transport of infested plants, we recommend a more intensive inspection during transport of plants, materials etc. between and from indoor heated buildings and especially from greenhouses to indoor tropical swimming pool infrastructures and reversely. BOER & VIERBERGEN (2008) assume that when hygienic and control measures increase, exotic ant species such as *Paratrechina longicornis* might decrease. In the Netherlands, this species was probably one of the first that has disappeared for this reason (BOER & VIERBERGEN, 2008).

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Effects of metal contamination on the activity and diversity of spiders in an ancient Pb-Zn mining area at Plombières (Belgium)

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Abstract

In the ancient Pb-Zn mining area of Plombières, spiders were monthly sampled with pitfall traps during one year. Based on the total soil concentrations of cadmium, copper, lead and zinc, it was expected that zinc would probably have the strongest adverse effect. Neither total zinc concentration, nor with water soluble and calciumchloride extractable concentrations affected total spider activity and species richness significantly. In fact, despite the high metal concentrations in the soil, it was not immediately clear that spider composition was affected in the study area. The apparent lack of effects at the high observed zinc concentrations was attributed to the relatively low bioavailability of zinc to the spiders at the study sites, which was also reflected by the low detected water soluble zinc concentrations. However, more detailed analysis revealed that the number web-building spiders decreased, while number of hunting spiders increased with increased calcium chloride extractable zinc concentrations.

Keywords : Araneae, bioavailability, zinc exposure.

Introduction

Numerous studies have reported on the toxicity of metals to invertebrates, the metal distribution in the organisms and the contribution of emissions to the environment from different sources. The effects of metal pollution on terrestrial ecosystems are, however, still hard to predict as the results from laboratory ecotoxicity experiments cannot be easily extrapolated to field situations (VAN STRAALEN & DENNEMAN, 1989). In the laboratory, organisms are tested under optimal conditions while in the field, biological availability of metals is usually lower than in laboratory experiments, organisms are exposed to metal mixtures, ecological compensation mechanisms are operating and adaptation to metal stress may occur (VAN STRAALEN & DENNEMAN, 1989). Field studies are therefore necessary to learn how evidence gathered during laboratory testing can be translated to the field.

Spiders are invertebrates with a high species richness that have been intensively studied. The group is known for its importance as invertebrate predators, which suggests that spiders may be exposed to high metal concentrations through biomagnification. However, the influence of metal contamination on spiders has only been the subject of a few studies. Spiders are known to assimilate large amounts of metals present in their prey, which are made inactive by storing them in intracellular granules in the midgut diverticulae (HENDRICK *et al.*, 2003a). HENDRICKX *et al.* (2003a) demonstrated that a high cadmium assimilation rate (69.5%) and an excretion rate approaching zero resulted in high Cd concentration factors for *Pirata piraticus* (Clerck, 1757), stressing the importance of cadmium biomagnification by spiders. Although this detoxification process is effective in enhancing survival at polluted sites, it was expected that this defence mechanism against metal intoxication is at the cost of reduced growth and reproduction since energy spend at detoxification can not be used for anything else (JONES & HOPKIN, 1998). Indeed, females from populations of *Pirata piraticus* with high metal concentrations showed a strongly reduced reproductive output and fecundity, indicating a high reduction in resource availability due to detoxification processes (HENDRICKX *et al.*, 2003b). Although spiders are known to be metal accumulators, only two studies recently assessed the influence of metal contamination on spider communities. JUNG *et al.* (2008) found that spider diversity tended to decrease with increasing Pb levels in soil although no statistical significance was obtained. Therefore, they indicated that spider communities may be not sensitive enough to discriminate moderate metal contamination in soil. Along a pollution gradient near a copper smelter, web-building spiders were replaced by cursorial spiders: the abundance of the families Lycosidae and Gnaphosidae increased while that of the family Linyphiidae decreased, which was attributed to the effect of metals on the vegetation as web-building spinning spiders need more structure in the vegetation (ZOLOTAREV, 2009).

