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THE MITES (ACARI) ASSOCIATED WITH BARK BEETLES IN THE KOLI NATIONAL PARK IN FINLAND

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ABSTRACT — Thirty-three taxa associated with *Ips typographus* were identified, of which fifteen species were phoretic. The most abundant species were *Insectolaelaps quadrisetus* (Mesostigmata), *Siculobata lentonycha* (Oribata), *Diapterobates humeralis* (Oribata), *Ereynetes propescutulis* (Prostigmata), *Aetiophenax ipidarius* (Prostigmata), and an unidentified species of *Nanacarus* (Astigmata). Eight species – *I. quadrisetus*, *Proctolaelaps fiseri*, *Trichouropoda polytricha*, *Mexecheles virginiensis*, *A. ipidarius*, *E. propescutulis*, *Bonomoia pini*, and *Boletoglyphus boletophagi* - and four genera - *Nanacarus*, *Elattoma*, *Schwiebia*, and *Parawinterschmidtia* – were new taxa in Finland.

KEYWORDS — Acari; phoresy; bark beetles; *Ips typographus*; Europe

INTRODUCTION

Bark beetles and their fungal and mite associates form complex symbiotic interactions. The mite assures the transmission of the fungus to the host tree (Moser *et al.*, 1989b, 2010). In the early phase of attack, the fungi assist bark beetles to overcome the resistance of host trees (Lieutier, 2002, 2004). Later, the overgrowth of fungi competes with bark beetle larvae in the phloem (Moser *et al.*, 1989a, 1989b). The spruce bark beetle has caused severe damage in Europe during the last one hundred years killing tens of millions m^3 spruce (Christiansen, 1988; Grégoire and Evans, 2004).

The bark beetles and their phoretic mites have been studied widely the world over. In Scandinavia, a study in Sweden of the mite associated *Ips typographus* was compiled in 1989 (Moser *et al.*, 1989a). The mites associated with spruce bark beetle are now summarized for the first time in Finland.

The mite species associated with *Ips typographus* were the target of this study. However, when bark beetles are trapped by pheromones, other insects and their predators also appear as non-target catches. All these insects can transport mites, but many mites in the alcohol sediments of the traps may be accidental, and may not be associated with insects. This study provides a survey of mites associated with bark beetles in Finland. The results are compared against the findings, mainly for Europe, reported in other articles. Scanning electron microscope (SEM) images of the most common species are also included

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TABLE 1: Location of study sites in 2005 (sites 1 – 8) and 2006-2008 (sites 1 – 11) in the Koli region, Lieksa, Finland. The geographical coordinates given are from the WGS84 system.

	Trap group / Site	Treatment	N / lat	E / lon
1	Paimenenvaara	mature forest	63° 5.134′	29° 47.704′
2	Paimenenvaara	mature forest	63° 5.635′	29° 47.633′
3	Ukko-Koli, lower slope	burning	63° 5.816′	29° 49.053′
4	Likolahti (along the road "Rantatie")	burning	63° 5.34′	29° 50.008′
5	Sikoniemi, Autiolahti	clear-cutting	63° 4.23′	29° 51.974′
6	Sikoniemi, Autiolahti	clear-cutting	63° 4.135′	29° 52.142′
7	Ala-Murhi	ring-barking	63° 2.42′	29° 55.516′
8	Ala-Murhi	ring-barking	63° 2.447′	29° 55.649′
9	Savikylä, Riihilahti	clear-cutting	63° 8.87′	29° 41.593′
10	Savilahti farm, Savilahti	clear-cutting	63° 7.733′	29° 39.561′
11	Ukko-Koli, lower slope	burning	63° 5.785′	29° 49.145′

MATERIAL AND METHODS

Study area and sites

The Koli National Park (NP) is located in one of the easternmost regions of Southern Finland and comprises the central areas of the Karelian forest hill area considered to be the Finnish national landscape. The Koli NP is particularly famous for its heritage landscapes, namely wooded pastures and meadows, which are the remnants of the traditional slash-and-burn agriculture that was widely practiced in Koli from the 18th century until the 1930s. The restoration of slash-and-burn-derived habitats and landscapes began in the NP in 1994 (e.g. Eerikäinen *et al.*, 2007). The forest inventories as well as habitat and species-specific surveys implemented in the 1990s revealed that the conservation status of the area was not optimal, since more than 20 % of the forests of Koli had been established by planting and were being managed intensively before the establishment of the NP in 1991. Because these forests lacked decayed wood and natural fires, spruces inevitably became dominant in these herb-rich forests.

