Chapitre 1

Mites from Belgian caves: an extensive study

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Abstract

Mites are largely ignored in most biospeleological studies up to now, for lack of taxonomical knowledge and adequate sampling techniques. Today, however, caves are endangered ecosystems. Prior to this study, only seven troglobitic mites were known in Belgium. This study explored the terrestrial acarological fauna of 25 Belgian caves by taking samples in earthy piles. Densities were highly variable. In unflooded locations, Oribatida and especially Oppiidae were the most abundant. At least six new species were

discovered. They are potential terrestrial troglobites. Veigaiidae, Endeostigmata-Sphaerolichida, Pygmephoroidea, Brachychthoniidae and Oppioidea, were particularly speciose and abundant. A multivariate analysis detected the very low spatial dependence of cave mite communities. The poor explanatory power of this analysis emphasised the fragmented nature of caves.

Résumé

Les acariens ont été ignorés dans la plupart des études biospéologiques jusqu'à ce jour, à cause d'un manque de connaissances taxonomiques et de l'inadéquation des techniques d'échantillonnage. Les cavernes sont cependant actuellement des écosystèmes menacés. Sept espèces d'acariens troglobies étaient connues en Belgique à ce jour. Cette étude a exploré la faune acarologique de 25 cavernes belges, en récoltant des échantillons de dépôts terreux. Les densités étaient très variables. Dans les sites non inondables, les Oribates et particulièrement les Oppiidae étaient les plus abondants. Au moins six nouvelles espèces ont été découvertes. Ce sont de potentiels troglobies terrestres. Les Veigaiidae, Endeostigmata-Sphaerolichida, Pygmephoroidea, Brachychthoniidae, et Oppioidea étaient particulièrement riches en espèces et abondants. Une analyse multivariée a détecté une très faible dépendance spatiale des communautés d'acariens. La faible puissance explicative de cette analyse met en évidence la structure fragmentée des cavernes.

Introduction

In the context of the global biodiversity crisis that we are experiencing, the tropical forest is often presented as the main reservoir of protection (see e.g.

Myers et al. 2000). However, a number of other endangered ecosystems may well house a lot of species still to be discovered. This is certainly true of caves.

The scarcity of reliable studies devoted to mites, among other cave-dwelling organisms, is remarkable. Two reasons could explain that. On the one hand, the lack of taxonomic expertise is evident (Behan-Pelletier & Newton 1999). On the other hand, the sampling methods classically used in biospeleology, hand-picking and bait trapping, are not efficient to collect a representative subset of a mite community. Indeed, hand-picking is effective only for the bigger species, which are not frequent among mites, and baits are attractive to only a portion of the taxa, depending on their nature. This was notably illustrated in a survey of Norwegian caves (Østbye et al. 1987): using hand-picking and pitfalls, only 4 mites were collected among 14 sampled caves.

Tercafs recently published a detailed review (Tercafs 2001) of all the factors threatening caves and the keys for their sound management, observing that the subterranean ecosystem is particularly vulnerable and should be given priority protection. This claim seems to have raised institutional interest in Belgium, as some cavities have gained the status of *Cavité souterraine d'intérêt scientifique* (subterranean cavities of scientific interest) which place them under the protection of an official committee authorised to take conservation measures. International agreements, like Natura 2000 and the Ramsar convention on wetlands, also affect caves. To assess the status of a cavern in order to monitor its evolution is of course a priority in that context. This is the reason why this study was undertaken.

Indeed, knowledge of cave mites is wanting in Belgium. Leruth (1939) recorded the whole invertebrate fauna (worms, arthropods and molluscs) of 48 caves. He identified 53 mite species with the taxonomic help of Willmann

