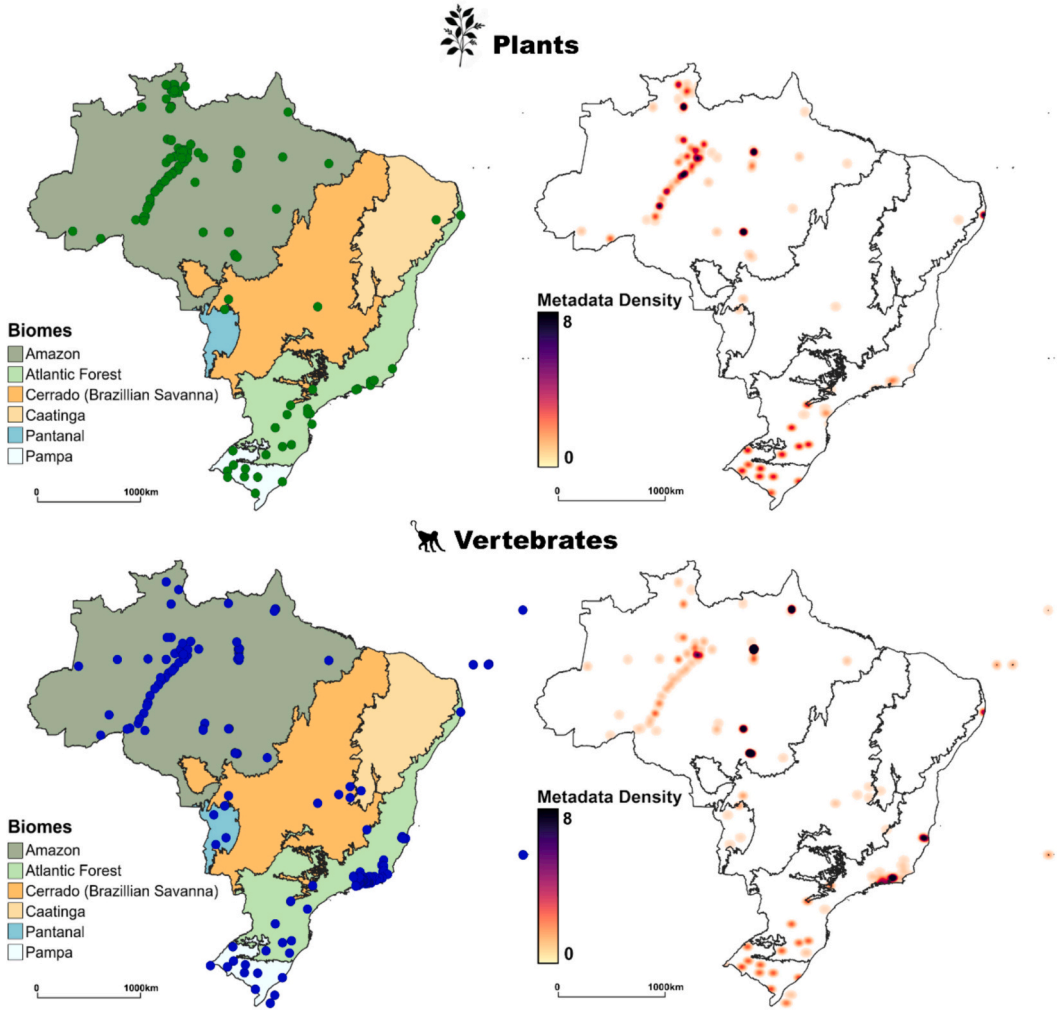

Fig. 2. Geographic locations of the metadata about studies conducted by the programs Long-Term Ecological Research (PELD) and Program for Biodiversity Research (PPBio) available in online repositories or sent directly by the data owners. The left side maps represent plants (top left, in green) and vertebrates (bottom left, in blue) metadata distribution represented by circles distributed in the biome where the original study was conducted. The right-side maps represent metadata density for plants (top) and vertebrates (bottom), calculated using a raster image of Brazil's geographical limits with a 5 km cell size and kernel density estimation with a 50 km radius, representing the concentration of metadata (darker pixels represent higher local densities). Points outside the limits of the country represent studies conducted in marine environments.

Table 1
Number of metadata about studies conducted by the Program for Biodiversity Research (PPBio) and the program for Long Term Ecological Research (PELD) available in online repositories or/and sent directly by the coordinators of each group.

Group	Amazon	Atlantic Forest	Caatinga	Cerrado	Pampa	Pantanal	NA
Terrestrial invertebrates	176	12		7	16		6
Aquatic invertebrates	6	2					20
Fungi	10	1					
Parasites	2						
Woody plants	244	77	1	3	16		
Non-woody plants	70				54		
Litter	71	16			6	1	
Aquatic non-woody plants	4	1					
Non-flying mammals	296	65		8			
Flying mammals	18	61				6	
Aquatic vertebrates	45	11			16		21
Other vertebrates	422	63		3	46		1
Total	**1364**	**309**	**1**	**21**	**154**	**7**	**48**

Supplementary table 1).

3.4. Not available (NA)

It was impossible to attribute 48 metadata to any Brazilian biome due to a lack of proper information in the files. We tried to contact the metadata owners but they did not reply.

4. Discussion

We found 1904 metadata from studies containing field information about biodiversity, which is concerning, given that Brazil has a vast legacy of research on the topic and is considered the world's most biodiverse country (Cibulski et al., 2020), which could indicate that the majority of information being collected is not available for a broader scientific audience. We are aware that there might be some metadata missing from our compilation, as we could not locate them or the responsible researchers. Many researchers from PELD and PPBio have not stored their metadata online and have not responded to our invitation e-mails to participate in this study. We hope that these and other researchers will update the information compiled in the future. The low adherence of Brazilian researchers regarding the deposition of metadata in repositories raises a red flag, because most of the data that is being collected in the country, costing millions of dollars, the majority from the public budget, is likely to end up in a researcher's drawer without being made available for a broader academic community and decision-makers. Also, the country's policy require that all data collected with public funding should be made available in the national repository SiBBr (system for information regarding Brazilian biodiversity), which, to date, doesn't happen. Even more worrisome is the fact that given the increasing pace of land conversion and species loss, this information could be of major relevance in the construction of science-informed policies on conservation. This scenario highlights the importance of investment in maintaining data repositories, databases and other alternatives that can mirror information from those sites in case some of them are shut down inadvertently. Also, there's a pressing need for public policies to make scientists aware of the importance of making their data available.

