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Honey bees as bioindicators of environmental pollution

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Abstract

Since 1962, the bee has increasingly been employed to monitor environmental pollution by heavy metals in territorial and urban surveys, pesticides in rural areas and also radionuclide presence in the environment.

The bee as biological indicator possesses several important morphological, ecological and behavioural requisites, and man's beekeeping assures an unlimited supply. The bee acts as a detector of environmental pollution in two ways, as it signals either via high mortality rates the presence of toxic molecules, or via the residues in honey, pollen, and larvae the presence of heavy metals, fungicides and herbicides that are harmless to it. Bee monitoring also contributes to the ecological impact statement by culminating in the charting of environmental health maps, which include such data as mortality rates, apicide number, type and risk-level of molecules detected, and so forth.

These general remarks are briefly exemplified by a few of Author's findings, and by the description of the large scale monitoring methodology.

Key words: *Apis mellifera*, bioindicators, monitoring, environmental pollution

When Ernst Haeckel, the famed German exponent of Darwinism, resorted to the tried and true method of lexical engineering in the latter half of the nineteenth century to coin the term ecology by spicing together the Greek words for discours, *logos*, and home, *oikos*, he not only enriched the vocabulary of the scientific community but heralded through apposite definitions a new way of seeing how organisms and the environment interrelate. In general terms we can say that each organism, and its home, form a mirrored pair, and it is not possible to deal separately with them. It is precisely this mirror-image of the living being and its biotope which enables us to resort to certain organisms in their capacity as biological indicators.

The function and use of bioindicators are well depicted if we take a look at the bee, an insect that my research staff and I have been working on for over twenty years. The idea of employing the bee in environmental monitoring is not a new one. It dates back to J. Svoboda, who in 1935 (Crane, 1984) felt that this insect could provide us with valuable data on the environmental impact of certain industries in given areas; twenty-five years later he and his co-workers reported via bee-monitoring an increase of the radionuclide strontioum 90 in the environment – the result in all likelihood of atmospheric nuclear testing (Svoboda, 1962). Since 1970, the bee has increasingly been employed to monitor environmental pollution heavy metals in territorial and urban surveys (Cavalchi and Fornaciari, 1983; Crane, 1984; Accorti and Persano Oddo, 1986; Celli *et al.*, 1987; Stein and Umland, 1987; Celli *et al.*, 1988b) and pesticides in rural areas (Atkins *et al.*, 1981; Celli, 1983; Mayer and Lunden, 1986; Mayer *et al.*, 1987; Celli *et al.*, 1988c; Celli and Porrini, 1991; Celli *et al.*, 1991; Porrini *et al.*, 1996) as well as radionuclides (Wallwork-Barker *et al.*, 1982; Gattavecchia *et al.*, 1987; Tonelli *et al.*, 1990) (for a review on the state of the research on these topics in Italy see Porrini *et al.*, 2002).

The bee as biological indicator possesses several important requisites. First, man's beekeeping assures an unlimited supply. Then, the bee is active throughout the area surrounding the hive: for, although an opportunist in the sense that it prefers to gather pollen in the flowered fields nearby, the bee can range over long distances, even up to ten kilometres under exceptional circumstances: a hive can keep an area of seven square kilometres "under its control" (Crane, 1984). And the number of bees in a given area is considerable. A quarter or ten thousand, of the forty thousand bees in a normal hive are active pollinators. It should be borne in mind that each one completes twelve to fifteen flights a day, and that it takes about a hundred apple flowers to fill the honey stomach and eighty or so pear flowers to lord the pollen basket.

The bee ethogram described above shows it to be an especially apt monitoring instrument: it issues from the hive and flies about the surrounding area casually picking up airborne particles with its body hairs, while busily harvesting plant and flowers. In other words, it takes samples for us, gathering nectar and pollen from flowers, propolis from the buds of various botanic species, especially poplars, honeydew from the aphids of infested plant and water from wells and irrigation ditches. All of which leads to the truly crucial moment of the bee's return to the hive with is precious cargo. The nectar an pollen are stored, honey is made, the propolis is used in the hive and the larvae are fed. These latter, which in certain cases accumulate residues in their bodies, can thus become biological indicators by stockpiling given contaminants via a nutritional body balance whose input is grater than its output. These indicators-accumulators constitute a special category that not only takes samples but highlights residues, thereby facilitating their determination.