(1935) and acknowledged four troglobites (= species living and breeding only in the cave habitat), all of them aquatic Astigmatids. Some decades later, another survey (Lebrun 1967) was dedicated to the oribatid mites from a small cave, and provided 45 individuals belonging to 7 species among which one was a terrestrial troglobite (*Gemmazetes cavatica*). Lebrun also raised *Belba lengersdorfi*, collected by Leruth (1939), to this status. In another study, Hubart (1980) collected 9 mite species in the Ramioul cave (ca 100 m of galleries), including 5 species already cited by Leruth (1939). Lastly, Dethier & Hubart (2000) added two Belbidae commonly found in litter to the list of cave mites. To sum up, 65 free-living mite species were collected from Belgian caves with 4 aquatic troglobites (*Schwiebea cavernicola*, *Soldanellonyx chappuisi*, *Parasoldanellonyx typhlops belgicus* and *Feltria subterranea*) and 2 acknowledged terrestrial troglobites (*Gemmazetes cavatica* and *Damaeus lengersdorfi*). However, among species from Leruth (1939), *Pachyseius angustiventris* is considered to be a cave dweller (Karg 1993) and has never been reported outside caves. So, the number of probable troglobitic mite species from Belgium is seven up to now.

The goal of this research was to collect mites from a number of Belgian caves using efficient sampling methods. This would allow a preliminary assessment of their current acarological status and make it easier for institutional officers to gauge their biological value in order to identify the most precious and endangered sites and protect them with appropriate conservation measures.

Materials and methods

Samples were collected in the Belgian karstic area, which crosses the country from east to west. Twenty-five caves were visited from 1999 to 2002 (Table 1.1 and Fig. 1.1), most of them dug in a Devonian limestone layer named Calestienne, which is the most karstified area of Belgium. All caves were at an altitude of 120 to 250 m in a rock layer covered by 1 to 10 m of unconsolidated soil.

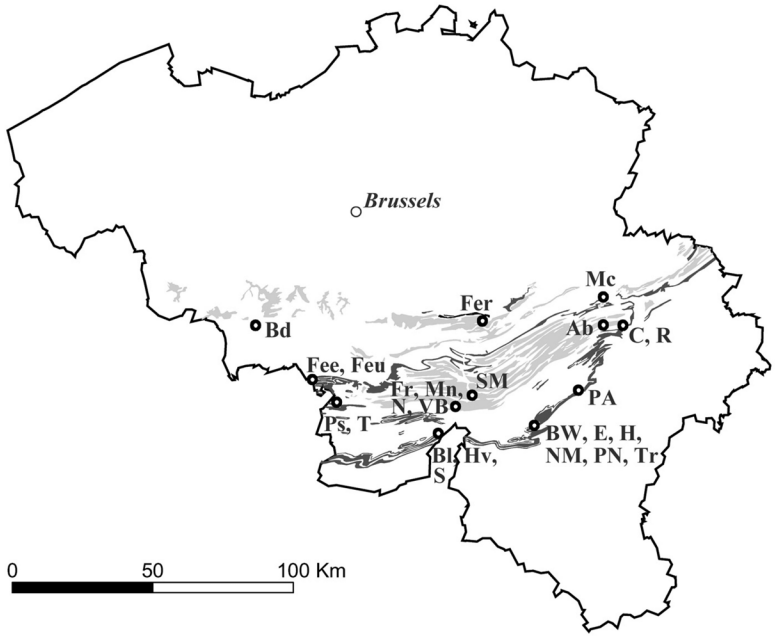

Figure 1.1. Karstic zone (light grey: Carboniferous limestone; dark grey: Devonian limestone) and geographic situation of the 25 sampled caves. Codes are defined in Table 1.1.

Particularly interesting caves were visited several times. Generally, only a limited number of samples were collected in one to five different locations in each cave, in order to avoid depleting the populations. Some of these

Table 1.1. List and descriptive parameters of sampled caves. Abb.=Abbreviation; samp.=number of samples; DBE=number of samples extracted with the DBE method; vol.=sample volume (cm^3); loc.=number of sampled locations; visits=number of visits; floods=type of flood occuring in the sampled locations: AV=aquifer level variation, OF=stream overflowing; freq.=frequency of flooding events ($year^{-1}$); geology: Carb.=Carboniferous limestone, Dev.=Devonian limestone; digging: nat.=natural, art.=artificial, enl.=enlarged by humans; length=total length of galleries (m); N°Akwa=reference in the "Atlas du Karst wallon" database (De Broyer et al. 1999). [a]: floods occuring in only some of the sampled locations

