Ecography

ECOG-01231
Viana, D. S., Figuerola, J., Schwenk, K., Manca, M., Hobæk, A., Mjelde, M., Preston, C. D., Gornall, R. J., Croft, J. M., King, R. A., Green, A. J. and Santamaría, L. 2015. Assembly mechanisms determining high species turnover in aquatic communities over regional and continental scales. – Ecography doi: 10.1111/ecog.01231

Supplementary material

APPENDIX 1. Sites and species lists.

Table A1. List of sampling sites ("lakes").

Region	Name	Latitude	Longitude
Spain	Puerto de Santa Maria	36.63333	-6.23333
	Laguna de	36.95887	-6.45043
	Cuquero	37.00885	-6.23645
	Laguna de Tollos	36.8497	-6.01665
	Laguna del Pilon	36.90318	-5.89827
	Laguna del Taraje, Sevilla	36.9	-5.89827
	Laguna Dulce de Zorrilla	36.85997	-5.86507
	Laguna Hondilla, Espera	36.87438	-5.8609
	Brazo del Este	37.18242	-6.03227
	Utrera 2	37.04308	-5.82312
	Alcaparrosa, Utrera	37.0481	-5.81675
	Laguna de Calderon, Lantejuela	37.3621	-5.1183
	Lantejuela, no name	37.38238	-5.1733
	Lantejuela, road	37.37218	-5.18673
	Cortijo Tranquila, Lantejuela	37.3621	-5.17667
	Laguna Dulce, Campillos, Malaga	37.04958	-4.83113
	Laguna de Santa Olalla	36.983	-6.48107
	Laguna Amarga, Jauja, Cordoba	37.31963	-4.61743
	Pond, Las Jarillas	37.78752	-5.83818
	Castillo de las Guardas	37.69086333	-6.376116667
Italy	Alserio	45.78472222	9.216666667
	Ghirla	45.91694444	8.822222222
	Idro	45.76666667	10.51666667
	Iseo	45.73333333	10.06666667
	Lugano	45.96666667	8.983055556
	Maggiore	45.96666667	8.9666765
	Mantova	45.15000133	10.8000035
	Mergozzo	45.95638889	8.463055556
	Mezzola	46.18334267	9.433337833
	Monate	45.78611111	8.664444444
	Montorfano	45.7825	9.1375
	Annone	45.80000567	9.333343
	Moro	45.86305556	10.1575
	Orta	45.81666667	8.4
	Piano	46.0333355	9.150007167
	Pusiano	45.80222222	9.273055556
	S.Maria	45.71666717	10.60000583
	Sartirana	45.7000095	9.416672
	Segrino	45.82916667	9.267222222
	Sirio	45.48333417	7.883334
	Varese	45.8	8.75
	Viverone	45.40138889	8.051388889
	Avigliana	45.05000883	7.383335333
	Candia	45.32361111	7.911944444
	Comabbio	46.76305556	8.691944444
	Como	46	9.266666667

	Endine	45.77777778	9.938055556
	Garda	45.66666667	11.7
	Garlate	45.81666917	9.400003333
Netherlands	Uitgeest	52.51667	4.733333
	Westerkoggenland	52.62842	4.925383
	Zwolle west	52.54408	6.0607
	Groningen	53.21667	6.633333
	Hilversum	52.25	5.1
	Drakensteun	52.18333	5.266667
	Sandbergen	52.18333	5.616667
	Posterenk	52.2013	6.11015
	Lindlust	52.03333	4.416667
	Gauda	52.03697	4.755633
	Huisen	51.93047	5.9466
	Dirksland	51.73512	4.061717
	Geeuw	53.0257	5.640283
	Korindijk	51.76998	4.33295
	Biesbos	51.76745	4.773117
	Werkendam	51.8094	4.7628
	Woudenhiem	51.81045	5.040267
	Vligmen	51.72043	5.246517
	Lith	51.81667	5.416667
	Cuigken	51.75253	5.809733
	Middenseeland	51.51667	3.733333
	Nieuwginneken	51.52585	4.818217
	Rigen	51.59168	4.891017
	Sandplat	51.3	3.733333
	Zwarte Meer	52.63333	5.95
	Drachten	53.0643	6.038833
	Ringwiel	52.98727	5.52855
	Britsiradeel	52.99043	5.57485
	Uitwellingerga	52.9843	5.74025
	Grote Vliet	52.7524	5.126717
Norway	Litlvatn (Kvingla)	64.89235	11.36077
	Blåvatn	64.91172	11.65295
	Sørvatn	64.91727	11.29623
	Storvatn	64.88693	11.38397
	Svantjørn	64.89992	11.12048
	Osplivatn	64.92523	11.05275
	Torkelvatn	64.90022	10.97293
	Staverengvatn	64.82703	11.30802
	Svarthamarvatn	64.91673	11.0269
	Grunntjørn	64.96397	11.8038
	Kvernhusvatn	64.82838	11.29055
	Væremsvatn	64.92342	11.52902
	Demmingsvatn	64.93918	11.7732
	Mølledalsvatn	64.91348	11.21475
	Storveavatn	64.84415	11.37553
	Litlvatn (Vikna)	64.91893	11.14423
	Vikestadvatn	64.91698	11.19638
	Lyngsnesvatn	64.96503	11.08058
	Jostakktjørn	64.92027	11.03165
	Kvernengvatn	64.93402	11.08397