The sites monitored until 2009 by means of spruce bark beetle pheromone trapping comprised two burnt and two ring-barked forest compartments which were used for sampling of bark beetles (Table 1). For reference data, we trapped insects in four fresh clear-cut areas and two mature managed forests in the surrounding areas of the Koli NP (Table 1). The monitoring began in 2005 and was based on two trap groups for each of the four restoration treatments (sites 1 – 8), but in 2006 it was enlarged to include two fresh logging sites, which had been logged during the previous winter 2005-2006 (sites 9, 10) (Eerikäinen *et al.*, 2009). In addition, one trap group (site 11) was located within the same restoration burning area as trap group 3, on the slope of Ukko-Koli.

Pheromone trapping

To monitor the possible changes in the spruce bark beetle (*I. typographus*) populations caused by forest restoration, a pheromone trapping program, implemented annually, was started in 2005. Spruce bark beetle trapping was conducted using the 1979 black drainage pipe trap model described by Bakke *et al.*, (1983) and manufactured by Borregaard Ind. Ltd., Sarpsborg, Norway. The tube was 135 cm long, 12 cm in diameter, and had about 900 evenly distributed holes. The traps were baited with Ipsowit® standard pheromone dispensers (Witasek PfanzenSchutz GmbH, Germany). The dispensers contained methyl-butenol, *cis*-verbenol, and ipsdienol permeated in a cellulose sheet enclosed in a

TABLE 2: The numbers of mites collected from different study sites. MA = mature forest, BU = burning, CC = clear-cutting, RB = ring-barking (number of sample units in parenthesis), % = the individual number of each species with respect to the total number of the specimens. The phoretic species* is given according to Klimov (1998) and Moser et al. (1984, 1989a and 2005). The species [1)] is reported ex. *I. typographus* from Sweden (Moser *et al.* 1989a).

Taxa	MA(11)	BU(46)	CC(38)	RB(3)	Σ(8)	%
Mesostigmata (order)						
Insectolaelaps quadrisetus (Berlese, 1910)*[1)]	152	320	293	24	789	42,06
Proctolaelaps fiseri Samsinák, 1960*[1)]	15	12	5		32	1,71
Vulgarogamasus sp. deutonymph*[1)]	16	10	5		31	1,65
Trichouropoda polytricha Vitzthum, 1923*[1)]		17	12		29	1,55
Uroobovella vinicolora Vitzthum, 1923*[1)]		8	12		20	1,07
Zercon sp. juv.			1		1	0,05
Eviphis sp.		1			1	0,05
Total	183	368	328	24	903	48,13
Oribatida (suborder)						
Siculobata leontonycha (Berlese, 1910)*[1)]		184	31	5	220	11,73
Diapterobates humeralis (Hermann, 1804)		44	75		119	6,34
Carabodes labyrinthicus (Michael, 1879)*[1)]	3	7	21	2	33	1,76
Ceratoppia bipilis (Hermann, 1804)	32	1			33	1,76
Chamobates borealis (Trägardh, 1902)				1	1	0,05
Cepheus latus C. L. Koch, 1835				1	1	0,05
Conchogneta traegardhi (Forsslund, 1947)				1	1	0,05
Micreremus brevipes (Michael, 1888)	1				1	0,05
Oppia splendens (C. L. Koch, 1841)			1		1	0,05
Oribatella calcarata (C. L. Koch, 1835)	1				1	0,05
Phthiracarus nitens (Nicolet, 1855)				1	1	0,05
Phauloppia rauschenensis (Sellnick, 1908)			1			0,05
Zygoribatula exilis (Nicolet, 1855)	1				1	0,05
Total	38	236	129	11	414	22,06
Astigmata (cohort)						
Nanacarus sp.* (+ *Parawinterschmidtia* sp.*)	10	304	4		318	16,95
Bonomoia pini Scheucher, 1957*		33	4		37	1,97
Boletoglyphus boletophagi (Turk, 1952)*		22	5		27	1,44
Schwiebea sp.*[1)]			3		3	0,16
Elattoma sp. [1)]		1	2		3	0,16
Histiostoma sp.		1	1		2	
Total	10	361	19		390	20,79
Prostigmata (suborder)						
Ereynetes propescutulis Hunter & Rosario, 1989* [1)]	2	77	15	1	95	5,06
Aethiophenax ipidarius (Redikortsev, 1947)* [1)]	2	49	9	3	63	3,36
Mexecheles virginiensis (Baker, 1949)*		5	1		6	0,32
Rhagidiidae			2	1	3	0,16
Bdellidae		1		1	2	0,11
Cunaxidae		1			1	0,05
Total	4	133	27	6	170	9,06
All together	235	1098	503	41	1877	99,99

polyethylene bag attached inside the pipe trap. The fluid containers of pipe traps were half filled with 70 % alcohol.

