Supporting information

Schmitt T., Hennige T., Maseluk A., Habel J.C., 2024. Long-term persistence of butterfly diversity in a sustainably managed forest ecosystem.

Figure S1 Bar plots showing the dominance structure of the butterfly and burnet moth species in the Oettinger Forest for the three sampling years. Red: Dominant species (10.0–31.9 %), orange: Sub-dominant species (3.2–9.9 %), green: Resident species (1.0–3.1 %). Blue bars represent sub-resident and sporadically occurring species.

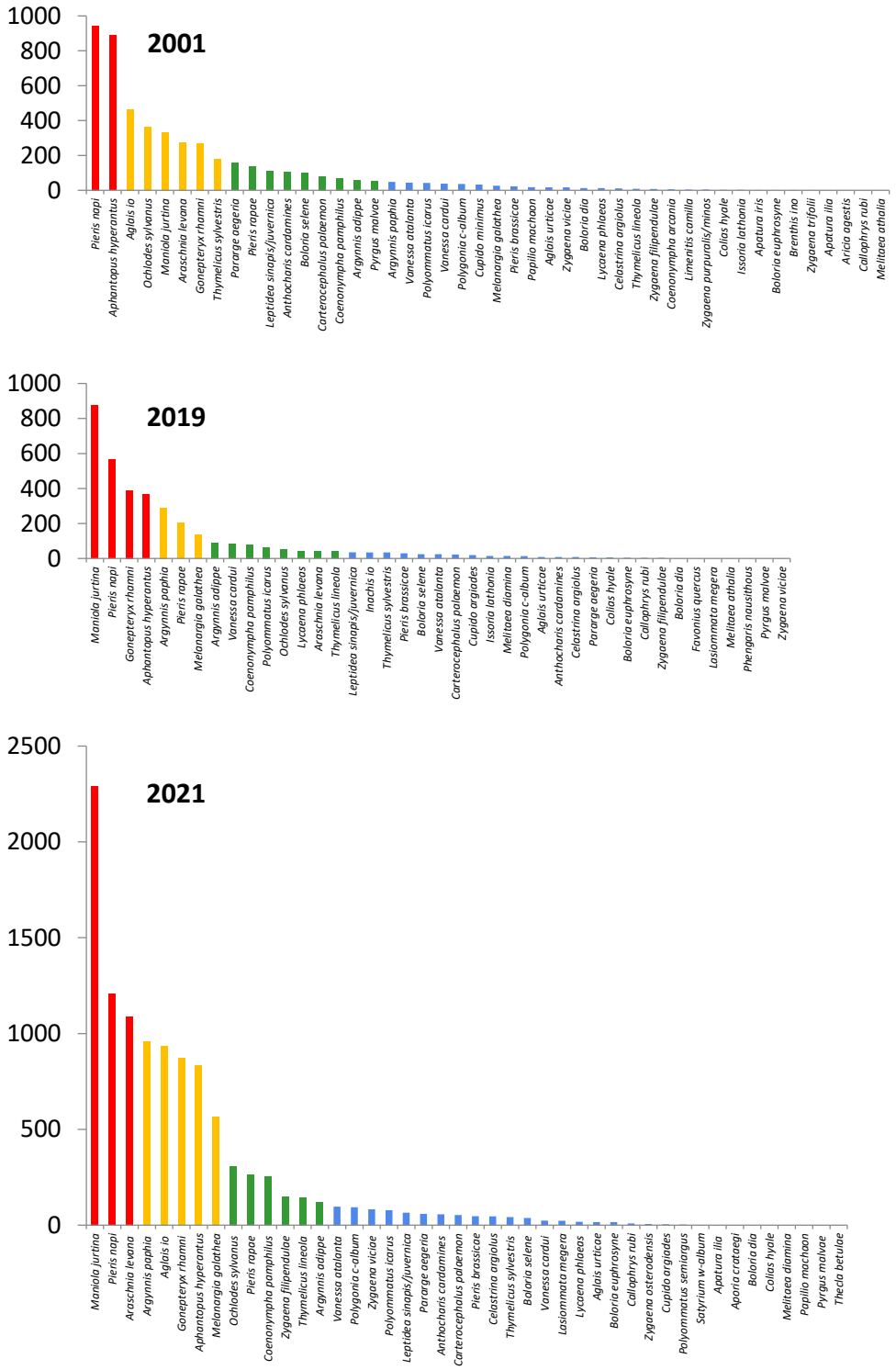

Figure S2 Dominance structure of the common species for the four different habitat types in the three study years in the Oettinger Forest (Franconia).

