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Animal inclusions in a sample of unselected Baltic amber

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Abstract. The proportions of animal inclusions and syninclusions in a sample of unselected Baltic amber from the Sambian deposit are presented.

Key words: unselected Baltic amber, inclusions, syninclusions.

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I. INTRODUCTION

Studies of inclusions are usually based on material from museum or private collections, and this has previously undergone multiple selections by amber workers, collectors and museum curators resulting in a collection of highly selected and complied specimens. Despite of this, most data on proportions of taxonomic groups in Baltic amber, as well as the amber forest, are based on collections from Zoological Museum in Copenhagen (LARSSON 1978) and Museum of the Earth in Warsaw (KULICKA 1990). To eliminate the multi-step selection factor, KLEBS (1910) conducted studies on unselected material obtained directly from the deposit. He examined 200 kg (22420 pieces) of unselected Baltic amber of layered structure from an amber mine on the Sambian Penisula. Of the examined samples, 7826 pieces (36%) contained 13877 zooinclusions. Arthropods have only been identified to orders, and until this day his work remains the only study of domination structure in unselected Baltic amber.

Since the middle of XIX century the occurrence of multiple animal inclusions has been debated in scientific publications (LOEW 1864; WHEELER 1915; SKALSKI 1985; KOTEJA 1986, 1989, 1996, 1998). Cited authors suggested that, with the uncertain origin of Baltic amber and range and character of amber forest, inclusions coexisting in a single piece of amber can provide important information on paleoecology and paleozoogeography. In 1989 the term s y n i n c l u s i o n s was added to the literature (KOTEJA 1989). Although the problem of co-occurrence has existed for almost 150 years the relations between co-occurring inclusions are not known, nor in the rate of pieces with multiple animal inclusions in Baltic amber.

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II. MATERIALS AND METHODS

In this study, 3875 pieces of Baltic amber from Samland deposits (42.6 kg) were examined in detail. This was unselected amber of layered structure with a thin, weathered surface. Smallest piece weighed 0.15 g and largest 117.5 g, with average mass of 11 g.

Examined pieces were ground and polished. Prepared pieces were examined carefully under a stereomicroscope with 4.8-94x magnification. Extremely layered pieces were examined wetted in water or 75% ethyl alcohol.

In this description, results obtained are reported as summaries. Full list including weight of pieces and contained inclusions is available at the Invertebrate Zoology Department of University of Gdańsk as a catalogue of the Museum of Amber Inclusions.

III. RESULTS

Of 3875 pieces (42610 g) only 1061 (9863 g) did not contain any organic inclusions visible under the stereomicroscope. Animal inclusions or plant fragments as syninclusion were entrapped in 1824 pieces (22278 g). Only 22 pieces (311 g) contained plant inclusions only not considering stellate hairs (Table I).

Table I

Inclusions in a sample of unselected, layered Baltic amber

	pieces	weight [gram]
examined	**3875**	**42610.5**
without organic inclusions	1061 **27.4%**	9863.3 **23.1%**
with organic inclusions:	2814 **72.6%**	32747.2 **76.9%**
– with zooinclusions	1824 **47.1%**	22277.7 **52.3%**
– with identified fitoinclusions	22 **0.6%**	311.4 **0.7%**
– with unidentified plant remains or stellate hairs only	968 **24.9%**	10158.1 **23.9%**

Those 1824 pieces contained 7111 specimens (Table II) of which 7079 were arthropods (2.2% were poorly preserved, preventing further classification). Most abundant were insects (4933 specimens) equalling 69.5% of arthropods.

In examined material, 42 pieces contained larvae of holometabolous insects. In those pieces 2 pupae and 53 larvae were discovered. In total, 58 pieces contained also exuvia, eggs and spider web.

Among the 1824 pieces containing animal inclusions, only 591 pieces (32%) contained a single zooinclusion. The remaining 1233 pieces (68%) contained 6520 specimens, equalling to 92% of discovered animals. Most pieces contained multi-group syninclusions as well as single-group and single-species syninclusions. Most arthropods co-occurred with other zooinclusions, i.e., in over 80% of pieces (Table II). Table III a,b,c lists number of pieces with co-occurring arthropods from different taxonomic groups.