	Dalavatn	64.89443	10.90487
	Vestervatn	64.85495	11.35443
	Klavavatn	64.91395	11.03488
	Laugen	64.85	11.3154
	Angeltjørn	64.96037	11.78692
	Eidshaugvatn	64.91577	11.44832
	Nordvatn	64.9313	11.3322
	Osavatn	64.9518	11.68672
	Aunevatn	64.9009	11.2732
	Damsgardvatn	64.90213	10.82935
Scotland	Alloa	56.01184	-3.78059
	Cockairney W	56.07854	-3.46225
	Coldrain	56.096	-3.49507
	Windyedge	56.27964	-3.52161
	Minkie Moss	56.28364	-3.48623
	Calais Muir Wood	55.97217	-3.39414
	Glenniston Quarry	56.02711	-3.26773
	Mugdrum	56.25937	-3.25925
	Innerleith	56.19767	-3.17663
	Gartmorn	56.03907	-3.74973
	Kilmux Farm	56.1454	-3.03016
	Gilston House	56.15534	-2.90162
	Harleswynd	56.19069	-2.9508
	Blebo	56.21759	-2.93534
	Newport on Tay	56.34259	-2.93839
	Morton Lochs	56.33413	-2.87348
	Balbuthie	56.11136	-2.8041
	Balmonth Resvr	56.15641	-2.74063
	Innergellie	56.14776	-2.69217
	Sheardale	56.05782	-3.68633
	U Glendevon Res	56.12809	-3.76987
	LGlendevon Res	56.12877	-3.72162
	Thorn	56.20084	-3.67648
	Charlestown E	55.95319	-3.48956
	Lurg Loch	56.06068	-3.46158
	Kettlehill	56.1627	-3.09504
	Loch Leven	56.10588	-3.41505
	Highholm	56.00732	-3.44352
	Glenquey Resvr	56.1118	-3.65653
	Loch Gelly	56.02694	-3.28377

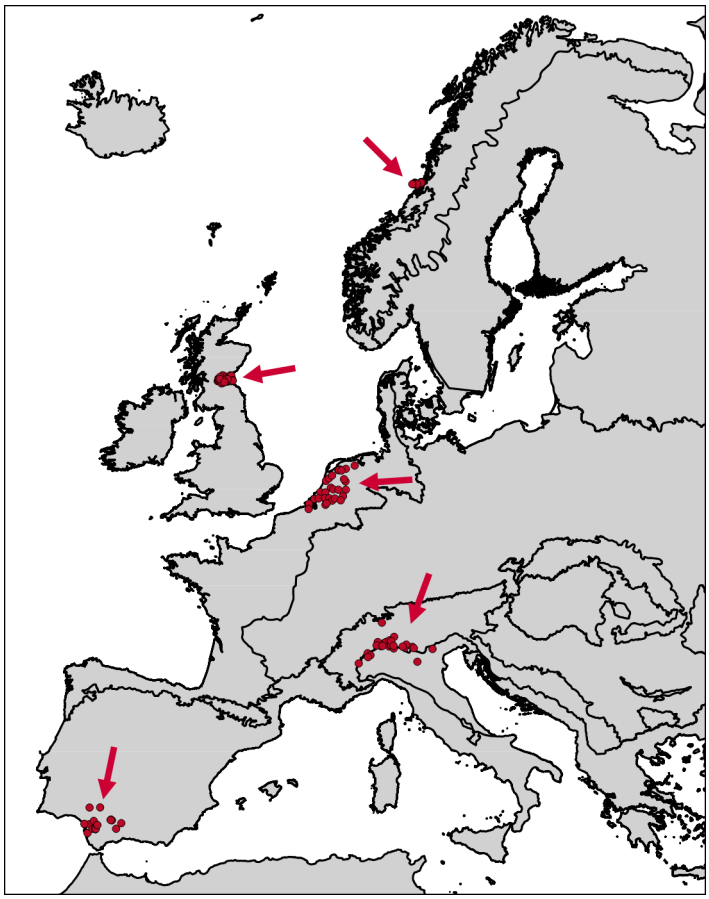
Table A2. List of species.

