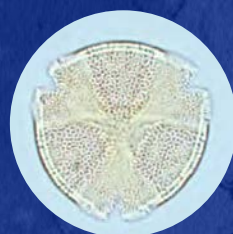
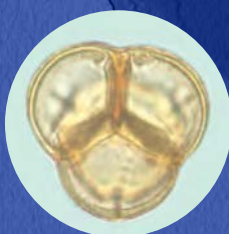
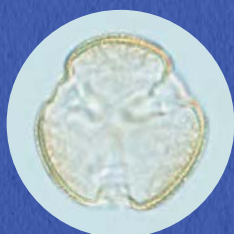
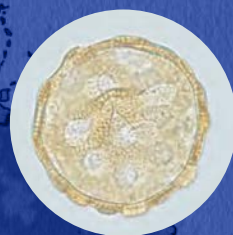
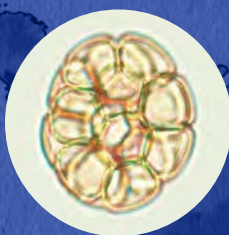
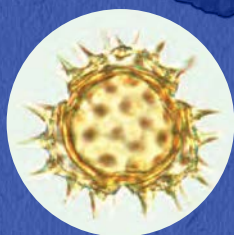


Atlas of pollen and plants used by bees

Cláudia Inês da Silva
Jefferson Nunes Radaeski
Mariana Victorino Nicolosi Arena
Soraia Girardi Bauermann
(organizadores)



Consultoria Inteligente
em Serviços Ecosistêmicos

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Atlas of pollen and plants used by bees

1st Edition

Rio Claro-SP
2020



Consultoria Inteligente
em Serviços Ecosistêmicos

Dados Internacionais de Catalogação na Publicação (CIP)
Lumos Assessoria Editorial
Bibliotecária: Priscila Pena Machado CRB-7/6971

A881 Atlas of pollen and plants used by bees [recurso eletrônico] / orgs. Cláudia Inês da Silva ... [et al.]. — 1. ed. — Rio Claro : CISE, 2020.
Dados eletrônicos (pdf).

Inclui bibliografia.
ISBN 978-65-86372-01-4

1. Palinologia - Catálogos. 2. Abelhas. 3. Pólen - Morfologia. 4. Ecologia. I. Silva, Cláudia Inês da. II. Radaeski, Jefferson Nunes. III. Arena, Mariana Victorino Nicolosi. IV. Bauermann, Soraia Girardi. V. Consultoria Inteligente em Serviços Ecossistemicos (CISE). VI. Título.

CDD 638.13

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Supported projects

Bayer
Online Pollen Catalogs Network (RCPol)
Intelligent Consulting in Ecosystem Services (CISE)
Foundation for the Technological Development of Engineering (FDTE)

Scientific content

National Council for Scientific and Technical Research – CONICET
Embrapa Western Amazon – EMPRAPA
Embrapa Eastern Amazon – EMPRAPA
Nova Esperança School of Medicine and Nursing – FACENE
National Amazon Research Institute – INPA
University of Magdalena – UNIMAG

Nueva Granada University - UMNG
University of International Integration of Afro-Brazilian Lusophony – UNILAB
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Federal University of Ceará – UFC
Federal Rural University of the Semi-Arid – UFRSA
Lutheran University of Brazil – ULBRA
University of Guelph

Collaboration

Antônio Mauro Saraiva (Escola Politécnica da Universidade de São Paulo)