Inclusions that “preserved” life activities were found in 17 pieces, mere 0.9% of examined pieces with zoological inclusions. Those were: copulation, egg laying, parasitization, predation and phoresis.

Table II

Animal inclusions in a sample of unselected, layered Baltic amber

	total		as syninclusions			
	No. of pieces	No. of inclusions	No. of pieces		No. of inclusions	
Mammalia	4	4	3		3	
Annelida	1	2	1		2	
Nematoda	1	8	1		8	
Arthropoda	1823	7097	1233	(68%)	6507	(92%)
Myriapoda	**4**	**4**	**3**		**3**	
Arachnida	**857**	**2008**	**730**	**(85%)**	**1881**	**(94%)**
Acari	566	1655	481	(85%)	1570	(95%)
Araneae	277	339	237	(86%)	299	(88%)
spider web	39	39	28		28	
Opilionidea	11	11	10		10	
Pseudoscorpionidea	3	3	2		2	
Insecta	**1618**	**4933**	**1214**	**(75%)**	**4529**	(92%)
Plecoptera	1	1	1		1	
Neuroptera	2	3	2		2	
Ephemeroptera	3	3	3		3	
Blattoptera	7	7	5		5	
Thysanura	9	9	8		8	
Heteroptera	11	12	9		10	
Isoptera	12	12	11		11	
Lepidoptera	19	22	16		19	
Psocoptera	20	20	17		17	
Trichoptera	42	58	39	(93%)	55	(95%)
Thysanoptera	42	50	29	(69%)	37	(74%)
Coleoptera	182	204	169	(93%)	191	(94%)
Homoptera	202	296	177	(88%)	271	(92%)
Aphidinea	115	177	101	(88%)	163	(92%)
Coccinea	55	74	45	(82%)	64	(86%)
Auchenorrhyncha	29	30	28	(97%)	29	(79%)
Hymenoptera	309	451	278	(90%)	420	(93%)
Formicidae	169	254	158	(93%)	243	(96%)
Chalcidoidea	83	99	71	(86%)	87	(88%)
Collembola	321	554	287	(89%)	520	(94%)

Table II cont.

	total		as syninclusions			
	No. of pieces	No. of inclusions	No. of pieces		No. of inclusions	
Diptera	1225	2947	952	(78%)	2674	(91%)
Chironomidae	629	1141	509	(81%)	1021	(89%)
Sciaridae	282	506	247	(88%)	471	(93%)
Dolichopodidae	186	271	157	(84%)	242	(89%)
Mycetophilidae	159	230	138	(87%)	209	(91%)
Ceratopogonidae	121	158	101	(83%)	138	(87%)
Cecidomyiidae	99	114	88	(89%)	103	(90%)
Psychodidae	69	89	63	(91%)	83	(93%)
Phoridae	50	65	43	(86%)	58	(89%)
Limoniidae	45	56	43	(96%)	54	(96%)
Empididae	38	52	31	(82%)	45	(87%)
Rhagionidae	8	8	7		7	
Scatopsidae	3	3	3		3	
Simuliidae	2	2	2		2	
Syrphidae	2	2	1		1	
Anisopodidae	1	1	1		1	
Drosophilidae ?	1	4	1		4	
Total	**1824**	**7111**	**1233**	**(68%)**	**6520**	**(92%)**

IV. DISCUSSION

The study shows that in unselected layered Baltic amber 48% of pieces contain animal and plant inclusions (Table I). KLEBS (1910) found lower percentage of pieces with inclusions, only 35%. This large difference could be caused by the quantity of amber studied – KLEBS examined 200 kg of amber. Another reason could be the quality of optics available 100 years ago and now.

In examined unselected Baltic amber prevailing arthropods are Diptera and Acari, 41.5% and 23.3% respectively, followed by Collembola (7.8%) and Hymenoptera (6.4%).

