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MELISSOCOENOLOGY: HISTORICAL PERSPECTIVE, METHOD OF SAMPLING, AND RECOMMENDATIONS TO THE "*PROGRAM OF CONSERVATION AND SUSTAINABLE USE OF POLLINATORS, WITH EMPHASIS ON BEES*" (ONU)

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ABSTRACT

Melissocoenotic studies are key for the conservation of plant biodiversity, because pollinators play an important role in the reproductive success and gene flow of many important plant groups to agriculture and forestry and these plants in turn are important food sources for pollinators.

Melissoecoenology emerged in southern Brazil after the development of a method to gather standardized samples of pollinators (Hymenoptera: Apoidea). The sampling of pollinators consists basically of collecting wild bees on flowers without random sweeping, in which the restricted sampling area and duration of the survey are previously fixed.

The analysis of five, long term surveys, carried out in the center of the city of Curitiba, PR and in the surroundings of the Airport Afonso Pena (São José dos Pinhais, PR) are presented. Some changes, mostly negative, in the patterns of bee species composition and their abundance allowed us to make some recommendations in order to preserve, restore and avoid the extinction of the wild bee populations in urban and agricultural areas.

INTRODUCTION

The demand for melissocoetic knowledge (the interactions of bees with their environment) is becoming a key issue in biological diversity studies. In parallel of the necessity of such data for implementing practical policies involving conservation issues, the number of worldwide contributions has also been increase quickly since the sixties, when the development of the melissocoenotic approach began. These kinds of studies require a multidisciplinary approach. In fact, it combines a multitude of disciplines ranging from meteorology, edaphology, phytochemistry, ethology, energetics, phenology, palynology and taxonomy, besides integrative fields such as geomorphology, paleoecology and biogeography. All studies characteristically require evolutionary approach. In other words, they are genuine ecological approaches.

The melissocoenology mainly emerged in southern Brazil, and some of its first steps were made in the early sixties by Sakagami and Laroca, they developed a method in order to gather standardized samples of pollinators (Hymenoptera: Apoidea), that permit quantitative comparisons, and therefore allow spatial/temporal analysis of bee assemblages. Sakagami came to the Universidade Federal do Paraná, Curitiba, Brazil in 1961 to study sociology of wild bees, halictines, following earlier work by Michener and Lange. Sakagami was especially interested in: weather effects on bee activities, annual cycle of particular species, their flower preferences, as well as some biogeographical correlations, as tools for his taxonomic and sociological studies. Laroca, as his field assistant, was interested in studying truly ecological interactions; so his studies were directed to meteorology, natural history (undergraduate), geomorphology (specialist), and entomology (M.Sc. and Ph.D., with concentration in community ecology and insect behavior).

The planning of the first census project (São José dos Pinhais survey) began in Paraguay, in 1961, when Sakagami and Laroca visited Schrottky and Bertoni's Hymenoptera collections and the rich and diversified ecosystems of the *Chaco*. Laroca (from March, 1962 to February, 1963) did most of the fieldwork, while Sakagami went to Rio Claro (São Paulo) to work with

Kerr and collaborators. The first study site, in the vicinities of the Aeroporto Afonso Pena (São José dos Pinhais, PR, Brazil), was chosen for its potentiality for high insect diversity as suggested by Marston (USDA) and Laroca in 1959. The first publication was that of Sakagami, Laroca and Moure (1967), a joint contribution between Hokkaido (Japan) and its antipode Paraná (Brazil). This paper presents one of the first attempts to establish a quantitative sampling of bees at their food site, with a standardized procedure in relation to space and time. Before Sakagami *et al.* (1967), there were only two similar papers, one on research from near the Chicago surroundings (Pearson, 1933), and another from the Ukrainian steppes (Osychnyuk, 1959).

The Pearson's paper is of particular interest because it has a heuristic relationship with the work of the "*Chicago School*" (such as the classical works of Cowles, Clements, and Shelford) immediately following Wraming's publication of *Lehrbuch der Oekologischen Pflanzengeographie*. While in Lagoa Santa (Minas Gerais) Brazil, Warming discovered and described the phenomenon of *ecological succession*.

In South America, besides the work of Schrottky (*e. g.,* Schrottky 1908 and 1909), we also draw attention to contributions of important mellitologists such as: Ducke, also a botanist (1901, 1902), Jensen-Haarup (1907, 1908) and Jörgensen (1909, 1912) and Nogueira-Neto (1997) and North-Americans such as Schwarz (1948), Michener (1954), Hurd and Moure (1963), Mitchell (1980), and Europeans such as: Smith (1863).

