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Environmental filtering and spatial effects on metacommunity organisation differ among littoral macroinvertebrate groups deconstructed by biological traits

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Table S1 Mean, minimum, maximum and coefficient of variation (CV) of the 35 measured water chemistry variables in the 70 sampling sites of the studied lake system.

	Mean	Min.	Max	CV (%)
Secchi depth (m)	2.1	0.6	4.8	46
pH	7.3	6.4	7.6	4
Alkalinity (mmol L ⁻¹)	0.29	0.13	0.51	27
Conductivity (µS cm ⁻¹)	41.9	20.6	63.9	23
O ₂ -concentration (mg L ⁻¹)	9.5	6.9	10.7	5
O ₂ -saturation (%)	93	88	101	3
Water colour (mg Pt L ⁻¹)	29	15	140	88
CODMn (Mg L ⁻¹)	5.4	3.8	15.0	42
DOC (mg L ⁻¹)	4.9	3.8	9.7	25
Suspended solids (mg L ⁻¹)	1.6	0.8	6.0	70
Inorganic suspended solids (mg L ⁻¹)	0.4	0.0	3.0	97
Organic suspended solids (mg L ⁻¹)	1.2	0.6	4.9	71
TOC (mg L ⁻¹)	4.8	3.7	9.3	24
TP (µg L ⁻¹)	12	5	75	98
TSP (µg L ⁻¹)	4.4	1.5	34.1	133
PO ₄ -P (µg L ⁻¹)	1.9	1	18	129
TN (µg L ⁻¹)	333	230	720	31
TSN (µg L ⁻¹)	260	180	510	26
NH ₄ -N (µg L ⁻¹)	4.0	2.5	17.0	66
NO ₂ + NO ₃ -N (µg L ⁻¹)	2.1	1.0	28.0	182
Chl- <i>a</i> (µg L ⁻¹)	6.1	0.5	47.2	127
Al (mg L ⁻¹)	0.031	0.005	0.306	164
B (mg L ⁻¹)	0.005	0.002	0.030	113
Ca (mg L ⁻¹)	4.2	1.9	7.4	27
Cd (mg L ⁻¹)	<0.007	<0.007	<0.001	-
Cr (mg L ⁻¹)	<0.001	<0.001	<0.001	-
Cu (mg L ⁻¹)	<0.001	<0.001	0.006	-
Fe (mg L ⁻¹)	0.124	0.005	1.490	218
K (mg L ⁻¹)	0.75	0.47	1.02	16
Mg (mg L ⁻¹)	1.38	0.71	2.43	26
Mn (mg L ⁻¹)	0.0017	0.0002	0.0270	219
Na (mg L ⁻¹)	1.18	1.03	1.46	6
Ni (mg L ⁻¹)	<0.002	<0.002	<0.002	-
Pb (mg L ⁻¹)	<0.005	<0.005	<0.005	-
S (mg L ⁻¹)	0.72	0.23	1.06	24
Si (mg L ⁻¹)	2.01	1.44	2.53	11
Zn (mg L ⁻¹)	0.007	0.005	0.032	72

Table S2 Mean body lengths (mm) and calculated mean maximal body dry weights (mg) of the macroinvertebrate taxa identified from the littoral zone of the Kitkajärvi lake system. Also, shown are taxon-specific parameter values for body dry weight calculations, and references for body lengths and parameter values for dry weight calculation. Body dry weights were calculated using the equation: $\ln \text{Body DW} = \ln a + b \cdot \ln \text{Mean BL}$, for other references except for Benke (1999), where dry weights were calculated as: $\text{DW} = a \text{BL}^b$. BL = body length and DW = dry weight. Classifications of dispersal mode (DM) and oviposition behaviour (O) of each species are also given with their references