Graphic project

Bruno Nunes Silva

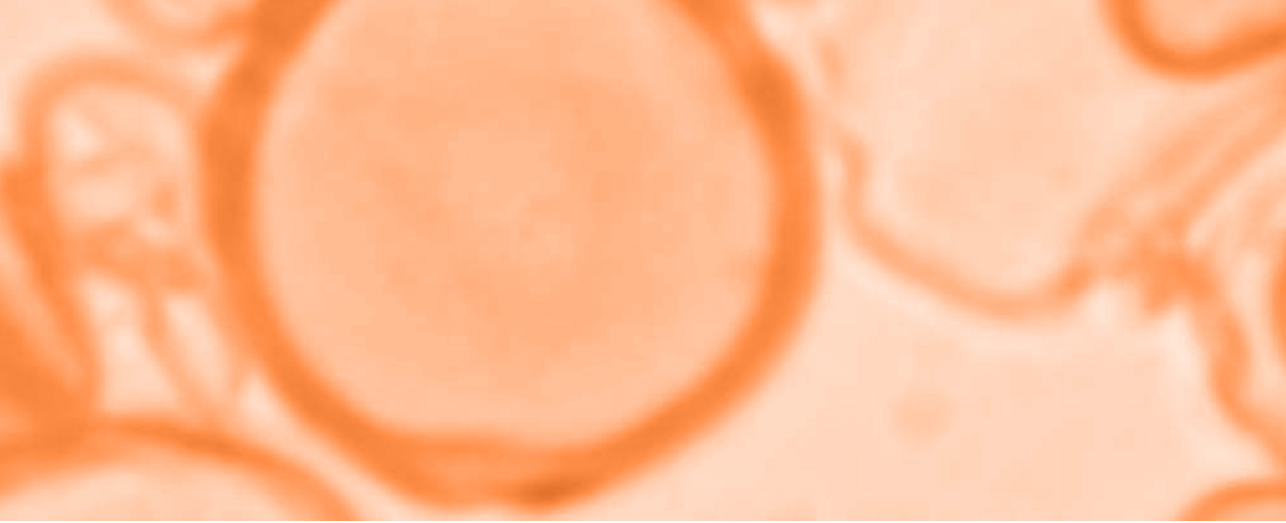
Technical support

Plant species identification: Carole Ann Lacroix (OAC Herbarium), PhD. Cíntia Luíza da Silva Luz (IBUSP), Deicy Paola Alarcón-Prado (UMNG), M.Sc. Eduino Carbonó de la Hoz (UNIMAG), M.Sc. Francisco Fajardo Gutiérrez (JBB), José Ramos (INPA), PhD. José Rubens Pirani (IBUSP), PhD. Luiz Wilson Lima-Verde (UFC), PhD. Maria Iracema Bezerra Loiola (UFC), Mariana Mesquita (INPA), M.Sc. Melissa Guerrero (UMNG), PhD. Milton Groppo (FFCLRP-USP), Osmar Ribas (UFPR), PhD. Rubens Teixeira de Queiroz (UFPB), M.Sc. Sandy C. Padilla-Báez.

Bee species identification: M.Sc. Carlos Poveda-Coronel (UMNG), Favízia Freitas de Oliveira (BIOSIS - UFBA), PhD. Marcio Oliveira (INPA), Ruben D. Martín-Rojas (UMNG), M.Sc. Thiago Mahlmann (INPA).

Pictures of pollen grains: RCPol's photographic collection, Cláudia Inês da Silva, Daniel Felipe Alvarado Ospino, Deicy Paola Alarcón-Prado, Jefferson Nunes Radaeski, Melissa Guerrero, Sandy C. Padilla-Báez.

Pictures of plants, flowers, bees, and nests: RCPol's photographic collection, Cláudia Inês da Silva, Carlos Poveda-Coronel, Cristiane Krug, Daniel Felipe Alvarado Ospino, Deicy Paola Alarcón-Prado, Epifânia Emanuela de Macêdo Rocha, Franciélli Cristiane Woitowicz-Gruchowski, Gercy Soares Pinto, Hugo A. Sanchez-Marroquín, Jefferson Nunes Radaeski, Kevin Farouk Miranda Deluque, Matheus Montefusco, Melissa Guerrero, Michael Hrcir, Paula Andrea Sepúlveda-Cano, Patrícia Nunes-Silva, Ruben D. Martín-Rojas, Sandy C. Padilla-Báez



The most intriguing insect on the planet is in focus again as we take a journey through the intricate details of bee life.

The incredible organization they apply to survive and thrive as a community has always been a matter of extreme interest to researchers and enthusiasts alike.

As a research and development company, Bayer has been dedicated to studying bees for more than thirty years. Understanding their relevance in pollination and in preserving biodiversity, the company has sponsored this project in order to establish a reference in literature.

This compilation of studies was published by the most important bee specialists.


We would like to thank all the entities and professionals involved, especially the coordination group for their dedication.

Claudia Quaglierini
Tropical Intelligence Manager
CEAT - BAYER

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The background of the entire page is a microscopic image of pollen grains, showing their intricate, circular or oval shapes with various surface textures. The color is a warm, orange-brown hue.

Online Pollen Catalogs Network: digital database of pollen and spores of current plants and fossils

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The Online Pollen Catalogs Network - RCPol (www.rcpol.org.br) was conceived in 2009, officially created in September 2013, and opened to the scientific community at the XIV International Palynological Congress and X International Organization of Palaeobotanical Conference in Salvador, State of Bahia, Brazil, in 2016. Since its conception, RCPol has been proposed with the main objectives of creating a digital repository of pollen and plant collections for their conservation and avoiding potential loss of material, becoming a free access tool to researchers (collaborators) and the global community.