The comparison of domination structure in unselected amber (present data) and museum collections (LARSSON 1978; KULICKA 1990) readily shows major differences in proportions of taxonomic groups (Fig. 1). Museum collections clearly exhibit influence of collector selection, resulting in low numbers of small arthropods such as Acari or Collembola, but in higher numbers of large Hymenoptera or Coleoptera. Such data show falsified proportions of taxonomic groups among inclusions in Baltic amber and, the same, in the fauna of the Eocene forest. Based on data from museums, KRUMBIEGIEL (1996) compared Baltic amber with that of Bitterfield and pointed to differences in proportions of taxonomic groups, but numerous species common for both ambers allowed to accept the hypothesis that Bitterfield and Baltic amber are of the same origin (SONTAG 2001).

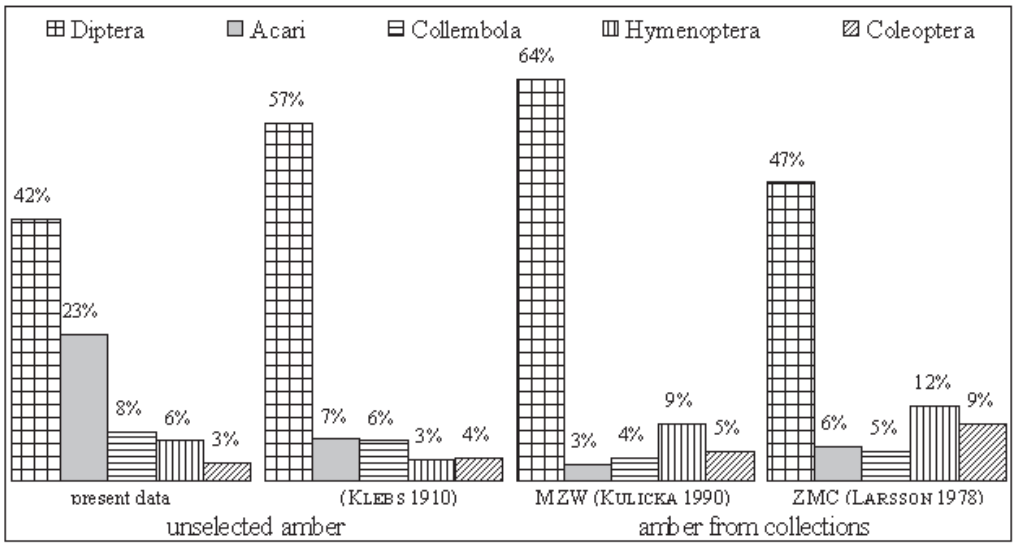

Fig. 1. Proportions of arthropods in unselected amber, and in collections (proportions of all zooinclusions). MZW – Museum of the Earth, Warsaw; ZMC – Zoological Museum, Copenhagen.

Differences in domination structure exist not only between unselected material and collections, but also between two samples of unselected amber. In a sample of Baltic amber examined by KLEBS (1910) the occurrence of Diptera and large arthropods is higher than in the present data, share of Acari is below 7% (Fig. 1). It is highly probable that this low occurrence of Acari was influenced by the mentioned inferior quality of optics. KLEBS discovered 13877 zooinclusions in 7826 pieces; and the present study resulted in 7111 zooinclusions from 1824 pieces. This correlates to 1.8 and 3.9 inclusions per piece and suggests that minuscule inclusions (such as mites) might have been overlooked in the earlier study.

It has been shown in this study that co-occurrence of zooinclusions is a common phenomenon. In unselected material 68% of pieces with zooinclusions contained more than one specimen and these pieces produced 92% of determinable animal inclusions.

In pieces with animal syninclusions, there was an average of 5.3 specimens per piece, as opposed to an average of 3.9 specimens in all pieces with zooinclusions.