Species	Mean BL (mm)	BL reference	ln a	a	b	Body DW (mg)	DW reference	Dispersal mode (DM)	DM reference	Oviposition (O)	O reference
OLIGOCHAETA											
Tubificida											
<i>Ripistes parasita</i>	5.25	1	-9.190		3.250	0.022	2	Flightless passive	3	Free eggs	3
<i>Slavina appendiculata</i>	11	1	-9.190		3.250	0.247	2	Flightless passive	3	Free eggs	3
<i>Spirosperma ferox</i>	27.5	1	-9.190		3.250	4.860	2	Flightless passive	3	Attached eggs	3
<i>Stylaria lacustris</i>	11.75	1	-9.190		3.250	0.307	2	Flightless passive	3	Free eggs	3
HIRUDINEA											
Rhynchobdellida											
<i>Glossiphonia complanata</i>	20	1	-2.120		2.000	48.013	4	Flightless passive	3	Ovoviviparous	3
<i>Helobdella stagnalis</i>	7.5	1	-2.740		2.120	4.626	4	Flightless passive	3	Ovoviviparous	3
BIVALVIA											
Veneroidea											
<i>Pisidium</i> spp.	3.8	5	-1.854		3.572	18.442	6	Flightless passive	3	Ovoviviparous	3
<i>Sphaerium</i> spp.	10	5	-1.854		3.572	584.545	6	Flightless passive	3	Ovoviviparous	3
GASTROPODA											
Pulmonata											
<i>Anisus vortex</i>	8.5	5	-3.332		3.140	29.623	7	Flightless passive	3	Attached eggs	3
<i>Bathymphalus contortus</i>	5.25	5	-3.332		3.140	6.524	7	Flightless passive	3	Attached eggs	3
<i>Gyraulus albus</i>	6.5	5	-3.332		3.140	12.758	7	Flightless passive	3	Attached eggs	3
<i>Gyraulus crista</i>	2.5	5	-3.332		3.140	0.635	7	Flightless passive	3	Attached eggs	3
<i>Gyraulus laevis</i>	5.25	5	-3.332		3.140	6.524	7	Flightless passive	3	Attached eggs	3
<i>Myxas glutinosa</i>	13.5	5	-4.76		3.19	34.556	8	Flightless passive	3	Attached eggs	3
<i>Radix peregra</i>	11	11	-4.76		3.19	17.980	8	Flightless passive	3	Attached eggs	3