A triangle comprising three traps spaced 2 m apart was placed at each collection site on 22 May 2005. Each of the trap groups was located in an open area about 50 m from the nearest forest edge. The traps were attached to dry wooden sticks about one meter from ground level. The traps were emptied once a month, around the 22nd day of the month, during the period from May to September. The methodology applied corresponds to that used by Weslien *et al.*, (1989) and Valkama *et al.*, (1997). In this paper, the trapping data reflect the occurrence of mites spanning the period from 2007 to 2009.

Sampling mites

The bark beetles were pheromone trapped from treated forests and mature managed forests (Table 1 and Appendix 1). Altogether 98 sample units containing mites were collected. Forty of these units consisted of separately picked bark beetles (241 exx.); *Ips typographus* (203 exx.), *Pityogenes chalcographus* (37 exx.), *Ips duplicatus* (1 ex.); in addition, one click beetle, *Sericus brunneus* (1 ex.), was collected. Aside from these, 58 sample units were collected consisting only of pheromone trap material containing alcohol vials with mites. Both sample units were chosen from each of the treated sites and mature forests. The mites obtained were summed for each area (Table 2). The effects of treatments on the mite community were not analyzed because all of the sample units were not equally representative.

The species were identified using the publications of Gilyarov and Bregetova (1977), Moser and Bogenschütz (1984), Volgin (1987), and Weigmann (2006). The mites were studied using light microscopes; the SEM images were taken by Scanning Electron Microscope, JEOL JSM-5200. The material has been deposited in Zoological Museum of the University of Turku.

Results and discussion

The phoretic, dominant species

A total of 1,877 mite specimens were found and 33 taxa were identified; there were 22 species, eight genera, and three families (Table 2). The species *Insectolaelaps quadrisetus* (Mesostigmata), *Siculobata leontonycha* (Oribata), *Diapterobates humeralis* (Oribata), *Ereynetes propescutulis* (Prostigmata), *Aetiophenax ipidarius* (Prostigmata) and an unidentified species of *Nanacarus* (Astigmata) were the most common taxa. *Insectolaelaps quadrisetus* (Figure 1a) was the most abundant species; comprising almost half of the nematophagous species. *Insectolaelaps quadrisetus* was also the most common phoretic mite on *I. typographus* (Maslov, 2006; Moser *et al.*, 1989a, 2009). According to Maslov (2006) *I. quadrisetus* was constantly present in *I. typographus* imago and larval galleries of main, sister and 2nd generations. Futhermore, mean bark beelte egg loss caused by these mites varied according to the sample years 2.2 – 9.7 % (Maslov, 2006). The second most common species was *Nanacarus* sp. (Figures 2a and b), which was seen in Germany, but only in low numbers (Moser and Bogenschütz, 1984). With the specimens *Nanacarus* sp., we also found an individual specimen of *Parawinterschmidtia* sp. Although this species has not previously been collected with *I. typographus*, the USDA Forest Service collection in Pineville contains several different species of *Parawinterschmidtia* from Europe and the U.S.A, collected from pine bark beetle pheromone traps, in pine bark beetle galleries, or phoretic on pine bark beetle predators. The combined number for each species group is given in Table 2. *Siculobates leontonycha* (Figure 3a) was the third most common species. It is the most general oribatid species attached to bark beetles (Moser and Bogenschütz, 1984; Moser *et al.*, 1989a, 1997; Pernek *et al.*, 2008; Moser, 2009). This species has been classified as a phoretic but non species-specific, because it was found to be phoretic on three different genera of beetles (Norton, 1980). However, phoresy must be important to the species, because it is equipped with a special, strong hook-like claw on the first leg (Figure 3b), with which the mite adheres to in-