Caves	Locality	Abb.	samp.	DBE	vol.	loc.	visits	floods	freq.	geology	digging	length	n° Akwa
Abîme	Comblain-au-Pont	Ab	14	-	50	3	1	-	-	Carb.	nat.	807	492-123
Baudour	St Ghislain	Bd	2	-	250	1	1	AV	1-2	Schist	art.	375	452-E12
Blaireau	Doische	Bl	4	2	50	1	1	-	-	Dev.	nat.	50	582-011
Bois de Warimont	Rochefort	BW	4	2	50	1	1	-	-	Dev.	nat.	141	592-010
Chalet	Aywaille	C	8	-	50	2	1	OF	5-10	Dev.	nat.	130	493-088
Éprave	Rochefort	E	4	1	50	1	1	-	-	Dev.	nat.	885	592-021
Fées	Erquelinnes	Fee	2	-	250	1	1	-	-	Dev.	nat.	25	521-003
Ferauge	Marche-les-Dames	Fer	2	-	250	2	1	AV	10-15	Dev.	art.	400	474-E03
Feuilles	Erquelinnes	Feu	2	-	250	1	1	-	-	Dev.	nat.	28	525-001
Freyr	Hastière	Fr	5	-	250	5	2	-	-	Carb.	nat.	266	538-109
Han	Rochefort	H	20	10	50	5	1	OF/-[a]	2-5	Dev.	nat.	10693	592-056
Hierges-Vaucelles	Doische	HV	4	2	50	1	1	-	-	Dev.	nat.	588	582-024
Moines	Hastière	Mn	2	-	250	2	1	-	-	Carb.	nat.	45	538-112
Monceau	Tilff	Mc	56	29	50	6	3	OF/-[a]	~10	Dev.	nat.	435	426-045
Nonne	Hastière	N	1	-	250	1	1	-	-	Carb.	nat.	12	538-111
Nou-Maulin	Rochefort	NM	18	8	50	1	2	OF	2-3	Dev.	nat.	1606	593-045
Paiens	Beaumont	Ps	1	-	250	1	1	-	-	Dev.	nat.	25	526-034
Père Noël	Rochefort	PN	8	1	50	2	1	AV/-[a]	1-2	Dev.	nat.	2115	592-070
Porte Aive	Hotton	PA	2	-	250	1	1	-	-	Dev.	nat.	53	555-024
Remouchamps	Aywaille	R	20	-	50	4	1	OF/-[a]	5-10	Dev.	nat.	3883	493-074
Salamandre	Doische	S	8	4	50	2	1	-	-	Dev.	nat.	203	582-009
Source Mouchenne	Dinant	SM	2	-	250	2	2	AV	1-2	Carb.	enl.	95	538-103
Tchampacane	Beaumont	T	2	-	250	1	1	OF	5-10	Dev.	nat.	150	526-022
Tridaine	Rochefort	Tr	2	-	250	1	1	OF	1-2	Dev.	enl.	295	592-002
Vieux Banc	Hastière	VB	2	-	250	2	1	-	-	Carb.	nat.	15	538-113

locations are usually flooded each year during winter (Table 1.1). Two types of flooding were distinguished: (1) stream overflowing, which is both short in time and usually frequent (several times a year), with a violent current carrying a lot of exogenous material (sediments, plant fragments, etc) and (2) variation of aquifer level, which lasts longer (i.e. typically a season), happens usually only once a year and has a gentler current carrying only endogenous material (e.g. clay arising from decalcification).

Piles of earthy material were chosen for sampling. Samples first amounted to 50 cm^3. Later we decided to increase this volume to 250 cm^3 as the mite density was usually low (Table 1.1). A total of 195 samples were taken.

Arthropods were extracted using either Berlese-Tullgren funnels or 1,2-dibromoethane (DBE) flotation method (Table 1.1). For the former, electric light bulbs (15 watts), 10 cm above the intact samples placed in plastic funnels, were lit one week after sampling. Extraction ended after 3 weeks. The mean temperature in the extraction room was 20 °C. DBE flotation method was implemented as described in Ducarme et al. (1998), but was no longer used in the recent samples as it was thought to be less efficient (see results).

