Ecography

ECOG-03137
Pinkert, S., Dijkstr, K.-D. B., Zeuss, D., Reudenbach, C., Brandl, R. and Hof, C. 2017. Evolutionary processes, dispersal limitation and climatic history shape current diversity patterns of European dragonflies. – Ecography doi: 10.1111/ecog.03137

Supplementary material

Appendix 1: Phylogenetic analysis

The backbone-topology was constructed according to the most comprehensive and recent phylogeny of European dragonflies (Dijkstra and Kalkman 2012). Additional studies enabled resolving some of the remaining multifurcations within the genera *Cordulegaster* (Froufe et al. 2014), *Chalcolestes* (i.e. *Lestes parvidens* and *Lestes viridis*), *Coenagrion*, *Erythromma* (Dumont et al. 2010) and *Trithemis* (Damm et al. 2010). For the final version of the topology see Fig. A2. In addition, sequences for up to nine different loci (COI, COII, ITS1, ITS2, 5.8S, 12S, 16S, 18S, 28S) and 121 species were automatically compiled from GenBank repository with PYLOGENERATOR (Pearse and Purvis 2013, accessed December 17th, 2015). Taxon sampling and GenBank accession numbers are given in Table A2. The data was aligned by hand and with MUSCLE algorithm in MEGA (Tamura et al. 2013). For each alignment, we ran separate model-tests in MEGA. Five different models of nucleotide substitution were selected according to highest Bayesian Information Criterion scores (BIC; Table A3). After adjusting taxon similarity among alignments by replacing missing sequences with blanks, we used BEAUTI (Drummond et al. 2012) to link the alignments and to integrate taxonomic information by enforcing monophyly at 90 internal knots (see tree in Fig. A3). Branch-lengths were inferred with an estimated lognormal relaxed molecular clock for 50 million MCMC simulations (Yule birth) with a Bayesian approach in BEAST (Drummond et al. 2012). Statistics were sampled every 5,000th iteration. We used diagnostics in TRACER to determine the burn-in based on the point of stationarity on the log-likelihood curves as well as split-frequencies and to evaluate the choice of the right molecular clock according to the coefficient of variation. We used ANNOTATOR (Drummond et al. 2012) to exclude an appropriate burn-in of 10% from the posterior sample, to summarize the statistics of the remaining trees and to annotate this information to the tree with the highest clade credibility. Trees were visualized and formatted in FIGTREE (Drummond et al. 2012).

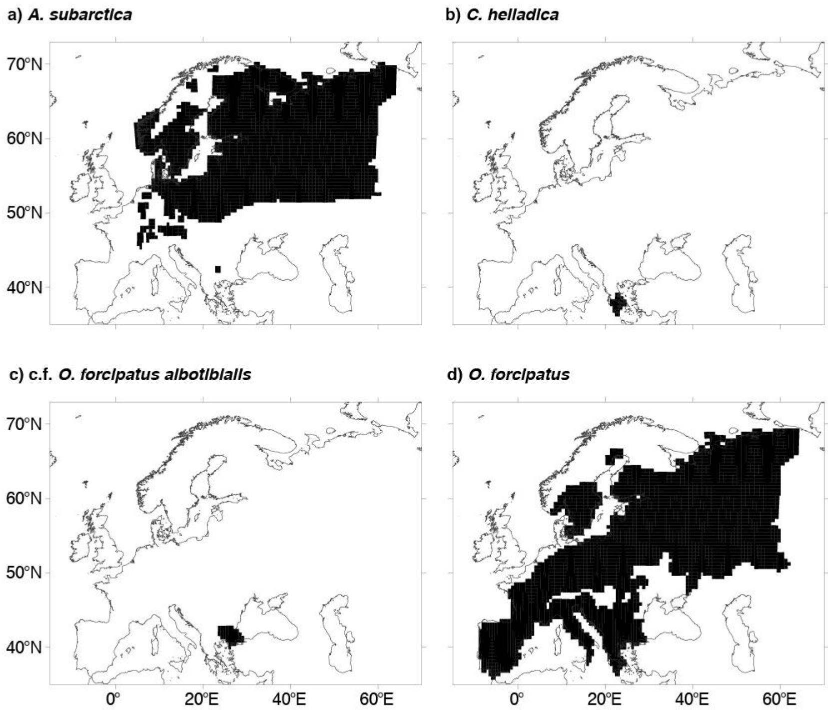

Figure A1. Geographical distribution of **(a)** *Aeshna subarctica*, **(b)** *Cordulegaster helladica* and **(d)** *Onychogomphus forcipatus*, which were redrawn from maps provided in Dijkstra and Lewington (2006) and in Boudot and Kalkman (2016) (EPSG: 4326; equal-area grid CGRS). The distribution of *Onychogomphus forcipatus* needed to be redrawn because **(c)** the maps provided by the IUCN (Riservato et al. 2009, Kalkman et al. 2010) only represent the occurrences of its eastern subspecies – *O. f. albotibialis*.

