Organization of American States

iabin
Red Interamericana de Información sobre Biodiversidad

Final Technical and Financial Report

IABIN Pollinators Thematic Network

CEPANN - Data Digitalization Grant

Grant: Digitize the Bee- Plant Relationships in the Records of Entomological Collection Paulo Nogueira Neto (CEPaNN) Bee Collection and Modify the Tool Webbee

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1. Executive Summary

The entomological collection Paulo Nogueira Neto (CEPANN) was originally digitized by a project supported by Sao Paulo State Reseacrh Foundation, FAPESP-Brazil and is available online in http://splink.cria.org.br/manager/detail?resource=CEPANN&setlang=pt. It is a reference collection for ecological studies, with 38.600 bees, among them 442 species identified by specialists and some more identified until genus (1694 bees). Those bees were collected in annual bee surveys in the Atlantic Rainforest, "Cerrado" (Brazilian savannah) fragments, gardens in antrophic areas, as well as in occasional bee collections in several areas and bees gotten from their nests. Nevertheless, we have also field books with data on the flowers where some bees were collected, available for 17.173 specimens. This proposal aimed at digitizing the information contained in field books, concerning bees and flowers where they were collected as well as bees and fragrances for Euglossini, in order to make them available on line. The bee collection from IBUSP is an official collection according to Brazilian laws, being able to receive additional samples, according to the rules established for biological collections by the Brazilian Ministry of Environment. The importance of its content is related to the temporal series of bees collected in important areas and different sizes of fragments of "cerrado". In this IABIN Grant project we were able to digitize 17,536 records, 88.10% of which (15,450 out of 17,536 records) correspond to specimens placed at our "Entomological Collection Paulo Nogueira-Neto (CEPANN)" and 11.90% (2,086 out of 17,536 records) are observational records, which were presented in a PhD thesis. The data refers to five bee families and 111 plant families and each record contains interaction data. Besides digitizing the data we performed important data quality checking and corrections for bee and plant names, and for geographic data. Further detail on the distribution of the data by family and by region is given.

data from this first part of the work data from 10.000 specimens were digitized from field books and are available on a spreadsheet, ready to be input to an online system.

In order to make the data available to IABIN PTN data portal the on line system WebBee had to be updated and modified to accommodate plant-bee interaction data and to follow the Interaction extension of Darwin core proposed by IABIN PTN. It also required that a data provider based on TAPIR protocol to be included on top of the database. After all the data was inserted, they were harvested by the IABIN PTN data portal (which can be accessed via IABIN PTN website http://pollinators.iabin.net/portal), under the supervision of IABIN PTN project technical team and is now available on-line. Administrative interfaces have been developed and can be accessed at http://pequi.pcs.usp.br/tapirlink/www/tapir.php/cepann_specimens for specimen data, at http://pequi.pcs.usp.br/tapirlink/www/tapir.php/cepann_interactions for interaction data between specimens, both refereeing to the TAPIR provider public interface, and at http://pequi.pcs.usp.br/pdd/grantees/index.php it can be viewed the data input interface used by the grantees to enter data (login necessary).

2. Programmed Products' Results and Reach of the Project

The proposal was to organize and digitize all the information relative to bees of the Entomological Collection CEPANN collected on bee surveys in several areas. The information was digitized from the field books.

The organized data consists of the following fields (English/Portuguese)

- Institution code - codigo_da_instituicao
- Collection doce - codigo_da_colecao
- Catalog number - catalogo
- Previous catalog number - numero_de_catalogo_anterior
- Day of collect - dia_da_coleta
- Month of collect - mês_da_coleta

- Year of collect - ano_da_coleta
- Date of collect - data_coleta
- Time - horario
- Temperature - temperatura
- Humidity - umidade
- Luminosity - luminosidade
- Sector - setor
- Number (plant) - numero(planta)
- Family - familia(planta)
- Genus (plant) - genero(planta)
- Cf/aff (plant) - cf/aff(planta)
- Species (plant) - especie (planta)
- Scientific name author (plant) - autor do nome cientifico (planta)
- Size - tamanho
- Simetry - simetria
- Color - cor
- Flowering - florada
- Habit - habito
- Height - altura
- Trap (essence) - armadilha_(essencia)
- Kingdom - reino
- Filum - filo
- Subfilum - subfilo
- Class - classe
- Order - ordem
- Suborder - subordem
- Infraorder - infraordem
- Superfamily - superfamilia
- Series - serie
- Family - familia

- Subfamily - subfamilia
- Tribe - tribo
- Genus - genero
- Subgenus - subgenero
- cf/aff.
- Species - especie
- Subspecies - subespecie
- Scientific name author - autor_do_nome_cientifico
- Identification day - dia_de_identificacao
- Identification month - mês_de_identificacao
- Identification year - ano_de_identificacao
- Identification data - data_identificacao
- Identified by - identificado_por
- Sex/cast - sexo/casta
- Popular name - nome_popular
- Locality - localidade
- Type of ambient - tipo_de_ambiente
- County - municipio
- State - estado
- Country - pais
- Continent or ocean - continente_ou_oceano
- longitude
- latitude
- datum
- source - fonte
- colector - coletor
- number of the colony - numero_da_colonia
- notes - notas

A spreadsheet was used to organize data as it was digitized from the field books. In order to allow insertion of the data into WebBee its database was redesigned and a new interface for data entry was developed. This was done in parallel with the digitization of bee data.

3. Employed methodology and activities done to achieve the programmed products.

The two main group of activities developed were data digitization and development of a tool to enable WebBee to receive bee-plant interaction data and to provide it to IABIN PTN data portal.

3.1 Digitization of plant-bee interaction data

All the specimens are in our "Entomological Collection Paulo Nogueira-Neto (CEPANN)". During the first stage of the current project, the spreadsheet was re-structured in such a way as to allow that all the information about a given bee specimen could be registered.

The majority of bees were already catalogued with their respective collection number. For those that were not catalogued, collection number labels were placed.

Bees collected by Pinheiro-Machado (1995-1996) were stored in the collection only with field code labels. For those, labels with information of locality, date and name of collector were placed. The information was present on researcher's field book.

The information was organised in 60 fields in an Excel spreadsheet, which comprised:

- survey notes: date, time, researcher's name;
- climatic factors: temperature, relative humidity, luminosity;
- geographic notes: locality, type of environment; city, state, country, continent, longitude, latitude, datum;

- taxonomic data about the bee specimen: family, subfamily, tribe, genus, subgenus, species, subspecies, scientific name's author; taxonomist responsible for the identification, date of identification; sex and/or caste, popular name;
- taxonomic data about the vegetal specimen: family, genus, species, scientific name's;
- vegetal characteristics: height, habit (herbal, shrub, tree), number of flowers, flower color, flower symmetry.

Overall, we digitized 17,536 records, and from these 88.10% (15,450 out of 17,536 records) correspond to specimens placed at our "Entomological Collection Paulo Nogueira-Neto (CEPANN)" and 11.90% (2,086 out of 17,536 records) are observational records, which were presented in a PhD thesis (Wilms, 1995). All the records were catalogued with their respective collection number or for those extracted from PhD thesis with new catalog number labels.

Besides digitizing the data we performed important data quality checking. For bee scientific names, we corrected them in accordance with the "*Catalogue of Bees (Hymenoptera, Apoidea) in the Neotropical Region*" website (www.moure.cria.org.br). For plant names we checked, updated and corrected them based on the "*Catalogue of Life: 2008-2009 Annual Checklist*" website (http://www.catalogueoflife.org/search.php). Geographic data such as latitude, longitude and datum was not explicitly available for many points. In order to obtain them we used the "*geoLoc*" tool (http://splink.cria.org.br/geoloc?criaLANG=pt), and based on the county name where the surveys were performed we were able to obtain the lat-long data.

3.1.1. Bee data

The vast majority of our database is composed by bees belonging to Apidae family (Fig. 1), and the first eight genera of Apidae (Apis, Bombus, Ceratina, Paratrigona, Plebeia, Scaptotrigona, Tetragonisca and Trigona) correspond to 61.32% of the records (10,753 out of 17,536 records; Fig. 2). On the other hand, just 54 bee genera had less than 10 records for each genus, which corresponds to 1.08% of all the records (189 out of 17,536 records; Fig. 3). In total, we recorded 107 bee genera.

