Silveira FA et all. 2002 Taxonomic Constraints for the Conservation and Sustainable Use of Wild Pollinators – The Brazilian Wild Bees. IN: Kevan P & Imperatriz Fonseca VL (eds) - Pollinating Bees - The Conservation Link Between Agriculture and Nature - Ministry of Environment / Brasília. p.41-50.

TAXONOMIC CONSTRAINTS FOR THE CONSERVATION AND SUSTAINABLE USE OF WILD POLLINATORS – THE BRAZILIAN WILD BEES

Fernando A. Silveira, Cynthia Pinheiro-Machado, Isabel Alves dos Santos, Astrid de M. P. Kleinert and Vera Lúcia Imperatriz-Fonseca

ABSTRACT

This paper analyses the taxanomic resources available for the identification of Brazilian bees. It looks at the taxanomic keys and how easy it would be for non-taxonomists to use them. It also looks at the current Brazilian bee classifications and how far research has come in this area. Recommendations are made as to how to go about improving the quality of identifications made in research by technicians and biologists and improving current taxanomic keys using both new research and preserving old collections. It also emphasizes the need for new research in systematics.

INTRODUCTION

Thousands of wild species from many different animal groups including mammals, birds and insects, play important roles as pollinators of cultivated and wild plants. It is generally agreed that bees are the one group that pollinates the largest number of plant species (Roubik 1995a).

Because of the recent crisis in the apicultural industry in temperate countries, and given the fact that honeybees are not efficient pollinators of many crops and wild plants, interest is growing in the sustainable use of wild insects and other animals for this task (Roubik 1995b). However, several limitations exist to the employment of these pollinators. We cannot use pollinators which we do not know exist, nor where or when to find, or even how to manage and we cannot use pollinators if we do not know which plants they pollinate.

To get the necessary information, we need to undertake regional faunal surveys as well as surveys of the plants visited by each species. In this way we can build a database of potential pollinators of wild and cultivated plants on which we can further study the bionomics and develop management techniques for specific pollinators. However, collecting specimens at flowers is not enough, it is necessary to be able to identify them to species so that communication about them can be exchanged and information about them can be found.

In this chapter we analyse the taxonomic impediment for those interested in recognising, conserving and employing potential pollinators, taking the Brazilian wild bee species as examples. We give special attention to publications containing taxonomic keys, because these are indispensable for the non-taxonomist for identifying the organisms with which he/she works. We also discuss the importance of sound classifications.

Knowledge of Brazilian-Bee Taxonomy: Development and Current Status

Linnaeus (1767) started the study of Brazilian bee taxonomy by describing several native species. During the 18th and 19th centuries, several European scientific expeditions to Brazil were organised by European countries and institutions. The bees collected during those trips were deposited in European museums and described by researchers like Fabricius (1793, 1804), Spinola (1853), and Smith (1854, 1879). In the late 1800's and early 1900's, Friese (1899, 1900) published monographs of Neotropical bees that included Brazilian species.

At the turn of the century, Curt Schrottky and Adolph Ducke were the first bee taxonomists to work in Brazilian institutions (Obrecht and Huber 1993; Nomura 1995) and published on Brazilian bees until the early 1920's. The next bee taxonomist to work in Brazil was also the

first Brazilian bee taxonomist: Father Jesus Santiago Moure. He started publishing on bees in 1940 and is still active as a Professor Emeritus. Currently, there are 6 active bee taxonomists in Brazil.

Until recently, most of the taxonomic studies done on Brazilian bees were only species descriptions in association with comprehensive, systematic revisions. Besides, even monographic works like those of Friese (1899, 1900) were based only on the original descriptions, without examining of the material. Those studies were also based on small series of specimens, generally from restricted regions. The result of all this was a plethora of synonymies and a complete confusion on the identity of species.

Schrottky (1902) made the first and last attempt to bring together all known taxonomic knowledge of Brazilian bees. His was a compilation of taxonomic descriptions and keys to genera and species and carried on many of the weaknesses of the preceding works.