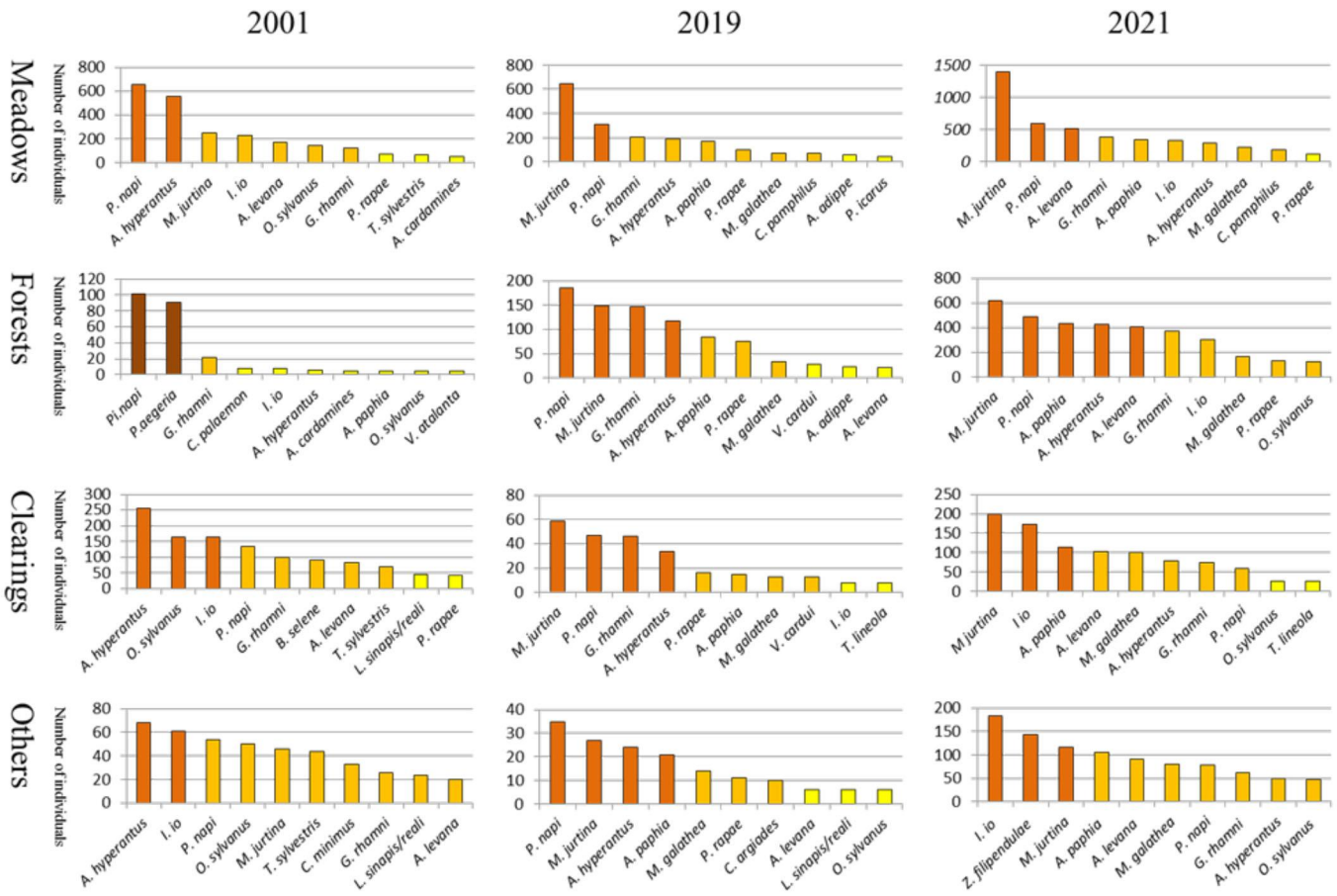

Table S1 Number of individuals per species in the three sampling years, modified individual numbers per sampling campaign (sum/ camp) and changes (i.e. increase or decrease) since 2001 in per cent.