4.1. Amazon

Most of the metadata available online originated from studies conducted in the Brazilian Amazon (1364 studies, with 834 available in online repositories, representing approximately 71.63 % of the 1904 metadata included in our study), and the majority were about other vertebrates (422), non-flying mammals (296) and woody plants (244). Even though the biome holds the majority of metadata available, the area is still largely underrepresented (Carvalho et al., 2023), with an index of metadata per biome extension of 0.0003. Most of the metadata about studies conducted in the Brazilian Amazon are concentrated near cities where access to sampling sites is relatively easy. There are several under-sampled areas in the biome due to difficulties of access, and some of them overlap with areas subjected to deforestation (da Ribeiro et al., 2022), fire (Dutra et al., 2022; Lapola et al., 2023) and predicted hotspots for climate change (Carvalho et al., 2023). Another important issue is the prevalence of mining activities (Villén-Pérez et al., 2022), land grabbing and drug traffickers in the wilderness areas of the biome. One of our long-term ecological research areas, the Maraca Ecological Station (ESEC MARACÁ) (Milliken and Ratter, 1998), used by PELD and PPBio, suffered an invasion by armed criminals who held the workers hostage and stole equipment, boats, motorcycles and other goods from the protected area, which has made research there without armed guards impossible for two years. This is just one example of a situation that is becoming increasingly common in the Amazon region and constitutes a serious threat to researchers' safety, making fieldwork, and consequently research, impractical in certain areas.

4.2. Atlantic forest

The Atlantic Forest was the biome with the second largest number of metadata available, with 309 studies – 75 available in online repositories, representing approximately 16.22 % of the total, with the majority of them being about woody plants (77), non-flying mammals (65), and flying mammals (61). The majority of the metadata (206) was collected in Protected Areas, including National Parks, State Parks, Reserves and other categories, which highlights the fact that most research in this biome is being concentrated in a few areas, possibly due to the high suppression of natural native areas (Brandes et al., 2021). Brazil was a Portuguese colony for three centuries, and the country's exploitation processes began on the coast, which concentrates most of the population and industrial development, as well as harbouring a large percentage of Atlantic Forest. This scenario has worsened in the past decades and has led to alarmingly high deforestation rates, which have culminated in only 12 % of the original area covered by Atlantic Forest being conserved (Fundação SOS Mata Atlântica and INPE, 2021), usually distributed in small forest patches (Taubert et al., 2018). Research in Atlantic Forest varies greatly according to its location and population size, and sampling sites might be biased towards places with easier access. The density of metadata available is small considering that this biome has the largest density of universities, research centres and contribution to the national GDP (Gross Domestic Product)(Bucciferro and Ferreira De Souza, 2020).

4.3. Pampa

We found 154 metadata about studies in the Pampa biome, representing approximately 8.08 % of the total. All the metadata from this biome was sent directly from the authors and were not available in

online repositories. Most of the metadata were from studies about non-woody plants (54), other vertebrates (46), woody plants (16) and aquatic vertebrates (16). There was no available information about fungi from this biome, which shows the necessity to advance in future projects and include groups of organisms or biological processes that have not been studied so far. The expansion of agricultural areas poses a threat to biodiversity research in the Pampa (MapBiomas, 2023), as the natural areas decreased from 9.3 million ha to 6.6 million ha between 1985 and 2020 (Andrade et al., 2023). The lack of information leads to a significant deficit in biodiversity protection (Overbeck et al., 2015), and several sampling gaps, as studies in the biome tend to be concentrated near research institutions (Andrade et al., 2023).

4.4. Cerrado

We found 21 metadata about ecological research in Cerrado, which represents approximately 1.1 % of the total, and the majority of them were about non-flying mammals (8), terrestrial invertebrates (7) and woody plants (3). Those numbers are concerning, given that the Cerrado is under great pressure, with alarmingly high deforestation rates due to agribusiness activities, such as plantation crops and cattle raising (Colli et al., 2020). Habitat loss is increasing as the Brazilian agribusiness movement is targeting the Cerrado because it is currently less scrutinized by the international community than the Amazon (Fernandes et al., 2023).

4.5. Pantanal

The Pantanal is the second least represented biome in terms of metadata about studies conducted by PPBio and PELD, with only seven metadata (0.36 % of the total), all of them available in online repositories. Six metadata were from studies about reptiles and one was about mammals. These data originate from only one grid using RAPELD methodology (Magnusson et al., 2005), installed at the Experimental Farm Nhumirim, a property of Embrapa Pantanal. This grid received funding from PELD in 1999 intending to gather data for 10 years, but the cited data wasn't found in our research. The Pantanal biome is suffering high conversion of its natural areas due to the widespread use of fire to reduce the forested areas and the introduction of pasture to cultivate livestock (Coelho-Junior et al., 2022; Ferrante and Fearnside, 2022). South America has the largest areas of tropical peatland, and Brazilian wetlands provide key ecosystem services, such as climate and hydrological regulation (Gumbricht et al., 2017), as well as retaining a large reservoir of soil carbon since the Holocene (Lahteenoja et al., 2009). Given the importance of the biome, the lack of metadata is concerning, and the need for providing standardised data that can provide detailed information to produce syntheses about this region is urgent (Gumbricht et al., 2017).

4.6. Caatinga

The Brazilian Caatinga is the least represented biome in terms of metadata about studies from PPBio and PELD. We were able to find only one record of metadata regarding plants in the region. Those results are alarming, given that the Caatinga Domain is home to the largest seasonally dry tropical forest of the New World (Queiroz et al., 2017) and has received public resources since the creation of PPBio in 2004 (PPBio Semi-árido), together with PPBio Amazonia. The scarcity of metadata from this region is likely related to social bias, as this part of Brazil has the lowest social indicators of the country, resulting in a lack of funding for research, which leads to a smaller number of published papers (Buainain and Garcia, 2013; Santos et al., 2011). There is also a chronic lack of financial investment from decision-makers in this region, which culminated in only 4 % of the total amount of money destined for biodiversity projects in the country being allocated to the Caatinga (Leal et al., 2005). Therefore, it is concerning that the extensive funding by the PPBio and PELD has not resulted in the availability of more data.

4.7. Solutions to mitigate the problem in the next decades

Possible solutions rely on two major challenges: researchers' engagement and investment in data repositories and databases. We expected researchers would be less hesitant to share metadata since it does not demand sharing raw field data. It is likely that many researchers do not understand the importance of metadata, not only to communicate what was done, but to make the raw data useful for future studies (Magnusson et al., 2013). Therefore, major programs, such as the PPBio and PELD, should invest heavily in capacity building for researchers in relation to data management and availability. Without this investment, data collection becomes irrelevant. It underscores the importance of investments being directed towards the several aspects involved in data sharing other than functioning and unified repositories, listed below.