Moure study of Brazilian bee type material in European and North American museums contributed greatly to the recognition of synonymies (*e.g.* Moure 1960a,b). He also recognised many new genera and subgenera (*e.g.* Moure 1945, 1947, 1950, 1951) and, alone or with others, contributed to the classification of important groups of the Brazilian bee fauna (*e.g.* Moure 1946; Moure and Michener 1955; Michener and Moure 1957; Hurd and Moure 1963). His contributions have been a sound basis for other taxonomists, but non-taxonomists could not readily employ the knowledge gained through his work because he produced few comprehensive reviews of species.

The number of generic revisions through time may measure the development of knowledge about the identity of Brazilian bee species because these papers are the ones most likely to offer the information necessary for sound identification of specimens. Table 1 shows the number of genera occurring in Brazil that were revised in the last five decades and the number of Brazilian species included in those reviews. Only the taxonomic work done in the last 50 years is considered because the earlier works include so many synonymies (of species and supraspecific taxa) that it is almost impossible for a non-taxonomist to use them for identifying bees.

TABLE 1. Evolution of the "taxonomic effort" in the last five decades on Brazilian bee taxa. GR = number of generic revisions including Brazilian bees. SI = number of species included in those genera.

	DECADES					**TOTAL**
	1950's	**1960's**	**1970's**	**1980's**	**1990's**	
GR	1	11	9	15	28	**59**[a]
SI	8	69	18	78	122	**295**[b]

a) Five genera where revised twice in the period. Each one was counted only once.
b) For the genera reviewed twice in the period, only the total number of species included in the last revision was considered.

Table 1 shows that the taxonomic effort has been increasing in the last decades. The number of genera reviewed is almost twice in the 90's compared to the 80's. But, at the current pace of 2.8 genera per year, it will take taxonomists another 60 years to review the remaining genera known to occur in Brazil. Moreover, it should be kept in mind that as bee sampling continues and as regions previously unsampled or undersampled are surveyed, new species belonging to the genera already reviewed are being continuously discovered. For example, the number of

known Brazilian species of *Gaesischia* and *Melissoptila* were, respectively, 15 and 12, when they were first reviewed by Urban (1968a,b). When these genera were reviewed again, the number of Brazilian species known in each of them increased to 25 and 31, respectively (Urban 1989, 1998).

If we look at species rather than at genera, things get even worse. While the genera revised in the last 50 years represent about 25% of the genera known to occur in Brazil, the species included in then resent only 6% - 10% of the 3,000 - 5,000 species estimated to occur in Brazil (Table 2). Some of the unreviewed genera are the richest in species of the Brazilian bee fauna. Some examples are: in Anthophoridae, *Paratetrapedia* accounts for up to 8% of local bee assemblages and *Centris* up to 13%; in Halictidae, *Augochlora* and *Augochloropsis* contribute, each, up to 10% of local faunas and, in Megachilidae, *Megachile* may represent up to 25% of the total number of species in a given area (Silveira and Campos 1995; Pinheiro-Machado *et al.* this book). Thus, if we consider the rate of 12 species reviewed per year during the 1990's, we conclude that it will take taxonomists from 200 to 400 years to review all the bee species estimated to occur in Brazil.

The "taxonomic effort" as measured by the number of genera reviewed is also not evenly distributed among families (Table 2). Thus, while about 55% of the genera in Megachilidae were reviewed at least once in the last 50 years, this number decreases to only about 30% in Apidae and Anthophoridae, 16% in Halictidae, and 7% in Colletidae and Andrenidae. This uneven distribution also occurs within each family. In Anthophoridae, for example, 50% of the reviewed genera belong to the Eucerini, which is one (although one of the largest) of 18 tribes in that family known to occur in Brazil.

TABLE 2. Distribution of the "taxonomic effort" among the bee families represented in Brazil. TG = total number of genera in each family; GR = number of genera reviewed in the last 50 years; SI = number of Brazilian species included in the reviews. % SI = percentage contribution of each family to the total number of species reviewed.

	BEE FAMILIES						**TOTAL**
	Andrenidae	**Anthophoridae**	**Apidae**	**Colletidae**	**Halictidae**	**Megachilidae**	
TG	14	68	29	29	31	31	**202**
GR	1	24	9	2	5	17	**58**
SI	1	123	72	7	29	61	**293**
% SI	0.3	42.0	24.7	2.4	9.9	20.9	**100.0**

Taxonomic Knowledge as an Impediment to the Conservation and Use of Bees.