In examined amber, co-occurring animals belonged to the same or more often to different taxonomic, ecological and trophic groups, they differed in size and locomotion abilities. Indisputable evidence of single and multi-species relations (copulation, predation, parasitization and phoresis) was discovered in only 0.9% of pieces.

Statistical analysis of all data revealed two trends in co-occurrence:

1. Single and multi-group syninclusions are more often created by taxonomic groups which are represented by many specimens.

2. Co-occurrences are not incidental. Detailed statistical analysis employing chi-square test shows that significantly more often than statistically expected single-group syninclusions occur in social Formicidae, socially feeding Aphidoidea, swarming Chironomidae and Cerapodogonidae as

well as numerous in forest environment Sciaridae, Dolichopodidae, Acari and Colembola. Connections between co-occurring zooinclusions are well illustrated by dendrogram of co-occurrence of animal inclusions (Fig. 2), where three groups can be distinguished: a) inhabiting moss and forest bed – Acari and Collembola, b) living on tree trunks – Araneae, Coleoptera, Formicidae and Dolichopodidae, c) shade and moisture preferring nematocerous flies from families Chironomidae, Sciaridae and Mycetophilidae.

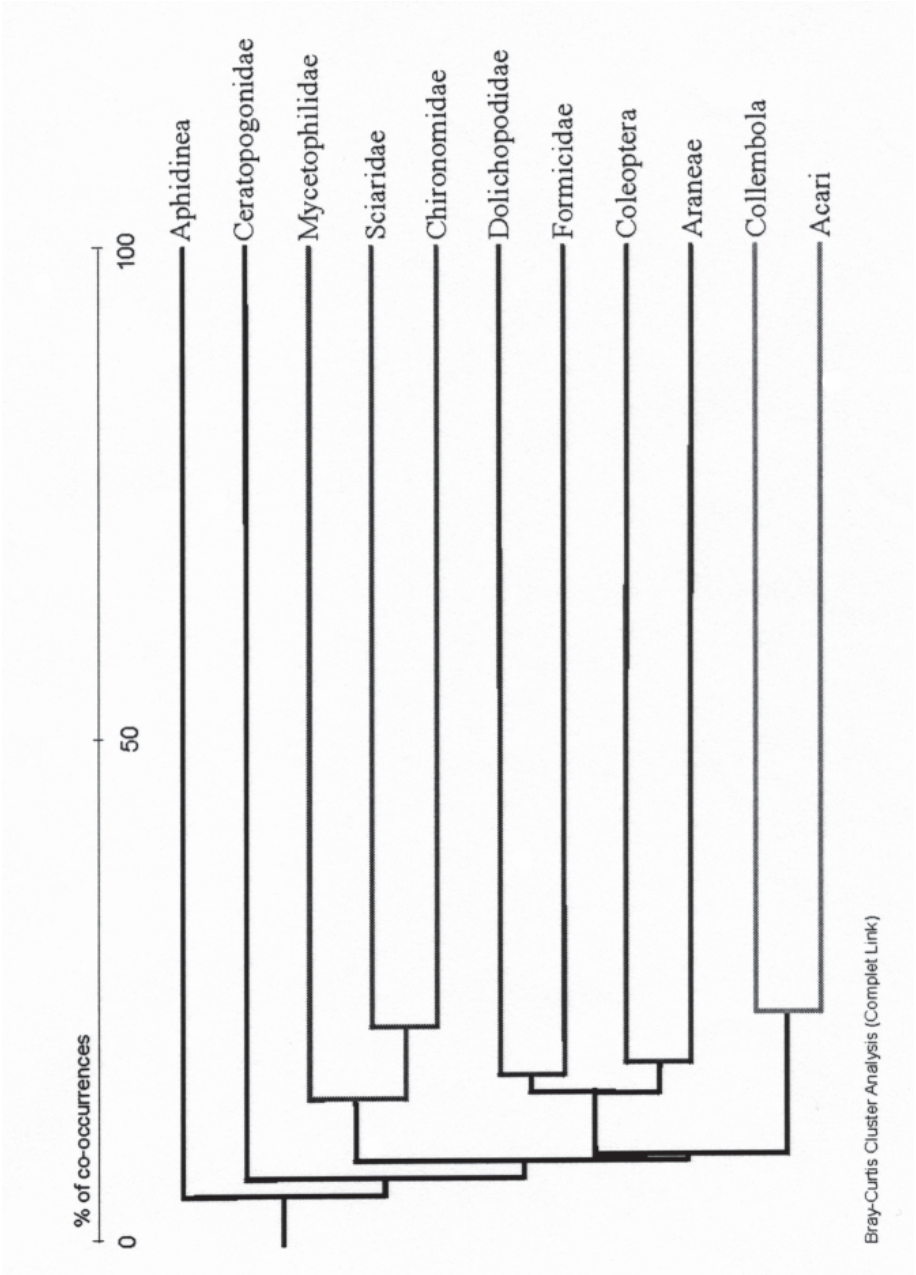

Fig. 2 Dendrogram of co-occurrences of animal inclusions (Biodiversity program used, Bray-Curtis Cluster Analysis).

Table IIIa

Co-occurrence of animal inclusions in Baltic amber (tables 3a,b,c lists numbers of pieces with syninclusions)