Establishing standardised formats and protocols for biodiversity data collection, storage, and sharing is crucial. This ensures interoperability among different databases and platforms, facilitating seamless collaboration and information exchange among researchers, organisations, and regions (Bergallo et al., 2023; Rosa et al., 2021). Embracing open metadata initiatives encourages transparency and accessibility, since making information about biodiversity datasets openly available, researchers worldwide can contribute to a collective understanding of global biodiversity patterns (see Carvalho et al., 2023; De Lima et al., 2023 for international cooperation examples). Open-data policies also foster innovation and accelerate scientific discoveries (Heberling et al., 2021). Also, using emerging technologies such as artificial intelligence and machine learning, can enhance the efficiency of biodiversity dataset management. Automated data processing, quality control, and pattern recognition contribute to more accurate analyses and rapid decision-making.

Creation of a data and metadata policy has the potential to increase metadata availability. Requiring researchers and programs financed with public resources to deposit data and metadata related to biodiversity on accessible platforms, adhering to a period of up to two years after the conclusion of the project and/or program might increase researchers adhesion to make their metadata available for a broader audience.

Future studies of biodiversity synthesis should aim to add information (e.g. metadata, presence and absence lists, abundance lists) in the gaps identified in our synthesis. Another important objective to be developed in the next years is to synthesize information regarding macroecological patterns and processes. Those measures can be pivotal to elaborate an extended plan to meet the UN Decade on Ecosystem Restoration resolution or the Kunming-Montreal Global Biodiversity Framework, which indicates that many environments, such as forests, oceans, wetlands and soil have the potential to act as sinks and reservoirs of greenhouse effects, and are essential to mitigate climate changes. Our findings can contribute to building scientifically informed strategies to increase the applicability of conservation and ecological restoration planning, identifying areas of high species diversity and richness, as well as identifying the areas of environmental risks or conflicts.

5. Conclusion

Our research was the first systematic attempt to synthesize the information available online about ecological metadata from two prominent publicly funded research programs in Brazil. Most of the metadata about studies synthesized in our research are narrow in spatial scale, leading to severe gaps of sampling in all biomes and limited information at a regional scale. These limitations impede the integration and interoperability of the metadata, restraining its use in broader syntheses, such as meta-analyses and literature reviews. Also, the majority of information about Brazilian biodiversity is stored as species occurrence

lists in fragmented and difficult-to-access repositories, historical publications, theses and dissertations, and its integration into global databases will take years of effort. Given the sparse funding available and the huge challenges to be met, using public funds to collect data that is not made available to the broader scientific community is no longer acceptable, and active collaboration between groups that are part of both programs is urgent. Unified accessibility and interoperability of biodiversity information through initiatives such as SIBBr (Sistema de Informacoes Sobre a Biodiversidade Brasileira), instead of each research group creating individual databases or repositories, is urgent to start integrating the existing platforms for all research groups and studied taxa.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2024.174880.

References

Alba, C., Levy, R., Hufft, R., 2021. Combining botanical collections and ecological data to better describe plant community diversity. PLoS One 16, e0244982. https://doi.org/10.1371/journal.pone.0244982.

Andrade, B.O., Dröse, W., Aguiar, C.A.D., Aires, E.T., Alvares, D.J., Barbieri, R.L., Carvalho, C.J.B.D., Bartz, M., Becker, F.G., Bencke, G.A., Beneduzi, A., Silva, J.B., Blochtein, B., Boldrini, I.I., Boll, P.K., Bordin, J., Silveira, R.M.B.D., Martins, M.B., Bosenbecker, C., Braccini, J., Braun, B., Brito, R., Brown, G.G., Büneker, H.M., Buzatto, C.R., Cavalleri, A., Cechin, S.Z., Colombo, P., Constantino, R., Costa, C.F.D., Dalzochio, M.S., Oliveira, M.G.D., Dias, R.A., Santos, L.A.D., Duarte, A.D.F., Duarte, J.L.P., Durigon, J., Da Silva, M.E., Ferreira, P.P.A., Ferreira, T., Ferrer, J., Ferro, V.G., Fontana, C.S., Freire, M.D., Freitas, T.R.O., Galiano, D., Garcia, M., Dos Santos, T.G., Gomes, L.R.P., Gonzatti, F., Gottschalk, M.S., Graciolli, G., Granada, C.E., Grings, M., Guimarães, P.S., Heydrich, I., Iop, S., Jarenkow, J.A., Jungbluth, P., Käffer, M.I., Kaminski, L.A., Kenne, D.C., Kirst, F.D., Krolow, T.K., Krüger, R.F., Kubiak, B.B., Leal-Zanchet, A.M., Loebmann, D., Lucas, D.B., Lucas, E.M., Luza, A.L., Machado, I. F., Madalozzo, B., Maestri, R., Malabarba, L.R., Maneyro, R., Marinho, M.A.T., Marques, R., Marta, K.D.S., Martins, D.D.S., Martins, G.D.S., Martins, T.R., Mello, A. S.D., Mello, R.L., Mendonça Junior, M.D.S., Morais, A.B.B.D., Moreira, F.F.F., Moreira, L.F.B., Moura, L.D.A., Nervo, M.H., Ott, R., Paludo, P., Passaglia, L.M.P., Périco, E., Petzhold, E.S., Pires, M.M., Poppe, J.L., Quintela, F.M., Raguse-Quadros, M., Pereira, M.J.R., Renner, S., Ribeiro, F.B., Ribeiro, J.R.I., Rodrigues, E.N.L., Rodrigues, P.E.S., Romanowski, H.P., Ruschel, T.P., Saccol, S.D.S.A., Savaris, M., Silveira, F.S., Schmitz, H.J., Siegloch, A.E., Siewert, R.R., Silva Filho, P.J.S.D., Soares, A.G., Somavilla, A., Sperotto, P., Spies, M.R., Tirelli, F.P., Tozetti, A.M., Verrastro, L., Vogel Ely, C., Da Silva, Â.Z., Zank, C., Zefa, E., Overbeck, G.E., 2023. 12,500+ and counting: biodiversity of the Brazilian Pampa. Front. Biogeogr. 15. Doi:10.21425/F5FBG59288.

Barlow, J., França, F., Gardner, T.A., Hicks, C.C., Lennox, G.D., Berenguer, E., Castello, L., Economo, E.P., Ferreira, J., Guénard, B., Gontijo Leal, C., Isaac, V., Lees, A.C., Parr, C.L., Wilson, S.K., Young, P.J., Graham, N.A.J., 2018. The future of hyperdiverse tropical ecosystems. Nature 559, 517–526. https://doi.org/10.1038/s41586-018-0301-1.