Species	Mean BL (mm)	BL reference	ln a	a	b	Body DW (mg)	DW reference	Dispersal mode (DM)	DMreference	Oviposition (O)	O reference
Ectobranchia											
<i>Valvata cristata</i>	3.25	5	-3.332		3.140	1.447	7	Flightless passive	3	Attached eggs	3
<i>Valvata pulchella</i>	5.25	5	-3.332		3.140	6.524	7	Flightless passive	3	Attached eggs	3
CRUSTACEA											
Isopoda											
<i>Asellus aquaticus</i>	12	9	-6.200		3.750	22.610	8	Flightless passive	3	Ovoviviparous	3
Amphipoda											
<i>Gammarus lacustris</i>	12.5	12	-4.783		3.258	36.361	7	Flightless passive	3	Ovoviviparous	3
INSECTA											
Plecoptera											
<i>Capnopsis schilleri</i>	6	14	-5.901		2.713	0.353	7	Aerial active	3	Ovoviviparous	3
<i>Diura bicaudata</i>	13	14	-5.072		2.697	6.334	7	Aerial active	3	Free eggs	3
<i>Nemoura avicularis</i>	8	16	-4.106		1.986	1.024	7	Aerial active	3	Attached eggs	3
Ephemeroptera											
<i>Caenis horaria</i>	5.8	17	-4.976		2.610	0.678	18	Aerial active	3	Attached eggs	3
<i>Centroptilum luteolum</i>	6.5	17	-4.020		2.930	4.325	8	Aerial active	3	Attached eggs	3
<i>Cloeon dipterum</i>	9	17	-4.020		2.930	11.222	8	Aerial active	3	Ovoviviparous	3
<i>Ephemera vulgata</i>	20	17	-5.570		2.971	27.945	7	Aerial active	3	Attached eggs	3
<i>Heptagenia dalecarlica</i>	11.5	17	-5.446		3.347	15.298	7	Aerial active	3	Attached eggs	3
<i>Kageronia fuscogrisea</i>	11.5	17	-5.446		3.347	15.298	7	Aerial active	3	Attached eggs	3
<i>Lophophlebia marginata</i>	10	17	-7.540		4.030	5.694	8	Aerial active	3	Attached eggs	3
Trichoptera											
<i>Agrypnia obsoleta</i>	21.5	20		0.0054	2.811	30.052	19	Aerial active	3	Attached eggs	3
<i>Agrypnia picta</i>	24	20		0.0054	2.811	40.942	19	Aerial active	3	Attached eggs	3
<i>Apatania hispida</i>	8.5	20	-5.219		2.966	3.091	7	Aerial active	3	Attached eggs	3
<i>Athripsodes aterrimus</i>	11.75	20	-4.260		2.350	4.618	8	Aerial active	3	Free eggs	30
<i>Athripsodes cinereus</i>	13	20	-4.260		2.350	5.857	8	Aerial active	3	Free eggs	30
<i>Cyrnus flavidus</i>	15	21	-5.627		3.000	12.148	18	Aerial active	3	Attached eggs	3
<i>Cyrnus trimaculatus</i>	10.5	21	-5.627		3.000	4.167	18	Aerial active	3	Attached eggs	3
<i>Goera pilosa</i>	13.5	20	-5.219		2.966	12.191	7	Aerial active	3	Attached eggs	3

Species	Mean BL (mm)	BL reference	ln a	a	b	Body DW (mg)	DW reference	Dispersal mode (DM)	DM reference	Oviposition (O)	O reference
<i>Hydroptila</i> spp.	3	12	-4.410		2.570	0.205	8	Aerial active	3	Attached eggs	3
<i>Limnephilus auricula</i>	11.5	20	-5.219		2.966	7.577	7	Aerial active	3	Attached eggs	3
<i>Limnephilus extricatus</i>	12.5	20	-5.219		2.966	9.703	7	Aerial active	3	Attached eggs	3
<i>Limnephilus rhombicus</i>	21	20	-5.219		2.966	45.203	7	Aerial active	3	Attached eggs	3
<i>Molanna albicans</i>	15.75	20	-5.219		2.966	19.257	7	Aerial active	3	Attached eggs	3
<i>Molanna angustata</i>	17.5	20	-5.219		2.966	26.322	7	Aerial active	3	Attached eggs	3
<i>Mystacides azurea</i>	9.75	20	-6.266		3.12	2.314	18	Aerial active	3	Free eggs	30
<i>Mystacides longicornis</i>	9.9	20	-6.266		3.12	2.427	18	Aerial active	3	Free eggs	30
<i>Oecetis lacustris</i>	9	20		0.0034	3.212	3.949	19	Aerial active	3	Free eggs	30
<i>Oecetis ochracea</i>	13.5	20		0.0034	3.212	14.525	19	Aerial active	3	Free eggs	30
<i>Oxyethira</i> spp.	3	12	-4.41		2.57	0.205	8	Aerial active	3	Attached eggs	3
<i>Phryganea bipunctata</i>	35	20		0.0054	2.811	118.241	19	Aerial active	3	Attached eggs	3
<i>Polycentropus flavomaculatus</i>	12.5	21	-5.627		3.000	7.030	18	Aerial active	3	Attached eggs	3
<i>Potamophylax latipennis</i>	19	20	-5.219		2.966	33.593	7	Aerial active	3	Attached eggs	3
<i>Tinodes waeneri</i>	10	22	-6.307		3.130	2.460	7	Aerial active	3	Attached eggs	3
Megaloptera											
<i>Sialis lutaria</i>	23	12	-5.776		2.900	27.576	18	Aerial active	3	Attached eggs	3
<i>Sialis sordida</i>	23	12	-5.776		2.900	27.576	18	Aerial active	3	Attached eggs	3
Odonata											
<i>Somatochlora metallica</i>	25	12		0.0096	3.1200	75.567	19	Aerial active	3	Free eggs	3
Hemiptera											
<i>Micronecta</i> spp.	1.9	23	-3.270		2.530	0.193	18	Flightless passive	3	Attached eggs	3
Coleoptera											
<i>Brychius elevatus</i>	3.9	24	-1.878		2.180	2.971	18	Aerial active	3	Attached eggs	3
<i>Elmis aenea</i>	2.1	25	-1.878		2.180	0.771	18	Aerial active	3	Attached eggs	3
<i>Halipus</i> spp.	3.4	24	-1.878		2.180	2.203	18	Aerial active	3	Attached eggs	3
<i>Halipus fulvus</i>	4.05	24	-1.878		2.180	3.226	18	Aerial active	3	Attached eggs	3
<i>Halipus lineolatus</i>	2.6	24	-1.878		2.180	1.228	18	Aerial active	3	Attached eggs	3
<i>Hydroporus incognitus</i>	3.65	26	-1.878		2.180	2.572	18	Aerial active	3	Attached eggs	3
<i>Hygrotus quinquelineatus</i>	3.35	26	-1.878		2.180	2.133	18	Aerial active	3	Attached eggs	3