	2001		2019			2021		
	#ind	sum/camp	#ind	sum/camp	change to 2001 [%]	#ind	sum/camp	change to 2001 [%]
Hesperiidae								
Carterocephalus palaemon	80	16.84	23	3.21	-81.0	54	7.71	54.2
Ochlodes sylvanus	362	76.21	50	6.97	90.9	309	44.14	42.1
Pyrgus malvae	51	10.74	1	0,14	98.7	1	0.14	98.7
Thymelicus lineola	9	1.89	41	5.71	201.6	144	20.57	985.7
Thymelicus sylvestris	180	37,89	35	4.88	-87.1	42	6.00	-84.2
Papilionidae								
Papilio machaon	18	3.79	0	0.00	-100.0	1	0.14	-96.2
Pieridae								
Anthocharis cardamines	103	21.68	9	1.25	-94.2	57	8.14	-62.5
Aporia crataegi	0	0.00	0	0.00	---	1	0.14	new
Colias hyale	3	0.63	6	0.84	32.4	1	0.14	-77.4
Gonepteryx rhamni	270	56.84	390	54.36	-4.4	870	124.29	118.7
Leptidea sinapis/juvernica	111	23.37	36	5.02	-78.5	65	9.29	-60.3
Pieris brassicae	23	4.84	30	4.18	-13.7	47	6.71	38.7
Pieris napi	943	198.53	566	78.89	-60.3	1206	172.29	-13.2
Pieris rapae	136	28.63	202	28.15	-1.7	265	37.86	32.2
Lycaenidae								
Aricia agestis	1	0.21	0	0.00	-100.0	0	0.00	-100.0
Callophrys rubi	1	0.21	4	0.56	164.8	9	1.29	510.7
Celastrina argiolus	11	2.32	9	1.25	-45.8	46	6.57	183.8
Cupido argiades	0	0.00	20	2.79	new	5	0.71	new
Cupido minimus	33	6.95	0	0.00	-100.0	0	0.00	-100.0
Favonius quercus	0	0.00	1	0.14	new	0	0.00	---
Lycaena phlaeas	13	2.74	42	5.85	113.9	18	2.57	-6.0
Phengaris nausithous	0	0.00	1	0.14	new	0	0.00	---
Polyommatus icarus	42	8.84	65	9.06	2.5	78	11.14	26.0
Polyommatus semiargus	0	0.00	0	0.00	---	3	0.43	new
Satyrium w-album	0	0.00	0	0.00	---	2	0.29	new
Thecla betulae	0	0.00	0	0.00	---	1	0.14	new
Nymphalidae								
Aglais urticae	17	3.58	9	1.25	-65.0	16	2.29	-36.1
Apatura ilia	1	0.21	0	0.00	-100.0	1	0.14	-32.1
Apatura iris	2	0.42	0	0.00	-100.0	0	0.00	-100.0
Aphantopus hyperantus	888	186.95	366	51.01	-72.7	832	118.86	-36.4
Araschnia levana	276	58.11	41	5.71	-90.2	1066	1152.29	162.1
Argynnis adippe	60	12.63	89	12.40	-1.8	118	16.86	33.5
Argynnis paphia	48	10.11	291	40.56	301.4	957	136.71	1252.9
Boloria dia	13	2.74	1	0.14	-94.9	1	0.14	-94.8
Boloria euphrosyne	2	0.42	5	0.70	65.5	19	2.71	554.6
Boloria selene	98	20.63	25	3.48	-83.1	38	5.43	-73.7
Brenthis ino	2	0.42	0	0.00	-100.0	0	0.00	-100.0
Coenonympha arcania	6	1.26	0	0.00	-100.0	0	0.00	-100.0
Coenonympha pamphilus	71	14.95	81	11.29	-24.5	252	36.00	140.9
Inachis io	465	97.89	35	4.88	-95.0	936	133.71	36.6
Issoria lathonia	3	0.63	15	2.09	231.0	0	0.00	-100.0
Lasiommata megera	0	0.00	1	0.14	new	24	3.43	new
Limenitis camilla	4	0.84	0	0.00	-100.0	0	0.00	-100.0
Maniola jurtina	334	70.32	874	121.81	73.2	2291	327.29	365.5
Melanargia galathea	26	5.47	134	18.68	241.2	564	80.57	1372.0
Melitaea athalia	1	0.21	1	0.14	-33.8	0	0.00	-100.0
Melitaea diamina	0	0.00	15	2.09	new	1	0.14	new
Pararge aegeria	158	33.26	7	0.98	-97.1	54	7.71	-76.8
Polygonia c-album	36	7.58	14	1.95	-74.3	94	13.43	77.2
Vanessa atalanta	44	9.26	25	3.48	-62.4	98	14.00	51.1
Vanessa cardui	38	8.00	83	11.57	44.6	24	33.43	57.1
Zygaenidae								
Zygaena filipendulae	8	1.68	4	0.56	-66.9	147	21.00	1146.9
Zygaena osterodensis	0	0.00	0	0.00	---	6	0.86	new
Zygaena purpuralis/minos	4	0.84	0	0.00	-100.0	0	0.00	-100.0
Zygaena trifolii	17	0.42	0	0.00	-100.0	0	0.00	-100.0
Zygaena viciae	17	3.58	1	0.14	-96.1	83	11.86	231.3
Total #individuals	5014	1055.58	3648	508.43		10847	1549.57	
Total #species	46			41		44		