Concerning the unknown bee species, 16.43% (2,881 out of 17,536 records) we just know the genus (Table 1) and Apidae was the family with the highest number of species not identified, followed by Halictidae, Colletidae, Megachilidae and Andrenidae (Table 1).

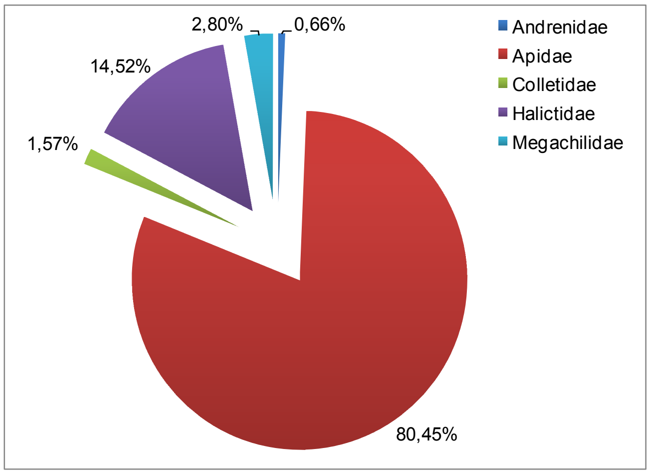

Figure 1. Relative frequencies of bee families present in the database (n=17,536 records).

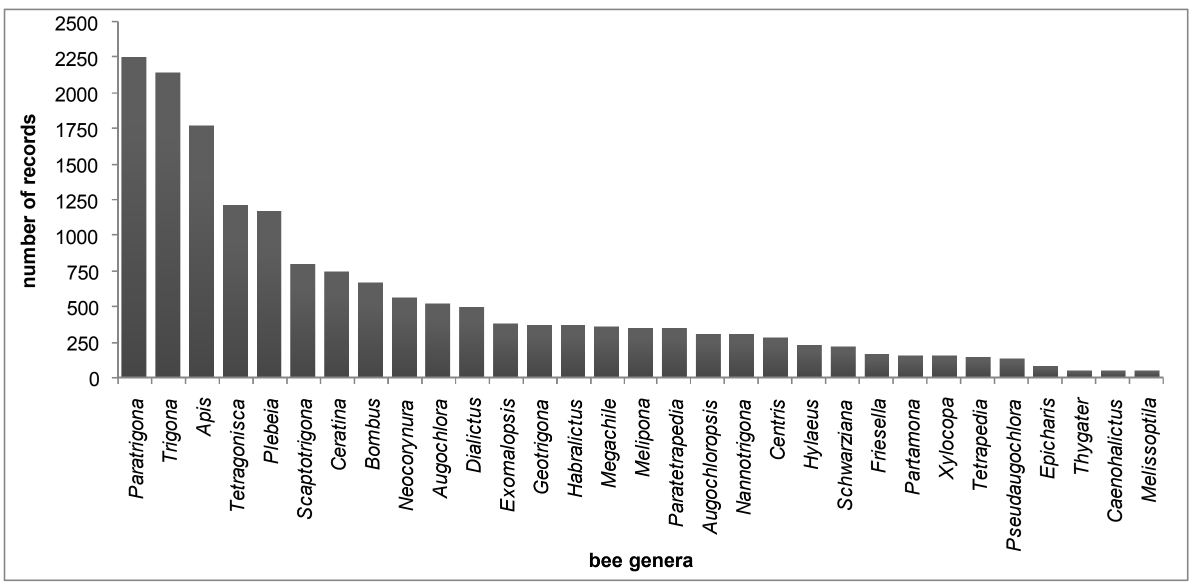

Figure 2. Number of records for the most representative bee genera (from 50 to 2,252 records).

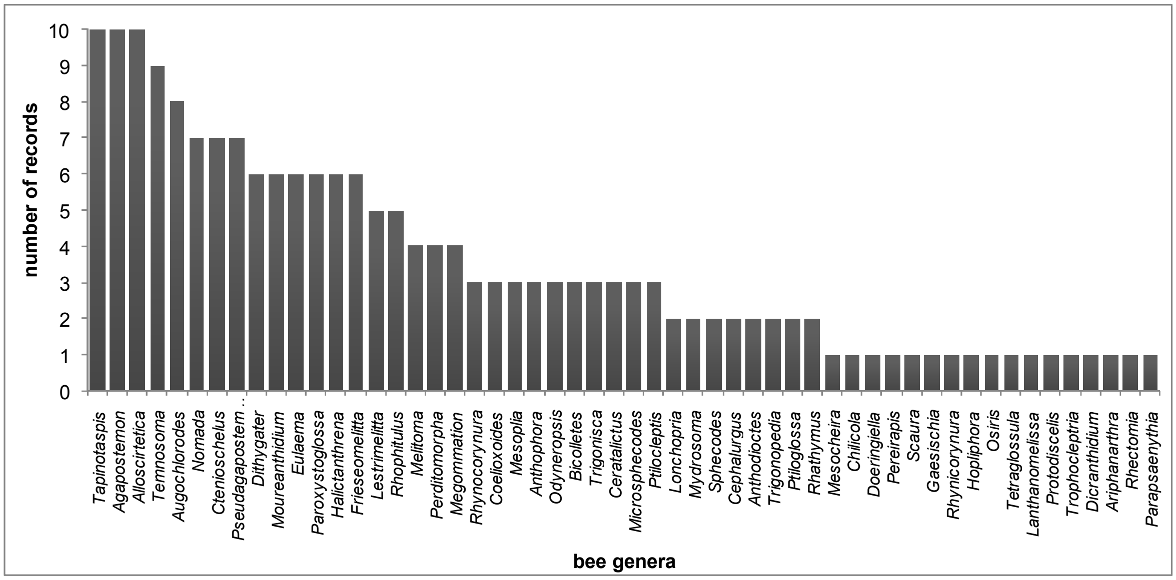

Figure 3. Number of records for the less representative bee genera.

Table 1. Number of records for each bee genus whose species was not identified (n=2,881 records).

Bee genera	Number of records	Relative frequency of families with unknown species records
Anthrenoides	4	
Oxaea	4	
Panurgillus	9	
Psaenythia	1	
Rhophitulus	5	
Andrenidae (total)	**23**	**0.80%**
Bombus	52	
Centris	10	
Ceratina	373	
Coelioxoides	1	
Diadasina	12	
Eufriesea	2	
Exomalopsis	150	
Florilegus	19	
Geotrigona	5	
Lanthanomelissa	1	
Melipona	2	
Melissoptila	1	
Monoeca	9	
Nannotrigona	1	
Nomada	3	
Osiris	1	
Paratetrapedia	178	
Paratrigona	59	
Partamona	73	
Plebeia	248	
Rhathymus	2	
Scaptotrigona	165	

Tapinotaspis	10	
Tetragona	3	
Tetrapedia	102	
Thygater	3	
Trigona	44	
Trigonisca	3	
Trigonopedia	1	
Trophocleptria	1	
Xylocopa	22	
Apidae (total)	**1556**	**54.01%**
Bicolletes	2	
Hylaeus	217	
Mydrosoma	1	
Zikanapis	7	
Colletidae (total)	**227**	**7.88%**
Agapostemon	3	
Augochlora	98	
Augochlorella	11	
Augochlorodes	3	
Augochloropsis	98	
Caenohalictus	26	
Ceratalictus	2	
Dialictus	408	
Habralictus	41	
Megommation	1	
Neocorynura	150	
Paroxystoglossa	2	
Pseudagapostemon	1	
Pseudaugochlora	104	
Ptilocleptis	1	
Rhynocorynura	2	
Sphecodes	2	
Temnosoma	4	
Halictidae (total)	**957**	**33.22%**
Coelioxys	32	
Epanthidium	1	
Hypanthidium	4	
Megachile	81	
Megachilidae (total)	**118**	**4.10%**

3.1.2. Plant data

In total we registered 111 plant families. The first nine families (Araliaceae, Asteraceae, Euphorbiaceae, Fabaceae, Lamiaceae, Rosaceae, Rubiaceae, Sapindaceae and Solanaceae) were the most representative in our database, corresponding to 60.77% of the records (10,656 out of 17,536 registers; Fig. 4). Considering the families with less than 10 registers for each, we had 36 families that composed just 0.91% of our database (160 out of 17,536 registers; Fig. 5).