Species	Mean BL (mm)	BL reference	ln a	a	b	Body DW (mg)	DW reference	Dispersal mode (DM)	DM reference	Oviposition (O)	O reference
<i>Hygrotus versicolor</i>	3.35	26	-1.878		2.180	2.133	18	Aerial active	3	Attached eggs	3
<i>Nebrioporus assimilis</i>	4.1	26	-1.878		2.180	3.313	18	Aerial active	3	Attached eggs	3
<i>Oulimnius tuberculatus</i>	1.8	25	-1.878		2.180	0.551	18	Aerial active	3	Attached eggs	3
<i>Oreodytes sanmarkii</i>	3.1	26	-1.878		2.180	1.801	18	Aerial active	3	Attached eggs	3
<i>Oreodytes septentrionalis</i>	3.3	26	-1.878		2.180	2.064	18	Aerial active	3	Attached eggs	3
<i>Platambus maculatus</i>	8.0	26	-1.878		2.180	14.034	18	Aerial active	3	Attached eggs	3
Diptera											
<i>Tipula</i> spp.	52	12, 27	-5.999		2.572	64.252	7	Aerial active	3	Free eggs	3
Chironomidae											
<i>Arctopelopia</i> spp.	9	29	-7.053		3.407	1.544	7	Aerial active	3	Free eggs	3
<i>Chironomus anthracinus</i>	23	29	-7.053		3.407	37.753	7	Aerial active	3	Free eggs	3
<i>Cladotanytarsus mancus</i>	4.5	29	-7.053		3.407	0.145	7	Aerial active	3	Free eggs	3
<i>Cladotanytarsus vanderwulpi</i>	4.5	29	-7.053		3.407	0.145	7	Aerial active	3	Free eggs	3
<i>Corynoneura arctica</i>	2.5	29	-7.053		3.407	0.020	7	Aerial active	3	Attached eggs	3
<i>Cricotopus cylindraceus</i>	7.5	29	-7.053		3.407	0.829	7	Aerial active	3	Attached eggs	3
<i>Cricotopus intersectus</i>	7.5	29	-7.053		3.407	0.829	7	Aerial active	3	Attached eggs	3
<i>Cricotopus tremulus</i>	7.5	29	-7.053		3.407	0.829	7	Aerial active	3	Attached eggs	3
<i>Cricotopus trifasciata</i>	7.5	29	-7.053		3.407	0.829	7	Aerial active	3	Attached eggs	3
<i>Cryptochironomus</i> spp.	14	29	-7.053		3.407	6.956	7	Aerial active	3	Free eggs	3
<i>Demicryptochironomus vulneratus</i>	11	29	-7.053		3.407	3.058	7	Aerial active	3	Free eggs	3
<i>Dicrotendipes pulsus</i>	10	29	-7.053		3.407	2.210	7	Aerial active	3	Free eggs	3
<i>Endochironomus albipennis</i>	15	29	-7.053		3.407	8.799	7	Aerial active	3	Free eggs	3
<i>Endochironomus dispar</i>	15	29	-7.053		3.407	8.799	7	Aerial active	3	Free eggs	3
<i>Endochironomus tendens</i>	15	29	-7.053		3.407	8.799	7	Aerial active	3	Free eggs	3
<i>Glyptotendipes barbipes</i>	16	29	-7.053		3.407	10.963	7	Aerial active	3	Free eggs	3
<i>Glyptotendipes pallens</i>	16	29	-7.053		3.407	10.963	7	Aerial active	3	Free eggs	3
<i>Heterotrissocladius marcidus</i>	8.5	29	-7.053		3.407	1.270	7	Aerial active	3	Attached eggs	3
<i>Microtendipes pedellus</i>	14	29	-7.053		3.407	6.956	7	Aerial active	3	Free eggs	3
<i>Orthocladius consobrinus</i>	11	29	-7.053		3.407	3.058	7	Aerial active	3	Attached eggs	3
<i>Parachironomus arcuatus</i>	11	29	-7.053		3.407	3.058	7	Aerial active	3	Free eggs	3