The present study focuses on the effect of metal contamination in an ancient Pb-Zn mining area on the activity and species richness of spiders. The hypothesis of the present study was that the high observed metal concentrations in the study area would negatively affect spider diversity. As the total metal content of a soil is a poor indicator of environmental risk (VAN GESTEL, 1997), also water soluble and calciumchloride extractable metal concentrations of the soils were measured. In addition, it was also assessed whether different feeding guilds were affected differently by metal pollution.

Methods

Study area

The study area is highly contaminated with the metals Pb, Zn and Cd due to the former Pb-Zn mining activities (UTM-coordinates: 31UGS0924). At Plombières (Belgium), the industrial operations mainly date from 1844-1845 until 1882 and mine activity in the whole area ceased around 1936 (SWENNEN *et al.*, 1994). The only remnants of this important industry are mine tailings which are presently the major sources of metal pollution, especially since the Geul river crosses the mine tailing deposits. The Geul is a meandering river in East Belgium; from its source to its confluence with the Meuse river, its length is 56 km. To create a recreational park, vast surfaces of the contaminated area were covered with silty soil in 1996-1997, *Lolium perenne* was sown and trees were planted on these soils. Objections of nature conservation organisations resulted in the protection of the remaining parts as a nature reserve because of its extraordinary botanical value which derives from the occurrence of plant species that are unique for metal enriched soils. The site is characterised by metallophytes such as *Viola calaminaria*, *Thlaspi caerulescens* subsp. *calaminare*, *Armeria maritima* subsp. *halleri*, *Silena vulgaris* subsp. *vulgaris* var. *humilis* and *Festuca ovina* subsp. *guestfalica* which results in a typical vegetation (DUVIGNEAUD & SAINTENOY-SIMON, 1998).

Sampling

Seven sites, differing in degree of metal contamination, were sampled (Fig. 1). All sites were characterised by the presence of trees, resulting in a humus layer on the soil surface. Site A was situated at the base of a mine tailing heap while site B was located on top of this heap. An area at the base of some rocks situated somewhat separated from the mine tailings was selected as site C. Site D was located in the area where the mine tailings were covered with a layer of loamy soil. Site E was located on the banks of the river Geul where the river crosses the mine tailings. Site F was situated on the edge of the mine tailings. Finely, site G was also located on the banks of the river Geul, but upstream of site E.

Per station, three pitfall traps with a diameter of 6.5 cm were placed, spaced 2 m apart. A 4 % formaldehyde solution was used for killing and fixation and some detergent was added to lower surface tension. Pitfalls were emptied every month. Sampling lasted from February 1999 till January 2000. Spiders were identified according to ROBERTS (1987, 1998). The number of animals caught was referred to as the activity, since a species can be very abundant without being capture with the pitfall traps when it is not actively walking around.

Soil analysis

At each site where spiders were captured using pitfalls, a soil sample was taken. Soils were digested in hot acid (HCl:HNO_3 1:5 v/v, microwave heating) and soil metal concentrations were measured using flame atomic absorption spectrometry (Varian, SpectrAA-100, Victoria, Australia). For zinc and lead, a deuterium background correction was applied. A calcareous loamy soil (CRM 141 R, Community Bureau of Reference, Brussels, Belgium) was used as certified reference material. Measured