We recorded 367 plant genera and from these *Fragaria* is the genus with the majority of records (n=2,270) followed by *Ocimum* (n=1,331). *Fragaria ananassa* is an important economic crop plant (strawberry) that is cultivated in greenhouses and stingless bees are used for pollination, mainly for Campinas, Dover, Sweet Charlie and Toionoka cultivars.

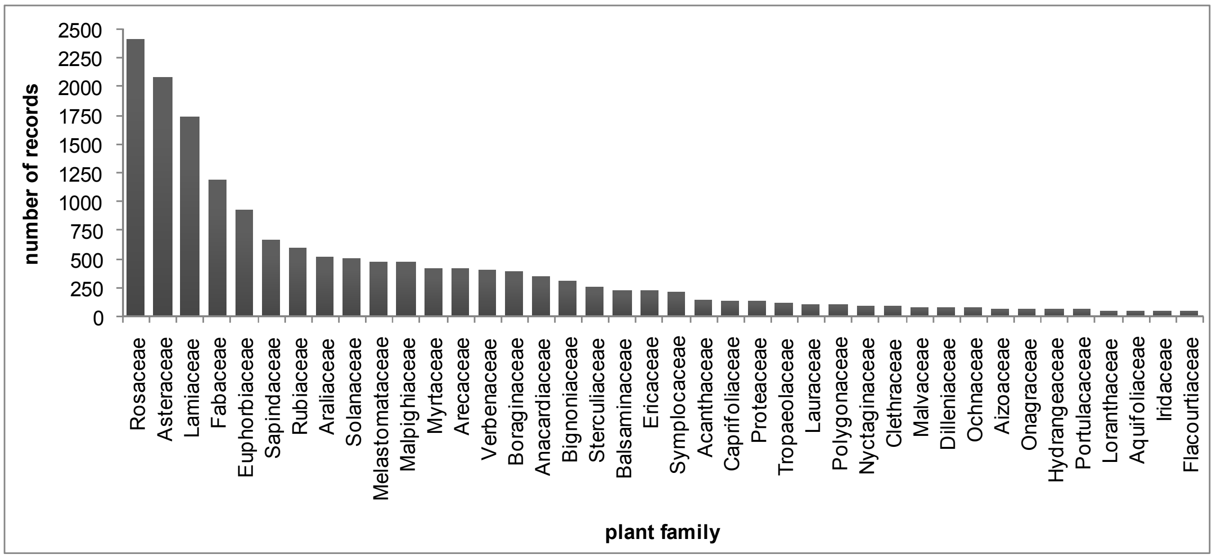

Figure 4. Number of records for the most representative plant families (from 50 to 2,415 records).

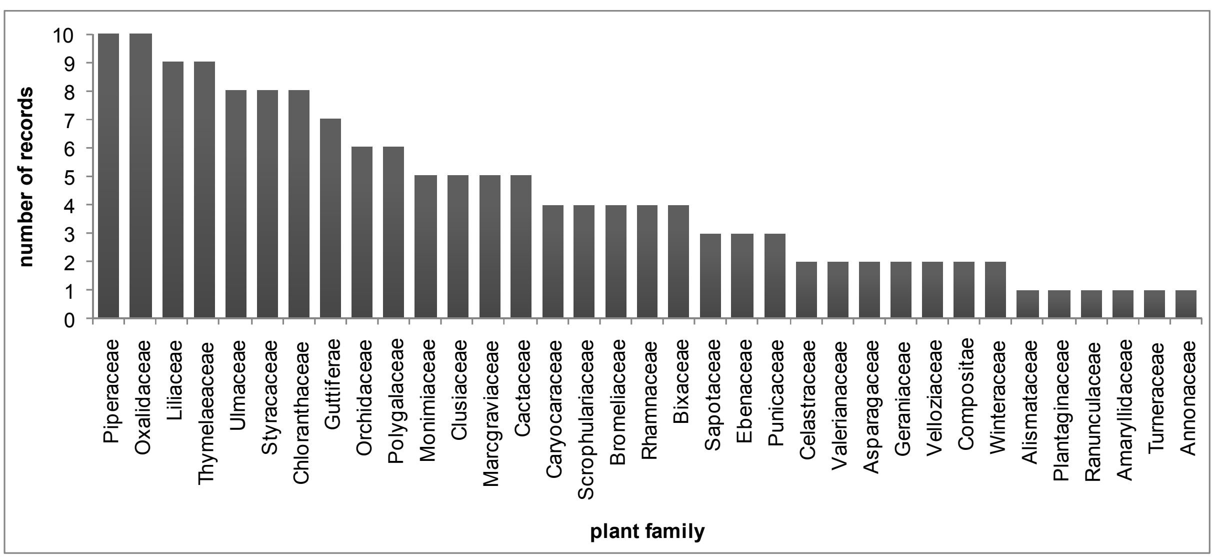

Figure 5. Number of records for the less representative plant families.

3.1.3. Bee-Plant interactions

Concerning the interactions between bee families and plant families (n=17,536 records), Apidae was the family with the majority of interactions (80.45%), followed by Halictidae (14.52%), Megachilidae (2.80%), Colletidae (1.57%) and Andrenidae (0.66%) (Table 2).

Table 2. Number of interactions between bee families and bee plants.

Plant families	**Bee families**					*Total*
	Andrenidae	Apidae	Colletidae	Halictidae	Megachilidae	
Acanthaceae	8	137		1		146
Agavaceae		19				19
Aizoaceae		52		13	1	66
Alismataceae			1			1
Alliaceae		36		3		39
Aloeaceae		16		1		17
Amaranthaceae		22		1		23
Amaryllidaceae		1				1
Anacardiaceae		316	5	36		357
Annonaceae		1				1
Apiaceae		33	2	11		46
Apocynaceae		24		8		32
Aquifoliaceae	1	49		3		53
Araliaceae		392	13	119		524
Arecaceae		117	2	296	1	416
Asclepiadaceae		8	4	8	1	21
Asparagaceae		2				2
Asteraceae	17	1332	35	528	162	2074
Balsaminaceae	1	225	1	9		236
Begoniaceae		17	1	16	4	38
Bignoniaceae	9	270		34	1	314
Bixaceae		3		1		4
Bombacaceae		15			1	16
Boraginaceae		280	7	109	2	398
Brassicaceae		22				22
Bromeliaceae		3		1		4
Burseraceae		44	3	2		49
Cactaceae		3	1	1		5
Caprifoliaceae		109	7	19	1	136
Caryocaraceae		3		1		4
Caryophyllaceae		17		3		20
Celastraceae		2				2
Chloranthaceae		5		3		8
Chrysobalanaceae		19				19
Clethraceae		64	9	21	1	95
Clusiaceae		4		1		5
Commelinaceae		28		15	2	45

Compositae		2				2
Connaraceae		16		2		18
Convolvulaceae		28		7		35
Cucurbitaceae		24		1	1	26
Cunoniaceae		22		5	2	29
Dilleniaceae		84				84
Ebenaceae		3				3
Ericaceae	3	220		8		231
Erythroxylaceae		7		4		11
Euphorbiaceae	1	809	14	60	48	932
Fabaceae	8	974	6	152	50	1190
Flacourtiaceae		23	5	20	1	49
Geraniaceae		1		1		2
Guttiferae		7				7
Hydrangeaceae		55	1	5		61
Iridaceae		41		9		50
Lamiaceae	10	1412	16	178	127	1743
Lauraceae		81	13	13		107
Liliaceae		9				9
Loranthaceae		35	2	16	4	57
Lythraceae	1	16		5	6	28
Malpighiaceae		424	3	43	1	471
Malvaceae	8	67	1	9	1	86
Maranthaceae		11				11
Marcgraviaceae		5				5
Melastomataceae		418	8	53	3	482
Meliaceae		10				10
Monimiaceae		5				5
Myrsinaceae		15		1		16
Myrtaceae		336	25	59	7	427
Nyctaginaceae		93		5		98
Nymphaeaceae		12		2		14
Ochnaceae		50	2	25		77
Olacaceae		14				14
Onagraceae	2	45	3	12		62
Orchidaceae		6				6
Oxalidaceae	1	6		2	1	10
Papaveraceae		16		1		17
Passifloraceae		11				11
Phytolaccaceae		7		4		11
Piperaceae		5		4	1	10
Plantaginaceae		1				1
Poaceae		17		5		21
Polygalaceae		4		1	1	6
Polygonaceae		77	3	20		100
Pontederiaceae		30		9		39
Portulacaceae		26		33		59
Proteaceae		120	2	10	1	133
Punicaceae		3				3
Ranunculaceae		1				1
Rhamnaceae		4				4
Rosaceae	3	2378	2	27	5	2415
Rubiaceae	14	358	7	195	30	604
Rutaceae		19	3	11	1	34

