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Ecotoxicological Evaluation of *Parallelomorphus laevigatus* (Coleoptera, Carabidae) as a Useful Bioindicator of Soil Metal Pollution

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Abstract

The importance of carabid beetles in environmental study is reported. Among this group *P. laevigatus* is a useful bio indicator of metal pollution. The burden of trace elements in animal tissue reflects the contamination level of investigated areas. The alteration of orientation performances by this species put the basis to consider orientation in space of *P. laevigatus* as a behavioral biomarker for exposure to trace metals contamination.

Keywords: Carabid beetles; *Parallelomorphus laevigatus;* Trace metals; Environmental assessment; Behavioral biomarker

Among soil invertebrates, the carabid beetles are predators considered useful ecological indicators [1-7]. This is because they play a key role in clarifying the route of contaminants in food webs; in fact, they are both predators of small invertebrates and prey for amphibians, reptiles, birds and small mammals [8].

This taxon is generally considered as poor accumulator of trace elements [9,10]; this is probably due to a series of detoxification enzymes [9,11] of which it is endowed. However, a few studies have shown that physiology of carabid beetles [5,11,12] as well as their susceptibility to additional stressors [13] can be affected by the accumulation of heavy metals.

Among these beetles, *Parallelomorphus laevigatus* (Fabricius) (homotypic synonym of *Scarites* (Parallelomorphus) *laevigatus* Fabricius, 1792) (Figure 1) did reserve a relative few interest from ecological point of view while has never been studied for an ecotoxicological analyses. It is a ground beetle widespread on the Atlantic coasts of the Mediterranean and Morocco and along the Mediterranean basin and the western coast of the Black Sea [14]. This species, living on sandy beaches, occurs in relatively dense populations in Sicily from April to October, while no specimens are visible during winter season. It has a highly precise orientation capacity; if it accidentally falls into the water, caused by waves or wind action (and this can occur whether by day or by night), it is able to float and swim on the sea surface using an effective swimming technique [15] and quickly lands by using a path perpendicular to the shoreline. During daytime, it uses the solar azimuth as an orientation cue (it carries out the chronometric compensation of the apparent motion of the sun using the photoperiod known as "Zeitgeber" [16]. Nocturnal tests have also discovered it has a lunar orientation [17] and is sensitive to the magnetic field [18].

P. laevigatus is particularly active on surface in the evening and in the night in summer [19] peaking after sunset. Conversely, it spends the daylight hours in an individual burrow in the sand near the shoreline. When active, the beetle uses its time hunting mainly *Talitrus saltator* [19,20].

Figure 1: *Parallelomorphus laevigatus.*

The progressive depletion of the population size due to human impacts [21] and the narrow habitat have made this species an excellent ecological indicator for sandy coastal environments [22].

The presence of one of largest refining and petrochemicals industries in Western Europe and the Mount Etna (the tallest active volcano in Europe) in the southern part of the Ionian coast of Sicily stimulated to investigate on the bioaccumulation capacity of trace elements in this species. For this investigation, 16 target metals, 11 of which are essential elements for living organisms (Co, Cr, Cu, Fe, Mn, Mo, Ni, Se, Sn, V and Zn) and four of which are toxic (As, Cd, Hg and Pb) were analyzed in adult specimens from four Sicilian locality (Figure 2). The sites were selected according a gradient of trace metal pollution and considering the site D, Vendicari Nature Reserve, located approximately 40 km south of Syracuse, as site control. It has been recognized as a wetland of international importance under the Ramsar Convention of 1971.

Our investigation pointed out that animal tissue from control area had the highest values of As, Cd, Cr, Hg, Ni, Pb, Se and Sn, while Fe and Mn were at the lowest values; moreover, the concentration of Hg, Cd and Se in the tissues of *P. laevigatus* differed among the four sites.

Assessing the possible transfer of each metal through the food chain, we considered the metal burden in *P. laevigatus* (predator) and in its prey *T. saltator*. We can affirm that the concentration of As, Cr, Cu, Ni and Se in animal tissue differs in the beetles and in the sandhoppers according to their trophic role inside the ecological net. Differences in concentration for Cd, Co, Fe, Hg and V were correlated to both trophic level and sampling site, while Mn concentration differed among sites in a different way for the prey and predator. Moreover, the transfer trophic coefficient (TTC) (i.e., the ratio of the metal concentration in the beetles to that in their prey) is particularly high (approximately 5) for Hg.