Barve, V., Hart, E., Guillou, S., 2022. Rinat: access "iNaturalist" data through APIs.

Bergallo, H.G., Cronemberger, C., Hipolito, J., Magnusson, W.E., Rocha, C.F.D. (Eds.), 2021. The Atlantic Forest: History, Biodiversity, Threats and Opportunities of the Mega-diverse Forest. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-030-55322-7.

Bergallo, H.G., Rosa, C., Ochoa, A.C., Manzatto, A.G., Guimaraes, A.F., Banhos, A., Castilho, C.V., Barros, C.F., Norris, D., Drucker, D.P., Rodrigues, D.J., Baccaro, F.B., Lourenço, I.H., Zuanon, J., Stegmann, L.F., Anjos, M.R., Silveira, M., Araújo, P.S.G., Bobrowiec, P.E.D., Fadini, R., Neckel-Oliveira, S., Emilio, T., Santorelli Junior, S., Magnusson, W.E., 2023. Long-term ecological research: chasing fashions or being prepared for fashion changes? An. Acad. Bras. Ciênc. 95, e20230051 https://doi.org/10.1590/0001-3765202320230051.

Bini, L.M., Diniz-Filho, J.A.F., Rangel, T.F., Bastos, R.P., Pinto, M.P., 2006. Challenging Wallacean and Linnean shortfalls: knowledge gradients and conservation planning in a biodiversity hotspot. Divers. Distrib. 12 (5), 475–482.

Brandes, A.F.D.N., Novello, B.Q., Siston, T., Nascimento, L.B.D., Tamaio, N., Barros, C.F., 2021. An interactive identification key for Atlantic Forest tree species based on macroscopic wood anatomy. Rodriguésia 72, e02402020. https://doi.org/10.1590/2175-7860202172128.

Brito, M.A., Oliveira, D., de Araujo Mamede, M., Randig, O., de Lacerda, F.S., 2020. Programa de pesquisa ecológica de longa duração–PELD/CNPq–desafios da gestão, avanços e perspectivas. Oecologia Australis 24 (2), 259–265.

Buainain, A.M., Garcia, J.R., 2013. Pobreza rural e desenvolvimento do semiárido nordestino: resistência, reprodução e transformação. A nova cara da pobreza rural: desenvolvimento e a questão regional. Brasília: IICA 217–305.

Bucciferro, J.R., Ferreira De Souza, P.H.G., 2020. The evolution of regional income inequality in Brazil, 1872–2015. In: Tirado-Fabregat, D.A., Badia-Miró, M., Willebald, H. (Eds.), Time and Space, Palgrave Studies in Economic History. Springer International Publishing, Cham, pp. 131–156. https://doi.org/10.1007/978-3-030-47553-6_6.

Carvalho, R.L., Resende, A.F., Barlow, J., França, F.M., Moura, M.R., Maciel, R., Alves-Martins, F., Shutt, J., Nunes, C.A., Elias, F., Silveira, J.M., Stegmann, L., Baccaro, F. B., Juen, L., Schietti, J., Aragão, L., Berenguer, E., Castello, L., Costa, F.R.C., Guedes, M.L., Leal, C.G., Lees, A.C., Isaac, V., Nascimento, R.O., Phillips, O.L., Schmidt, F.A., Ter Steege, H., Vaz-de-Mello, F., Venticinque, E.M., Vieira, I.C.G., Zuanon, J., Ferreira, J., Carvalho, R.L., Resende, A.F., Barlow, J., França, F., Moura, M.R., Maciel, R., Alves-Martins, F., Shutt, J., Nunes, C.A., Elias, F., Silveira, J. M., Stegmann, L., Baccaro, F.B., Juen, L., Schietti, J., Aragão, L., Berenguer, E., Castello, L., Costa, F.R.C., Guedes, M.L., Leal, C.G., Lees, A.C., Isaac, V., Nascimento, R.O., Phillips, O.L., Schmidt, F.A., Ter Steege, H., Vaz-de-Mello, F., Venticinque, E.M., Vieira, I.C.G., Zuanon, J., Ferreira, J., Geber Filho, A.N.D.S., Ruschel, A., Calor, A.R., De Lima Alves, A., Muelbert, A.E., Quaresma, A., Vicentini, A., Piedade, A.R.D., Oliveira, A.A.D., Aleixo, A., Casadei-Ferreira, A., Gontijo, A., Hercos, A., Andriolo, A., Lopes, A., Pontes-Lopes, A., Santos, A.P.M.D., Oliveira, A.B.D.S.D., Mortati, A.F., Salcedo, A.K.M., Albernaz, A.L., Fares, A.L., Andrade, A.L., Oliveira Pes, A.M., Faria, A.P.J., Batista, A.P.B., Puker, A., Bueno, A. S., Junqueira, A.B., Holanda De Andrade, A.L.R., Ghidini, A.R., Galuch, A.V., Menezes, A.S.O.D., Manzatto, A.G., Correa, A.S.A.S., Queiroz, A.C.M., Zanzini, A.C. D.S., Olivo Neto, A.M., Melo, A.W.F.D., Guimaraes, A.F., Castro, A.B., Borges, A., Ferreira, A.B., Marimon, B.S., Marimon-Junior, B.H., Flores, B.M., De Resende, B.O., Albuquerque, B.W., Villa, B., Davis, B., Nelson, B., Williamson, B., Melo, B.S.B.D., Cintra, B.B.L., Santos, B.B., Prudente, B.D.S., Luize, B.G., Godoy, B.S., Rutt, C.L., Duarte Ritter, C., Silva, C.V.J., Ribas, C.R., Peres, C.A., Azevêdo, C.A.S.D., Freitas, C., Cordeiro, C.L., Brocardo, C.R., Castilho, C., Levis, C., Doria, C.R.D.C., Arantes, C.C., Santos, C.A.D., Jakovac, C.C., Silva, C.A., Benetti, C.J., Lasmar, C., Marsh, C.J., Andretti, C.B., Oliveira, C.P.D., Cornelius, C., Alves Da Rosa, C., Baider, C., Gualberto, C.G., Deus, C.P.D., Monteiro Jr., C.D.S., Santos Neto, C.R.D., Lobato, C.M. C., Santos, C.R.M.D., Penagos, C.C.M., Costa, D.D.S., Vieira, D.L.M., Aguiar, D.P.P.D., Veras, D.S., Pauletto, D., Braga, D.D.L., Storck-Tonon, D., Almeida, D.D.F., Douglas, D., Amaral, D.D.D., Gris, D., Luther, D., Edwards, D.P., Guimarães, D.P.,