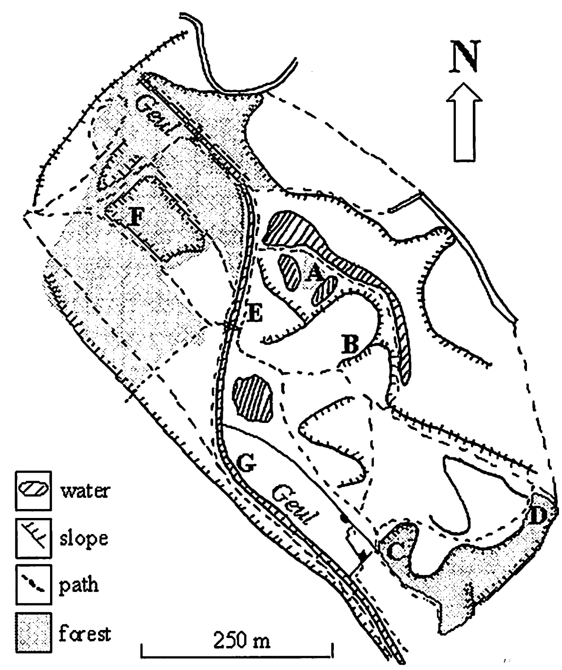

Fig. 1. Map of the Plombières mining area (Belgium) with indication of the locations of the pitfall traps.

concentrations were always within 10% of the certified values.

Lead is usually strongly bound to the soil and consequently hardly bioavailable at the measured concentrations, while cadmium and copper occurred at much lower concentrations in comparison with zinc. Based on toxicity data for earthworms and springtails, zinc was expected to have the highest toxicity. However, toxicity data for spiders were to scarce in order to formulate any prior expectations. Anyway, the different extractable zinc fractions were studied into more detail. Water soluble and calciumchloride extractable zinc fractions were obtained by shaking 5 g of soil for 2 h at 200 rpm with 50 ml deionised water or 50 ml of a 0.01 M $CaCl_2$ solution, followed by filtration through a 0.45 µm cellulose membrane filter (Gelman Sciences, Michigan, USA). Zinc concentrations in the extracts were measured by flame atomic absorption spectrometry (Varian, SpectrAA-100, Victoria, Australia) with a deuterium background correction.

Because pH and cation exchange capacity (CEC) were reported to be the most important soil parameters influencing metal bioavailability (LOCK *et al.*, 2000; LOCK & JANSSEN, 2001a), these soil characteristics were measured at the different sampling locations. pH (KCl) was measured (Consort pH meter, P407, Turnhout, Belgium) at a 1:2.5 soil:liquid ratio with 1 M KCl (ISO 1994). CEC was determined with the

AgTu method in 0.4 M ammoniumacetate at pH 7 (CHHABRA *et al.*, 1975).

Calculation of diversity

Diversity was calculated as Hill's diversity numbers (HILL, 1973). This set of indices incorporates the most widely used diversity measures in a continuum of indices of the orders -∞ to +∞. The indices differ in their tendency to include or to ignore the relatively rarer species: the impact of dominance increases and the influence of species richness decreases with an increasing order of the diversity number. Of particular interest are:

$N_0 = S$ with S = the number of species

$N_1 = e^H$ with H = Shannon-Wiener index $H = -\sum p_i \ln(p_i)$ (p_i = the relative abundance of the i^{th} dominant species)

$N_2 = SI^{-1}$ with SI = Simpson's dominance index; $SI = \sum p_i^2$

$N_\infty = p_1^{-1}$ with p_1 = the relative abundance of the most abundant species.

In addition, spiders were assigned to feeding guilds according to the classification of UETZ *et al.* (1999): Clubionidae, Dysderidae, Gnaphosidae, Liocranidae, Lycosidae and Zoridae were classified as runners; Salticidae and Thomisidae as stalkers/ambushers; Agelenidae, Amaurobiidae, Atypidae and Hahniidae as sheet webbuilders; Linyphiidae as wandering weavers; Tetragnathidae as orb weavers and Titanoecidae as space webbuilders. Because these feeding guilds were not all well represented in the present study, these guilds were grouped in two group for the analysis: hunting spiders (runners and stalkers/ ambushers) and webbuilders.

Results

In total, 1381 spiders were captured, belonging to 84 different species (Table 1). The number of species varied from 24 species at site E up to 37 species at site A, while the activity, expressed as the number of animals caught, varied from 94 at site E up to 273 at site A.