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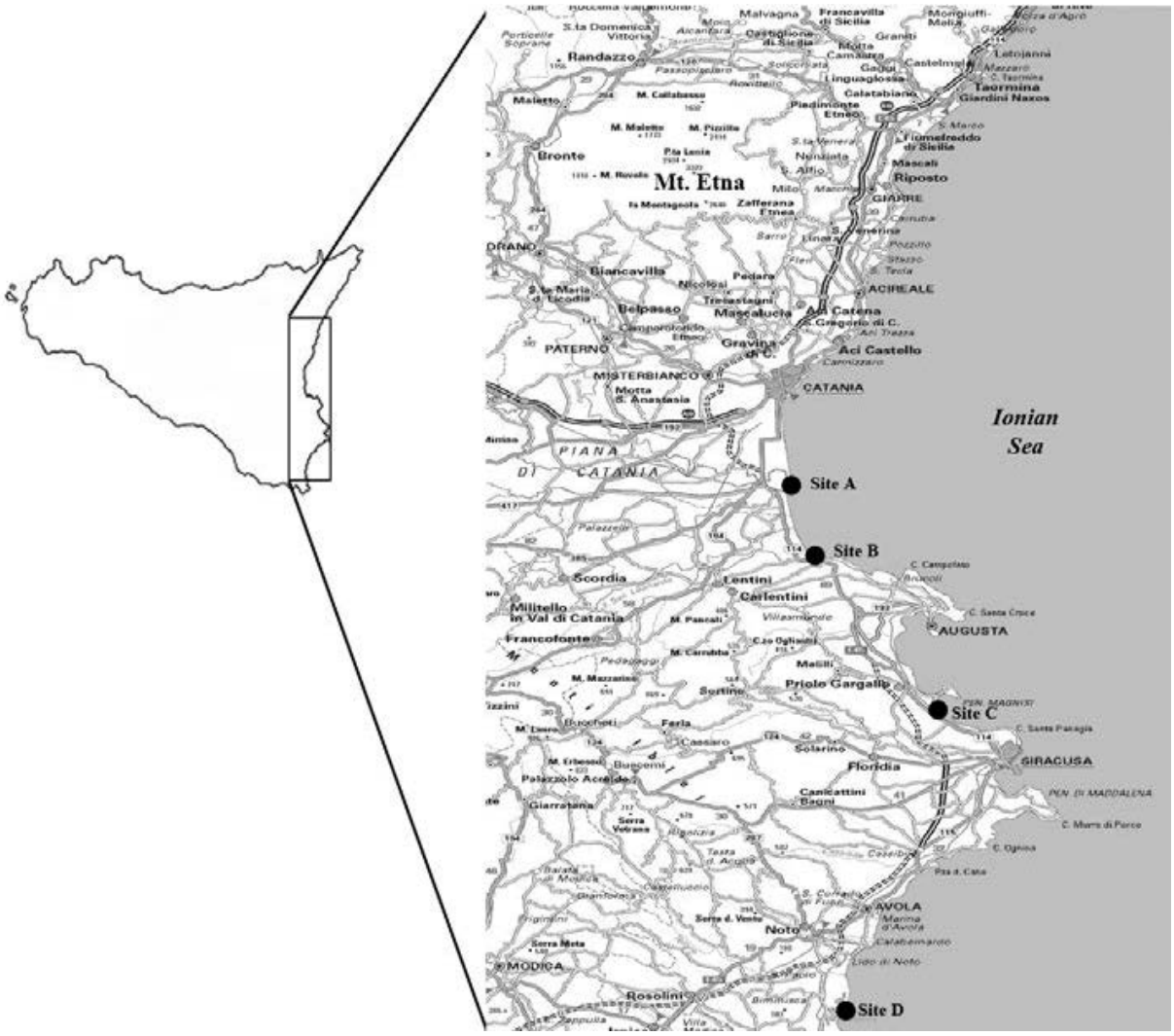

Figure 2: Sampling sites on the Ionian sandy coast of Sicily: A (Simeto mouth); B (Agnone Bagni beach); C (Marina di Priolo); D (Vendicari beach).

On the best of my knowledge *P. laevigatus* is the first psammo-halophilous species used for ecotoxicological purpose. An interesting first result of this survey is the confirmation of increasing Hg concentrations across the simplified trophic net of sandy beaches and the ability of this pollutant to biomagnificate.

Furthermore, based on the results obtained, the Ionian sandy coast of Sicily can be divided into a northern region (sites A and B), where there is the influence of Mount Etna, and a southern region (sites C and D), where there is the anthropogenic influence. Both conditions can cause metal pollution, however, of these two; the most dangerous seems to be the man-made one.

Many of trace metals measured (i.e., Fe, Mn, V, Zn and Cr) are present in lava soil and volcanic ash, causing sand contamination [23-29]. However, the long-term contribution of heavy metals to the environment by the volcano has allowed living organisms to adequately adapt.

The assessment of the southernmost area is very different. The high values of numerous trace metals detected in beetles right from the control site are mainly due to the emissions sources of the nearby industrial plants; but also the intense agricultural activity in nearby areas certainly contributes, at least for cadmium, very abundant in both prey and predators [30]. Particularly alarming is the very high concentration of Hg in insect tissues from this site; on the other hand, a huge burden of this dangerous metal has already been found in this southern area of eastern Sicily in previous research on both sediments and animal tissues [31-34]. Indeed, various authors (e.g. Sprovieri et al. [32], Di Leonardo et al. [33]) have considered this area to be a mercury point source for the entire Mediterranean Sea.

These first outcomes confirm the possibility to consider *P. laevigatus* as a useful bioindicator of trace metal contamination in sandy beaches. Further experiments on the alteration of orientation behavior strengthen this hypothesis. Indeed, an investigation on the influence of trace metals (namely Cu, Zn and Hg) intake on the spatial orientation performances of the carabid beetle *Parallelomorphus laevigatus* [35], showed alteration of the correct directional choices by this insect. Beetles performed a progressive and significant counterclockwise displacement of the angle of orientation and a corresponding progressive reduction in the precision in the directional choices. This recent study also allows considering the orientation in space of *P. laevigatus* as a behavioral biomarker for exposure to trace metals contamination.

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