Mites were mounted in lactic acid, or in Hoyer medium if needed. All mites except Astigmata and some early stases were identified to the species level. Some species could not be identified accurately, because only immatures were found or because of the lack of taxonomic revision in some families.

Species collected in this study can be related to four out of seven orders constituting the Acari (Evans 1992, p. 382), namely Mesostigmata, Prostigmata, Astigmata and Oribatida. However, mite taxonomy is undergoing drastic changes due to the recent use of cladistic methods. Norton (1998) has demonstrated that Astigmata originate from a group of

Oribatida, i.e. the Desmonomata. Yet, in this study, data on Oribatida and those on Astigmata were analysed separately, to facilitate the comparison between our results and those of previous studies. Likewise, Endeostigmata, traditionally classified within Prostigmata, were considered to be paraphyletic by O'Connor (1984) and therefore split into two distinct groups: Sphaerolichida close to Prostigmata, and Endeostigmata *sensu stricto* close to Oribatida. Sphaerolichida scarcely appeared in our study (only 2 specimens collected), and so we decided to cluster them with Prostigmata, while Endeostigmata *s.s.* were treated as a separate order.

Results and discussion

Mite density

Mite density in caves was highly variable, ranging from 0 to nearly 500 mites/dm³ (Table 1.2). Of course, the generally low number of samples induced inaccuracy in density estimates, especially in less populated caves. So, it seems unlikely that Père Noël and Hierges-Vaucelles caves were really free of mites. The variability of mite density was nevertheless so great as to be unquestionable.

Density of mites was negatively linked to the size of the caves (Spearman r=-0.54, P=0.006, n=25) as sampling locations were situated further from the entrance in large caves. In most biospeleological studies (see Howarth 1983), animal density is higher near the cave entrance because of the greater number of accidentals and abundance of organic matter. Another factor could have an important effect on mites in caves affected by stream overflowing. One can suppose that coarse exogenous particles are quickly deposited, near the cave entrance, in any location where the flow slows

down. And coarse particles may promote a higher mite density, through a higher porosity (Ducarme 1998).

Table 1.2. Number of collected mite specimens (n) and mean density of mite orders and total Acari (individuals/dm³) in sampled caves. Meso=Mesostigmata; Pro=Prostigmata; Endeo=Endeostigmata; Ori=Oribatida; A=Astigmata.

Caves	n	Meso	Pro	Endeo	Ori	A	Acari
Abîme	1	0	0	0	1	0	1
Baudour	5	4	2	0	4	0	10
Blaireau	9	5	10	5	25	0	45
Bois de Warimont	14	0	0	0	70	0	70
Chalet	8	0	3	0	18	0	20
Éprave	3	0	0	5	10	0	15
Fées	1	2	0	0	0	0	2
Ferauge	6	8	2	2	0	0	12
Feuilles	104	2	2	6	176	22	208
Freyr	622	8	5	11	474	0	498
Han	21	1	19	1	0	0	21
Hierges-Vaucelles	0	0	0	0	0	0	0
Moines	137	8	16	22	228	0	274
Monceau	44	2	2	1	11	0	16
Nonne	9	4	4	12	16	0	36
Nou-Maulin	97	19	39	11	31	8	108
Paiens	50	12	60	8	116	4	200
Père Noël	0	0	0	0	0	0	0
Porte Aive	59	34	0	4	78	2	118
Remouchamps	6	1	1	0	4	0	6
Salamandre	8	0	0	3	18	0	20
Source Mouchenne	85	18	0	2	16	134	170
Tchampacane	28	2	14	22	10	8	56
Tridaine	1	0	2	0	0	0	2
Vieux Banc	128	6	2	32	216	0	256

Oribatida, and particularly Oppiidae, made up the majority of the fauna of densely populated caves (Table 1.2). A closer look at the caves where more than 10 individuals were collected reveals that all locations not flooded during winter were dominated by Oribatids and that all caves liable to

flooding were dominated by Prostigmata, Endeostigmata or Astigmata. This is odd, as some Oribatids are known to survive immersion using taenidia or cerotegument (e.g. Travé 1986; Pugh 1996; Franklin et al. 2001). Thus floods are probably not a direct cause of mortality, even if some individuals are expected to be washed away from caves. Maybe floods could affect the development of elements associated with the complex trophic behaviour of some Oribatids, such as e.g. an obligatory sapromycophagy (de Saint-Georges-Gridelet 1981; Lebrun 1981), but this remains highly speculative and would require validation.