Aquatic angiosperms	**Cladocera**
Alisma plantago-aquatica	*Acroperus harpae*
Apium inundatum	*Alona affinis*
Callitriche hermaphroditica	*Alona guttata*
Callitriche spp.	*Alona intermedia*
Callitriche truncata	*Alona* spp.
Ceratophyllum demersum	*Alona quadrangularis*
Elodea canadensis	*Alona rectangula*
Elodea nuttallii	*Alona rustica*
Hippuris vulgaris	*Alonella excisa*
Isoetes echinospora	*Alonella exigua*
Isoetes lacustris	*Alonella nana*
Juncus bulbosus	*Alonella* spp.
Lagarosiphon major	*Alonopsis elongata*
Lemna minor	*Anchistropus emarginatus*
Lemna trisulca	*Anchistropus minor*
Littorella uniflora	*Bosmina longirostris*
Lobelia dortmanna	*Bosminidae* spp.
Mentha aquatica	*Bythotrephes longimanus*
Myriophyllum alterniflorum	*Camptocercus rectirostris*
Myriophyllum spicatum	*Ceriodaphnia dubia*
Najas marina	*Ceriodaphnia laticaudata*
Nelumbo nucifera	*Ceriodaphnia* spp.
Nuphar lutea	*Ceriodaphnia pulchella*
Nuphar pumila	*Ceriodaphnia quadrangula*
Nymphaea alba	*Ceriodaphnia reticulata*
Nymphoides peltata	*Chydorus piger*
Polygonum amphibium	*Chydorus* spp.
Potamogeton alpinus	*Chydorus sphaericus*
Potamogeton berchtoldii	*Daphnia ambigua*
Potamogeton crispus	*Daphnia cristata*
Potamogeton filiformis	*Daphnia cucullata*
Potamogeton friesii	*Daphnia galeata*
Potamogeton gramineus	*Daphnia galeata* hybrid
Potamogeton lucens	*Daphnia galeata* × *cucullata*
Potamogeton natans	*Daphnia hyalina*
Potamogeton nodosus	*Daphnia hyalina* × *galeata*
Potamogeton obtusifolius	*Daphnia hylaina* × *cucullata*
Potamogeton pectinatus	*Daphnia longispina*
Potamogeton perfoliatus	*Daphnia magna*
Potamogeton polygonifolius	*Daphnia* spp.
Potamogeton pusillus	*Daphnia pulex*
Potamogeton trichoides	*Daphnia pulicaria*
Potamogeton × *nitens*	*Daphnia rosea*
Potamogeton × *sparganiifolius*	*Daphnia similis*
Potamogeton × *suecicus*	*Daphnia tenebrosa*
Ranunculus subgen. *Batrachium*	*Diaphanosoma brachyurum* group
Ruppia drepanensis	*Diaphanosoma laticaudata*
Ruppia maritima	*Diaphanosoma* spp.
Sparganium angustifolium	*Disparalona rostrata*
Sparganium emersum	*Dpahnia obtusa*

Sparganium hyperboreum
Stratiotes aloides
Subularia aquatica
Trapa natans
Utricularia intermedia
Utricularia minor
Utricularia vulgaris
Vallisneria spiralis
Zannichellia palustris/pedunculata/major
Zannichellia peltata/obtusifolia