A small technical group was responsible for carrying out the essential task of building the computer system and a group of collaborators established standards and protocols to be followed by the members of the network (Silva et al. 2014a, b; Figure 1). The achievement of this first major objective resulted in a digital platform through the development of a computational tool called “interactive key with multiple entries

for species identification”, by the coordinators of RCPol, Cláudia Inês da Silva, Antonio Mauro Saraiva and researchers from the Polytechnic School of the University of São Paulo, a stage made possible by the financing of the project by the University and Bayer.

Since 2016, the database has three interactive keys, Palynotaxonomy, Palynoecology and Paleopalynology, in which morphological traits of pollen and flower of current angiosperms can be consulted, in addition to scattered pollen and spores from the Quaternary. Each key has a glossary of terms and a template sheet that allows the network collaborator to upload the morphological and location information of their plant specimens and pollen grains contained in the plant and pollen collections (Table 1, Figure 2).

In 2016, it was proposed the expansion of the database to contain information about Gymnosperms and spores of Ferns and Lycophytes. In 2017, the process of building the interactive spore key and its corresponding glossaries and spreadsheets was carried out, and in



Figure 1. Workshop held at the University of São Paulo in 2016, in which researchers from various lines of research participated to help build the RCPol site.

Table 1. Example of the information incorporated by collaborators in the interactive key with multiple entries for species identification.

Institution	Number of specimens	Year	Key
CICYTTP	13	2017	Spores
ULBRA	14	2017	
UFRJ	54	2018	
ULBRA	106	2017	Paleopalynology
GOETTINGEN	225	2017	
FFCLRP-USP	99	2016	Palynoecology
UFC	364	2016	
UFU	77	2016	
UFERSA	64	2017	
UFC	82	2017	
UMNG	48	2018	
IBUSP	217	2019	
ULBRA	132	2017	Palynotaxonomy
FFCLRP-USP	99	2016	
UFC	364	2016	
UFU	77	2016	
UFERSA	64	2017	
UFC	82	2017	
UMNG	48	2018	
ITV	14	2017	
ULBRA	95	2018	
UFPR	29	2019	
IBUSP	169	2019	
FML	13	2019	
CBUMAG	71	2019	
ROM	29	2019	
UOFG	98	2019	
UEM	144	2020	

2018 the information from collections in Brazil and Argentina was made available online (Table 1, Figure 2).

In 2020, the key that contains essential information about the interaction of plants and bees to characterize their food resources was also made available (Figure 3). Funders and members of RCPol considered this issue to be of great importance. Fundamental financial support was provided to face numerous challenges that successfully materialized several achievements:

1. Four interactive keys are available with their glossaries of terms;
2. Outstanding increase in the number of species in each key and specimens belonging to various pollen collec-

tions, from many institutions in several countries (Table 1);

3. Seventeen collections were added to the network;
4. More than 12,830 pictures of plants (958), flowers (901), pollen (Palynotaxonomy = 6636; Palynocology = 3604; Paleopalynology = 331; Spores of = 324) and bees (76) were added;
5. More than 1,200 participants joined 7 workshops and 12 scientific meetings, given by 30 instructors at scientific institutions and events in Brazil and other countries, and expressed their support and intention to collaborate with the information in their collections (see www.rcpol.com.br, Figure 4).

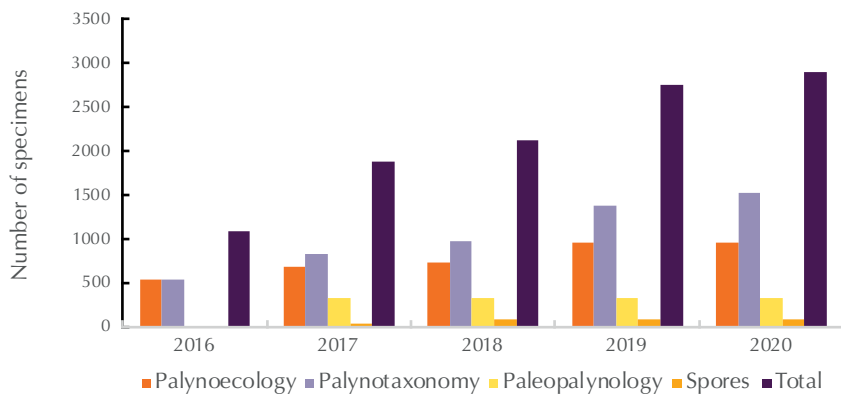


Figure 2. Evolution of the loading of pollen collection specimens in the RCPol from 2016 to 2020.