Based on the total metal concentrations in the soils (Table 2), it was expected that zinc probably would have the strongest ecotoxic effect. The total zinc concentration varied from

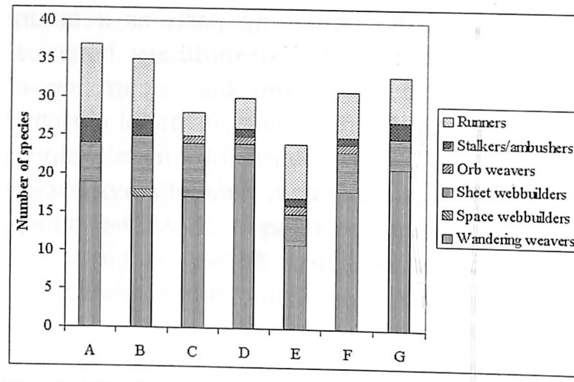

Fig. 2. Number of species per sampling station with indication of the feeding guilds: webbuilders (stripes, four categories) and hunters (dots, two categories).

859 mg.kg^{-1} dry weight at site C up to 5000 mg.kg^{-1} dry weight at site E. Calciumchloride extractable concentrations in the same soils were 4.10 and 247 mg.kg^{-1} dry weight, respectively. Water soluble concentrations varied from 2.16 mg.kg^{-1} dry weight at site G up to 9.52 mg.kg^{-1} dry weight at site F. The water soluble fractions of metals can often be related to soil properties. However, in the present study, pH and CEC could not be used to predict the water soluble zinc fraction from the total concentration.

Despite the high zinc concentrations detected in Plombières, relationships between the species richness or the activity of spiders and the total, water soluble or calciumchloride extractable zinc concentrations were never significant (Table 3). However, the number of webbuilding spiders decreased significantly (Spearman rank r=-0.78; p<0.05), while the number of hunting spiders significantly increased (Spearman r=0.79; p<0.05) with increasing calciumchloride extractable zinc concentrations (Fig. 2).

Discussion

Site E contained the highest concentrations of zinc, cadmium and was also characterised by copper and the lowest species richness. However, differences were small and despite the high observed metal concentrations, the spider community did not seem to be affected to a great extent in the study area. The apparent lack of correlation between the total activity and diversity of spiders and the soil zinc

Table 1. Spiders caught per location (three pitfall traps) during one year, with indication of Hill's diversity numbers.