Drepanothrix dentata
Duhnevedia crassa
Eubosmina coregoni
Eubosmina longicornis
Eubosmina longicornis × *coregoni*
Eubosmina longispina
Eubosmina longispina × *coregoni*
Eubosmina longispina × *longicornis*
Eubosmina spp.
Eurycercus lamellatus
Eurycercus lamellatus/glacialis
Graptoleberis testudinaria
Holopedium gibberum
Ilyocryptus sordidus
Latona setifera
Leptodora kindti
Leydigia acanthocercoides
Leydigia leydigi
Leydigia spp.
Macrothricidae spp.
Moina affinis
Moina brachiata
Moina micrura
Moina spp.
Monospilus dispar
Ophryoxus gracilis
Oxyurella tenuicaudis
Pleopis polyphemoides
Pleuroxus aduncus
Pleuroxus denticulatus
Pleuroxus spp.
Pleuroxus spp. (not *truncatus*)
Pleuroxus striatus
Pleuroxus trigonellus
Pleuroxus truncatus
Pleuroxus uncinatus
Pleuroxus validentatus
Polyphemoidae (family)
Polyphemus pediculus
Pseudochydorus globosus
Rynchotalona falcata
Scapholeberis mucronata
Sida crystallina
Sididae (family)
Simocephalus expinosus
Simocephalus spp.
Simocephalus serrulatus
Simocephalus vetulus

Figure A1. Map showing the sampling locations (points) in five different regions across Europe (arrows). Black borders delimit biogeographic regions.



APPENDIX 2. Sampling of cladocerans.

Living cladocerans were sampled by vertical hauling in the water column using 90 μm mesh plankton nets with 30 cm of diameter, except in shalow lakes less than 1.5 m deep, where we used horizontal hauls along a transect of 10 m. "Live" samples were screened under a dissecting microscope, and species were identified largely following Flössner (2000), except for bosminids, which were identified according to Flössner (1972) and Lieder (1996). Putative hybrids within the *Daphnia longispina* complex and those resulting from *Bosmina* (*Eubosmina*) species were identified after Wolf and Mort (1986) and Lieder (1983, 1996) respectively. To obtain a fully representative sample of both littoral and pelagic cladocerans covering the recent history of the lake, we also took samples of sediments at the deepest part of each lake (one sample per lake). Sediments accumulate remains from all microhabitats over seasons and years, therefore providing an overview of all species present in the lake in recent years. Sediment samples were taken using corers or small van Veen grabs; in both cases, only the top (i.e. recent) sediments were collected. Cladoceran remains were analysed according to Frey (1986). Wet sediment was deflocculated in 100 ml of 10% KOH at 100ºC for 20 minutes and passed through a 40 micron sieve. The residue was then transferred into 5% formalin. We counted all remains (headshields, shells, postabdomens, postabdominal claws, mandibles, and others) until at least 200 individuals had been accounted for (excluding Bosminids, which usually dominated numerically). *Bosmina* was divided into subgenera (*Eubosmina* and *Bosmina*) based on the location of the lateral head pores (Goulden and Frey 1963; Hofmann 1984).

References (for Appendix 2 only)

Flössner, D. 1972. Krebstiere, Crustacea. Kiemen- und Blattfüsser, Branchiopoda. Fischläuse, Branchiura. – Tierwelt Deutschlands 60.

Flössner, D. 2000. Die Haplopoda und Cladocera (ohne Bosminidae) Mitteleuropas. – Backhuys Publisher.

Frey, D. G. 1960. The ecological significance of cladoceran remains in lake sediments. – Ecology 41:684-699.

Frey, D. G. 1986. Cladocera analysis – In: B. E. Berglund (ed.), Handbook of Holocene palaeoecology and palaeohydrology. Wiley-Interscience; John Wiley & Sons.

Goulden C. E. and Frey, D. G. 1963. The occurrence and significance of lateral head pores in the genus Bosmina (Cladocera). – Int. Rev. Gesamten Hydrobiol. Hydrogr. 48: 513-522.

Hofmann W. 1984. Morphological variation in a late glacial population of Bosmina longispina Leydig (Crustacea, Cladocera) from the Lobsigensee (Swiss Plateau). Studies in the Late-Quaternary of Lobsigensee. – Schweiz. Z. Hydrol. 46: 139-146.