Sapindaceae	2	564	46	55	6	673
Sapotaceae		3				3
Scrophulariaceae		3		1		4
Solanaceae	21	360	14	105	1	501
Sterculiaceae		210		42	1	253
Strelitziaceae		10			1	11
Styracaceae		8				8
Symplocaceae		203	5	3		211
Theaceae		14		2		16
Thymelaeaceae		8		1		9
Tiliaceae		28			7	35
Tropaeolaceae		102		14	1	117
Turneraceae		1				1
Ulmaceae		8				8
Valerianaceae		2				2
Velloziaceae		1		1		2
Verbenaceae	6	365	2	36	6	415
Vochysiaceae		19	1	1		21
Winteraceae		2				2
Xanthorrhoeaceae		44		4		48
Total	116	14108	275	2546	491	17536

The vast majority of our data was collected in São Paulo state (n=17,440 records) including 17 counties (Fig. 6), however other Brazilian states were also sampled (n=95 records; Fig. 7). If we concentrate just in S. Paulo state, the anthropic areas were more sampled than Atlantic Rainforest or Cerrado/Savannah fragments (Fig. 8). The high number of interactions recorded in anthropic areas was due to several surveys conducted during 1981-2, 1985-6 and 2002-4 at São Paulo University gardens, for future comparisons concerning bee and plant richness, and in other university gardens. We also have interactions between bees and strawberry cultivars inside greenhouses in two S. Paulo counties, Atibaia (n=2,122 records) and Valinhos (n=148 records), as well as for other economic crops as mango (*Mangifera indica*) and *Citrus* sp.. For Atlantic Rainforest, some PhD theses focusing bee richness were conducted in several fragments inside S. Paulo State: Cantareira Park, a remnant of Atlantic Forest in S. Paulo city; Morro Grande Reserve, an important forested area nearby S. Paulo city; Boracéia Biological Station and Juréia Ecological station, both in the coast of S. Paulo state. Four Cerrado fragments were sampled in the same geographic region (Santa Rita do Passa Quatro and Luís Antônio cities).

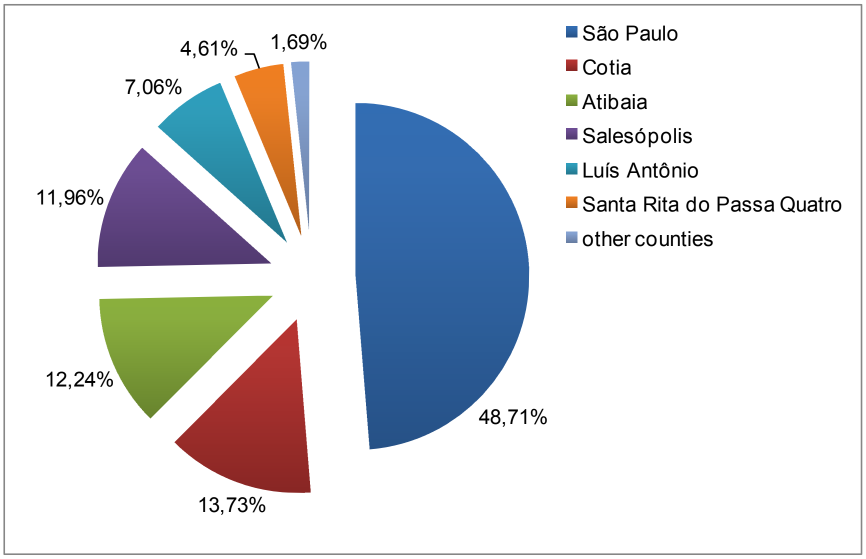

Figure 6. Relative frequencies of interactions between bee and plants recorded in São Paulo state by county (n=17,440 records).

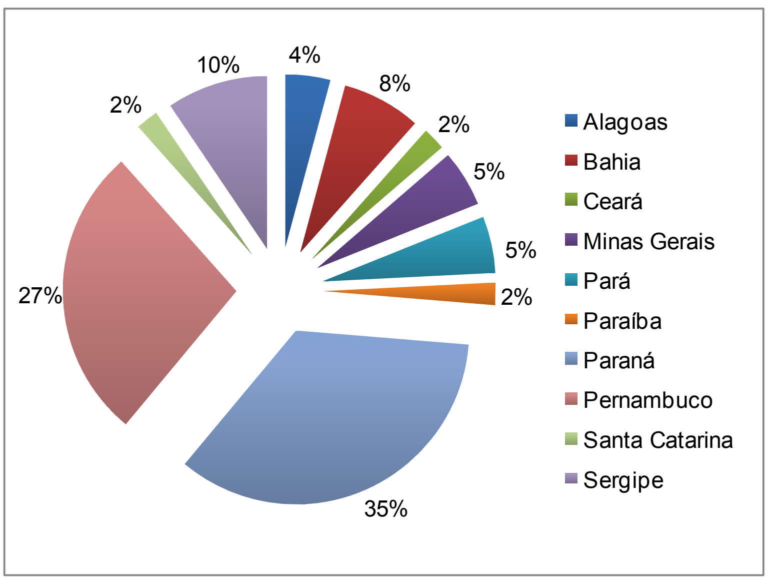

Figure 7. Relative frequencies of interactions between bee and plants recorded in other Brazilian states by state (n=95 records).

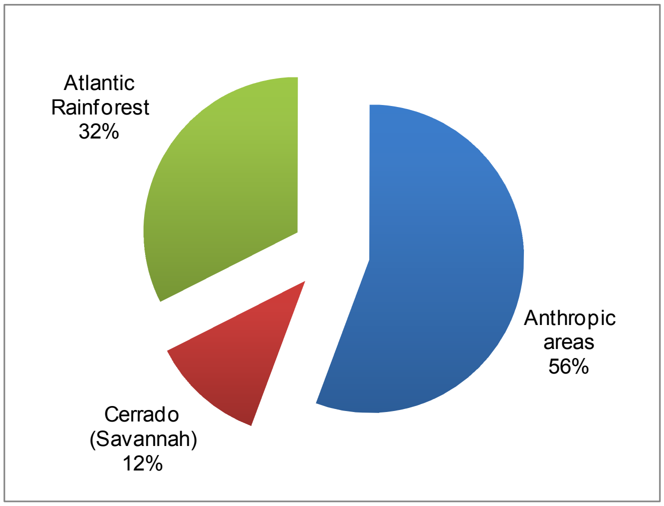

Figure 8. Relative frequencies of interactions between bee and plants recorded in anthropic areas, Atlantic Rainforest and Cerrado fragments in São Paulo state (n=17,433 records).

3.1.4. Potential applications for bee-plant interaction data

Computational techniques to analyze ecological niche and geographic distribution of species, such as modeling and computational tools based on GIS (Geographic Information System), have been increasingly used and improved. In addition, there is an effort to develop international databases on biodiversity. The animal collections and herbaria are important primary data sources, and several initiatives have emerged in recent years to digitize, to standardize and make information available (Canhos et al. 2004; Graham et al. 2004; Soberon & Peterson 2004).

Basically, the niche modeling seeks to estimate the potential area of a given species, and can be performed using environmental data concerning the known areas of occurrence. Combining different variables, we can design a scenario that identifies the potential suitable areas for the presence of a given species (Stockwell & Peters 1999; Peterson 2001; Raxworthy et al. 2003; Chefaoui et al. 2005). The delineation of geographical distribution of species, using methods such as modeling, has a wide range of ecological applications, such as management and the conservation of endangered species (Gaubert et al. 2006), the development of maps for conservation (Loiselle et al. 2003) and the study of the relationship between environmental parameters and species richness (Mac Nally & Fleishman 2004). The comprehension of functioning and structure of bee communities, considering their association with particular habitats and the existent interactions with the plant species, is very useful for identifying the vulnerability of these organisms to landscape changes, as well as for evaluate the potential of bee species to adapt to the agricultural environment and their potential for sustainable use as pollinators (Pinheiro-Machado et al., 2002).