Table S2 Individuals/campaigns for each species and year including the 2001 to 2021 trend. Changes < 10% = "=" (constant), ≥ 10% "v / ^" (moderate), ≥ 35% "vv / ^^" (strong), ≥ 60% "vvv / ^^^" (very strong). "nf" refers to species not found in 2021. Superscripted s = small number of individuals. Horizontal and vertical marks in the columns "Germany (2011)" and "Bavaria (2016)" refer to moderate, strong and very strong trend increase/decrease in the respective Red List. Abbreviations for commonness (com) are r = rare, mc = moderately common, c = common, vc = very common (Voith, 2016). Abbreviations in the red data book categories (RDB-cat) column represent the IUCN categories: EN = endangered, VU = vulnerable, NT, near threatened, LC least concern and DD = data deficient.

	sum/campaign				Germany (2011)				Bavaria (2016)			
	2001	2019	2021	trend	com	st-trend	lt-trend	RDB-cat	com	st-trend	lt-trend	RDB-cat
Hesperiidae												
Carterocephalus palaemon	16.84	3.21	7.71	vv	c	(v)	<	LC	mc	(v)	<	NT
Ochlodes sylvanus	76.21	6.97	44.14	vv	vc	=	=	LC	c	=	=	LC
Pyrgus malvae	10.74	0.14	0.14	vvv	c	vv	<<	NT	mc	(v)	<	NT
Thymelicus lineola	1.89	5.71	20.57	^^^	vc	=	=	LC	c	=	=	LC
Thymelicus sylvestris	37.89	4.88	6.00	vvv	vc	=	=	LC	c	=	=	LC
Papilionidae												
Papilio machaon	3.79	0.00	0.14	vvv^{s}	vc	=	<<	LC	c	=	<	LC
Pieridae												
Anthocharis cardamines	21.68	1.25	8.14	vvv	vc	=	=	LC	c	(v)	<	LC
Aporia crataegi	0.00	0.00	0.14	new	vc	^	<<	LC		=	<	LC
Colias hyale	0.63	0.84	0.14	vvv^{s}	vc	vv	<<	LC	mc	=	(<)	G
Gonepteryx rhamni	56.84	54.36	124.29	^^^	vc	=	=	LC	vc	=	=	LC
Leptidea sinapis/juvernica	23.37	5.02	9.29	vv	?	?	?	DD	r	?	?	DD
Pieris brassicae	4.84	4.18	6.71	^^	vc	(v)	=	LC	c	=	(<)	LC
Pieris napi	198.53	78.89	172.29	=	vc	=	=	LC	vc	=	=	LC
Pieris rapae	28.63	28.15	37.86	^^	vc	=	=	LC	vc	=	=	LC
Lycaenidae												
Aricia agestis	0.21	0.00	0.00	nf	c	^	<	LC	r	=	<	NT
Callophrys rubi	0.21	0.56	1.29	^^^^{s}	c	((v)	(<)	NT	mc	(v)	<	NT
Celastrina argiolus	2.32	1.25	6.57	^^^	vc	=	=	LC	c	=	=	LC
Cupido argiades	0.00	2.79	0.71	new	r	^	<<	NT	vr	^	?	LC
Cupido minimus	6.95	0.00	0.00	nf	c	(v)	<	LC	r	=	<<	VU
Favonius quercus	0.00	0.14	0.00	2019	c	=	=	LC	r	=	=	LC