Lieder U. 1983. Revision of the genus Bosmina Baird, 1845 (Crustacea, Cladocera). – Int. Rev. Gesamten Hydrobiol. Hydrogr. 68, 121-139.

Lieder U. 1996. Crustacea Cladocera Bosminidae. Susswasser Fauna von Mitteleuropa. Band 8/Heft 2-3. – Fisher Verlag.

Wolf A.G and M. Mort. 1986. Inter-specific hybridization underlies phenotypic variability in Daphnia populations. – Oecologia 68: 507-511.

APPENDIX 3. Supplementary tables and figures

Table C1. Statistical information for the global and exclusive fractions of all components considered in the variation partitioning analysis. Global fractions: E, environmental component; B, biotic component; R, regional component (variation among regions); C, connectivity component (within regions). Unique fractions are denoted as A|B,C,R; B|A,C,R; C|A,B,R; and R|A,B,C.

Taxon	Source	adjR^2	d.f. model	d.f. residuals	F	p
Plants	A	0.370	10	92	4.739	0.001
	B	0.338	3	99	12.935	0.001
	C	0.116	4	98	3.288	0.001
	R	0.330	4	98	9.546	0.001
	A|B,C,R	0.094	10	81	1.653	0.001
	B|A,C,R	0.092	3	81	3.850	0.001
	C|A,B,R	0.031	4	81	1.412	0.009
	R|A,B,C	0.035	4	81	1.500	0.009
Cladocera	A	0.340	9	93	4.825	0.001
	B	0.309	3	99	11.812	0.001
	C	0.075	4	98	2.385	0.001
	R	0.315	4	98	9.231	0.001
	A|B,C,R	0.070	9	82	1.487	0.001
	B|A,C,R	0.096	3	82	3.961	0.001
	C|A,B,R	0.009	4	82	0.856	0.826
	R|A,B,C	0.034	4	82	1.524	0.002

Table C2. Statistical information for the global and unique fractions of all components considered in the variation partitioning analysis using the complete-cases dataset (i.e., only sites without missing data, N=67). Global fractions: E, environmental component; B, biotic component; R, regional component (variation among regions); C, connectivity component (within regions). Unique fractions are denoted as A|B,C,R; B|A,C,R; C|A,B,R; and R|A,B,C.

Taxon	Source	adjR^2	d.f. model	d.f. residuals	F	p
Plants	A	0.435	9	57	4.774	0.001
	B	0.287	2	64	11.192	0.001
	C	0.144	4	62	3.046	0.001
	R	0.344	3	63	9.615	0.001
	A|B,C,R	0.145	9	48	1.967	0.001
	B|A,C,R	0.047	2	48	2.347	0.001
	C|A,B,R	0.049	4	48	1.541	0.012
	R|A,B,C	0.055	3	48	1.979	0.001
Cladocera	A	0.492	9	57	5.645	0.001
	B	0.446	3	63	13.740	0.001
	C	0.094	4	62	2.215	0.002
	R	0.399	3	63	11.719	0.001
	A|B,C,R	0.138	9	47	1.921	0.001
	B|A,C,R	0.075	3	47	2.516	0.001
	C|A,B,R	0.011	4	47	0.796	0.892
	R|A,B,C	0.016	3	47	0.993	0.493

Table C3. Global fractions of the constrained analysis of principal coordinates and variation partitioning results (between brackets) for each region and taxonomic group (aquatic plants, upper values; cladocerans, lower values). Variables entering the variation partitioning analysis were forward-selected for each matrix (abiotic, biotic, connectivity and spatial matrices) with a relaxed alpha level (= 0.1) as the stopping criterion. Significance (alpha < 0.05) in indicated in bold. Non-significant values (NS) were assessed for the biotic component by cross-validatory fit values ≤ 0 in the CoCA analysis.