3.2 Technical Manual: Modification of the tool Webbee

The changes in the tool WebBee involved in broad terms, redesigning the database, creating a new user interface to input the data, and create a data provider based on TAPI protocol.

3.2.1 Database changes

The database which is the core of WebBee already contained plant-bee relationship in its structure (Figure 9). However it had some limitations: it was based on species data and so did not allow inserting locality data for a specimen and its interaction; did not allow different types of interaction but only “visit”. The solution adopted was to change the database structure to store specimens and interactions data using standard schemas, such as Darwin Core (v1.4) and its extensions, developed on the IABIN PTN project and published at the TDWG web site (under DwC extensions).

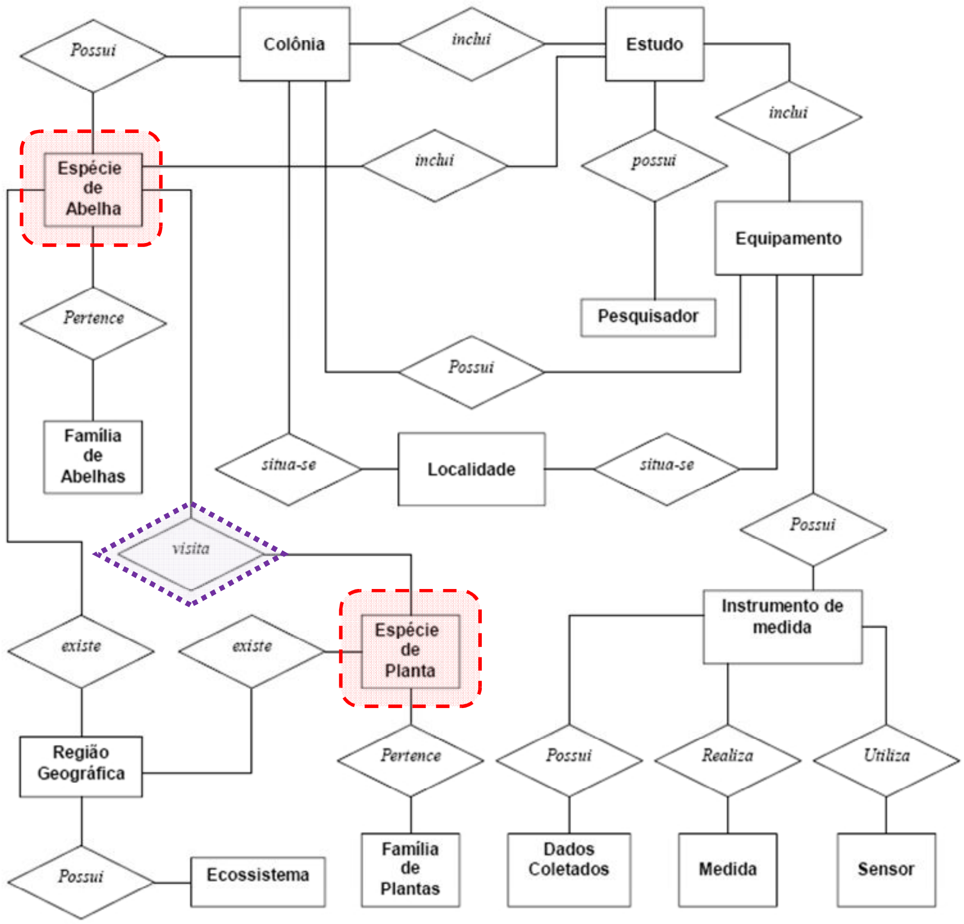

Figura 9 – Original E-R Diagram of WebBee's database.

The Darwin Core (v1.4) conceptual schema and its extensions were only used to indicate information to be considered in the case of specimens and interaction data. They are flat schemas, i.e., do not have a hierarchy, and a structure relational had to be created to be deployed in the MySQL (10), used by WebBee. All elements of Darwin Core (draft v1.4) were considered: Taxonomic elements, Locality, elements, etc., as well as the elements of the Interaction schema, also published on the TDWG portal. The implementation is represented on Figure .