Lycaena phlaeas	2.74	5.85	2.57	=^{s}	vc	=	=	LC	mc	=	=	LC
Phengaris nausithous	0.00	0.14	0.00	2019	mc	(v)	<	NT	mc	(v)	<	NT
Polyommatus icarus	8.84	9.06	11.14	^	vc	=	=	LC	vc	=	<	LC
Polyommatus semiargus	0.00	0.00	0.43	new	c	=	<	LC	mc	(v)	<	NT
Satyrium w-album	0.00	0.00	0.29	new	mc	=	<	LC	r	=	<	NT
Thecla betulae	0.00	0.00	0.14	new	c	=	=	LC	r	=	=	LC
Nymphalidae												
Aglais urticae	3.58	1.25	2.29	v^{s}	vc	=	=	LC	c	=	=	LC
Apatura ilia	0.21	0.00	0.14	v^{s}	c	=	<<	NT	r	=	<	NT
Apatura iris	0.42	0.00	0.00	nf	c	(v)	<<	NT	r	=	<	NT
Aphantopus hyperantus	186.95	51.01	118.86	v	vc	=	=	LC	vc	=	=	LC
Araschnia levana	58.11	5.71	152.29	^^^	vc	=	=	LC	vc	=	=	LC
Argynnis adippe	12.63	12.40	16.86	^^	mc	vv	<<	VU	mc	(v)	<	NT
Argynnis paphia	10.11	40.56	136.71	^^^	c	^	<	LC	c	=	<	LC
Boloria dia	2.74	0.14	0.14	vvv^{s}	c	^	<<	LC	mc	=	<<	NT
Boloria euphrosyne	0.42	0.70	2.71	^^^^{s}	mc	(v)	<<<	EN	r	(v)	<<	EN
Boloria selene	20.63	3.48	5.43	vvv	c	vv	<<	NT	mc	(v)	<<	VU
Brenthis ino	0.42	0.00	0.00	nf	c	=	>	LC	mc	=	<<	NT
Coenonympha arcania	1.26	0.00	0.00	nf	c	(v)	<	LC	mc	=	<	LC
Coenonympha pamphilus	14.95	11.29	36.00	^^^	vc	=	=	LC	vc	=	=	LC
Inachis io	97.89	4.88	133.71	^^	vc	=	=	LC	c	=	=	LC
Issoria lathonia	0.63	2.09	0.00	nf	vc	=	=	LC	mc	=	=	LC
Lasiommata megera	0.00	0.14	3.43	new	vc	vv	<	LC	mc	=	<	LC
Limenitis camilla	0.84	0.00	0.00	nf	c	vv	<<	NT	mc	=	<	LC
Maniola jurtina	70.32	121.81	327.29	^^^	vc	=	=	LC	c	=	=	LC
Melanargia galathea	5.47	18.68	80.57	^^^	vc	=	>	LC	c	=	<	LC
Melitaea athalia	0.21	0.14	0.00	nf	c	vv	<<<	VU	mc	(v)	<<	VU
Melitaea diamina	0.00	2.09	0.14	new	mc	vv	<<	VU	mc	(v)	<<	VU
Pararge aegeria	33.26	0.98	7.71	vvv	vc	=	>	LC	c	=	=	LC
Polygonia c-album	7.58	1.95	13.43	^^^	vc	=	=	LC	c	=	=	LC
Vanessa atalanta	9.26	3.48	14.00	^^	vc	=	=	LC	vc	=	=	LC
Vanessa cardui	8.00	11.57	3.43	vv	vc	=	=	LC	vc	=	=	LC
Zygaenidae												
Zygaena filipendulae	1.68	0.56	21.00	^^^	c	=	<<	LC				LC
Zygaena osterodensis	0.00	0.00	0.86	new	r	(v)	<<<	EN				EN
Zygaena purpuralis/minos	0.84	0.00	0.00	nf	mc/c	vv/(v)	<<	VU/NT				NT/VU
Zygaena trifolii	0.42	0.00	0.00	nf	c	vvv	(<)	VU				EN
Zygaena viciae	3.58	0.00	11.86	^^^	c	=	<	LC				LC