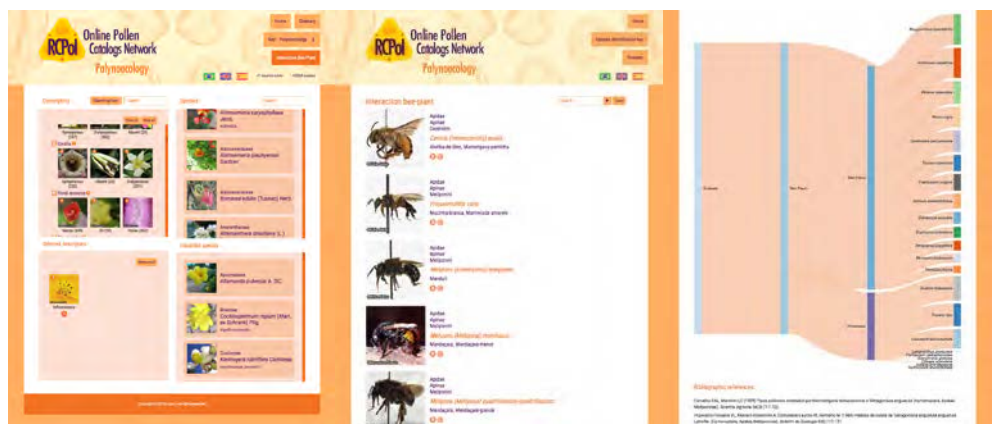


Figure 3. Palynoecology key and its application in the bee conservation.



Figure 4. Sample of activities carried out in workshops offered at different institutions in Brazil and other countries.

The information provided by RCPol allows the identification of current and Quaternary species as the first link in the development of applied studies in different lines of Palynology (e.g. Melissopalynology, Aeropalynology, Archeopalynology, Forensic palynology, Paleopalynology, Actuopalynology), Botany, Ecology, Zoology, Agronomy, etc. They are also essential information to generate good flora management in natural and cultivated areas, in order to preserve pollinator species that use pollen grains and other flower products as food resources. Studies on pollinator food preferences, typical of each region, allow to maintain or even improve fruit and seed production. Also are good tools to the conservation strategies in protected areas, which are the refuge of natural pollinators. The studies also allow us to know how these pollinators could adapt to natural or man-made environmental changes. A permanent challenge is to expand the collaborators base to add new collections and data.

The RCPol website (www.rcpol.org.br) also provides several information related to the institutions that host the collections and their managers (collaborators), in addition to bibliographic references used as support, news, events and courses of interest to the scientific community. It is also possible to download published regional flora catalogs that have adopted a format similar to that of RCPol.

A strategy to publicize the network and present successive advances included participation in scientific events and the provision of workshops and training courses at events and institutions in many countries. Different aspects were addressed in these events and courses, such as the use of computational tools for data loading and, fundamentally, the standardization of data quality in the morphological description of plants and pollen. This data quality control, as established in the network standards, is carried out by a group of scientists to allow the incorporation of the information in the database.

Another important point is the data usage policy of the RCPol network. It was very important to define the obligations and rights of those responsible for the data for each pollen collection and the conditions for access and use by users. In the first case, aspects such as data quality were considered and it was agreed that the data incorporated into the network must follow a standard quality policy. A collection of different data policy models was carried out to serve as a basis for discussing the policy that RCPol would adopt. It is important to note that the data come from researchers and their institutions and not from RCPol, which has only the tools for aggregating and disseminating information. This favors the meeting of researchers and information about their collections and work.

RCPol has a complex information system behind its website and its development faced five challenges in Biodiversity Informatics: 1) Data Integration; 2) Data Standardization; 3) Data Quality; 4) Data Internationalization; and 5) Data Publishing. The RCPol goal was to integrate high quality data provided by several researchers spread over several institutions and countries. These data must be standardized to allow integration and be easily used by a many people from around the world, with different interests, who can benefit from this pollen-related information. Enabling the access to integrated data from different sources enhances the usefulness of the data for application in a wide range of research, which could expand the scientific knowledge in several areas.