Santos, D.C.D., Campana, D.R.D.S., Nogueira, D.S., Silva, D.R.D., Dutra, D.B.D.S., Rosa, D.C.P., Silva, D.A.S.D., Pedroza, D., Anjos, D.V., Melo Lima, D.V., Silvério, D. V., Rodrigues, D.D.J., Bastos, D., Daly, D., Barbosa, E.M., Arenas, E.R.C., Oliveira, E. A.D., Santos, E.A.D., Santana, E.C.C.D., Guilherme, E., Vidal, E., Campos-Filho, E.M., Van Den Berg, E., Morato, E.F., Da Silva, E.R., Marques, E.E., Pringle, E.G., Nichols, E., Andresen, E., Farias, E.D.S., Siqueira, E.L.S.D., De Albuquerque, E.Z., Görgens, E.B., Cunha, E.J.R.D., Householder, E., Novo, E.M.M.D.L., Oliveira, F.F.D., Roque, F.D.O., Coletti, F., Reis, F., Moreira, F.F.F., Todeschini, F., Carvalho, F.A., Coelho De Souza, F., Silva, F.A.B., Carvalho, F.G., Cabeceira, F.G., d'Horta, F.M., Mendonça, F.P., Florêncio, F.P., Carvalho, F.R.D., Arruda, F.V.D., Nonato, F.A.D.S., Santana, F.D., Durgante, F., Souza, F.K.S.D., Obermuller, F.A., Castro, F.S.D., Wittmann, F., Sales, F.M.D.S., Neto, F.V., Salles, F.F., Borba, G.C., Damasco, G., Barros, G.G., Brejão, G.L., Jardim, G.A., Prance, G.T., Lima, G.R., Desidério, G.R., Melo, G.D.C.D., Carmo, G.H.P.D., Cabral, G.S., Rousseau, G.X., Da Silva, G.C., Schwartz, G., Griffiths, H., Queiroz, H.L.D., Espírito-Santo, H.M.V., Cabette, H.S.R., Nascimento, H.E.M., Vasconcelos, H.L., Medeiros, H., Aguiar, H.J.A.C.D., Leão, H., Wilker, I., Gonçalves, I.C., De Sousa Gorayeb, I., Miranda, I.P.D.A., Brown, I.F., Santos, I.C.S., Fernandes, I.O., Fernandes, I., Delabie, J.H.C., De Abreu, J.C., Gama Neto, J.D.L., Costa, J.B.P., Noronha, J.C., De Brito, J.G., Wolfe, J., Santos, J.C., Ferreira-Ferreira, J.E., Gomes, J.O., Lasky, J.R., De Faria Falcão, J.C., Costa, J.G., Cravo, J.S., Guerrero, J.E.B., Muñoz Gutiérrez, J.A., Carreiras, J., Lanna, J., Silva Brito, J., Schöngart, J., Mendes Aguiar, J.J., Lima, J., Barroso, J.G., Noriega, J.A., Pereira, J.L.D.S., Nessimian, J.L., Souza, J.L.P.D., De Toledo, J.J., Magalhães, J.L.L., Camargo, J.L., Oliveira, J.M.B., Ribeiro, J.M.F., Silva, J.O.D.A., Da Silva Guimarães, J.R., Hawes, J.E., Andrade-Silva, J., Revilla, J.D.C., Da Silva, J.S., Da Silva Menger, J., Rechetelo, J., Stropp, J., Barbosa, J.F., Do Vale, J.D., Louzada, J., Cerqueira Silva, J.C., Da Silva, K.D., Melgaço, K., Carvalho, K.S., Yamamoto, K.C., Mendes, K.R., Vulinec, K., Maia, L.F., Cavalheiro, L., Vedovato, L.B., Demarchi, L.O., Giacomin, L., Dumas, L.L., Maracahipes, L., Brasil, L.S., Ferreira, L.V., Calvão, L.B., Maracahipes-Santos, L., Reis, L.P., Da Silva, L.F., De Oliveira Melo, L., Carvalho, L.C. D.S., Casatti, L., Amado, L.L., De Matos, L.S., Vieira, L., Prado, L.P.D., Alencar, L., Fontenele, L., Mazzei, L., Navarro Paolucci, L., Zanzini, L.P., Carvalho, L.N., Crema, L.C., Brulinger, L.F.B., Montag, L.F.D.A., Naka, L.N., Azara, L., Silveira, L.F., Nunes, L.G.D.O., Rosalino, L.M.D.C., Mestre, L.A.M., Bonates, L.C.D.M., Coelho, L.D. S., Borges, L.H.M., Lourenço, L.D.S., Freitas, M.A.B., Brito, M.T.D.S., Pombo, M.M., Da Rocha, M., Cardoso, M.R., Guedes, M.C., Raseira, M.B., Medeiros, M.B.D., Carim, M.D.J.V., Simon, M.F., Pansonato, M.P., Dos Anjos, M.R., Nascimento, M.T., Souza, M.R.D., Monteiro, M.G.T., Da Silva, M.J., Uehara-Prado, M., Oliveira, M.A.D., Callisto, M., Vital, M.J.S., O Santos, M.P.D., Silveira, M., Oliveira, M.V.N.D., Pérez-Mayorga, M.A., Carniello, M.A., Lopes, M.A., Silveira, M.A.P.D.A., Esposito, M.C., Maldaner, M.E., Passos, M.I.S., Anacléto, M.J.P., Costa, M.K.S., Martins, M.P., Piedade, M.T.F., Irume, M.V., Costa, M.M.S.D., Maximiano, M.F.D.A., Freitas, M.G., Cochrane, M.A., Gastauer, M., Almeida, M.R.N., Souza, M.F.D., Catarino, M., Costa Batista, M., Massam, M.R., Martins, M.F.D.O., Holmgren, M., Almeida, M., Dias, M. S., Espírito Santo, N.B., Benone, N.L., Ivanauskas, N.M., Medeiros, N., Targhetta, N., Félix, N.S., Ferreira, N., Hamada, N., Campos, N., Giehl, N.F.D.S., Metcalf, O.C., Silva, O.G.M.D., Cerqueira, P.V., Moser, P., Miranda, P.N., Peruquetti, P.S.F., Alverga, P.P.D.P., Prist, P., Souto, P., Brando, P., Pompeu, P.D.S., Barni, P.E., Graça, P.M.D.A., Morandi, P.S., Cruz, P.V., I Silva, P.G.D., Bispo, P.C., Camargo, P.B. D., Sarmento, P.S.D.M., Souza, P., Andrade, R.B.D., Braga, R.B., Boldrini, R., Bastos, R.C., Assis, R.L.D., Salomão, Rafael P., Leitão, R.P., Mendes, R.N.G., Carpanedo, R.D.S., Melinski, R.D., Ligeiro, R.E., Pérez, R.E.P., Barbosa, R.I., Cajaiba, R.L., Silvano, R.A.M., Salomão, Renato Portela, Hilário, R.R., Martins, R.T., Perdiz, R.D.O., Vicente, R.E., Silva, R.J.D., Koroiva, R., Solar, R., Silva, R.D.C., S de Lima, R.B., Silva, R.D.S.A.D., Mariano, R., Ribeiro, R.A.B., Fadini, R.F., Oliveira, R.L. C.D., Feitosa, R.M., Matavelli, R., Mormul, R.P., Da Silva, R.R., Zanetti, R., Barthem, R., Almeida, R.P.S., Ribeiro, S.C., R Costa Neto, S.V.D., Nienow, S., Oliveira, S.A.V.D., Borges, S.H., Milheiras, S., Ribeiro, S.P., Couceiro, S.R.M., Sousa, S.A.D., Rodrigues, S.B., Dutra, S.L., Mahood, S., Vieira, S.A., Arrolho, S., Silva, S.S.D., Triana, S.P., Laurance, S., Kunz, S.H., Alvarado, S.T., Rodrigues, T.H.A., Santos, T.F.D., Machado, T.L.D.S., Feldpausch, T.R., Sousa, T., Michelan, T.S., Emilio, T., Brito, T.D.F., André, T., Barbosa, T.A.P., Miguel, T.B., Izzo, T.J., Laranjeiras, T.O., Mendes, T.P., Silva, T.S.F., Krolow, T.K., Begot, T.O., Baker, T.R., Domingues, T.F., Giarrizzo, T., Bentos, T.V., Haugaasen, T., Peixoto, U., Pozzobom, U.M., Korasaki, V., Ribeiro, V.S., Scudeller, V.V., Oliveira, V.H.F., Landeiro, V.L., Santos Ferreira, V.R., Silva, V.D.N.G., Gomes, V.H.F., Oliveira, V.C. D., Firmino, V., Santiago, W.T.V., Beiroz, W., Almeida, W.R.D., Oliveira, W.L.D., Silva, W.C.D., Castro, W., Dáttilo, W., Cruz, W.J.A.D., Silva, W.F.M.D., Magnusson, W.E., Laurance, W., Milliken, W., Paula, W.S.D., Malhi, Y., Shimabukuro, Y.E., Lima, Y.G.D., Shimano, Y., Feitosa, Y., 2023. Pervasive gaps in Amazonian ecological research. Curr. Biol. S0960982223008631 https://doi.org/10.1016/j.cub.2023.06.077.