Family	Species	A	B	C	D	E	F	G
Agelenidae	*Cicurina cicur* (Fabricius 1793)	2	1	1	5	1	2	6
	Coelotes terrestris (Wider 1834)			20	3	2	23	13
	Histopona torpida (C.L. Koch 1837)			7			3	7
	Malthonica picta (Simon 1870)	8	8	1		1		2
	Malthonica silvestris (L. Koch 1872)		1	1		1		
	Tegenaria agrestis (Walckenaer 1802)	3						
	Tegenaria atrica C.L. Koch 1843		1					
Amaurobiidae	*Amaurobius similis* (Blackwall 1861)			1				
Atypidae	*Atypus affinis* Eichwald 1830	1	1				3	
Clubionidae	*Clubiona comta* C.L. Koch 1839		1					
	Clubiona lutescens Westring 1851					1	2	1
Dysderidae	*Dysdera erythrina* (Walckenaer 1802)			1	2			
Gnaphosidae	*Haplodrassus signifer* (C.L. Koch 1839)		2					
	Zelotes petrensis (C.L. Koch 1839)	1	9			1		
Hahniidae	*Antistea elegans* (Blackwall 1841)	1						
	Hahnia montana (Blackwall 1841)		4				1	
	Hahnia pusilla C.L. Koch 1841		2	3				
Linyphiidae	*Bathyphantes gracilis* Lebert 1877	2	3		9	2	8	3
	Bathyphantes parvulus (Westring 1851)				1			
	Centromerita concinna (Thorell 1875)	3	8		2	3		
	Centromerus incilium (L. Koch 1881)	3	5					1
	Centromerus prudens (O. P.-Cambridge 1873)	1						
	Centromerus sylvaticus (Blackwall 1841)	30	1	6	22	11	14	26
	Dicymbium nigrum (Blackwall 1834)				1			3
	Dicymbium tibiale (Blackwall 1836)			1	3			
	Diplocephalus cristatus (Blackwall 1833)			1		3		20
	Diplocephalus latifrons (O. P.-Cambridge 1863)			11	5			4
	Diplocephalus picinus (Blackwall 1841)	1		53	8			1
	Diplostyla concolor (Wider 1834)				25	2		4
	Drapetisca socialis (Sundevall 1833)						1	
	Erigone atra Blackwall 1833				1		1	
	Erigone dentipalpis (Wider 1834)					1		
	Gonatium rubellum (Blackwall 1841)	1					1	2
	Gonatium rubens (Blackwall 1833)	8		2	1	1		1
	Gongylidiellum vivum (O. P.-Cambridge 1875)				1			
	Gongylidium rufipes (Linnaeus 1758)				1			
	Helophora insignis (Blackwall 1841)						4	
	Lepthyphantes minutus (Blackwall 1833)			3				27
	Linyphia hortensis Sundevall 1830						1	
	Linyphia triangularis (Clerck 1757)		1					
	Maro minutus O. P.-Cambridge 1906			1				
	Maso sundevalli (Westring 1851)	22	8				1	3
	Meioneta saxatilis (Blackwall 1844)	1						
	Micrargus apertus (O. P.-Cambridge 1871)			3				1
	Microneta viaria (Blackwall 1841)			1				
	Monocephalus fuscipes (Blackwall 1836)			2				
	Neriene clathrata (Sundevall 1830)	4	1		1		1	1
	Neriene montana (Clerck 1757)	1						
	Oedothorax fuscus (Blackwall 1834)	1			1		3	1
	Palliduphantes pallidus (O. P.-Cambridge 1871)		1	4				
	Pelecopsis radicicola (L. Koch 1872)						1	

	Pocadicnemis juncea Locket & Millidge 1953		1		1			
	Poeciloneta variegata (Blackwall 1841)	1	6	2			1	
	Stemonyphantes lineatus (Linnaeus 1758)	2	2		1	1		
	Tenuiphantes flavipes (Blackwall 1854)	3	2	30		4	7	1
	Tenuiphantes mengei (Kulczynski 1887)	4		25	2		13	29
	Tenuiphantes tenebricola (Wider 1854)				1			
	Tenuiphantes tenuis (Blackwall 1852)	5	30	8	44	19	3	16
	Tenuiphantes zimmermanni (Bertkau 1890)		1	9	2	2		18
	Trichoncus saxicola (O. P.-Cambridge 1861)		2					
	Walckenaeria acuminata Blackwall 1833						1	6
	Walckenaeria antica (Wider 1834)		2					
	Walckenaeria atrotibialis (O. P.-Cambridge)				1		2	2
	Walckenaeria furcillata (Menge 1869)		1				2	
	Walckenaeria obtusa Blackwall 1836	1						
Liocranidae	*Phrurolithus festivus* (C.L. Koch 1835)	1	16					
Lycosidae	*Alopecosa pulverulenta* (Clerck 1757)	15	10			3		2
	Pardosa amentata (Clerck 1757)		1	3	7	7		
	Pardosa hortensis (Thorell 1872)						1	1
	Pardosa proxima (C.L. Koch 1847)	1						
	Pardosa pullata (Clerck 1757)	1						
	Pardosa saltans (Topfer-Hofmann 2000)	1				3	13	4
	Pirata hygrophilus (Thorell 1872)	11			1	6	91	15
	Trochosa terricola Thorell 1856	119	18	3	12	9	34	5
	Xerolycosa nemoralis (Westring 1861)	2	2					
Salticidae	*Euophrys frontalis* (Walckenaer 1802)	3	2					
	Evarcha falcata (Clerck 1757)	1						
	Neon reticulatus (Blackwall 1853)							1
Tetragnathidae	*Metellina mengei* (Blackwall 1870)			1				
	Pachygnatha clercki Sundevall 1823				1	1		
	Tetragnatha montana Simon 1874						1	
Thomisidae	*Ozyptila praticola* (C.L. Koch 1837)	7	4		5	9	1	13
Titanoecidae	*Titanoeca quadriguttata* (Hahn 1833)		1					
Zoridae	*Zora spinimana* (Sundevall 1833)	1					1	
Activity		273	159	204	170	94	241	240
N_0		37	35	28	30	24	31	33
N_1		10.3	19.3	12.7	13.5	15.3	10.3	18.9
N_2		4.60	12.6	8.05	8.24	11.0	5.43	14.3
N_∞		0.436	0.189	0.260	0.259	0.202	0.378	0.121