To allow data integration, a data standardization process must be carried out. The Biodiversity Information Standards (TDWG - www.tdwg.org) supported the standardization of data on biodiversity, focusing mainly on data on the occurrence of biological species. However, in the specific case of pollen data, RCPol had to create a new data standard to support the integration of pollen data. We adopted the Darwin Core (DwC)

standard as much as possible (Wieczorek et al. 2012) and developed specific terms (its syntax and semantics) to accommodate the need to describe pollen data not addressed by DwC. This was done in conjunction with the members of RCPol and based on international literature to provide a solid foundation. The result can be consulted in a glossary of terms available in three languages (English, Brazilian Portuguese and Spanish) at <http://chaves.rcpol.org.br/profile/glossary/eco>.

To provide reliable data for data consumers, RCPol has adopted a data quality assurance policy. All datasets provided by RCPol members are evaluated by RCPol palynology specialists and, when a dataset is compatible with the RCPol's data quality policy, these data are published on the web-based system (<http://chaves.rcpol.org.br>). This data quality assessment used to be performed manually by specialists and was time consuming and subject to failure due to the large volume of data. To support the data quality assessment in a more automated and effective way, a data quality tool was developed that implements a series of mechanisms to measure, validate and improve integrity, consistency, compliance, accessibility and exclusivity of the data, before the manual evaluation by experts.

The system was designed according to the conceptual framework proposed in Task Group 1 of the TDWG Biodiversity Data Quality Interest Group (Veiga et al. 2017). For each dataset, the data quality tool generates a set of measurement asser-

tions, validations and amendments for the records and the dataset itself, according to a data quality profile defined for RCPol. As RCPol has adopted a quality assurance approach (only data that are compatible with all quality requirements are published in the system), only datasets with 100% of integrity, consistency, compliance, accessibility and exclusivity are published.

This web-based tool is available at <http://chaves.rcpol.org.br/admin/data-quality>. Although this system contributes to significantly reduce the amount of work by specialists, some data may still contain values that cannot be easily and automatically assessed (for example, validating whether the content of an image corresponds to its scientific name). Thus, manual evaluation by specialists remains necessary in some cases. After the system reports that the data conforms to the profile, a manual assessment must be carried out by the experts (using the data quality report to support them) and, only after this process, will the dataset be ready for publication (Figure 5).

To make the RCPol data useful for most people from different countries, needs and backgrounds, the entire system and data are available in three languages. A mechanism was developed that translates datasets from their original language into English, Portuguese and Spanish, based on the RCPol standardized metadata scheme. Therefore, when a dataset originally created in English, for example, is published in the RCPol system, it is automatically available in three

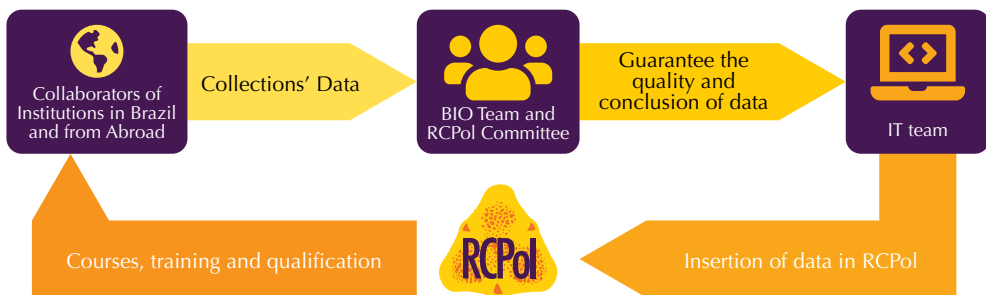


Figure 4. Process carried out by RCPol members.

languages for the RCPol data user, without any effort from our data providers to do the manual translation.

To enhance the usefulness of all data provided by RCPol members, these data are used to present information in an easier way for non-technical people. The RCPol system publishes data-based information in six ways: 1) interactive keys, to facilitate species identification based on pollen, flower and plant features; 2) species profiles, which provide various useful information about a species, compiled from several samples of specimens from the same taxon; 3) specimen profiles, containing information for each specimen provided by RCPol members, and which allow the generation of species profiles and interactive keys; 4) institution profiles, with contact information about RCPol members, to promote interactions between data providers and consumers; 5) bee-plant interactions, with information on interactions presented according to geographic regions; and 6) glossaries of terms, integrated with the interactive keys, species profiles, specimen profiles and interaction networks, which help non-technical people use and interpret RCPol's shared data.