Although not directly related to the subject at hand, Michener *et al.*'s study (1958), based on an assemblage of bee nests in earth around Curitiba, considers associative ecology germane applied to the study of pollinators and their conservation.

More recent papers on melissocoenoses are by, Sakagami and Fukuda (1973) from the campus of the Hokkaido University.

Then from 1976 to 1978, one of us (SL) made censuses in three temperate melissocoenoses in the surroundings of Lawrence (Kansas) as part of his Ph.D. studies. Unfortunately most of the data are not yet published.

Since the beginning of the eighties, in Brazil, from the steppes (*pampas*) of Rio Grande do Sul to the Amazonian rain forest region, several excellent thesis and articles have been presented and/or published.

Those contributions together with those our group from the Universidade Federal do Paraná deal with melissocoenotics under several conditions, ranging from typical urban to agricultural and little disturbed nearly wild habitats. In this chapter, we describe the methodologies and compare long term studies done in a single community of bees (Hymenoptera: Apoidea). Thus, we wish to contribute to diversity monitoring at the community level in the "*International Program on the Conservation and Sustainable Use of Pollinators in Agriculture, with Emphasis on Bees".*

MATERIALS AND METHODS

The following methodology for sampling pollinators has been compiled from Laroca (1983) based on the studies described above. Basically, it consists of collecting wild bees on flowers or in flight near the flowers without selecting which bees are to be taken. The samples are separated on an hourly basis. Each bee is collected individually or in a group, but not by random sweeping. The specimens are transferred to various killing tubes according to the flowers visited (the number of killing tubes corresponds to the number of species of plants in bloom in each collecting day). A sampling day is divided up into four collecting hours. In each hour 1/4 of the study area is sampled. Prolonged collecting in a particular spot should be avoided. For instance, in dense flower patches, which attracted many bees, as many specimens as possible are captured at a precise moment, then the collector moves on, not waiting for the arrival of more bees.

Weather conditions (temperature, wind velocity, relative humidity, cloud cover, and insulation) are recorded at the start of each collecting hour. In the laboratory, each specimen is labeled according to the date, hour, and flower visited. In our samplings, *Apis* was not taken but its relative abundance on the flowers in the study sites was recorded.

The results obtained by the above method are not free from sampling biases. Some sources of error are: influence of the removal of individuals from the total assemblage, adoption of individual capture instead of random sweeping, relative ease of capture based on specific differences, differences in distinctive flower visiting habits, and varying efficiency of the parts of collectors.

Influence of removal of individuals upon the total assemblage
This is a serious defect of the method but inevitable because it is almost impossible to identify many of the bees in the field. Linsley and MacSwain (1959) use capture-identify-release method in estimating the number of andrenid bees visiting *Ranunculus* flowers. Heinrich (1976) counted the number of easily identifiable foraging bumblebees in walking transects, without capture. This method is more accurate in gauging temporal changes in the composition of the bee populations on flowers in a given area than capture and removal of the bees from the flowers would be. The influence of removal is more drastic for rare species, especially if collecting is selective. In most cases this effect is probably small because collecting is: normally only four hours per week. Every effort has to be made to avoid selectively collecting rare species.

Adoption of the individual capture method instead of random sweeping
Random sweeping is sometimes efficient. For instance, for small and inconspicuous bees (such as *Perdita, Hylaeus, Lasioglossum, Ceratinula* , and *Leurotrigona*) might be missed by using one-by-one capture method. On the other hand, the efficiency of random sweeping for capturing sensitive, strong flying insects, such as large bees which are visiting (not inhabiting) flowers, is relatively low.

Relative ease of captures resulting from specific differences
Generally, the larger, slower, less sensitive bees with conspicuous coloration or other peculiarities are more easily discovered and caught than those with opposite features. Species with painful stings, such as bumblebees, require more time to transfer from the net to killing tubes. On the other hand, bees such as *Niltonia, Plebeia, Tetragonisca, Melipona, Trigona* and certain *Andrena* that do not sting are easier to manipulate. Noisy fliers, such as *Megachile, Xylocopa*, are also more easily discovered. Excessively hot or cold conditions differentially affect the bee species, inhibiting activities of stenotherms. Also, nocturnal and crepuscular species one usually ignored by daytime sampling.

Flower characteristics and their influences on bee sampling
The estimation of relative abundance of oligolectic bees tends to deviate from the actual density because the flowers visited by these bees are either dispersed or patchily distributed, so that the rate of discovery varies from case to case. Bees that visit spiny plants are often difficult to collect, and the capture of bees visiting flowers on tall trees is usually impossible. This is particularly important in habitats in which tall trees, lianas and epiphytes are abundant but is not important in open areas, such as prairies, steppes, tundra, savannas and shrubby vegetation. The contrast between flower color and visitor color seems to be important too. Generally the bees tend to be dark and, therefore, when visiting flat, open, pale colored flowers, they are easy to see and catch. Finally, there is a natural attraction of individual collectors towards peculiar flower colors and shapes and that can bias sampling of bees.