Table 2. Metal concentrations (mg.kg^{-1} dry weight), cation exchange capacity (CEC, cmol.kg^{-1}) and pH of the soil samples.

Site	Zn (total)	Zn (water soluble)	Zn ($CaCl_2$ extractable)	Pb (total)	Cd (total)	Cu (total)	CEC	pH
A	1530	8.84	207	1920	5.46	13.2	7.99	4.26
B	2150	8.11	103	2790	4.58	17.2	5.93	4.89
C	859	3.21	4.10	560	6.80	22.8	8.61	7.35
D	2930	2.82	7.96	3370	9.33	75.7	7.66	6.67
E	5000	6.53	247	922	59.4	306	4.33	6.71
F	2600	9.52	82.0	1170	10.3	46.4	3.41	5.94
G	1150	2.16	26.1	186	2.85	14.6	7.22	6.32

Table 3. Spearman correlation coefficients (significance level p (n=7)) of the relationships between the spider activity or diversity and the total, water soluble and calcium chloride extracted zinc concentrations ($mg.kg^{-1}$ dry weight).

	Zn (total)	Zn (water soluble)	Zn ($CaCl_2$ extracted)
Activity	-0.50 (0.25)	0.32 (0.48)	-0.14 (0.76)
N_0	0.36 (0.43)	0.32 (0.48)	0.21 (0.64)
N_1	0.036 (0.94)	-0.54 (0.22)	0.11 (0.82)
N_2	0.036 (0.94)	-0.64 (0.12)	-0.036 (0.94)
N_∞	-0.036 (0.94)	0.64 (0.12)	0.036 (0.94)

concentration may be due to acclimatisation or adaptation of the animals to high metals levels in their habitat. In Plombières, adaptation has already been demonstrated for the isopod *Porcellio scaber* and the springtail *Orchesella cincta* (POSTHUMA & VAN STRAALEN, 1993). However, it is unlikely that acclimatisation or adaptation alone are responsible for this apparent lack of effects. It is more probable that the high metal concentrations do not cause detrimental effects because these metals are hardly available to the spiders. In fact, the observed water soluble zinc concentrations in Plombières (Table 2) were below the 21d EC_{50} cocoonproduction for *Eisenia fetida* exposed to zinc (SPURGEON & HOPKIN, 1996) and also below the 42d EC_{50} reproduction for *Folsomia candida* exposed to zinc (VAN GESTEL & HENSBERGEN, 1997). The latter two invertebrates are the most frequently used test organisms in ecotoxicity assays.

The low available zinc concentration in the soils of Plombières can be explained by the fixation of metals in the soil. While metal solutions in ecotoxicological toxicity testing are usually added to the test substrate just before testing, metals have been present in the soils of Plombières for many decades. During this time, metals have had time to reach an equilibrium with the soil leading to relatively low water soluble metal concentrations (LOCK & JANSSEN, 2001b, 2002, 2003a-b).