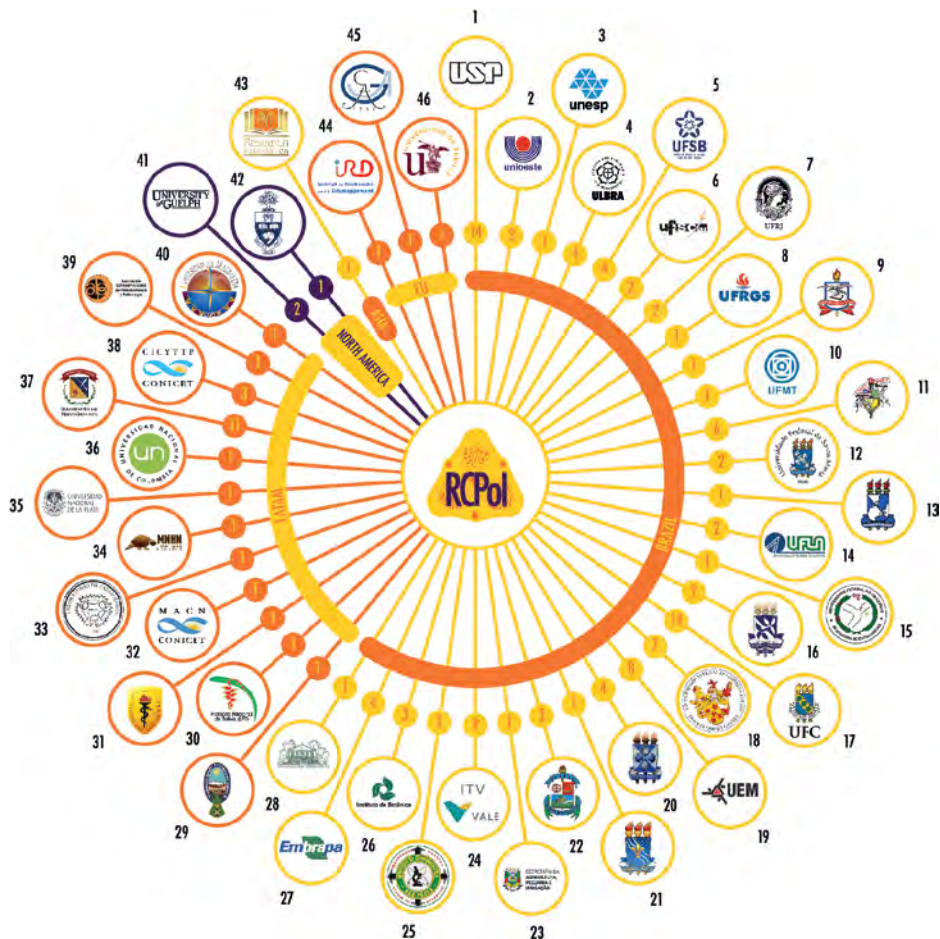
So far, the RCPol website has more than 194,000 accesses and, as a demon-

stration of the system's impact, the data published by RCPol have been accessed 52,000 times and reached more than 11,000 people from more than 1,000 cities in 68 countries worldwide, according to Google analytics on April 1, 2020.

Acknowledgments: This work was supported by the research funding from the Bayer to RCPol - Online Pollen Catalogs Network (FDTE process # 001505). The coordinators of RCPol and the authors of this chapter thank all the collaborators of RCPol and the technician team, who received a technical support scholarship during the development of this project: Bruno Nunes Silva (FDTE process # TA 1505.01.15), Jefferson Nunes Radaeski (FDTE process # TA 1505.03.15), Allan Koch Veiga (FDTE process # BP 1505.02.16 and BP 1505.01.17), Ana Carolina Oliveira da Silva (FDTE process # BTT 1505.02.17 and BTT 1505.01.19), Elisa Pereira Queiroz (FDTE process # BTT 1505.02.15), Isabelle G. F. dos Santos (FDTE process # BIC 1505.03.16), José Elton de M. Nascimento (FDTE process # BTT 1505.01.16), Patrick Eli Catach (FDTE process # BIC 1505.01.15), Cíntia Luíza da Silva Luz (FDTE process # BTT 1505.01.18) and Cláudia Inês da Silva (FDTE process # BP 1505.04.15).

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46. University of Sevilla

RCPol partner institutions and number of researchers and collaborators between 2015 and 2020 (<http://rcpol.org.br/en/about-us/team/>)



Bombus atratus visiting flower of *Pentas lanceolata*



Eucera pruniosa visiting flower of *Cosmos bipinnatus*