The analysis of faunistic surveys made in Brazil in the last 40 years show how the lack of taxonomic knowledge has impacted the results of other studies. Below we make an analysis of 46 such surveys. The sources of these data can be found in Pinheiro-Machado *et al.* (this volume). Of the 3,187 morphospecies recognised in 46 surveys, only 26% could be positively identified; 6% were recognised as new species; 4% had dubious identification *(confer, affinis)* and 64% could not be identified at all (Table 3).

TABLE 3. Status of identification of species in 46 surveys of local and regional bee faunas in Brazil expressed as a percentage of the total number of species collected in each family. aff = *affinis* (similar to, but different from); cf = *confer* (probably equal to, but deserving confirmation); sp = species that could not be identified; nd = species which were already recognized as new by taxonomists, but which had not been described up to the publication of the survey; id =

identified; u = undescribed species recognized as new; N = total number of species in all surveys.

FAMILY	Status of Identification of Species (percentages)						*N*
	Dubious			Certain			
	aff	cf	Sp.	u	nd	Id	
Andrenidae	–	1.0	63.7	14.5	5.7	15.0	193
Apide	2.1	4.7	32.1	2.6	1.6	56.8	190
Anthophoridae	0.6	5.4	56.7	2.9	1.5	33.0	946
Colletidae	0.9	4.3	63.9	7.4	1.3	22.2	230
Halictidae	0.9	3.2	73.3	3.2	1.1	18.4	1013
Megachilidae	0.3	2.0	70.1	2.9	1.3	23.4	615
TOTAL	**0.7**	**3.6**	**64.0**	**4.0**	**1.6**	**26.0**	3187

It should be clear that the total numbers of species in Table 3 are overestimations of the numbers of species collected in all surveys analysed. This is because species that could not be identified are being considered more than once if they were collected in more than one of the survey. The percentages, however, may be interpreted as the chance that any morphospecies has to be identified in a sample of bees collected in Brazil.

It is clear, from Table 3, that bees from different groups have different chances of being identified. Thus, although apids are identified 56% of the time, andrenids are determined only 17% of the time. It is interesting to note that the number of species that are actually identified in each family is quite different from the number of species in each family that was included in taxonomic reviews (Table 4). That difference may be taken as a measure of how reliant people who are working with bee biology and ecology are as taxonomists even for the identification of the 26% of bees that are recognisable. From the above, two assumptions can be made: 1) species included in reviews can be identified by non-taxonomists through the use of the published keys and 2) bees not included in reviews can only be identified with certainty by taxonomists. Table 4 shows us that, as a whole, 64% of bees identified in the Brazilian faunistic surveys had to be identified by taxonomists. This number varies among families, from 33% in Apidae to 97% in Andrenidae.

Of course, there are common bees not included in reviews that are easily identified by non-specialists. However, many researchers working with bee biology and ecology are not able even to sort their bees to tribal, let alone generic level. This makes it impossible for them to use the few available keys to species and as a consequence, their dependence on taxonomists is still greater.

TABLE 4. Dependence of taxonomists for bee species identification in Brazil. SI = Number of species included in generic reviews in each family; ID = Number of species identified in each family in 46 local faunistic surveys. % = Percentage of ID that is not included in taxonomic reviews.

	Andrenidae	Anthophoridae	Apidae	Colletidae	Halictidae	Megachilidae	TOTAL
SI	1	125	72	7	29	61	**295**
ID	29	312	108	51	186	144	**830**
%	**97**	**60**	**33**	**86**	**84**	**58**	**64**

The degree of taxonomic knowledge also varies from region to region and from biome to biome (Table 5). Thus, although 37% of the species in temperate grasslands could not be identified or had dubious identification, this number increases to 71% in temperate/subtropical rainforests and savannah-like *cerrados* of central Brazil.

TABLE 5. Status of species identification in a number of surveys (NS) in different biomes in Brazil expressed as a percentage of total (N) of species in all surveys. aff = *affinis* (similar to, but different from); cf = *confer* (probably equal to, but deserving confirmation); id = identified; u = undescribed species recognized as new; nd = species which were already recognised as new by taxonomists, but which had not been described up to the publication of the survey; sp = species that could not be identified.