Astigmata were usually rare, except in a Source Mouchenne location where they were locally abundant near an accumulation of organic debris (wood and diverse waste). This is in agreement with previous works showing that Astigmata were dominant in organic-rich locations such as guano piles (Welbourn 1999).

We compared the efficiency of both extraction methods on locations housing mites. The Berlese-Tullgren method extracted on average more mites than the DBE method: 56 vs 36 individuals/dm³. As the Berlese-Tullgren method was cheaper and less time-consuming, we decided not to use the DBE method in later samples.

Mite species

At least 77 mite species (excluding Astigmata, which included at least 5 morphospecies) were identified with respectively 16, 24, 4 and 33 species of Mesostigmata, Prostigmata, Endeostigmata and Oribatida (Tables 1.3 to 1.6). Among them, a lot of small-sized species were collected (e.g. Nanorchestidae, Iolinidae, Brachychthoniidae, Oppiidae), which strongly

contrasts with the known Belgian cave fauna and legitimates our sampling and extraction methodology.

Table 1.3. List of Mesostigmata species. Distribution: cave code (see Table 1.1) followed by number of collected individuals between brackets. imm.=immatures

Taxa	Distribution
Eviphididae	
Crassicheles holsaticus Willmann	NM(1)
Macrochelidae	
Geholaspis cf. aeneus Krauss	VB(1)
Pachylaelapidae	
Pachyseius angustiventris Willmann	H(1) NM(8)
Hypoaspididae	
Hypoaspis claviger (Berlese)	Bd(1)
Haemogamasidae	T(1)
Ascidae	
Arctoseius sp.	NM(1)
Zerconidae	
Prozercon sp.	Mn(2) NM(2)
Rhodacaridae	
Rhodacarellus apophyseus Karg	PA(6) Mn(1)
Rhodacarus sp. (imm.)	NM(1)
Parasitidae	
Eugamasus cf. prosapialis Athias-Henriot	NM(1)
Lysigamasus cf. puerilis Karg	Fr(4)
Veigaiidae	
Veigaia cf. decurtata Athias-Henriot	Fr(1) N(1) Mc(1)
Veigaia exigua (Berlese)	Mn(1) Ps(1) VB(1)
Veigaia planicola (Berlese)	Fr(3) PA(1) SM(8) Mc(2) Feu(1) VB(1)
Veigaia sp4	PA(1)
Uropodina	PA(1)

Table 1.4. List of Prostigmata and Sphaerolichida species. Distribution coded as in Table 1.3. imm.=immatures; undet. gen.=undetermined genus

Taxa	Distribution
Sphaerolichida	Fr(1) Mc(1)
Eupodidae	
sp1	NM(5)
sp2	N(1) Mn(1) Ps(1)
sp3	Mn(1)
Rhagidiidae	
Coccorhagidia clavifrons (Canestrini)	Fr(1)
Poecilophysis (Dentocheles) wankeli (Zacharda)	Fr(2)
Shibaia sp. (imm.)	Mn(4) VB(1)
Iolinidae	
Coccotydaeolus sp.	T(1)
Paratydaeolus sp.	T(1)
n.gen. n.sp.	Mc(2)
Ereynetidae	
Ereynetes (Gymnereynetes) sp.	Ps(1)
Riccardoellinae *n.gen. n.sp.*	H(18)
Bdellidae	Tr(1)
Cunaxidae	Bd(1) MC(1) NM(2)
Pygmephoridae	
Bakerdania sp1	NM(5)
Bakerdania sp2	NM(10)
Pygmephorus sp.	NM(1) T(3)
sp1 (undet.gen.)	Feu(1)
sp2 (undet.gen.)	T(1)
sp3 (undet.gen.)	NM(4)
Scutacaridae	
sp1 (undet.gen.)	Fr(1) Ps(13)
sp2 (undet.gen.)	Bl(2)
Tetranychidae	Mc(1)
Hydrachnidia	NM(1)

Table 1.5. List of Endeostigmata species. Distribution coded as in Table 1.3.