	Diptera	Acari	Collembola	Hymenoptera	Araneae	Homoptera	Coleoptera	Trichoptera	Thysanoptera	Lepidoptera	Psocoptera	Heteroptera	Isoptera	Opilionidea	Thysanura	Blattoptera	Pseudoscorpionidea	Myriapoda	Ephemeroptera
Diptera	614	329	197	201	181	128	129	32	23	15	12	7	10	7	4	5	2	1	3
Acari	329	217	129	106	84	82	60	16	17	7	6	2	4	5	2	1	–	–	–
Collembola	197	129	83	63	66	38	43	9	9	5	7	3	3	6	1	2	–	–	–
Hymenoptera	201	106	63	83	65	40	50	9	9	6	5	1	2	2	3	–	–	–	–
Araneae	181	84	66	65	40	27	40	12	3	6	2	2	1	3	1	3	–	–	1
Homoptera	128	82	38	40	27	37	24	3	6	6	2	1	2	3	3	1	1	1	–
Coleoptera	129	60	43	50	40	24	9	8	6	3	4	3	2	1	–	1	–	1	1
Trichoptera	32	16	9	9	12	3	8	8	1	–	–	1	2	–	–	–	–	1	–
Thysanoptera	23	17	9	9	3	6	6	1	6	–	–	–	1	–	–	1	–	–	–
Psocoptera	12	6	7	5	2	2	4	–	–	1	–	–	1	–	–	1	–	–	–
Isoptera	10	4	3	2	1	2	2	2	1	–	1	–	–	–	–	–	–	–	–
Opilionidea	7	5	6	2	3	3	1	–	–	–	–	–	–	–	–	1	–	–	–
Heteroptera	6	2	3	1	2	1	3	1	–	–	–	1	–	–	–	–	–	–	–
Lepidoptera	8	5	3	3	2	3	3	–	–	1	1	–	–	–	–	–	–	–	–
Thysanura	4	2	1	3	1	3	–	–	–	–	–	–	–	–	–	–	–	–	–
Blattoptera	5	1	2	–	3	1	1	–	1	–	1	–	–	1	–	–	–	–	–
Ephemeroptera	3	–	–	–	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–
Pseudoscorpionidea	2	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–
Diplopoda	1	1	1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
Chilopoda	1	–	–	–	–	1	1	1	–	–	–	–	–	–	–	–	–	–	–
Plecoptera	1	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mammalia	3	1	1	1	1	1	–	1	–	–	–	–	–	1	–	–	–	1	–
spider web	16	12	4	9	3	2	1	–	2	–	–	–	–	–	–	–	–	–	–

Table IIIb

Co–occurrence of arthropods with Diptera, Hymenoptera and Homoptera in a sample of unselected Baltic amber