Biogeographical Realms and Provincences (Udvardy, 1975	**NS**	***Status of Identification of Species*** **Dubious** Certain						**N**
		aff	**cf**	**Sp.**	**n**	**nd**	**id**	
Tropical Humid Forests	**11**	**1.1**	**3.3**	**43.4**	**4.9**	**2.4**	**44.9**	**880**
Tropical Savannahs (*Cerrado*)	**12**	**0.9**	**5.6**	**51.0**	**2.5**	**0.4**	**29.5**	**1119**
Tropical Dry Forests/Woodlands *(Caatinga)*	**2**	_	**3.9**	**36.4**	_	_	**59.7**	**77**
Subtropical/Temperate Rainforests	**13**	**0.2**	**1.5**	**69.3**	**1.6**	**1.8**	**25.6**	**311**
Temperate Grasslands	**9**	_	**0.8**	**36.1**	**7.1**	**1.6**	**54.4**	**509**
TOTAL	**47**	**0.7**	**3.6**	**64.0**	**4.0**	**1.6**	**26.0**	**3187**

In general, ease of identification is inversely correlated to species richness of the biome (measured by the average number of species found in each survey), however, there are discrepancies for several reasons. The number of identified species tends to raise, for example: 1) when relatively well studied groups are well represented in the regional assemblages; 2) when the regional fauna is well represented in the collections of active taxonomists and 3) when the number of endemic species is low.

DISCUSSION

It is obvious that Brazilian bees are largely unknown and our ability to identify them for other studies is hampered by a lack of taxonomic knowledge.

In the last 40 years, faunistic surveys produced a large amount of data on bee biogeography and ecology, including data on plants visited by bees. Such surveys are the obvious sources of data for those interested in starting searches for potential native pollinators of wild and

cultivated plants. However, these data are largely inaccessible because more than 60% of the species are not correctly identified. How can we search for information or start a research program on, in a hypothetical example, the bionomy of *Paratetrapedia* sp.1? How can a conservation biologist be concerned with the preservation of an unnamed or unidentified species?

This situation is an incentive for the introduction of foreign pollinators, for which bionomical and management knowledge is readily available. Introduction of foreign pollinators, however, is a practice we should avoid. Some of its drawbacks were already pointed out by Bohart (in Mcgregor 1976). Important points to consider are: 1) imported species may not be effective as pollinators in the new environment as they were in their native habitats; 2) imported species may introduce new parasites and diseases; 3) imported species may outcompete native species at nesting sites and/or food sources, which may lead to pollination problems in non-target cultivated and wild plants.

The identification of Brazilian bees to tribal or generic levels is still basically a task for specialists. Currently, there are only six active bee taxonomists in Brazil (of which two are retired and one has a temporary position. Given the great diversity of bees and the growing need for species identification, specialists will be needed to handle this job. Moreover, the primary work of taxonomists is not identification of specimens, but to study the organisms, develop classificatory schemes that organise our knowledge about them, and facilitate the communication of this knowledge to others. This kind of work is also what makes identification of species possible. When taxonomists are overloaded with other peoples' specimens for identification, they are unable to produce the very knowledge needed for identification to be made by themselves and by others.

Although the lack of taxonomic literature can be pointed out as a factor that inhibits biologists, conservationists and managers of wild pollinators from devoting time and energy to the identification of bees, there are other points to be made. With taxonomy's loss of prestige during the latter part of this century, training of biologists in this subject ceased in most Biology programs. As a result, professionals are not acquainted with the aims, methods and literature related to systematics, feeling themselves unable to deal with the task of identification. With the lack of interest in Systematics at universities, progressively fewer students are recruited to do taxonomic work and the few of them that do want to pursue a carrier in systematics are discouraged by the lack of positions for taxonomists in research and teaching institutions.

Up to now the problem of identification has been emphasised. However, another way the lack of taxonomic knowledge in an impediment to the sustainable use of wild pollinators is the lack of robust phylogenetic hypotheses. These hypotheses give us predictive power with which we can save time and energy, focusing our search for species with given abilities. A way to focus the search for a native pollinator species of an introduced plant, for instances, is to look for species closely related to the known pollinator(s) of that plant. Classifications by themselves are frequently not good estimators of phylogenetic relatedness because most of them include paraphyletic groups in which evolutionary relationships are often masked.