In comparison with most organisms that are used in ecotoxicity testing, spiders are not endogeic and therefore, uptake via the pore water might be less important. As essential elements such as zinc are already regulated by their prey, spiders are possibly not exposed to high zinc concentrations through oral uptake. The same could be true for non-essential elements which are excreted or at least detoxified by their prey. In Plombières, it was previously reported that detrivorous springtail diversity was significantly correlated with the calciumchloriode extractable zinc concentration (Lock *et al.*, 2003), while predatory carabid beetle diversity did not seem to be affected (LOCK *et al.*, 2001). This is also supported by the observations of JUNG *et al.* (2008), who stated that spider communities may not be sensitive enough to discriminate moderate metal contamination in soil. Also SPURGEON *et al.* (1996) detected no effects of metals on spider diversity at contaminated sites around smelting works, whereas earthworms were relatively sensitive. Since most spiders are opportunistic generalist predators, they could switch to alternative prey when some prey organisms decline in response to metal contamination. In addition, ERALY *et al.* (2010) indicated for the wolf spider *Pardosa saltans* (Topfer-Hofmann 2000) that the production of metallothionein-like proteins may be an important mechanism enabling spider populations to persist in ecosystems polluted with high metal concentrations.

ZOLOTAREV (2009) indicated that web-building spiders such as Linyphiidae indirectly suffered from high metal concentrations due to the disappearance of shrubs and trees. Although all sampling sites in the present study were characterised by the presence of trees, the number of web-building spiders was negatively correlated with the calcium chloride extractable zinc concentration, while the number of hunting spiders was positively correlated with this fraction. These results indicate that other factors besides a change in vegetation structure might be responsible for the apparent higher sensitivity web-building spiders to zinc pollution. WICKZEK & MIGULA (1996) and WILCKZEK *et al.* (2005) reported that metal accumulation in hunting spiders was higher than in web-building spiders, indicating the higher sensitivity of web-building spiders is probably not due to a higher uptake. However, more detailed research is needed to confirm if web-building spiders are actually more sensitive to metal pollution than hunting spiders and the possible causes for this difference need to be clarified.

Conclusions

Despite high metal concentrations in the soil samples of the study area, the total spider activity and diversity did not seem to be greatly affected. The lack of a correlation between metal concentrations and spider activity and diversity could be explained by the relatively low metal bioavailability. This was reflected by the low water and calciumchloride soluble zinc concentrations that were measured. However, web-building spiders seemed to decrease, while hunting spiders increased with increasing calcium chloride extractable zinc concentrations.

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Nouvelle donnée pour *Dinocampus coccinellae* (Schrank) (Hymenoptera, Braconidae) en tant que parasitoïde d'*Harmonia axyridis* (Pallas) (Coleoptera, Coccinellidae)

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Abstract

A first data of parasitism of the Asian ladybird *Harmonia axyridis* (Pallas) by the braconid wasp *Dinocampus coccinellae* (Schrank) in the Brussels-Capital region is reported. Both species protagonists of this relationship are presented.

Keywords : Coleoptera, Hymenoptera, *Harmonia axyridis*, *Dinocampus coccinellae*, Belgium.

Résumé

Une première donnée de parasitisme de la coccinelle asiatique *Harmonia axyridis* (Pallas) par la guêpe braconide *Dinocampus coccinellae* (Schrank) dans la Région de Bruxelles-Capitale est signalée. Les deux espèces protagonistes de cette relation sont présentées.

You must collect things for reasons you don't yet understand - D. J. BOORSTIN (*in* RATCLIFFE & HOFMANN, 2011)

Le premier cas avéré de parasitisme en nature d'adultes d'*Harmonia axyridis* (Pallas) par l'hyménoptère braconide *Dinocampus coccinellae* (Schrank) en Belgique a été observé sur trois exemplaires en 2005 lors d'une étude de terrain par N. BERKVENS (donnée non publiée *in* BERKVENS *et al.*, 2010). Un autre exemplaire de *D. coccinellae* a aussi pu être obtenu en avril 2006 à partir d'un adulte d'*H. axyridis* (Pallas)