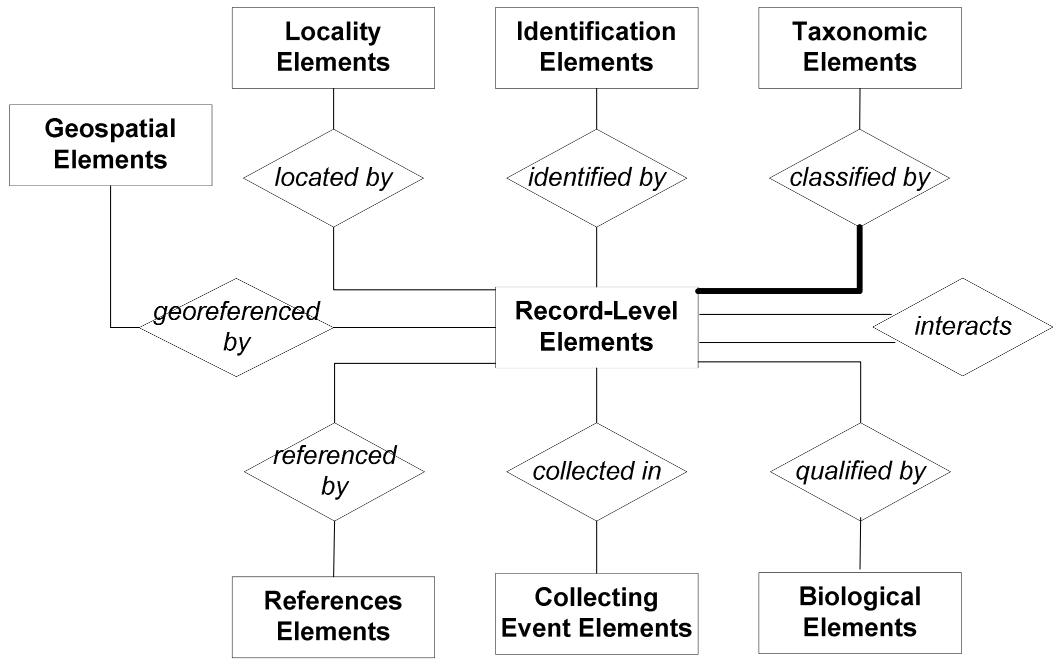

Figure 10 - Relational structure of the DarwinCore and Interaction schemas

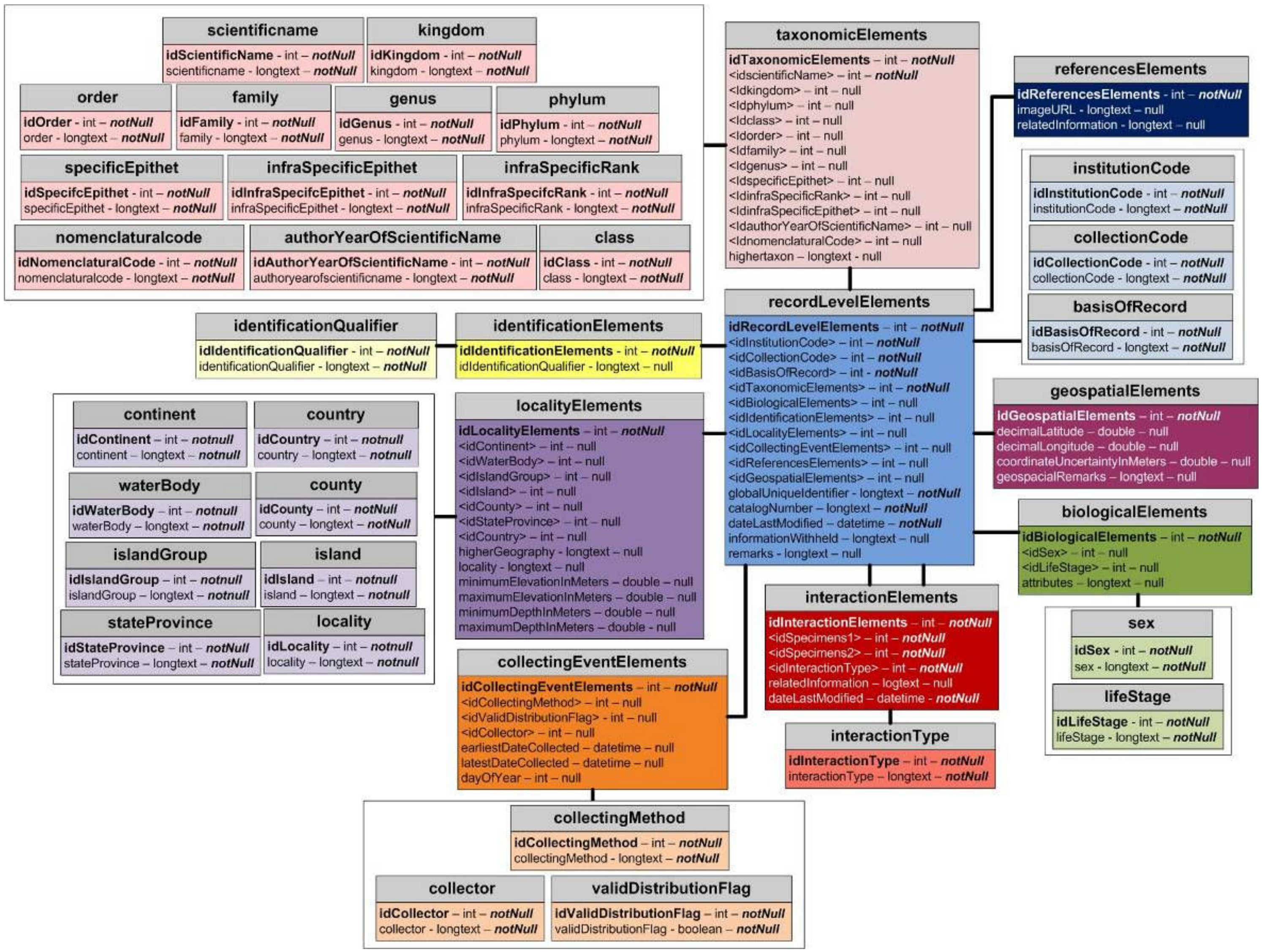

Figure 11 - Data structure of Webbee: species, specimen and interaction data.

3.2.2 Administrative interface structure

Over the new structure of WebBee's database a new administrative interface was created to input the specimens and interaction data. The previous one was based on MS Visual Basic for cadastre of species data (Figure 12).

It was decided to change to a new platform, based on open source software for web development. The tool was built using PHP to access the MySQL database, to develop dynamic HTML pages e publish them on the Internet using an Apache web server.

The first version of the tool allows us to cadastre individual specimens 9without interaction data) as in Figure 13. It also allows cadastre of two specimens and their interaction (Figure 14); in this case the form demands data of the Darwin core elements of the two interacting specimens (green and blue) and data of their interaction (brown)

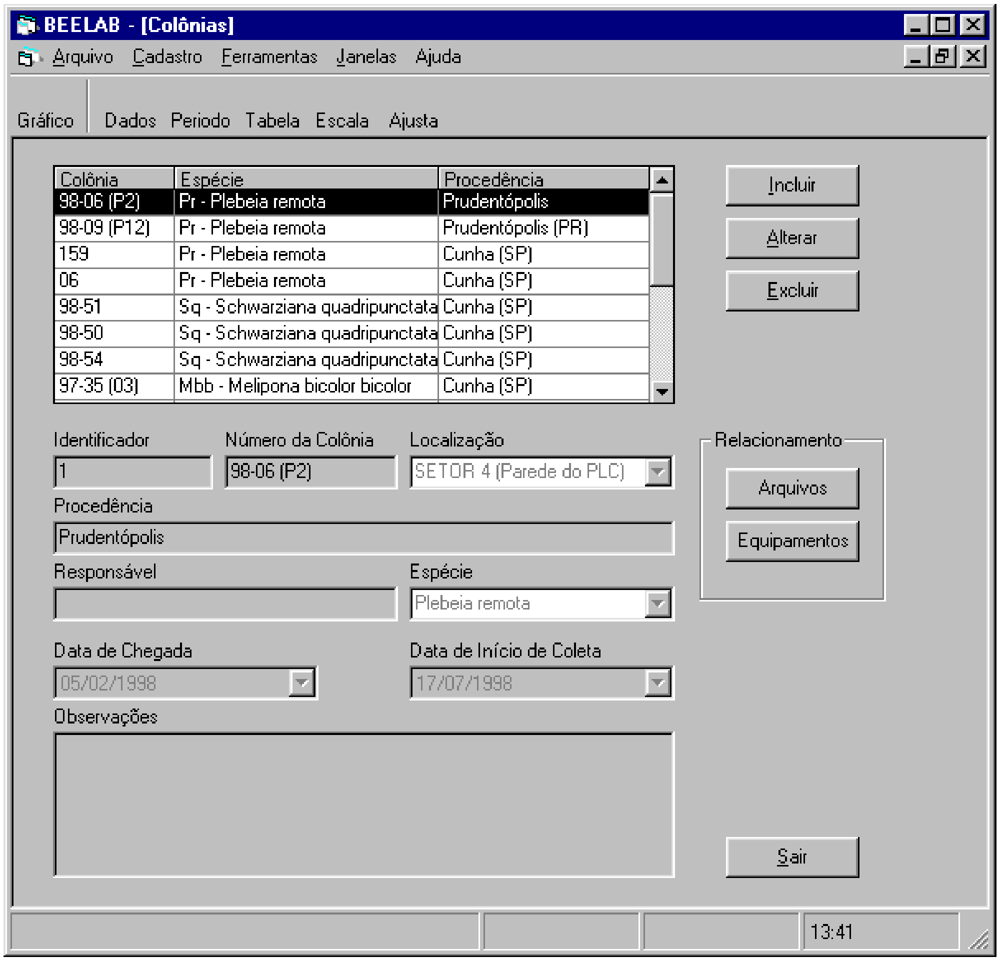

Figure 12 – Example screen shot of the original data entry tool of Webbee

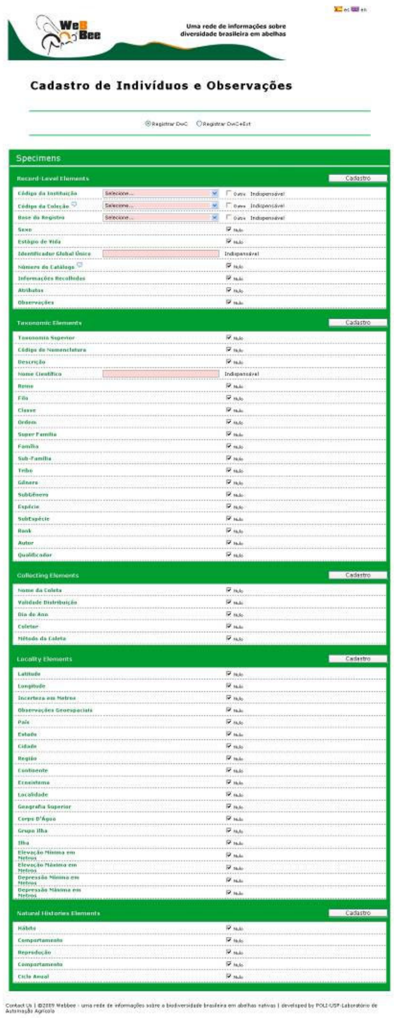

Figure 13 – First interface for specimen Data cadastre with Darwin Core schema.