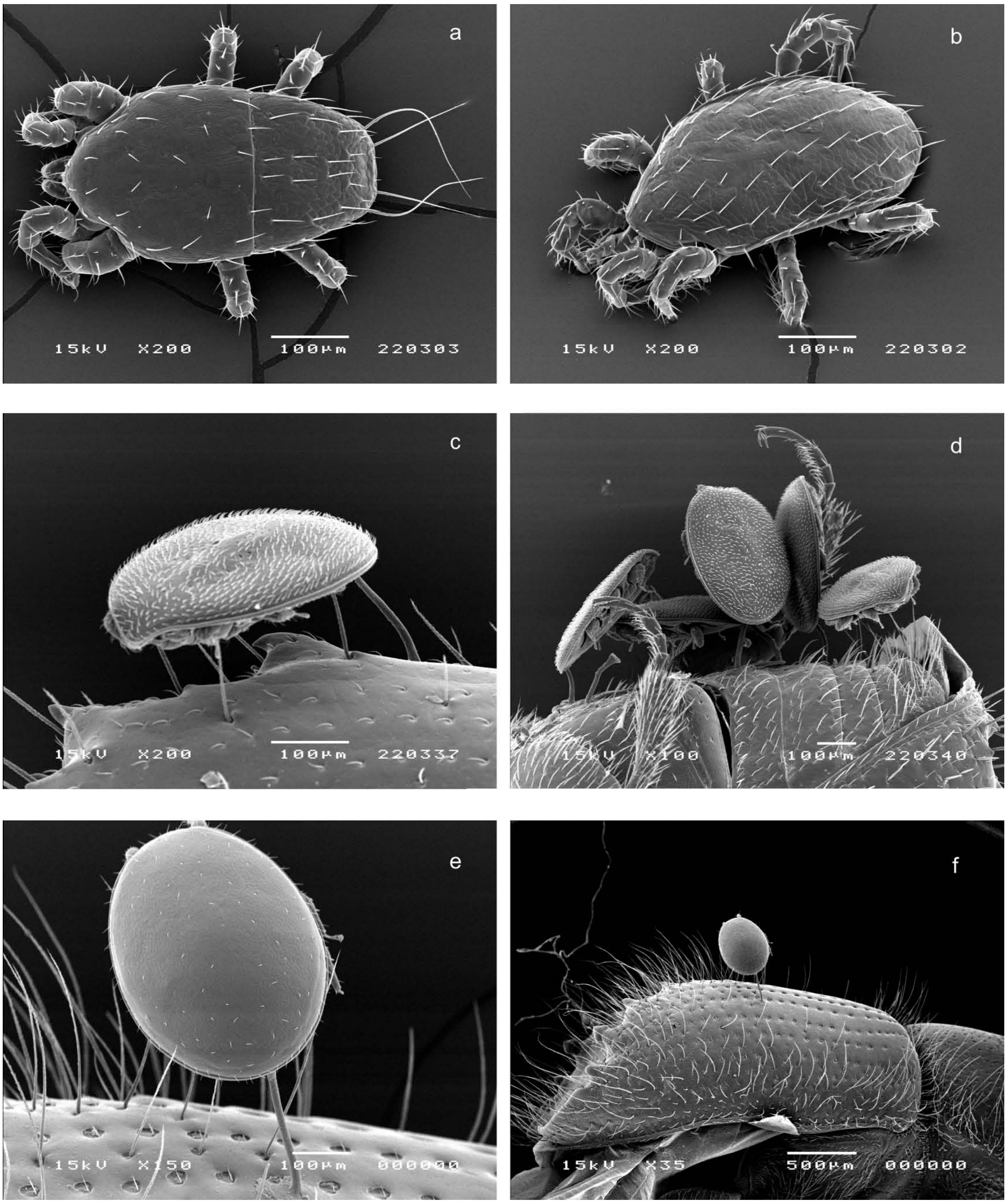

FIGURE 1: (Mesostigmata): a – *Insectolaelaps quadrisetus*; b – *Proctolaelaps fiseri*; c – *Trichouropoda polytricha*; d – *T. polytricha* specimens on ventral abdomen of *I. typographus*; e – *Uroobovella vinicolora*; f – *U.vinicolora* specimen attached on elytra of *I. typographus*.