	Diptera						Hymenoptera		Homoptera		
	Chironomidae	Sciaridae	Dolichopodidae	Mycetophilidae	Ceratopogonidae	Cecidomyiidae	Formicidae	Chalcidoidea	Aphidinea	Coccinea	Auchenorrhyncha
Diptera	288	180	108	104	80	66	108	56	71	37	20
Acari	173	89	49	59	40	34	63	28	47	25	10
Collembola	96	60	35	25	28	22	41	19	23	8	7
Hymenoptera	87	66	51	28	23	27			26	8	7
Araneae	99	45	39	30	16	21	39	16	13	10	3
Coleoptera	61	40	31	29	15	13	30	10	13	7	4
Homoptera	58	44	26	21	18	16	22	11			
Trichoptera	21	5	4	5	2	4	8	2	1	2	0
Thysanoptera	13	8	3	3	3	3	7	4	4	0	1
Psocoptera	6	5	3	1	2	4	1	2	1	1	0
Isoptera	4	2	3	1	2	0	1	1	2	0	0
Lepidoptera	6	2	2	1	2	0	1	1	2	1	0
Heteroptera	3	2	1	1	1	0	1	1	1	0	0
Opilionidea	6	2	2	1	0	1	0	1	2	0	1
Blattoptera	2	2	2	1	1	1	0	0	1	0	0
Thysanura	3	1	0	1	0	0	3	1	2	0	1
Ephemeroptera	2	1	0	1	0	0	0	0	0	0	0
Pseudoscorpionidea	1	0	1	0	1	0	0	0	1	0	0
Diplopoda	2	0	0	1	0	0	0	0	1	0	0
Chilopoda	1	0	0	0	0	0	0	0	1	0	0
Mammalia	2	1	0	2	1	0	0	0	0	0	0
spider web	5	1	3	1	2	2	6	2	1	1	0

Table IIIc

Co-occurrence of Diptera, Hymenoptera and Homoptera in a sample of unselected Baltic amber

		Diptera											Hymenoptera		Homoptera		
		Chironomidae	Sciaridae	Dolichopodidae	Mycetophilidae	Ceratopogonidae	Cecidomyiidae	Psychodidae	Phoridae	Limoniidae	Empididae	Rhagionidae	Formicidae	Chalcidoidea	Aphidinea	Coccinea	Auchenorrhyncha
Diptera	Chironomidae	238	112	45	59	49	30	28	16	15	16	3	43	29	36	13	8
	Sciaridae	112	91	32	39	18	20	18	8	7	7	1	39	18	25	13	8
	Dolichopodidae	45	32	44	19	14	13	8	13	6	5	1	30	13	16	7	3
	Mycetophilidae	59	39	19	39	11	13	9	4	4	2	2	15	7	7	8	6
	Ceratopogonidae	49	18	14	11	18	15	8	3	4	4	0	11	5	7	6	3
	Cecidomyiidae	30	20	13	13	15	10	7	1	7	3	0	16	9	8	4	3
	Psychodidae	28	18	8	9	8	7	12	1	1	4	0	9	7	6	5	0
	Phoridae	16	8	13	4	3	1	1	8	3	1	0	4	5	2	1	0
	Limoniidae	15	7	6	4	4	7	1	3	8	0	1	8	4	6	0	1
	Empididae	16	7	5	2	4	3	4	1	0	10	1	4	1	5	1	1
	Rhagionidae	3	1	1	2	0	0	0	0	1	1	0	2	1	2	0	0
Hymenoptera	Formicidae	43	39	30	15	11	16	9	4	8	4	2	43	14	16	2	5
	Chalcidoidea	29	18	13	7	5	9	7	5	4	1	1	14	11	7	3	2
Homoptera	Aphidinea	36	25	16	7	7	8	6	2	6	5	2	16	7	20	3	4
	Coccinea	13	13	7	8	6	4	5	1	0	1	0	2	3	3	11	0
	Auchenorrhyncha	8	8	3	6	3	3	0	0	1	1	0	5	2	4	0	1

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