Taxa	Distribution
Alicorhagiidae	
Alicorhagia sp.	Mn(3) H(1) NM(10) T(1)
Oehserchestidae	
Oehserchestes sp.	Feu(2)
Nanorchestidae	
Nanorchestes sp.	VB(16)
Terpnacaridae	
Alycosmesis sp.	Mc(1)

It is of course inconclusive to try to compare the number of species of different caves, as only a few samples were taken in most of them. As a matter of fact, using a species saturation curve and given a sufficient number of samples, it is possible to estimate the real number of species present in one location. This way, we observed (chap. 3) that 146 samples provided only 73% of the mite species in the Nou Maulin cave and as little as 58% in the Han cave.

A large number of species (65%) were present in one cave only and 13% in two caves. These probably include a majority of accidental species, but also some potential troglobites.

As a matter of fact, no less than 6 species are certainly new to science (Tables 1.3 to 1.6). Iolinidae *n.gen. n.sp.* is unique in having no visible empodium. Ereynetidae *n.gen. n.sp.* belongs to a new genus close to *Riccardoella* and will be described elsewhere, as will *Hypogeoppia n.sp*. *Ramusella (Insculptoppia) n.sp.* is close to *berninii* but has no rostrum emargination. *Machuella n.sp.* is close to *ventrisetosa* but differs clearly by

Table 1.6. List of Oribatida species. Distribution coded as in Table 1.3. imm.=immatures

Taxa	Distribution
Adelphacaridae	
Adelphacarus sellnicki Grandjean	R(1)
Hypochthoniidae	
Hypochthonius rufulus (Koch)	R(2)
Brachychthoniidae	
Liochthonius cf. strenzkei Forsslund	Bl(4) S(1) Fr(15) Mn(2) Ps(1) T(1) Feu(6) VB(5)
Liochthonius simplex (Forsslund)	Fr(80) SM(4) Mn(9) Mc(1) Feu(3)
Paraliochthonius occultus (Niedbala)	BW(1)
Verachthonius cf. laticeps (Strenzke)	BW(3) S(4)
Phthiracaridae	
Phthiracarus anonymus Grandjean	NM(1)
Phthiracarus sp2	NM(3)
Phthiracarus sp3	NM(3)
Steganacarus magnus (Nicolet)	NM(1)
Camisiidae	
Platynothrus cf. grandjeani Sitnikova	NM(1)
Nanhermanniidae	
Nanhermannia (imm.)	NM(14)
Nanhermannia nana (Nicolet)	S(1)
Belbidae	
Metabelba papillipes (Nicolet)	Fr(6)
Oppiidae	
Berniniella sigma conjuncta (Strenzke)	Fr(188) N(1) Mn(44) VB(33)
Ctenobelba cf. obsoleta (Koch)	PA(1)
Hypogeoppia n. sp.	BW(6) Fr(119) PA(5) Mn(7) C(3) Ps(4) Mc(21) Feu(35) VB(24)
Lauroppia cf. maritima (Willmann)	E(1) Fr(1) PA(2) Mc(2)
Machuella n.sp.	VB(3)
Medioppia obsoleta (Paoli)	N(1) Mn(2) T(1)
Microppia minus (Paoli)	PA(1)
Oppiella cf. uliginosa (Willmann)	Bd(1) Mn(1)
Quadroppia cf. paolii Woas	Fr(131) PA(27) Mn(17)
Quadroppia quadricarinata (Michael)	Bd(1) Ab(1) N(1) C(4) Ps(23) Mc(2) Feu(43) VB(14)

Table 1.6 (continued)