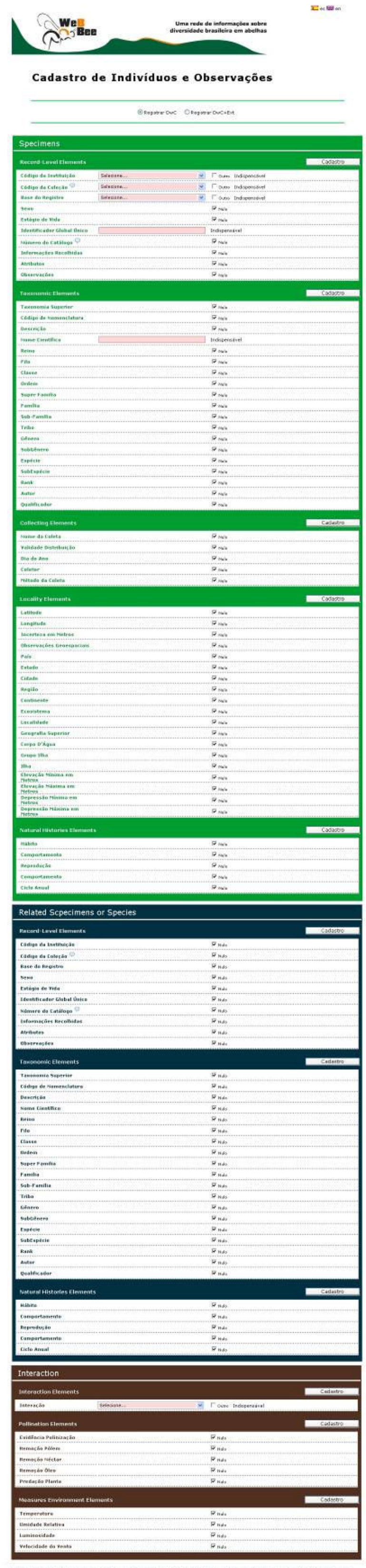

Figure 14 – First prototype interface for cadastre of specimen interaction data.

The main feature of this interface is the simplicity of operation and the flexibility to manage the data will be entered. All process is done with webpage forms (HTML WebPages) that can be accessed remotely over the Internet in the WebBee's administration area.

These web forms are dynamically created with PHP scripts and use XML files that describe all items (fields) that must be displayed and their attributes: required or not, tables in the database, visibility, restrictions, etc. These XML files were created using the relational structure (Figure) and were also used to generate the SQL scripts to create the Webbee's database (Figure).

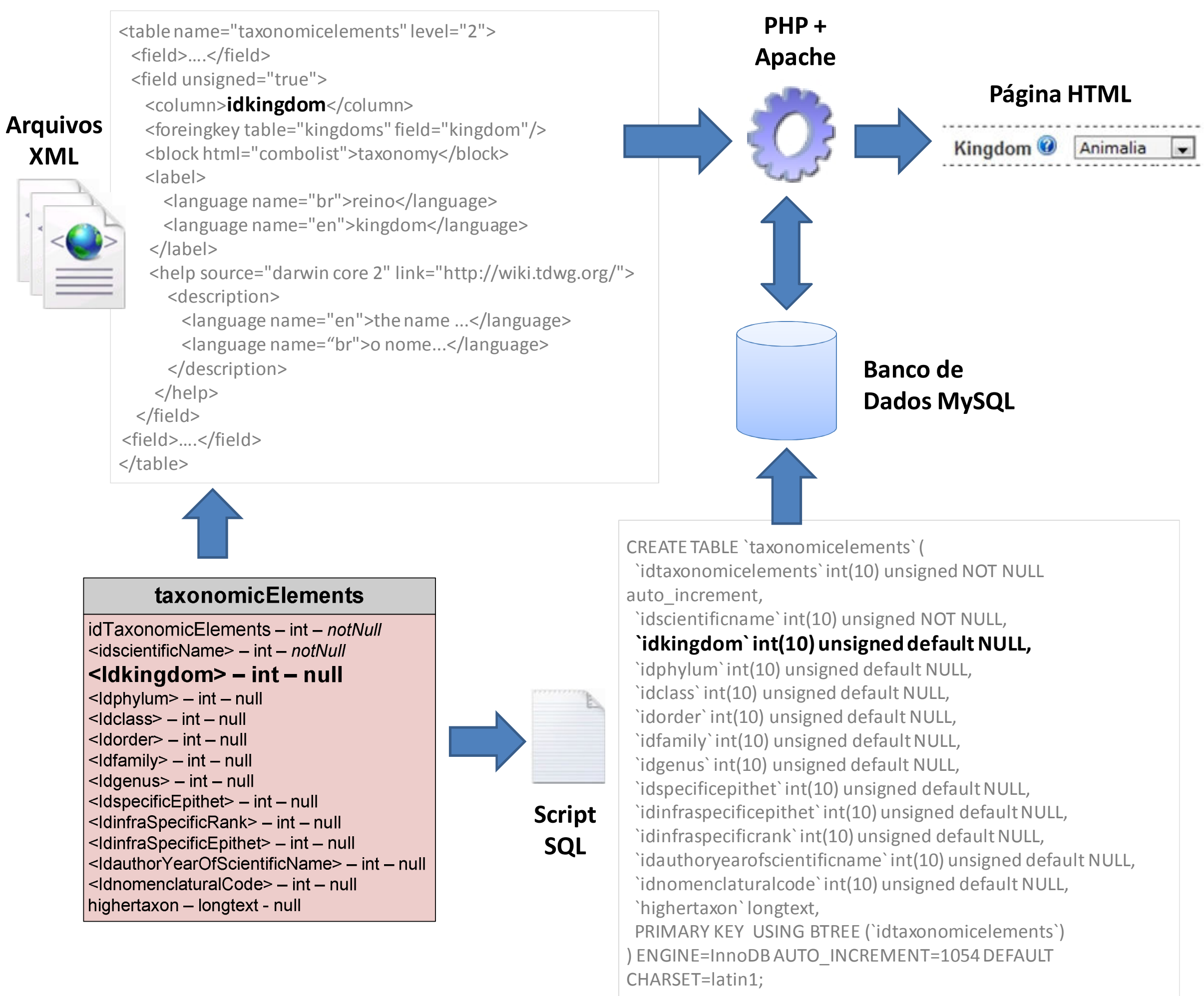

Figure 15 - Software architecture of the administrative interface.

3.2.2 Administrative interface operation

The administrative interface follows the Darwin Core and Interaction Schema structure. To input a specimen record, the user uses a single form with all Darwin Core elements organized in blocks: taxonomic elements, record-level elements, etc (Figure). In the interaction case, two specimens must have previously recorded, to be identified by their Global Unique Identifiers (Figure).

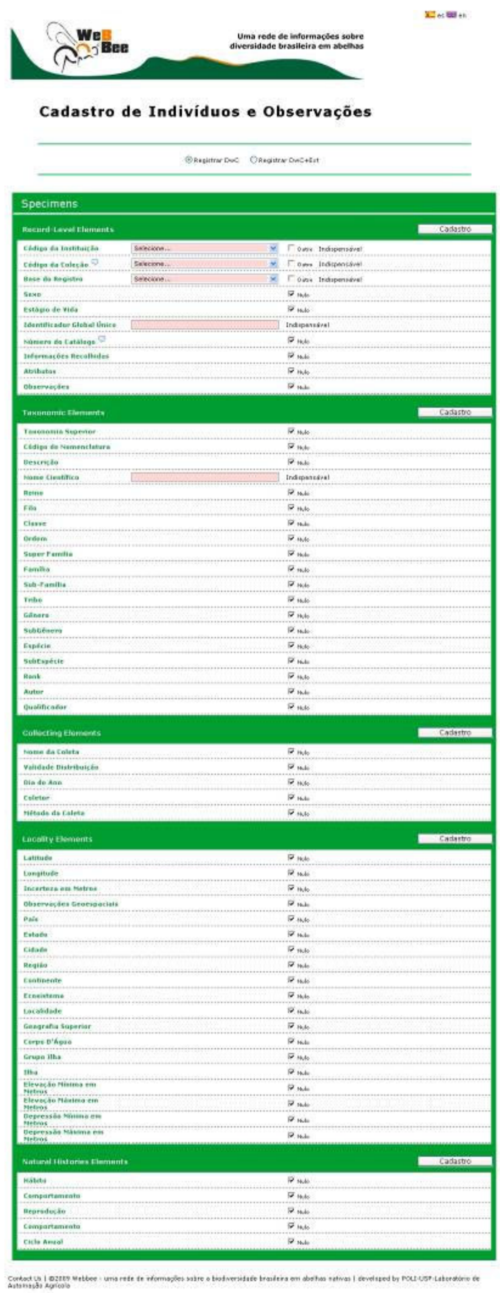

Figure 16 – Data entry form based on Darwin Core schema to input specimen data.