Table S3 Changes of plot occupation of butterfly species present in all three study years. Only species with significant p-values are presented. The first three columns show the percentage of occupied plots, followed by the results of the Cochran Q test and the paired McNemar PostHoc test. The last three columns show the outcome of the PostHoc test.

	2001 [%]	2019 [%]	2021 [%]	Q	df	p_{total}	$p_{2001\text{-}2019}$	$p_{2001\text{-}2021}$	$p_{2019\text{-}2021}$
Hesperiidae									
Carterocephalus palaemon	60.5	24.4	60.0	14.07	2	$8.8 * 10^{-4}$	0.003	0.808	0.001
Ochlodes sylvanus	89.5	41.5	97.5	35.58	2	$1.9 * 10^{-8}$	$1.3 * 10^{-5}$	0.180	$7.1 * 10^{-6}$
Pyrgus malvae	42.1	2.4	2.5	26.47	2	$1.8 * 10^{-6}$	$1.1 * 10^{-4}$	$2.8 * 10^{-4}$	>0.999
Thymelicus lineola	13.2	31.7	80.0	34.36	2	$3.5 * 10^{-8}$	0.166	$9.6 * 10^{-7}$	$1.3 * 10^{-5}$
Pieridae									
Anthocharis cardamines	71.1	19.5	57.5	18.00	2	$1.2 * 10^{-4}$	$2.4 * 10^{-4}$	0.134	0.003
Leptidea sinapis/juvernica	73.7	43.9	57.5	9.91	2	$7.0 * 10^{-4}$	0.005	0.166	0.052
Pieris rapae	52.6	87.8	87.5	15.16	2	$5.1 * 10^{-4}$	0.003	0.003	>0.999
Lycaenidae									
Celastrina argiolus	21.1	19.5	55.0	11.08	2	0.004	0.763	0.016	0.003
Cupido argiades	0.0	14.6	2.5	8.40	2	0.015	0.025	0.317	0.046
Nymphalidae									
Araschnia levana	79.0	58.5	95.0	12.70	2	$2.0 * 10^{-4}$	0.108	0.014	$7.9 * 10^{-4}$
Argynnis paphia	50.0	92.7	100.0	32.95	2	$6.3 * 10^{-5}$	$6.3 * 10^{-5}$	$1.3 * 10^{-5}$	0.083
Boloria euphrosyne	5.3	7.3	22.5	6.20	2	0.655	0.655	0.034	0.058
Inachis io	81.6	46.3	95.0	27.71	2	$4.7 * 10^{-4}$	$4.7 * 10^{-4}$	0.059	$1.3 * 10^{-5}$
Issoria lathonia	7.9	19.5	0.0	8.22	2	0.157	0.157	0.083	0.008
Maniola jurtina	65.8	90.2	97.5	16.71	2	0.007	0.007	$5.3 * 10^{-4}$	0.180
Melanargia galathea	29.0	63.4	90.0	27.92	2	0.005	0.005	$7.1 * 10^{-6}$	0.002
Pararge aegeria	73.7	12.2	50.0	28.07	2	$1.6 * 10^{-5}$	$1.6 * 10^{-5}$	0.052	$1.1 * 10^{-4}$
Polygonia c-album	34.2	26.8	70.0	19.83	2	0.564	0.564	$4.7 * 10^{-4}$	$1.6 * 10^{-4}$
Vanessa atalanta	65.8	34.2	85.0	17.84	2	0.012	0.012	0.058	$2.1 * 10^{-4}$
Vanessa cardui	50.0	80.5	42.5	15.08	2	0.005	0.005	0.317	$2.8 * 10^{-4}$
Zygaenidae									
Zygaena viciae	21.1	2.4	47.5	17.79	2	$1.4 * 10^{-4}$	0.0200	0.033	$1.1 * 10^{-4}$