Phylogenetic analyses of bee taxa are being produced at a pace slower than that of other taxonomic works. The relationships among higher taxa, such as families or tribes, have been addressed recently (*e.g.* Roig-Alsina and Michener 1993; Alexander and Michener 1995; Silveira 1995), but studies including phylogenetic analyses among species of a genus are still rare (*e.g.* Camargo and Moure 1994, 1996). Unfortunately, these are the more useful ones for searching for pollinator species.

CONCLUSIONS

Although we have concentrated our discussion on Brazilian bees, the problems discussed above are certainly the same for other organisms and other countries, tropical and temperate. The crisis through which taxonomy is passing is an international one and the consequences of this crisis are similar everywhere. To ameliorate the situation by removing the taxonomic impediment for the conservation and sustainable use of wild pollinators, the following needs are presented.

- We urgently need comprehensive taxonomic revisions and phylogenetic studies of bee taxa in Brazil. We should invest in alternative presentations of taxonomic literature for use by non-taxonomists such as computer based interactive keys posted on the Internet
- For taxonomic work to be undertaken at the necessary pace, the formation and employment of new bee systematists must be encouraged and supported. This is not just for scientific reasons, but because a lack of knowledge will eventually negatively effect human food supply through pollination shortages.
- Biologists, in general, should be encouraged and trained to use taxonomic literature and to recognise at least the major taxonomic groups they work with.
- Technicians should be trained in the identification of important groups. The technicians, similar to the parataxonomists of the "Instituto Nacional de Biodiversidad" of Costa Rica, are not to be fully trained taxonomists, but would be able to identify bees belonging to regional or national faunas and assist taxonomists in their work.
- For taxonomic and identification work to be feasible, the creation of new collections should be encouraged, and especially the maintenance and improvement of the existing ones should be supported.

REFERENCES

Alexander BA, Michener CD. Phylogenetic studies of the families of short-tongued bees (*Hymenoptera: Apoidea*). The University of Kansas Science Bulletin 1995; 55(11): 377-424.

Bohart GE. Introduction of foreign pollinators. In: McGregor SE. Insect pollination of cultivated crop plants. Washington(DC): United States Department of Agriculture; 1976. (Agriculture Handbook, 496)

Camargo JMF, Moure JS. Meliponinae neotropicais: os gêneros *Paratrigona* Schwarz, 1938 e *Aparatrigona* Moure, 1951 (Hymenoptera, Apidae). Arquivos de Zoologia 1994; 32(2): 33-109.

Camargo JMF, Moure JS. Meliponini neotropicais: o gênero *Geotrigona* Moure, 1943 (Apinae, Apidae, Hymenoptera), com especial referência à filogenia e biogeografia. Arquivos de Zoologia 1996; 33(3): 95-161.

Fabricius JC. Entomologia systematica emendata et aucta, secundum classes, ordines, genera, species, adjectis synonymis, locis, observationibus, descriptionibus. Hafniae: impensis CG Proft; 1793. v2.

Fabricius JC. Systema Piezatorum: secundum ordines, genera, species, adjectis synonymis, locis, observationibus, descriptionibus. XIV. Brunsvigae: Carolum Reichard; 1804.

Friese H. Monographie der Bienengattungen *Exomalopsis, Ptilothrix, Melitoma* und *Tetrapedia*. Annalen des Kaiserlich Königelichen Naturhistorischen Hofmuseums 1899; 14: 247-304.

Friese H. Monographie der Bienengattung *Centris* (s. lat.). Annalen des Kaiserlich-Koniglichen Naturhistorischen Hofmuseums 1900; 15: 237-350.

Hurd Jr. PD, Moure JS. A classification of the large carpenter bees (Xylocopini) (Hymenoptera: Apoidea). University of California Publications in Entomology 1963; 29: 1-366.

Linnaeus C. Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus e differentiis. 12nd ed. Holmiae: L. Salvii, 1767.

Michener CD, Moure JS. A study of the classification of the more primitive non-parasitic anthophorine bees (Hymenoptera, Apoidea). Bulletin of the American Museum of Natural History 1957; 112(5): 395- 452.