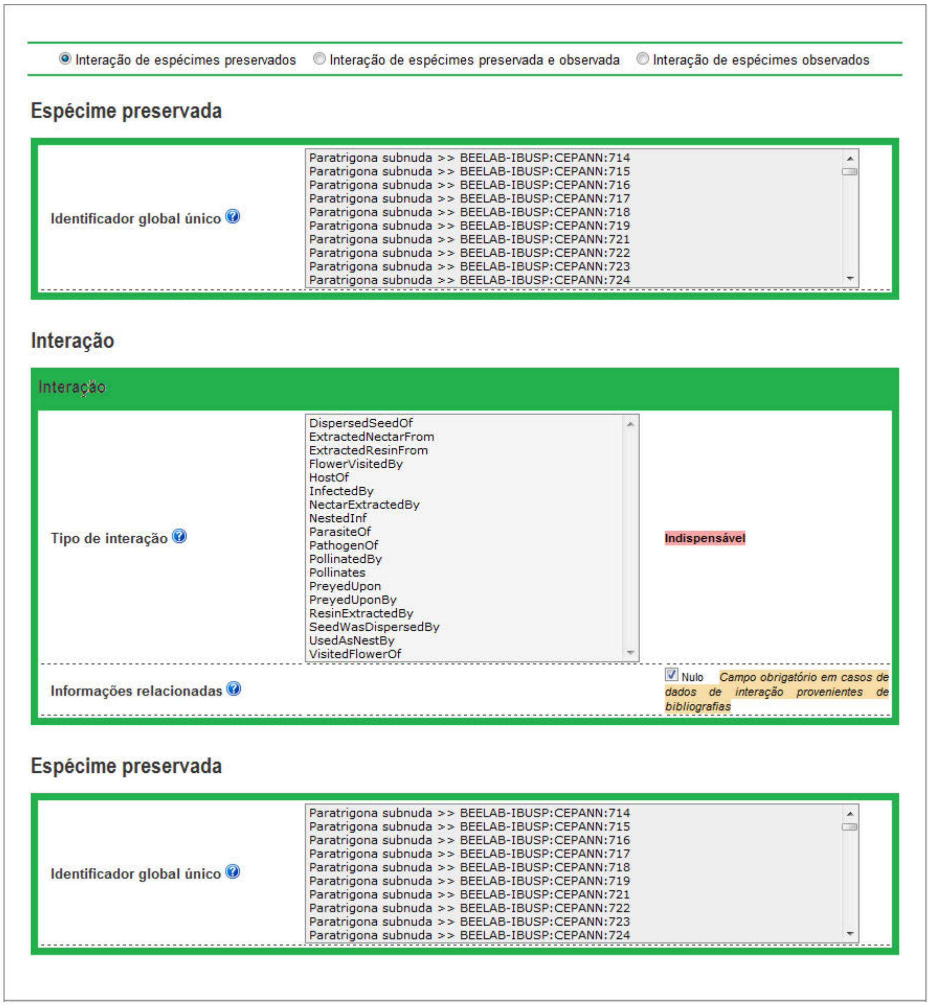

Figure 17 – User interface to input interaction data.

The data-entry interface is meant to be used only by the CEPANN collection curators so, although the user access page can be viewed on the web at http://pollinators.iabin.net/digitizer (under the icon Grantees) its access is restricted and requires user authentication (login necessary).

3.2.2 Tapir provider

A TAPIR provider was implemented to publish all specimens and interaction data according Darwin Core and Interaction schemas. This provider is the responsible to provide data to IABIN-PTN Portal (Figure). It was used the Tapirlink software as a module of the WebBee to implement the provider.

Access to the administrative interface of the TAPIR provider is available at http://200.144.189.73/tapirlink/www/tapir.php/cepann_specimens for specimen data, at http://200.144.189.73/tapirlink/www/tapir.php/cepann_interactions for interaction data between specimens, both refereeing to the TAPIR provider public interface.

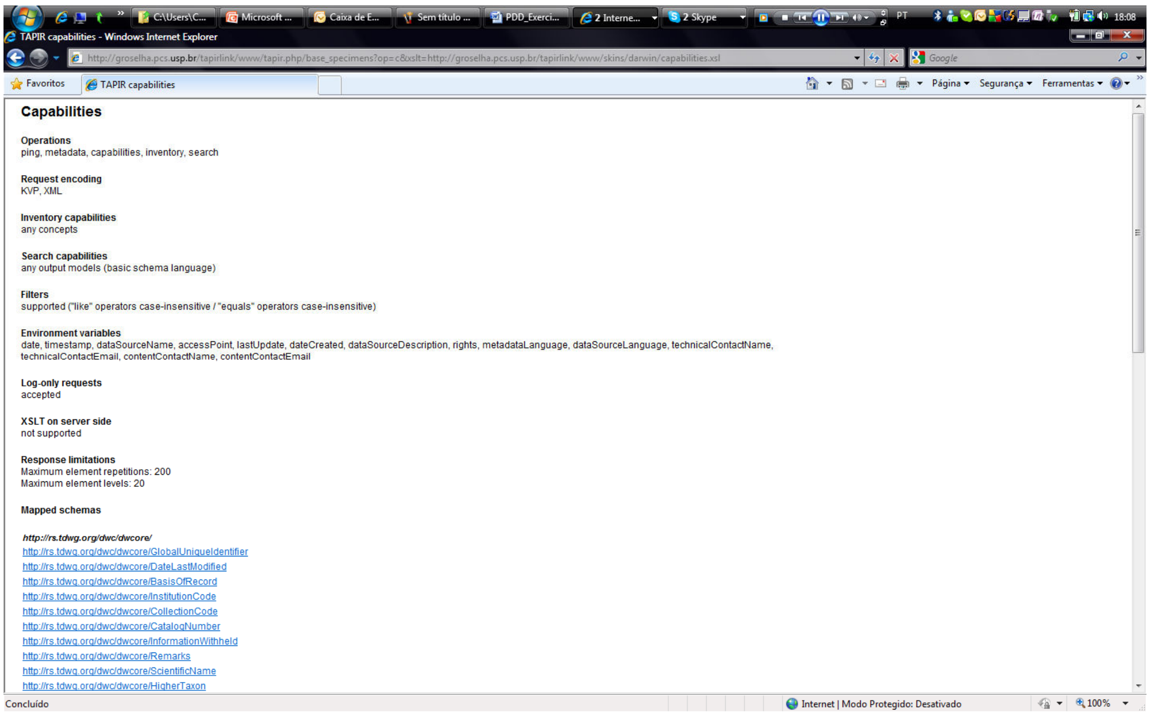

Figure 18 - TAPIR Provider's interface.

4. Lessons learned, problems and viable solutions.

Digitizing is very time consuming, especially when it demands other steps before, such as collecting data from field books. Checking names against the authority files and systems, as well as checking locality data demanded a lot of time and effort but are very important to assure data quality. We are sure that the effort made on this subject was very important.

As for the development of the tool, some of the issues that had to be dealt with were: designing a friendly interface; offering support to many languages while keeping this flexibility simple to implement; understanding and implementing a data provider with TAPIR link. None of these were specially difficult but taken as a whole they involve many concepts and functionalities which at the end become a lot to consider.

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6. Parallel Financing Report.

The parallel Financing report was also submitted at the on-line system provided by IABIN at http://cofinance.iabin.net/index.php?len=en . and goes also attached in the spreadsheet "financial report-final cepann.xls".

7. Financial Report.

See attached file "ReporteDeGastos final CEPANN.xls"

8. Annexes

a. **Annex 1** – Software Code for the changes in the data input tool for Webbee database on specimens and interactions data (See attached file "WebBee.rar").

b. **Annex 2** – spreadsheet with the data digitized. See attached zipped file "IABIN_CEPANN_bee-plant interactions_3.zip"

c. **Annex 3** – spreadsheet with the financial report "ReporteDeGastos final CEPANN.xls"

d. **Annex 2** – spreadsheet with the parallel financing "financial report-final cepann.xls"