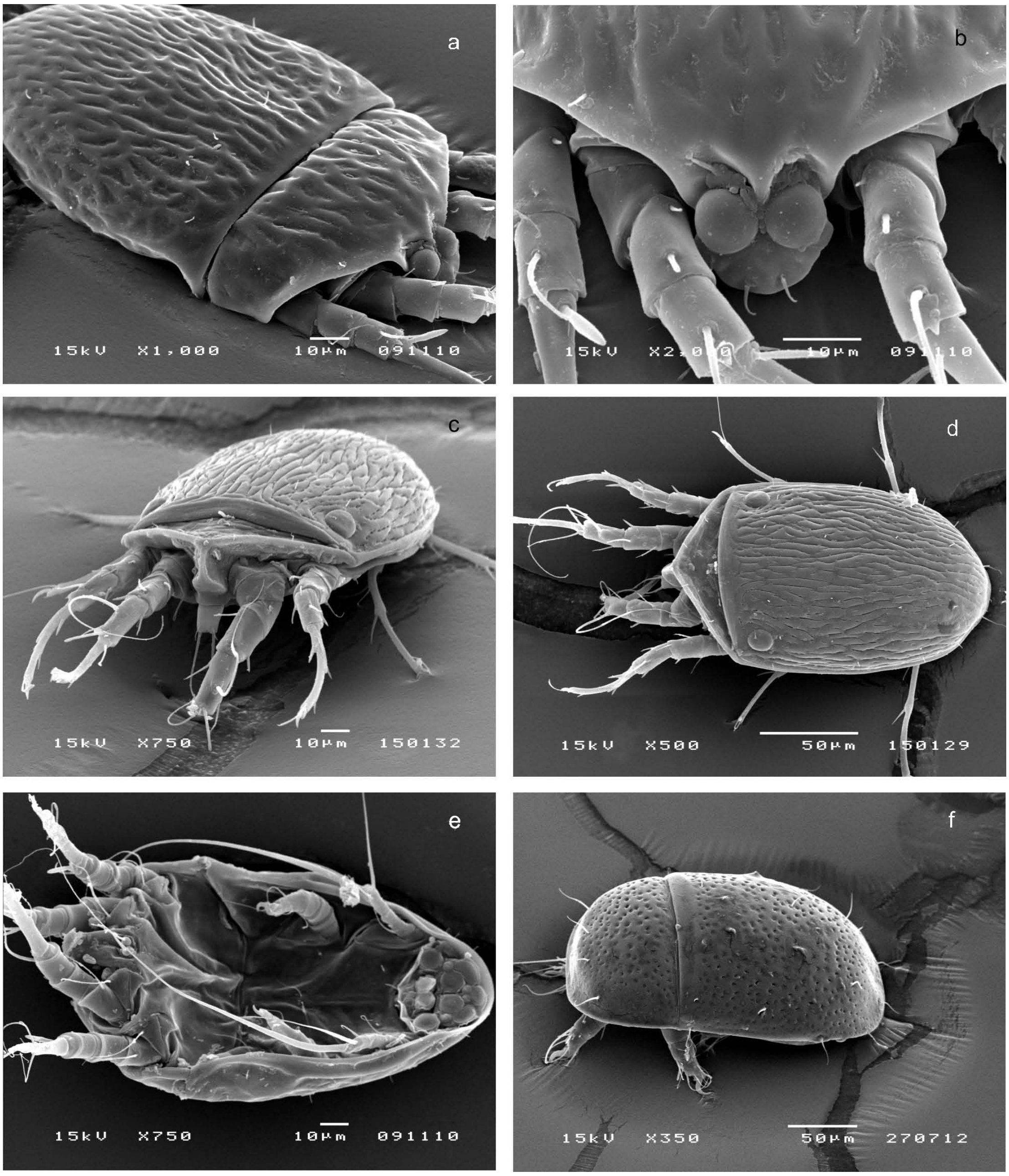

FIGURE 2: (cohort Astigmata): a – *Nanacarus* sp.; b – "Eyes" of *Nanacarus* sp.; c – Frontal view of *Bonomoia pini*; d – Dorsal side of *B. pini*; e – Ventral side of *B. pini*; f – *Boletoglyphus boletophagi*.