Ramusella (Insculptoppia) cf. fusiformis (Wallwork)	Feu(1)
Ramusella (Insculptoppia) n.sp.	Bl(1)
Ramusella sp3	T(1)
Suctobelbidae	NM(1)
Suctobelbella sarekensis (Forsslund)	R(1)
Suctobelbella subcornigera (Forsslund)	Ps(1)
Banksinomidae	
Gemmazetes cavatica (Kunst)	BW(2) Fr(3)
Oribella pectinata (Michael)	T(1)
Microzetidae	
Miracarus n.sp.	Fr(2) SM(4) Mn(1) VB(10)
Ceratozetidae	
Edwardzetes edwardsi Nicolet	NM(1)

having four pairs of notogastral lines. Finally, *Miracarus n.sp.* has, among other features, the inner apical tooth of the lamella much longer than the outer one, which makes it different from the cave dwelling *M. senensis* Bernini 1975, and longer lamellar setae than *M. discrepans* Mahunka 1966. All these species could well be troglobites, as they have only been caught in a cave environment.

The number of caves housing *Hypogeoppia n.sp*., 9 out of 25, as well as the abundance of this species, are remarkable. This oppiid is clearly a common cave dweller in Belgium. Its troglobite status could be questioned, as it was often collected a dozen or so meter from the cave entrance. However, Bernini (1980) has described two oribatid troglobites from small caves that he supposed were specialised for the twilight zone. This is probably the case of *Hypogeoppia n.sp.*, as they have never been found in the soil, where Oribatida have often been widely studied (Lebrun et al. 1989).

In addition, a number of species could not be related for sure to a known taxon. Some of these are probably new, but their identification would need a detailed taxonomic and morphological study, which goes beyond the scope of our paper.

Among the more speciose and abundant groups, we found Veigaiidae (4 species), Endeostigmata-Sphaerolichida (5 species), Pygmephoroidea (8 species), Brachychthoniidae (4 species) and Oppioidea (12 species).

Veigaia species are considered to be hemiedaphic, living in the litter of forests and meadows (Karg 1993). Perhaps their light integument does not provide an efficient water-loss protection, which explains why strongly humid caves might suit them.

Endeostigmata and Sphaerolichida are known to occur frequently in extreme soil habitats, such as cold or hot deserts and deep soil (Kethley 1990; Walter 2001). They are characterised by a number of primitive features, for instance folds indicating remnants of opisthosomal segmentation. Such early derivatives, or relics, frequently occur in caves. A common explanation (see Holsinger's review 2000) is that they used the subterranean habitat as shelter when surface climate changed, after Ice Ages for instance. The evolutionary path of arthropods, from water to terrestrial habitat through water saturated environment (Ghilarov 1959; Vannier 1973, 1987; Villani et al. 1999), suggests another possibility: some taxa settled in caves and never adapted to the surface environment.

Pygmephoroidea were represented by Pygmephoridae and Scutacaridae. These families include a majority of phoretic mites. Phoresy is thought to be an ideal mode of dispersal in a fragmented habitat such as caves (Athias-Binche 1994).

The Brachychthoniidae were exclusively represented by genera having a lower cuticle sclerification than typical soil-dwelling sister genera such as *Sellnickochthonius* or *Synchthonius* (Grandjean 1963, and personal observations). The same was observed by Skubala & Klys (2002) in Polish mines and Ducarme et al. (chap. 4) in an intensive study of the Han and Nou Maulin caves. This probably could be put on account of the higher humidity in caves, allowing mites to have a cuticle permeable to water vapour without risking water loss.

Oppioidea were the most abundant cave dwellers. Three of the new species belonged to this group. They are also numerous among the mites described (Valle 1951; Lombardini 1952; Subias & Arillo 1996; Iturrondobeitia & Arillo 1997) or observed (Bernini 1980) in European caves. *Hypogeoppia n.sp.* already revealed some potential cave adaptations (unpubl. data). This family appears to be the most promising mite group for scientists willing to study troglomorphisms, as was done for Rhagidiidae (Zacharda 1979) more than 2 decades ago. Given their diversity (more than 1600 described species up to now), they also provide good material for a phyletic study, which is a prerequisite for identifying cave adaptations or test hypotheses on evolutionary processes (Desutter-Grandcolas 1997). Like for Oribatida on the whole, the best collection sites are the earthy piles that are never flooded.