Species	Mean BL (mm)	BL reference	ln a	a	b	Body DW (mg)	DW reference	Dispersal mode (DM)	DM reference	Oviposition (O)	O reference
<i>Paracladopelma doris</i>	9	29	-7.053	3.407	1.544	7	Aerial active	3	Free eggs	3	
<i>Parakiefferiella</i> spp.	3.5	29	-7.053	3.407	0.062	7	Aerial active	3	Attached eggs	3	
<i>Paratanytarsus penicillatus</i>	6.5	29	-7.053	3.407	0.509	7	Aerial active	3	Free eggs	3	
<i>Polypedilum bicrenatum</i>	8.5	29	-7.053	3.407	1.270	7	Aerial active	3	Free eggs	3	
<i>Polypedilum pullum</i>	8.5	29	-7.053	3.407	1.270	7	Aerial active	3	Free eggs	3	
<i>Polypedilum sordens</i>	8.5	29	-7.053	3.407	1.270	7	Aerial active	3	Free eggs	3	
<i>Potthastia longimana</i>	9	29	-7.053	3.407	1.544	7	Aerial active	3	Free eggs	31	
<i>Procladius</i> spp.	8	29	-7.053	3.407	1.033	7	Aerial active	3	Free eggs	3	
<i>Psectrocladius flavus</i>	10	29	-7.053	3.407	2.210	7	Aerial active	3	Attached eggs	3	
<i>Psectrocladius sordidellus</i>	10	29	-7.053	3.407	2.210	7	Aerial active	3	Attached eggs	3	
<i>Pseudochironomus prasinatus</i>	10	29	-7.053	3.407	2.210	7	Aerial active	3	Free eggs	3	
<i>Pseudosmittia</i> spp.	4.5	29	-7.053	3.407	0.145	7	Aerial active	3	Attached eggs	3	
<i>Sergentia coracina</i>	16	29	-7.053	3.407	10.963	7	Aerial active	3	Free eggs	3	
<i>Stictochironomus rosenschoeldi</i>	12	29	-7.053	3.407	4.114	7	Aerial active	3	Free eggs	3	
<i>Synorthocladius semivirens</i>	3.5	29	-7.053	3.407	0.062	7	Aerial active	3	Attached eggs	3	
<i>Tanytarsus glabrescens</i>	6.5	29	-7.053	3.407	0.509	7	Aerial active	3	Free eggs	3	
<i>Tanytarsus lugens</i>	6.5	29	-7.053	3.407	0.509	7	Aerial active	3	Free eggs	3	
<i>Tanytarsus mendax</i>	6.5	29	-7.053	3.407	0.509	7	Aerial active	3	Free eggs	3	
<i>Tanytarsus nemorosus</i>	6.5	29	-7.053	3.407	0.509	7	Aerial active	3	Free eggs	3	
<i>Tanytarsus pallidicornis</i>	6.5	29	-7.053	3.407	0.509	7	Aerial active	3	Free eggs	3	
<i>Tribelos intextus</i>	10.5	29	-7.053	3.407	2.610	7	Aerial active	3	Free eggs	3	