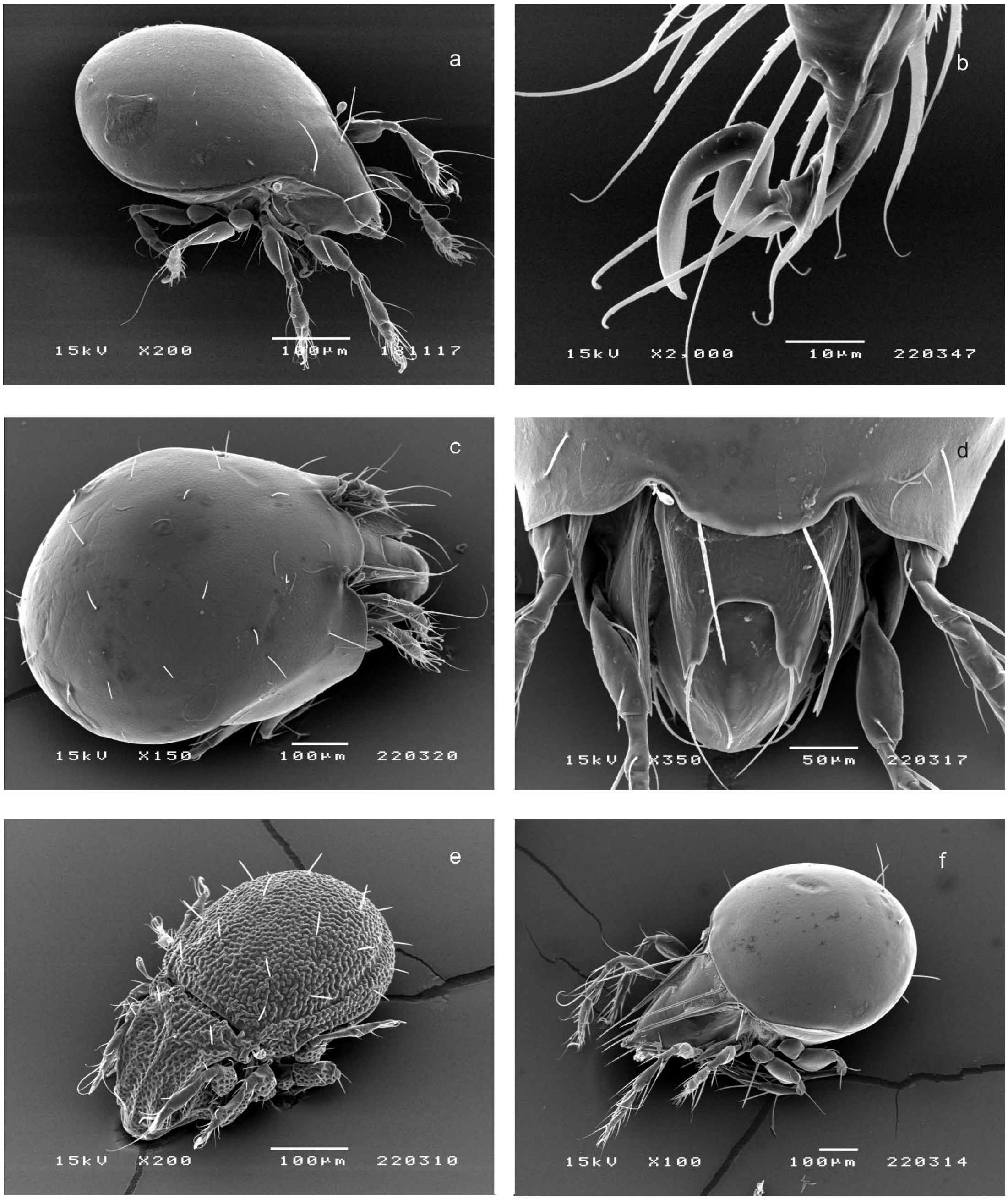

FIGURE 3: (Oribatida): a – *Siculobata leontonycha*; b – A claw of tarsus I of *S. leontonycha*; c – *Diapterobates humeralis*; d – Frontal part of *D. humeralis*; e – *Carabodes labyrinthicus*; f – *Ceratoppia bipilis*.