Moure JS. Notas sobre os Epicharitina (Hymenopt., Apoidea). Revista de Entomologia 1945; 16(3): 293-314.

Moure JS. Contribuição para o conhecimento dos Meliponinae (Hym., Apoidea). Revista de Entomologia 1946; 17(3): 437-443.

Moure JS. Novos agrupamentos genéricos e algumas espécies novas de abelhas sulamericanas. Publicações Avulsas 1947; 3: 1-37.

Moure JS. Alguns agrupamentos novos de abelhas neotropicais (Hymenopt.–Apoidea). Dusenia 1950; 1(6): 385-394.

Moure JS. Notas sobre Meliponinae (Hymenopt., Apoidea). Dusenia 1951; 2(1): 25-70.

Moure JS. Os tipos das espécies neotropicais de *Hylaeus* da coleção Vachal no Museu de História Natural de Paris (Hymenoptera, Apoidea). Boletim do Museu Paraense Emilio Goeldi, Zoologia, 1960a; 27: 1-104.

Moure JS. Notes on the types of the neotropical bees described by Fabricius (Hymenoptera: Apoidea). Studia Entomologica 1960b; 3 (1-4): 97-160.

Moure JS, Michener CD. A contribution toward the classification of Neotropical Eucerini (Hymenoptera, Apoidea). Dusenia 1955; 6(6): 239-331.

Nomura H. Vultos da zoologia brasileira, v. 6. Mossoró: Fundação Vingt-Un Rosado; 1995. [Coleção Mossoroense, série C, v. 861]

Obrecht E, Huber C. Ducke type specimens and other Brazilian insect types in the Emil A. Goeldi collection in the Natural History Museum Bern (Switzerland): an annotated catalogue. Jahrbücher Naturhistorischen Museum Bern 1993; 11: 163-84.

Roubik DW. Applied pollination in tropical America. FAO Agricultural Services Bulletin 1995a; 118: 66-73.

Roubik DW. Stingless bee colonies for pollination. FAO Agricultural Services Bulletin 1995b; 118: 150-3.

Roig-Alsina A, Michener CD. Studies of the phylogeny and classification of long-tongued bees (Hymenoptera: Apoidea). The University of Kansas Science Bulletin 1993; 55(4): 123-73.

Schrottky C. Ensaio sobre as abelhas solitárias do Brazil. Revista do Museu Paulista 1902; 5: 330-613.

Silveira FA. Phylogenetic relationships and classification of Exomalopsini with a new tribe Teratognathini (Hymenoptera: Apoidea). The University of Kansas Science Bulletin 1995; 55(12): 425-54.

Silveira FA, Campos MJO. Abelhas silvestres (Hymenoptera: Apoidea) de Corumbataí (SP) e Paraopeba (MG) e uma discussão sobre a biogeografia das abelhas do cerrado. Revista Brasileira de Entomologia 1995; 39: 371-401.

Smith F. Catalogue of hymenopterous insects in the collection of the British Museum. Part II: Apidae. London: printed by order of the trustees; 1854.

Smith F. Descriptions of new species of Hymenoptera in the collection of the British Museum. London;1879.

Spinola M. Compte rendu des Hyménoptères inédits provenants du voyage entomologique de M. Ghiliani dans le Para en 1846. Memorie della Reale Academia delle Scienze di Torino 1853; 12 (13): 19-94.

Urban D. As espécies do gênero *Melissoptila* Holmberg, 1884 (Hymenoptera – Apoidea). Revista Brasileira de Entomologia 1968a; 13(1): 1-94.

Urban D. As espécies de *Gaesischia* Michener, LaBerge and Moure, 1955. (Hymenoptera, Apoidea). Boletim da Universidade Federal do Paraná, Zoologia, 1968b; 3(4): 79-129.

Urban D. Espécies novas e notas sobre o gênero *Gaesischia* Michener, LaBerge and Moure, 1955 (Hymenoptera, Apoidea). Revista Brasileira de Entomologia 1989; 33(1): 75-102.

Urban D. Espécies novas de *Melissoptila* Holmberg da América do Sul e notas taxonômicas (Hymenoptera, Anthophoridae). Revista Brasileira de Zoologia 1998; 15(1): 1-46.