Varying efficiencies by personal differences of collectors

The ability to discover and catch bees varies among persons. Some knowledge of bees, their flower visiting habits and locomotion patterns, is needed. The fatigue of the collector has also to be considered, but division of each sampling day into separate periods can reduce the effect.

DATA BANK STRUCTURE AND MANIPULATION OF COMMUNITY INFORMATION

One of us (SL) developed (1976, Laroca *in lit.*) a structure of a data bank and a FORTRAN program to manipulate it for information about ecological communities. Several versions of this program (Fortran IV, Basic, and dBase) are available. The data banks are described and discussed in Cure and Laroca (1984), Schwartz and Laroca (1998, in press) and Jamhour (1998).

Diversity monitoring parameters for pollinators, and recommendations, based in two long term melissocoenotic studies

Two long-term melissocoenotic studies in Curitiba (one around Airport Afonso Pena (Município de São José dos Pinhais) and the other city center of Curitiba (Passeio Público) were made detect general ecological patterns. For the Airport site we have two one-year samplings, from March 1962 to March 1963, and from March 1981 to March 1982. In the last few years, this site was practically destroyed. The one-year samplings at Passeio Público were as follows: from January to December 1975 (approx. once a week); from June 1986 to June 1987 (once a week) and from June 1992 to May 1993 (once every two weeks). Passeio Público is a public zoological garden situated just in the central part of the city of Curitiba. The collecting site suffers air pollution by solid particles and chemicals, intensive gardening, large and increasing number of human visitors, strict control of honeybee colonies by heavy use of insecticides, loud noisy and vibration from vehicular traffic, etc. Thus there are frequent radical and erratic changes. The only factor that was more or less stable was the presence of native and exotic species of trees (*Ligustrum*, oak tree etc.).

The data are discussed in the strict field of melissocoenotics but also in specialized books (*e.g.,* Roubik 1992); textbooks (Laroca 1995) and educational biology papers (Nagasawa, 1969). Reports on the melissocoenoses of Passeio Publico are by Laroca, Cure-Hakim and Bortoli (1982), Taura and Laroca (1991), Almeida and Laroca (1988); and thesis: Taura (1990 and 1998).

The effort of capture in the two periods and places was different. In 1962/63, 130 hours of effective collecting were performed but in 1981/82, 150 hours. The number of species recorded is the same in both periods (167 spp.), but the number of individuals is very different: 4,218 individuals in 1962/63, and 1,906 individuals in 1981/82 (average number of individuals 32,4 and 12,7 per hour respectively). The diminished populations seem to be related to intensification of agricultural (horticulture) activities and reduction in the abundance and possibly diversity of native plants.

A group that nearly faded out the between first and second survey was the parasitoid bees, including the extinction from the Airport site of seven genera. In *Coelioxys* for instance, there were five species represented in the 1962/63 sample, but only one remained in 1981/82. On the other hand, the number of potential host species (Megachilidae), although with lower populations increased, perhaps as a result of the decrease of parasitoid species but possibly also because of the increase of diversity of appropriate leaves for constructing their nests. In Andrenidae there was a light increase in number of species, as well as in Anthophoridae. In Meliponinae, in 1962/62, there were three species (*Trigona spinipes*, *Plebeia emerina* and *Melipona q. quadrifasciata*), but in 1981/82 only one (*Trigona spinipes*) remained. The population of the remaining species decreased drastically (from 675 individuals to 9 individuals). This pattern seems to be linked to the extinction of appropriate nesting substrates.

In both samples there were three species of bumblebees, two more generalists in terms of habitats: *Bombus morio* and *Bombus atratus* and one, possibly, more specialized and distributed in the natural open fields of South Brazil and Argentina (*Bombus bellicosus*). The relative abundance of *Bombus bellicosus* decreased greatly from 1962/63 to 1981/82 but the relative abundance of *Bombus morio* and *Bombus atratus* increased.

In Anthophoridae, the number of species, from 1962/63 to 1981/82, increased a little, but the parasitoid genera: *Trophocleptria* and *Isepeopus* present in 1962/63 did not occur in 1981/82 sample. In Halictidae, the number of species decreased (from 88 in 1962/63 to 79 species in 1981/82). A unique genus of parasitoid bee (*Temnosoma*) disappeared from 1962/63 to 1981/82 sample and in Collectidae the same tendency was seen (from 10 species in 1962/63 to 7 species in 1981/82).