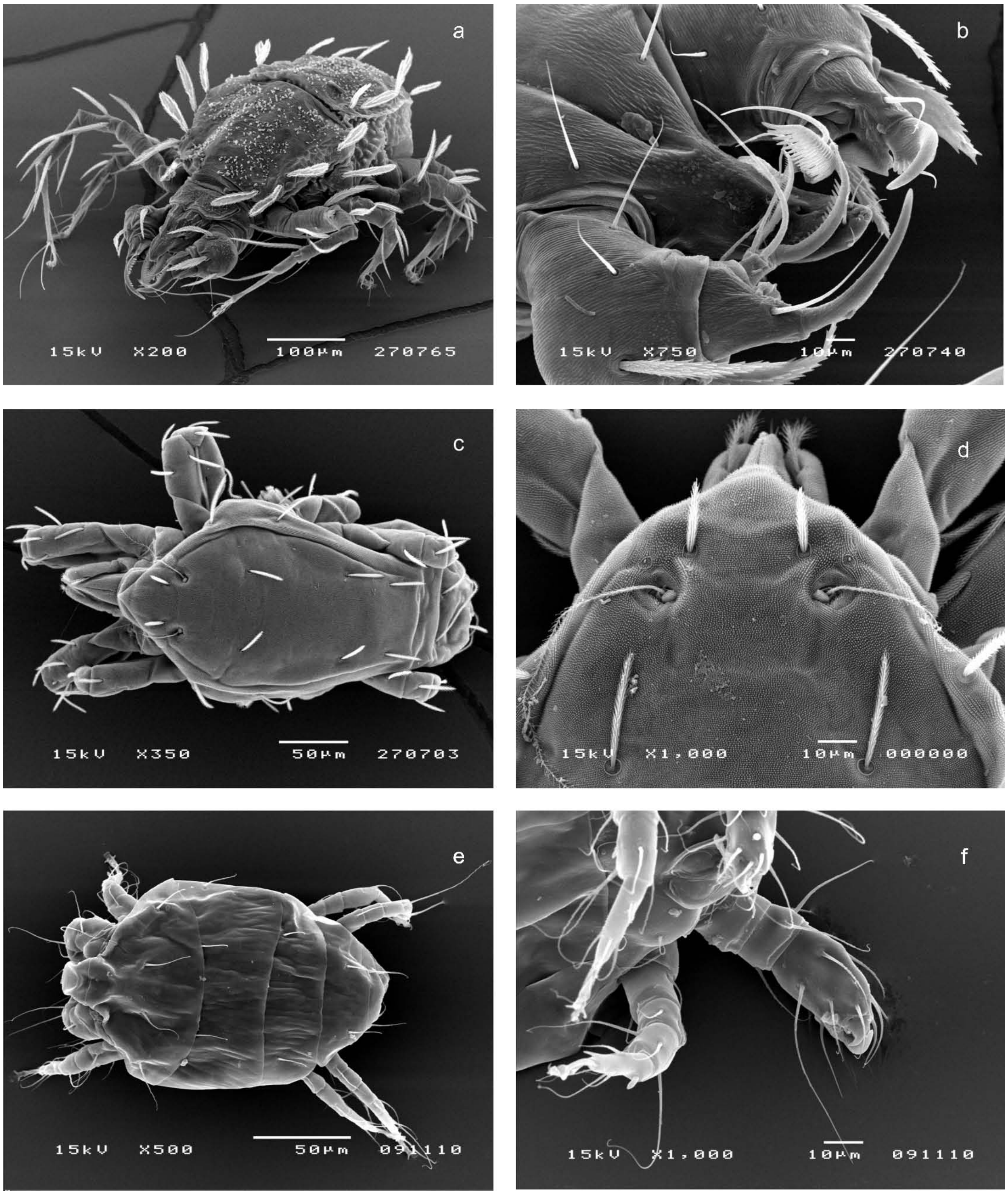

FIGURE 4: (Prostigmata): a – *Mexecheles virginiensis*; b – Under site of pedipalpus of *M. virginiensis*; c – *Ereynetes propescutulis*; d – Frontal part of *E. propescutulis*; e – *Aethiophenax ipidarius*; f – Leg I of *A. ipidarius*.

sects in order to assist it in reaching galleries. The species, *S. leontonycha,* like the most of the oribatids, is fungivorous (or detritivorous) mite (Kranz, 2009). The species as well as another oribatid, *D. humeralis* (Figures 3 c and d), are classified as arboreal (Weigmann, 2006).

Ereynetes propescutulis (Figures 4c and d) was found at every study site. This species was described relatively recently from North America on the basis of material associated with the bark beetles *Ips confuses, Ips calligraphus,* and *Dendroctonus frontalis* (Hunter *et al.*, 1989). According to Hunter *et al.* (1989) and Moser *et al.* (1989a) three specimens, identified as *Ereynetes* nr. *scutulis* with *I. typographus* from Sweden, are apparently conspecific with *E. propescutulis*. *Ereynetes propescutulis* has also been reported to occur in Georgia, Asia in association with *I. typographus* (Moser *et al.*, 2009). According to Walter and Proctor (1999), perhaps this species feeds on small mites, eggs, or nematodes, such as the species *Ereynetes macquariensis* Fain, 1962. *Aetiophenax ipidarius* (Figure 4e) was found at every study site. It was also reported to occur in Sweden and Russia (St. Petersburg) (Moser *et al.*, 1989a; Khaustov, 1999) in addition to Germany, Poland, North America and Japan (Moser and Roton, 1971; Moser and Bogenschütz, 1984; Moser *et al.*, 1997; Magowski and Łabędzki, 2008). *Aetiophenax* is classified as an egg parasitoid (Moser, 2009). Hence, it should increase the mortality of bark beetles.

Rare or infrequent mites

Proctolaelaps fiseri (Figure 1b) appeared only in small numbers, as did deutonymphs of *Vulgarogamasus* sp., *Uroobovella vinicolora* (Figure 1e), and *Trichouropoda polytricha* (Figure 1c). All of these phoretic species were also reported from Germany and Sweden (Moser and Bogenschütz, 1984; Moser *et al.*, 1989a). In Poland, *P. fiseri* and *T. polytricha* has been found both from free and on the bodies of *I. typographus* and *Uroobovella* sp. as free (Gwiazdowicz *et al.*, 2011, 2012). The oribatid species *Carabodes labyrinthicus* (Figure 3e) dwells in lichen and moss on forest soil and trunks (Niemi *et al.*, 1997). Here it was found, in small numbers, in alcohol sediments at every study site. Moser *et al.* (1989a) considered it possibly phoretic. The species *Ceratoppia bipilis* (Figure 3f) was found almost the same number as *C. labyrinthicus* but only at one study site. The species *Bonomia pini* (Figures 2c, d and e) was described in 1957 from subcorticolous material of pine collected in Germany (Scheucher, 1957). In Central European Russia, this species was recorded with *Selatosomus aeneus* (Elateridae) beetles (Yermilov *et al.*, 2006). *Bonomoia* sp. has been reported to occur in Switzerland, associated with *Pityokteines curvidens* (Pernek *et al.*, 2008). In our study it was found to be fairly abundant, especially at the burnt site. The species of this genus obviously feed on organic detritus or micro-organisms, as do many species of the family Histiostomatidae (Krantz and Walter, 2009). Thus, they only ride bark beetles. *Boletoglyphus boletophagi* (Figure 2f) is a holarctic species phoretic on *Boletophagus reticulatus* (Tenebrionidae). It was associated with the polypore fungius (*Fomes fomentarius*) near St. Petersburg, Russia (Klimov, 1998).