Cibulski, S., De Lima, F.E.S., Roehe, P.M., 2020. Coronaviruses in Brazilian bats: A matter of concern? PLoS Negl. Trop. Dis. 14, e0008820 https://doi.org/10.1371/journal.pntd.0008820.

Coelho-Junior, M.G., Diele-Viegas, L.M., Calheiros, D.F., Silva Neto, E.C., Fearnside, P. M., Ferrante, L., 2022. Pantanal port licence would threaten the world's largest tropical wetland. Nature Ecology & Evolution 6, 484–485.

Colli, G.R., Vieira, C.R., Dianese, J.C., 2020. Biodiversity and conservation of the Cerrado: recent advances and old challenges. Biodivers. Conserv. 29, 1465–1475. https://doi.org/10.1007/s10531-020-01967-x.

da Ribeiro, R.S., Vicente, R.E., Arrolho, S., Fearnside, P.M., 2022. Amazon deforestation restrictions likely to be circumvented. ERDE 216–217. https://doi.org/10.12854/erde-2022-621.

De Lima, R.B., Görgens, E.B., Da Silva, D.A.S., De Oliveira, C.P., Batista, A.P.B., Caraciolo Ferreira, R.L., Costa, F.R.C., Ferreira de Lima, R.A., Da Silva Aparício, P., De Abreu, J.C., Da Silva, J.A.A., Guimaraes, A.F., Fearnside, P.M., Sousa, T.R., Perdiz, R., Higuchi, N., Berenguer, E., Resende, A.F., Elias, F., De Castilho, C.V., De Medeiros, M.B., De Matos Filho, J.R., Sardinha, M.A., Freitas, M.A.F., Da Silva, J.J., Da Cunha, A.P., Santos, R.M., Muelbert, A.E., Guedes, M.C., Imbrózio, R., De Sousa, C.S.C., Da Silva Aparício, W.C., Da Silva e Silva, B.M., Silva, C.A., Marimon, B. S., Junior, B.H.M., Morandi, P.S., Storck-Tonon, D., Vieira, I.C.G., Schietti, J., Coelho, F., Alves de Almeida, D.R., Castro, W., Carvalho, S.P.C., Da Silva, R.D.S.A., Silveira, J., Camargo, J.L., Melgaço, K., De Freitas, L.J.M., Vedovato, L., Benchimol, M., De Oliveira de Almeida, G., Prance, G., Da Silveira, A.B., Simon, M. F., Garcia, M.L., Silveira, M., Vital, M., Andrade, M.B.T., Silva, N., De Araújo, R.O., Cavalheiro, L., Carpanedo, R., Fernandes, L., Manzatto, A.G., De Andrade, R.T.G., Magnusson, W.E., Laurance, B., Nelson, B.W., Peres, C., Daly, D.C., Rodrigues, D., Zopeletto, A.P., De Oliveira, E.A., Dugachard, E., Barbosa, F.R., Santana, F., Do Amaral, I.L., Ferreira, L.V., Charão, L.S., Ferreira, J., Barlow, J., Blanc, L., Aragão, L., Sist, P., De Paiva Salomão, R., Da Silva, A.S.L., Laurance, S., Feldpausch, T.R., Gardner, T., Santiago, W., Balee, W., Laurance, W.F., Malhi, Y., Phillips, O.L., Da Silva Zanzini, A.C., Rosa, C., Tadeu Oliveira, W., Pereira Zanzini, L., José Silva, R., Mangabeira Albernaz, A.L., 2023. Giants of the Amazon: how does environmental variation drive the diversity patterns of large trees? Glob. Chang. Biol. 29, 4861–4879. https://doi.org/10.1111/gcb.16821.

Dutra, D.J., Anderson, L.O., Fearnside, P.M., Graça, P.M.L.D.A., Yanai, A.M., Dalagnol, R., Burton, C., Jones, C., Betts, R., Aragão, L.E.O.E.C.D., 2022. Fire dynamics in an emerging deforestation frontier in southwestern Amazonia, Brazil. Fire 6, 2. https://doi.org/10.3390/fire6010002.