Among the known cave species, *Gemmazetes cavatica* is a troglobite, which has already been observed by Lebrun (1967) in another Belgian cave. *Poecilophysis (Dentocheles) wankeli* is presented by Zacharda (1980) as a troglophile (= species that can live and breed in the cave habitat), frequent but not abundant in caves and sometimes in the forest litter or the grass rhizosphere.

Adelphacarus sellnicki is another interesting species, because it was seldom observed; it has been reported in an anthill in Sweden (Grandjean 1952) and in the litter and hemiorganic horizon of beech and/or oak forests in France (Lions 1972), Germany (Beck & Woas 1991) and Belgium (Ducarme 1998). It belongs to the Palaeosomata, also an early derivative group of mites.

Connectivity of caves

A Detrended Correspondance Analysis (Legendre & Legendre 1998) was carried out on mite species logarithmic abundance in the different caves for the purpose of finding out if there was a spatial structure in the data, that is, if geographically close caves housed similar mite communities. The result (Fig. 1.2) shows that the caves in the Hastière municipality (Fr, Mn, N, VB) are grouped together, but no general geographical pattern was outlined.

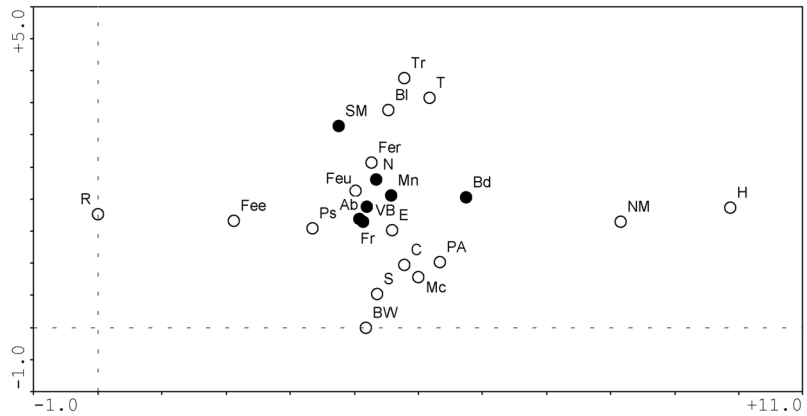

Figure 1.2. DCA ordination plot showing caves dug in Carboniferous (black circles) or Devonian (white circles) rock.

Geology does not seemingly affect mite communities: caves dug in Carboniferous rock were not distinct from Devonian ones in the ordination plot. The DCA having a poor explanatory power (cumulative percentage

variance of species data of first and second axes: 19%), a Canonical Correspondence Analysis could not be used to further explain the mite community distribution. This poor power denoted very variable communities composition, linked to the fragmented structure of caves already invoked to explain the use of phoresy for dispersal.

Conservation

Little is known about factors affecting the terrestrial cave mite fauna, but according to Tercafs (2001), potential threats are destruction (e.g. by quarries) or modification of environmental conditions (agricultural pollution, acid rains, visiting). As our study was particularly aimed at earthy material fauna, compaction by trampling may be regarded as a serious issue. It is therefore recommended to limit access to the seemingly richest caves: the cavities around Hastière (particularly Freyr) as well as Monceau, Feuilles and Tchampacane. A modification of flooding pattern is another potential threat, as we showed in this study that it had a major impact on mite density and species composition. Drainage works, vegetation clearance, dam building, aquifer pumping or gallery filling-in could cause such change.
Conservation measure should of course be accompanied by periodic sampling in order to monitor the faunal evolution.

Conclusion

This study allowed us to collect at least six new mite species including a very abundant and frequent one. This clearly demonstrated the lack of knowledge of cave mites. However, cave organisms are ideal targets for the study of current and still puzzling evolutionary themes, such as speciation, adaptation, mutation and regression (see e.g. part VI of Wilkens et al. 2000).

We hope this study will help to raise interest in mites as scientific models for such important questions, since we have demonstrated that some species, especially among oppiids, were frequent, abundant and specialised to the cave environment. This study also provided data about the biological value of a number of caves likely to help decision-makers provide the selected sites with the appropriate protection status.