Sporadically found species

Six specimens of *Mexecheles virginiensis* (Figures 4a and b) were found. Records of this species are quite scanty. This predator feeds on psocids, and has never been seen in large populations with bark beetles (Moser, 2009; Smiley and Moser, 1970). Only three specimens of an unidentified species of *Schwiebea* and *Elattoma* were found. *Schwiebea* sp. was also reported in small numbers in Sweden and Germany (Moser *et al.*, 1984, 1989a), but *Elattoma* sp. was seen only in Sweden. Single specimens of the oribatid species - *Chamobates borealis*, *Phthiracarus nitens*, *Cepheus latus*, *Conchogneta traegardhi*, *Oppia splendens*, *Micreremus brevipes*, *Zygoribatula exilis*, *Oribatella calcarata*, and *Phauloppia rauschenensis* - may have accidentally occurred in the samples. However, the latter species has often been found with bark beetles (Moser and Bogenschütz, 1984). The other sporadic taxa were unidentifiable (Table 2).

Attached mites

Most specimens were dislodged in alcohol sediments, because of the repeated handling of samples or may not be associated with the insects. The deutonymphs of *U. vinicolora* and *T. polytricha* were an exception. They were attached by the anal pedicles on the elytra and ventral abdomens of the insects (Figures 1d and f). Also, some specimens of *A. ipidarius* were fastened to ventral sites, between the coxae of legs I and II. They were apparently attached there by the two heavy claws present on the thickened tarsus of leg 1 (Figure 4f). However, they were not fastened very tightly, because the gentle touch of a pin easily dislodged the mites.

The mites at different study sites

Almost all of the dominant taxa - *I. quadrisetus*, *A. ipidarius, E. propescutulis,* and *Nanacarus* sp. - occurred at every study site. The exceptions were *Nanacarus* sp., which was absent from the ringbarking site, and the oribatids *S. leontonycha* and *D. humeralis,* which were absent from the mature forest. The large number of sample units probably explains the large diversity of the species in the burnt site. Also according to Gwiazdowicz *et al.* (2012) mesostigmatid mite communities associated with *I. typographus* in natural and managed forests are very similar in relation to species richness and abundance.

New species in Finland

Eight species and four genera were identified for the first time in Finland. These new species were *I. quadrisetus*, *P. fisheri*, *T. polytricha*, *M. virginiensis*, *A. ipidarius*, *E. propescutulis*, *B. pini*, *B. boletophagi*, and the new genera, *Elattoma*, *Schwiebea*, *Nanacarus*, *Parawinterschmidtia*. In addition, *S. leontonycha* was previously recorded in Finland only once, as a subfossil oribatid mite (Niemi, 1989). However, the present study proves that the species *S. leontonycha* lives in Finland associated with bark beetles.

Conclusion

Fifteen species found here can be classified as phoretic according to Klimov (1998) and Moser *et al.* (1984, 1989a, 2005) (Table 2). The large number of *D. humeralis* may also indicate a phoretic relationship, as does the moderate number of *Ceratoppia bipilis*. Ten of these fifteen species were also reported earlier in Sweden (Table 2), but *M. virginiensis*, *B. pini*, *B. boletophagi*, and *Parawinterschmidtia* sp. were not found in either Sweden or Germany. In addition, *Nanacarus* sp. was not seen in Sweden, nor was *E. propescutulis* found in Germany.

The ecology of the many phoretic species is still unknown; moreover, the number of phoretic mites constantly increases. The role of subcortical phoretic mites ranges widely, from parasitoids, predators, and filter feeders to mycetophagous, nematophagous and general feeders (Stephen *et al.*, 1993). In addition, several new species have not been described. In many cases, the relationships between bark beetles, their phoretic mites, and their associated hyperphoretic fungi are uncertain. Insects carry both mites and fungi, and the phoretic mites riding on insects often transmit fungi. These fungi may not only provide food for the mite but they may aid the insects by overcoming the resistance of the host tree. Some species, like *I. quadrisetus*, increase mortality of bark beetles. All this missing information indicates the need for further studies on the role and significance of beetle-mite-fungus interactions.

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APPENDIX 1

Location of study sites in the Koli region, Lieksa, Finland. The numbers refer to the data given in Table 1. (Background maps / National Land Survey of Finland)