Fernandes, G.W., Oliveira, H.F.M., Bergallo, H.G., Borges-Junior, V.N.T., Colli, G., Fernandes, S., Fonsêca, N.C., Garda, A.A., Grelle, C.E.V., Nunes, A.V., Perillo, L.N., Rocha, T.C., Rodrigues, D.J., Da Silveira-Filho, R.R., Streit, H., Toma, T.S.P., Viana, P.L., Roque, F.O., 2023. Hidden costs of Europe's deforestation policy. Science 379, 341–342. https://doi.org/10.1126/science.adg2983.

Ferrante, L., Fearnside, P.M., 2022. Brazil's Pantanal threatened by livestock. Science 377, 720–721. https://doi.org/10.1126/science.ade0656.

Fundação SOS Mata Atlântica, INPE, 2021. Fundação SOS Mata Atlântica e INPE.

Gumbricht, T., Roman-Cuesta, R.M., Verchot, L., Herold, M., Wittmann, F., Householder, E., Herold, N., Murdiyarso, D., 2017. An expert system model for mapping tropical wetlands and peatlands reveals South America as the largest contributor. Glob. Chang. Biol. 23, 3581–3599.

Heberling, J.M., Miller, J.T., Noesgaard, D., Weingart, S.B., Schigel, D., 2021. Data integration enables global biodiversity synthesis. Proc. Natl. Acad. Sci. 118, e2018093118 https://doi.org/10.1073/pnas.2018093118.

Hijmans, R., 2023. Spatial Data Analysis_. R package version 1, 7–55. https://CRAN.R-project.org/package=terra.

Hochkirch, A., Samways, M.J., Gerlach, J., Böhm, M., Williams, P., Cardoso, P., Cumberlidge, N., Stephenson, P.J., Seddon, M.B., Clausnitzer, V., Borges, P.A.V., Mueller, G.M., Pearce-Kelly, P., Raimondo, D.C., Danielczak, A., Dijkstra, K.B., 2021. A strategy for the next decade to address data deficiency in neglected biodiversity. Conserv. Biol. 35, 502–509. https://doi.org/10.1111/cobi.13589.

Hortal, J., De Bello, F., Diniz-Filho, J.A.F., Lewinsohn, T.M., Lobo, J.M., Ladle, R.J., 2015. Seven shortfalls that beset large-scale knowledge of biodiversity. Annu. Rev. Ecol. Evol. Syst. 46, 523–549. https://doi.org/10.1146/annurev-ecolsys-112414-054400.

IBGE, 2019. Biomas e sistema costeiro-marinho do Brasil : compatível com a escala 1:250 000. Rio de Janeiro.

Jones, M.B., Slaughter, P., Nahf, R., Boettiger, C., Jones, C., Read, Jordan, Walker, Lauren, Hart, Edmund, Chamberlain, Scott, 2016. dataone: R interface to the DataONE network of data repositories. https://doi.org/10.5063/F1M61H5X.

König, C., Weigelt, P., Schrader, J., Taylor, A., Kattge, J., Kreft, H., 2019. Biodiversity data integration—the significance of data resolution and domain. PLoS Biol. 17, e3000183 https://doi.org/10.1371/journal.pbio.3000183.

Lahteenoja, O., Ruokolainen, K., Schulman, L., Oinonen, M., 2009. Amazonian peatlands: an ignored C sink and potential source. Glob. Chang. Biol. 15, 2311–2320.

Lapola, D.M., Pinho, P., Barlow, J., Aragão, L.E.O.C., Berenguer, E., Carmenta, R., Liddy, H.M., Seixas, H., Silva, C.V.J., Silva-Junior, C.H.L., Alencar, A.A.C., Anderson, L.O., Armenteras, D., Brovkin, V., Calders, K., Chambers, J., Chini, L., Costa, M.H., Faria, B.L., Fearnside, P.M., Ferreira, J., Gatti, L., Gutierrez-Velez, V.H., Han, Z., Hibbard, K., Koven, C., Lawrence, P., Pongratz, J., Portela, B.T.T., Rounsevell, M., Ruane, A.C., Schaldach, R., Da Silva, S.S., Von Randow, C., Walker, W.S., 2023. The drivers and impacts of Amazon forest degradation. Science 379, eabp8622. https://doi.org/10.1126/science.abp8622.

Leal, I.R., Silva, J.M.C., Tabarelli, M., Lacher, T.E., 2005. Changing the Course of Biodiversity Conservation in the Caatinga of Northeastern Brazil.

Leon, L.F., Silva, B., Aviles-Rodriguez, K.J., Buitrago-Rosas, D., 2023. Harnessing the omics revolution to address the global biodiversity crisis. Curr. Opin. Biotechnol. 80, 102901. https://doi.org/10.1016/j.copbio.2023.102901.

Lewinsohn, T.M., Prado, P.I., 2005. How many species are there in Brazil? Conserv. Biol. 19, 619–624. https://doi.org/10.1111/j.1523-1739.2005.00680.x.

Lomolino, M.V., 2004. Conservation biogeography. Frontiers of Biogeography: new directions in the geography of nature 293.

Magnusson, W.E., Lima, A.P., Luizão, R., Luizão, F., Costa, F.R.C., Castilho, C.V.D., Kinupp, V.F., 2005. RAPELD: a modification of the gentry method for biodiversity surveys in long-term ecological research sites. Biota Neotropica 5, 19–24. https://doi.org/10.1590/S1676-06032005000300002.

Magnusson, W.E., Braga-Neto, R., Pezzini, F.F., Baccaro, F., Bergallo, H.G., Penha, J., Domingos, R., Verdade, L.M., Lima, A., Albernaz, A.L., Hero, J.M., 2013. Biodiversity and Integrated Environmental Monitoring (Attema Design).

Magnusson, W.E., Ishikawa, N.K., Lima, A.P., Dias, D.V., Costa, F.M., de Freitas, M.A., de Rodrigues, D. J., Pezzini, F.F., Barreto, M.R., Baccaro, F.B., Emilio, T., Vargas-Isla, R., 2016. A linha de véu: a biodiversidade brasileira desconhecida 21.

Maldonado, C., Molina, C.I., Zizka, A., Persson, C., Taylor, C.M., Albán, J., Chilquillo, E., Rønsted, N., Antonelli, A., 2015. Estimating species diversity and distribution in the era of B ig D ata: to what extent can we trust public databases? Glob. Ecol. Biogeogr. 24, 973–984. https://doi.org/10.1111/geb.12326.