Region	Abiotic		Biotic		Connectivity		Spatial	
	adjR²	**p**	**adjR²**	**p**	**adjR²**	**p**	**adjR²**	**p**
Spain	0.248 (0.299)	**0.027 (0.018)**	NS	NS	0.357 (0.163)	**0.043** (0.067)	NS	0.738
	0.122	**0.01**	NS	NS	NS	0.534	NS	0.262
Italy	0.122	**0.011**	NS	NS	NS	0.286	NS	0.602
	0.18	**0.001**	NS	NS	NS	0.198	NS	0.601
Netherlands	0.545	**0.014**	NS	NS	NS	0.111	NS	0.606
	0.319	**0.042**	NS	NS	NS	0.422	NS	0.11
Scotland	0.385 (0.180)	**0.024 (0.033)**	0.533 (0.430)	**0.001 (0.001)**	0.15 (0.008)	**0.027** (0.716)	NS	0.759
	0.324	**0.003**	NS	NS	NS	0.634	NS	0.903
Norway	0.48 (0.142)	**0.001 (0.001)**	0.332 (0.118)	**0.001 (0.001)**	0.125 (0.007)	**0.034** (0.622)	0.287 (0.118)	**0.018 (0.026)**
	0.267	**0.073**	NS	NS	NS	0.191	NS	0.225

Table C4. Forward selection of environmental variables. Values indicate the (unadjusted) coefficient of determination (R^2). All selected variables are statistically significant ($p<0.05$). Tmean, mean annual temperature; Tmin; mean temperature of the coldest month; Tmax, mean temperature of the warmest month; TP, total phosphorus.

Variable	Plants	Zooplankton
Precipitation	0.096	0.101
Tmean	0.012	0.043
Tmin	0.037	0.039
Tmax	0.051	Not selected
Altitude	0.012	0.017
Area	Not selected	0.012
Depth	0.011	Not selected
Secchi	0.019	0.013
Ca	0.020	0.013
TP	0.016	0.017
Conductivity	Not selected	0.015
pH	0.018	Not selected

Figure C1. Cross-validatory fits of the co-correspondence analysis (CoCA) for plants (A; effect of cladoceran species composition) and cladocerans (B; effect of plant species composition).

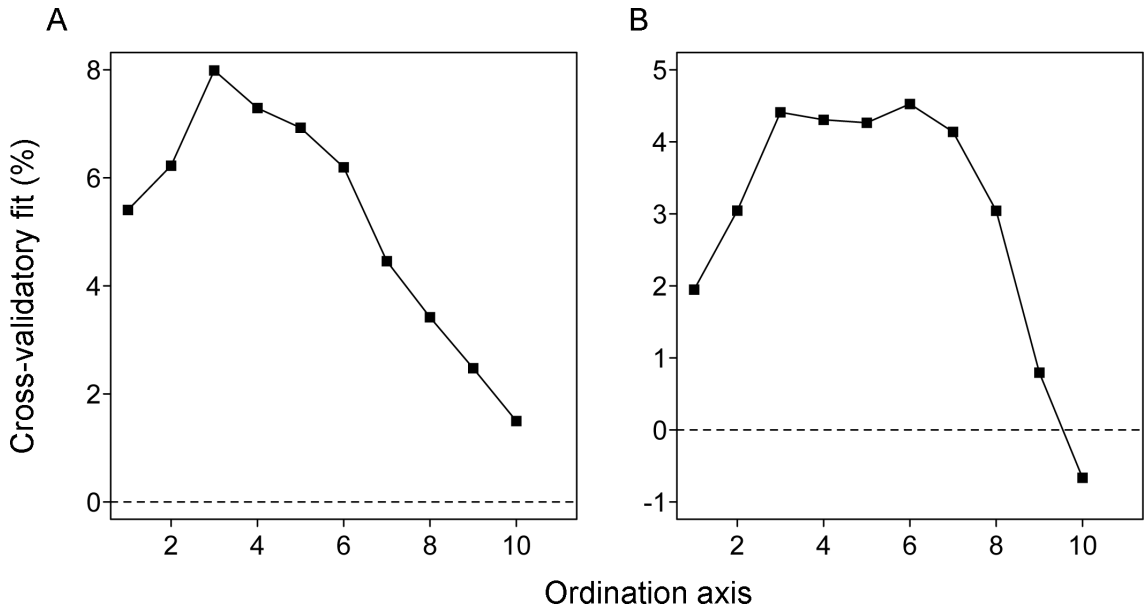


Figure C2. Mantel correlograms for aquatic plants and cladocerans in each surveyed region. Species data was linearly detrended. Filled and empty circles denote significant and non-significant correlations respectively.