The bee then acts as a detector of environmental pollution in two ways. Its signals either via high mortality rates, even blanket apicides, the presence of molecules that are toxic to it, or via the residues in honey, pollen, larvae and so forth, the presence of certain heavy metals and of many fungicides and herbicides that are harmless to it (Celli, 1983; Porrini *et al*., 2002). Mortality and residues are thus the keys enabling us to take an X-ray via the bee of the environment surrounding the hive.

These general remarks can be best, and briefly, exemplified by a few of our findings. One of the most significant study dates back to the Seventies, when a research was run to assess the impact of chlorinated hydrocarbon insecticides, like Endosulfan, on foraging bees. The general aim of our research was to obtain a more strict pesticides regulation which could prevent their use during flowering, and to force the companies and the legislators towards a classification of pesticides' toxicity more respectful for the bees. A very hard laboratory and field work was needed, which showed that Endosulfan was highly toxic to the bees by contact - and this was known - but also by ingestion of contaminated nectar, which significantly elongated the risky period to the bee (Giordani *et al*., 1978). Several years and many researches were needed to obtain that a significant limiting of pesticide use during crops'flowering.

Than, a pioneer large scale and ambitious monitoring project was run from 1983 to 1986, for which a net of several hundred monitoring stations were deployed in northern Italy. A sampling station consists of two healthy beehives strategically deployed either at the centre of areas that are more or less intensively farmed and, hence, under different chemical pressure, or in peripheral, low-contamination zones for comparative analysis. Each hive fitted with a Gary cage to collect dead bees. Dead bees were counted weekly, although the resulting number was but a conservative estimate in that particularly lethal molecules kill many pollinators in the field, before they can return to the hive. Yet, despite the approximate nature of these counts, both the Gary- and the more recently developed "underbasket" cage proved to be a fairly reliable register of what happened in the field precisely because the bee is a stubbornly homing insect. Whenever the death rate exceeded the threshold of 500-700 individuals per station per week (now it has been reduced to 200-250), the dead bees were analysed. During the years 1983-1986, the number of apicides peaked at 581. In the 76% of the registered mass-death it was possible to determine the molecule responsible. The most significant compounds in this connection were dimethoate and parathion (15% each) followed by azinphos-methyl (12%) carbaryl (11%) and methyl-parathion (10%) (Celli *et al*., 1988a, 1988c). The contaminants most frequently detected in the bees were dithiocarbamates, which recurred in 70% of the samples that tested positive. These fungicides, which appear to be substantially ubiquitous in the environment, are listed in the 1987 report of the U.S.Academy of Sciences as the most hazardous compounds in terms of cancer-causing potential (Triolo, 1988). The bee thus enables us to throw light on a situation of environmental risk that otherwise would have remained hidden in shadow.

While the bee as a quantitative indicator can only provide us with educated guesses that have to be complemented by other data, it has proven to be highly effective and precise in detection the spatial range and quality of molecular contamination. An extensive bee monitoring survey we conducted in Ferrara Province in 1987 and 1988 found that the compounds most often registered by the bees were precisely the retail market leaders, and hence those most sprayed throughout the area (Celli *et al*., 1991).

Bee monitoring also contributes to the ecological impact statement on pesticides by culminating in the charting of environmental health maps, which include such data as mortality rates, apicide number, type and risk-level of molecules detected, and so forth. In Forlì Province (Emilia Romagna region, Northern Italy), where our work began over 20 years ago, we were able to draw up an historical atlas, so to speak, of environmental health maps. They chart the evolution – for the better, as it turns out – of the impact of synthetic molecules on farmland and, hence, covering most of the province itself (Celli and Porrini, 1991). The environment monitoring through the bee allowed us to register also local, critical situations without the risk of a significant alteration of the general "depict" of environmental health made by the complex of the monitoring stations. In 1995, in the Ravenna Province (nearby the Forlì Province) a particular worrisome situation came to light with the discovery of lindane in two inhabited areas of the town where the use of this substance could not be justified by the local conditions. Dangerous and obsolete molecules such as parathion and endosulfan also indicated the difficulty of local agriculture in relinquishing the old methods of protection cultivation, even in an overall medium-low level of contamination of the investigated area (Porrini *et al*, 1998).

For some time now in the Romagna Region both integrated pest management, which seeks to limit the use of pesticides and at the same time to combine their use with alternative methods, and biological pest control, which strives towards the complete elimination of synthetic compounds, have been in operation, and the bees have probably registered the resulting, first few ecological benefits.

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