MapBiomas, 6.0 version, 2023. Validation and refinement system for deforestation alerts with high resolution images.

Milliken, W., Ratter, J.A., 1998. Maraca: The Biodiversity and Environment of an Amazonian Rainforest.

Moraes, M.A., Borges, R.A.X., Martins, E.M., Fernandes, R.A., Messina, T., Martinelli, G., 2014. Categorizing threatened species: an analysis of the red list of the flora of Brazil. Oryx 48, 258–265. https://doi.org/10.1017/S003060531200018X.

Moura, M.R, Jetz, W., 2021. Shortfalls and opportunities in terrestrial vertebrate species discovery. Shortfalls Oppor. Terr. Vertebr. Species Discov. 5, 631-639. Doi:; doi:https://doi.org/10.1101/2020.10.23.352690.

Moura, A.M.d.C., Porto, F., Vidal, V., Magalhaes, R.P., Maia, M., Poltosi, M., Palazzi, D., 2015. A semantic integration approach to publish and retrieve ecological data. Semantic Integr. Approach Publ. Retrieve Ecol. Data 87–119.

Mugal, M.A., Wani, S.A., Dar, F.A., Islam, T., Gulzar, R., Malik, A.H., Reddy, C.S., Khuroo, A.A., 2023. Bridging global knowledge gaps in biodiversity databases: a comprehensive data synthesis on tree diversity of India. Biodivers. Conserv. 32, 3089–3107. https://doi.org/10.1007/s10531-023-02659-y.

Oliveira, U., Paglia, A.P., Brescovit, A.D., De Carvalho, C.J.B., Silva, D.P., Rezende, D.T., Leite, F.S.F., Batista, J.A.N., Barbosa, J.P.P.P., Stehmann, J.R., Ascher, J.S., De Vasconcelos, M.F., De Marco, P., Löwenberg-Neto, P., Dias, P.G., Ferro, V.G., Santos, A.J., 2016. The strong influence of collection bias on biodiversity knowledge shortfalls of B razilian terrestrial biodiversity. Divers. Distrib. 22, 1232–1244. https://doi.org/10.1111/ddi.12489.

Overbeck, G.E., Vélez-Martin, E., Scarano, F.R., Lewinsohn, T.M., Fonseca, C.R., Meyer, S.T., Müller, S.C., Ceotto, P., Dadalt, L., Durigan, G., Ganade, G., Gossner, M. M., Guadagnin, D.L., Lorenzen, K., Jacobi, C.M., Weisser, W.W., Pillar, V.D., 2015. Conservation in Brazil needs to include non-forest ecosystems. Divers. Distrib. 21, 1455–1460. https://doi.org/10.1111/ddi.12380.

QGIS Association, 2021. QGis.

Queiroz, L.P., Cardoso, D., Fernandes, M.F., Moro, M.F., 2017. Diversity and Evolution of Flowering Plants of the Caatinga Domain 23–63.

Roque, F.D.O., Uehara-Prado, M., Valente-Neto, F., Quintero, J.M.O., Ribeiro, K.T., Martins, M.B., De Lima, M.G., Souza, F.L., Fischer, E., Da Silva, U.L., Ishida, F.Y., Gray-Spence, A., Pinto, J.O.P., Ribeiro, D.B., Martins, C.D.A., Renaud, P.C., Pays, O., Magnusson, W.E., 2018. A network of monitoring networks for evaluating biodiversity conservation effectiveness in Brazilian protected areas. Perspect. Ecol. Conserv. 16, 177–185. https://doi.org/10.1016/j.pecon.2018.10.003.

Rosa, C., Baccaro, F., Cronemberger, C., Hipólito, J., Barros, C.F., Rodrigues, D.D.J., Neckel-Oliveira, S., Overbeck, G.E., Ricardo, E., Anjos, M.R.D., Ferreguetti, Á.C., Akama, A., Bonifácio, M., Tomas, W.M., Santos, S.A., Ferreira, V.L., Cunha, C.N.D., Penha, J., Pinho, J.B.D., Salis, S.M., Pillar, D., Podgaiski, L.R., Menin, M., Bígio, N.C., Aragón, S., Gilberto, A., Vélez-Martin, E., Mortati, F., Giacomin, L.L., Almeida, T.E., André, T., Pinheiro, M.A., Silveira, D.A., Padial, A.A., Marques, R., Bitar, Y.O.C., Silveira, M., Morato, E.F., Pagotto, D.C., Strussmann, C., Machado, R.B., Fernandes, G.W., Oki, Y., Novais, S., Ferreira, G.B., Barbosa, F.R., Ochoa, A.C., Mangione, A.M., Gatica, A., Carrizo, M.C., Retta, L.M., Jofré, L.E., Castillo, L.L., Neme, A.M., Rueda, C., Toledo, J.J.D., Grelle, C.E.V., Vale, M.M., Vieira, M.V., Cerqueira, R., Higashikawa, E.M., De, F.P., 2021. The Program for Biodiversity Research in Brazil: The Role of Regional Networks for Biodiversity Knowledge, Dissemination, and Conservation.

Santos, J.C., Leal, I.R., Almeida-Cortez, J.S., Fernandes, G.W., Tabarelli, M., 2011. Caatinga: the scientific negligence experienced by a dry tropical Forest. Trop. Conserv. Sci. 4, 276–286. https://doi.org/10.1177/194008291100400306.

Taubert, F., Fischer, R., Groeneveld, J., Lehmann, S., Müller, M.S., Rödig, E., Wiegand, T., Huth, A., 2018. Global patterns of tropical forest fragmentation. Nature 554, 519–522. https://doi.org/10.1038/nature25508.

Vanderbilt, K., Ide, J., Gries, C., Grossman-Clarke, S., Hanson, P., O'Brien, M., Servilla, M., Smith, C., Waide, R., Zollo-Venecek, K., 2022. Publishing ecological data in a repository: an easy workflow for everyone. Bull. Ecol. Soc. Am. 103 https://doi.org/10.1002/bes2.2018.

Villén-Pérez, S., Anaya-Valenzuela, L., Conrado Da Cruz, D., Fearnside, P.M., 2022. Mining threatens isolated indigenous peoples in the Brazilian Amazon. Glob. Environ. Chang. 72, 102398. https://doi.org/10.1016/j.gloenvcha.2021.102398.

Waide, R.B., Brunt, J.W., Servilla, M.S., 2017. Demystifying the landscape of ecological data repositories in the United States. BioScience 67, 1044–1051. https://doi.org/10.1093/biosci/bix117.

Wickham, H., François, R., Henry, L., 2022. Müller, K. dplyr: A grammar of data manipulation. *R package*, version 0.8, 3..