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Table S3 Redundancy analysis model (based on environmental variables) selected to explain variation in the assemblage structure of small-sized species

Variable	Cumulative adj. R ²	F	P
Wind fetch	0.07	6.03	≤0.002
Substratum diversity	0.08	2.15	0.008
Substratum mean particle size	0.10	2.03	0.016
Conductivity	0.11	2.04	0.016
Slope	0.12	1.78	0.018
NO ₂ +NO ₃ -N	0.13	1.72	0.032

Table S4 Redundancy analysis model (based on environmental variables) selected to explain variation in the assemblage structure of medium-sized species

Variable	Cumulative adj. R ²	F	P
Wind fetch	0.04	3.95	≤0.002
Periphyton biomass	0.07	3.39	≤0.002
Al	0.10	2.83	≤0.002
Substratum mean particle size	0.12	2.41	0.020
Substratum diversity	0.13	1.85	0.044
NO ₂ +NO ₃ -N	0.14	1.81	0.034

Table S5 Redundancy analysis model (based on environmental variables) selected to explain variation in the assemblage structure of large-sized species

Variable	Cumulative adj. R ²	F	P
Wind fetch	0.08	7.00	≤0.002
Total phosphorus	0.13	4.99	≤0.002
Macrophyte coverage	0.16	3.64	≤0.002
Fish biomass	0.18	2.01	0.044
Substratum mean particle size	0.20	2.84	0.010
Substratum diversity	0.22	2.97	≤0.002
NH ₄ -N	0.24	2.19	0.028

Table S6 Redundancy analysis model (based on environmental variables) selected to explain variation in the assemblage structure of non-flying species

Variable	Cumulative adj. R ²	F	P
Total phosphorus	0.04	3.70	0.010
Macrophyte coverage	0.08	4.19	0.004
Fish biomass	0.10	2.69	0.028
Substratum mean particle size	0.13	3.09	0.004
Substratum diversity	0.16	3.22	0.004
Wind fetch	0.19	3.07	0.004
NH ₄ -N	0.20	2.31	0.050

Table S7 Redundancy analysis model (based on environmental variables) selected to explain variation in the assemblage structure of flying species

Variable	Cumulative adj. R ²	F	P
Wind fetch	0.07	5.83	≤0.002
Total phosphorus	0.09	2.68	≤0.002
Periphyton biomass	0.10	2.15	≤0.002
NO ₂ +NO ₃ -N	0.11	1.74	0.012
Al	0.12	1.87	0.012
Substratum mean particle size	0.13	1.63	0.034
Substratum diversity	0.14	1.80	0.004
Conductivity	0.15	1.58	0.028

Table S8 Redundancy analysis model (based on environmental variables) selected to explain variation in the assemblage structure of species laying their eggs freely to the water

Variable	Cumulative adj. R ²	F	P
Total phosphorus	0.05	4.87	≤0.002
Wind fetch	0.08	2.77	≤0.002
Substratum diversity	0.09	2.21	≤0.002
Substratum mean particle size	0.11	2.38	0.006
Conductivity	0.12	1.79	0.014