The assemblage of the plants visited by the bees has also been modified. In both samples, the bees were collected on the flowers of 118 species of plants. From this total, 32 species are common in both periods, but 35 species are exclusive to 1962/63, and 51 species are exclusive to 1981/82. Exotic plant species comprised 4 in 1962/63 and 10 species in 1981/82. Thus, the number of invading plant species greatly increased.

Changes in the pollinators (Apoidea) community inside the metropolitan city of Curitiba (Paraná, Brazil)

In Passeio Publico, the decline in species was great: respectively from 74 species (1975), 70 species (1986/87) to 49 species (1992/93). The changes seem to be related to the growing urbanization, local extinction of some plants, such as *Polygonum puctatum* (habitat destruction), *Abutilon bedfordianum*, *Cosmus* sp. (cultivated), that were the main food resources for many bee taxa, construction of barriers (wide streets) and insecticides for control of Africanized bees.

It seems that the success of certain species of Meliponinae species in an urban biotope inside a large city such as Curitiba, reflects the ecotonal preferences of the Meliponinae species involved.

The observed population sizes for the samples (as a whole) varied: 34,38 (1975), 40,20 (1986/87), and 19,54 individuals/hour of capture effort. And the average number of individuals per species also varied: 33,96 (1975), 45,95 (1986/87) and 34,69 (1992/93).

Taura (1998) grouped the species according to classes of abundance (see Preston, 1948), but data from the three surveys did not adjust well to the lognormal curve. This finding suggests instability in the community and such abnormalities seem to result from habitat disturbances such as from human activities (Laroca et al. 1989; Kevan et al. 1997).

Local extinction of 5 genera was observed: 25 genera were present in 1975, 24 genera in 1986/87 and 21 genera in 1992/93. As well local extinction of 2 families has occurred: Megachilidae: 3 genera in 1975, 0in 1986/87 and 0 in 1992/93; and Andrenidae: 3 genera in 1975, 2 in 1986/87 and 0 in 1992/93. Great reduction in the number of species was also observed in Colletidae: 4 in 1975, 2 in 1986/87 and 1 in 1992/93. Incidentally, the remaining species of Colletidae is an oligolectic Paracolletinae (*Bicolletes*) visiting *Vassobia breviflora*. The number of species of Halictidae has also decreased drastically: 45 in 1975, 47 in 1986/87 and 32 in 1992/93.

Local extinction of genera and families in urban biotopes is a very serious problem, but the severity of these problems could be diminished by the use of local ornamentals instead of exotic plants.

On the basis of the foregoing, and in summary, we present ten recommendations:

Thus, our **first recommendation** is the immediate cessation of the expansion of the agricultural frontiers, without regard to pollinating bees. Corresponding efforts must be made in regard to agricultural productivity and food distribution so as to address the needs of the hungry.

Thus, our **second recommendation** is to preserve and improve environmental heterogeneity in agricultural landscapes, aimed at conditions for pollinators and their associates.

Our **third recommendation** is for a special program of research on pollination life history aimed at increased knowledge of nesting requirements. To reach this goal, joint contributions of people such as scientists and farmers, scientists and designers, and scientists and the press (including modern media such as television and Internet).

Our **fourth recommendation** is the development of a special program on behavior and ecological studies of parasitoids that enable a germane *praxis* of conservation and control of these organisms

Our **fifth recommendation** is that for agricultural ecosystems, ecological studies on the influence of combination of exotic and native plants on the conservation of the diversity of potential pollinators are needed.

Our **sixth recommendation** is for discussion, on an international level, of new land use policies, specially for the construction of new architectonic structures, such as airports, industrial plants, roads, dams, mines, large buildings etc., and to encourage reutilization of areas already allocated for such purposes in order to minimize adversity to agricultural ecosystems including potential pollinators.

Our **seventh recommendation,** given that much data exists but remains unevaluated and unavailable because of financial constraints, is to implement an effective policy of data analysis, meta-analysis and scientific publication diffusion of pollinator issues, especially for developing countries and regions.

Our **eighth recommendation** is the development of an immediate international program of ecolo-ethological studies on the interactions between exotic honeybees (*Apis*) and native pollinators in the various regions of the world in order to enable a germane *praxis* of conservation and control of these organisms, and a rational conjugation of both categories (exotic and wild) pollinators.

Our **ninth recommendation** is that special care must be given to the pollinator assemblages of the contact (or ecotone) zones between the great vegetational formations of the Earth, especially in the xeric-mesic as well as in mesic zones where we can find the highest diversity of potential pollinators.

The **tenth recommendation** that is the promotion of the local and regional native plants, and recognition of their aesthetic values and value in pollinator conservation.

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