Table S9 Redundancy analysis model (based on environmental variables) selected to explain variation in the assemblage structure of species attaching their eggs to the substrates

Variable	Cumulative adj. R ²	F	P
Wind fetch	0.07	6.42	≤0.002
Total phosphorus	0.10	2.89	≤0.002
Macrophyte coverage	0.13	3.36	≤0.002
Fish biomass	0.15	2.36	0.004
Substratum mean particle size	0.16	2.25	0.014
Al	0.17	1.93	0.008
NO ₂ +NO ₃ -N	0.19	1.94	0.016
NH ₄ -N	0.20	2.27	0.004
Substratum diversity	0.22	2.03	0.022

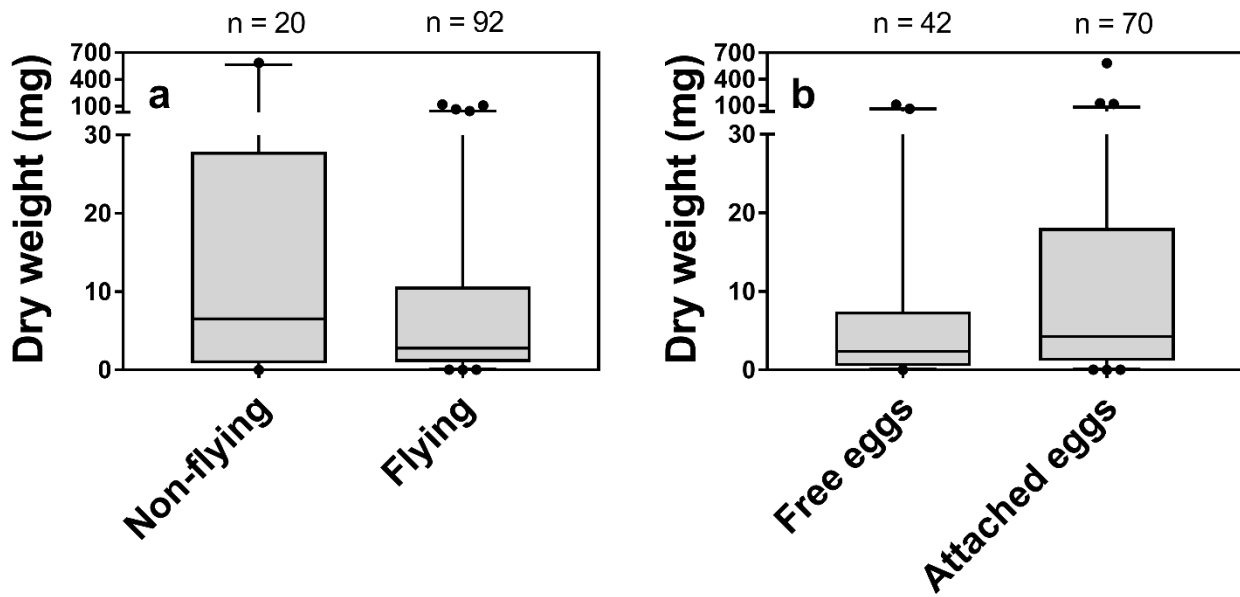


Fig. S1 Body size covariation with the other studied biological traits. **a** Body size variation among non-flying and flying macroinvertebrate species. **b** Body size variation among the species laying their eggs freely and among those attaching their eggs.

Table S10 Cross-tabulation of the numbers and relative proportions (%) of species in the groups of dispersal mode (non-flying and flying) and oviposition behaviour (free eggs and attached eggs).

	Number of species		% of species	
	Non-flying	Flying	Non-flying	Flying
Free eggs	3	39	15	42
Attached eggs	17	53	85	58
Total	20	92	100	100