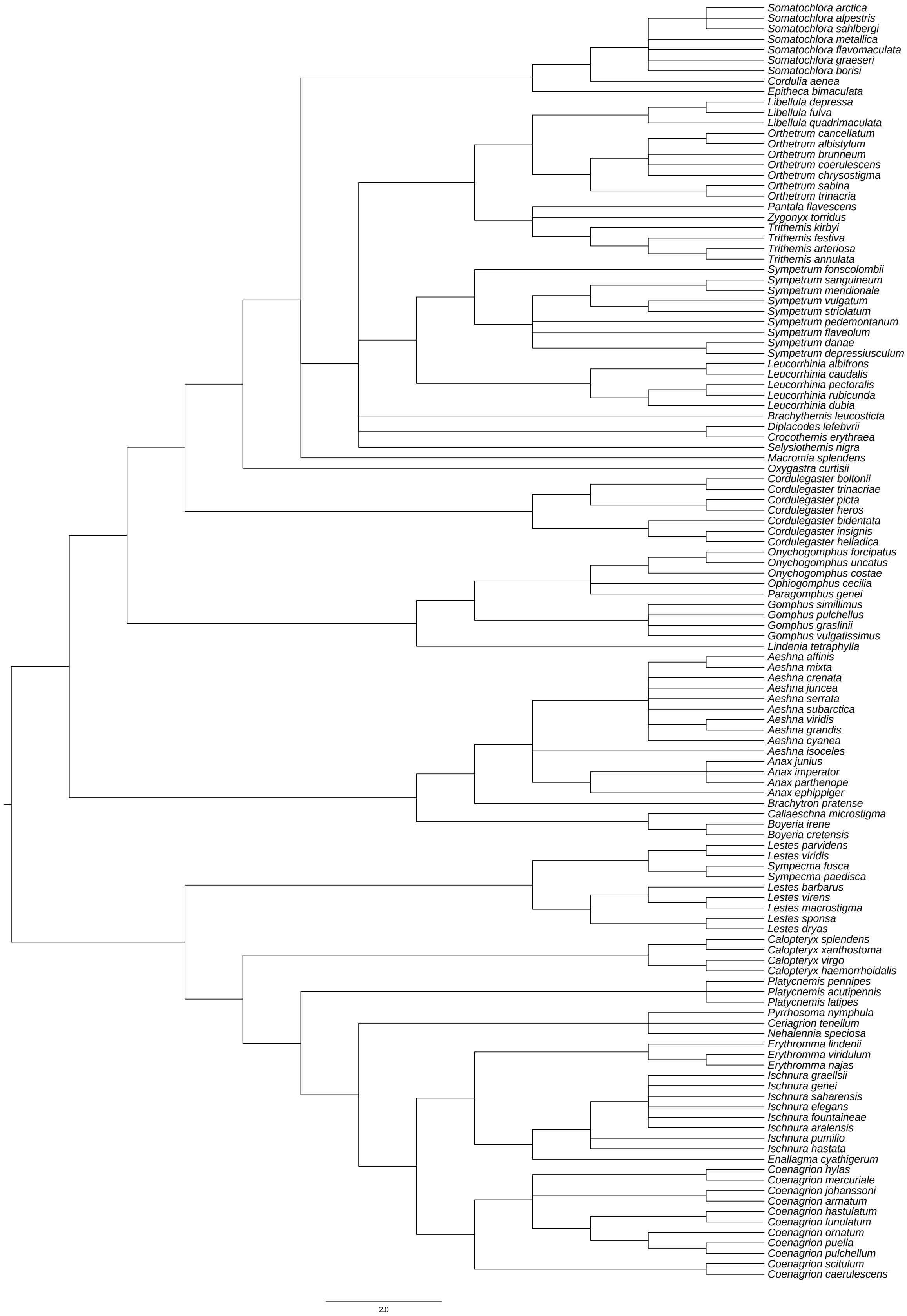

Figure A2. Unresolved backbone-topology representing available taxonomic information on 122 of in total 138 European dragonfly species. Note that this tree is the consensus of several literature-sources, cited in the Appendix A1.

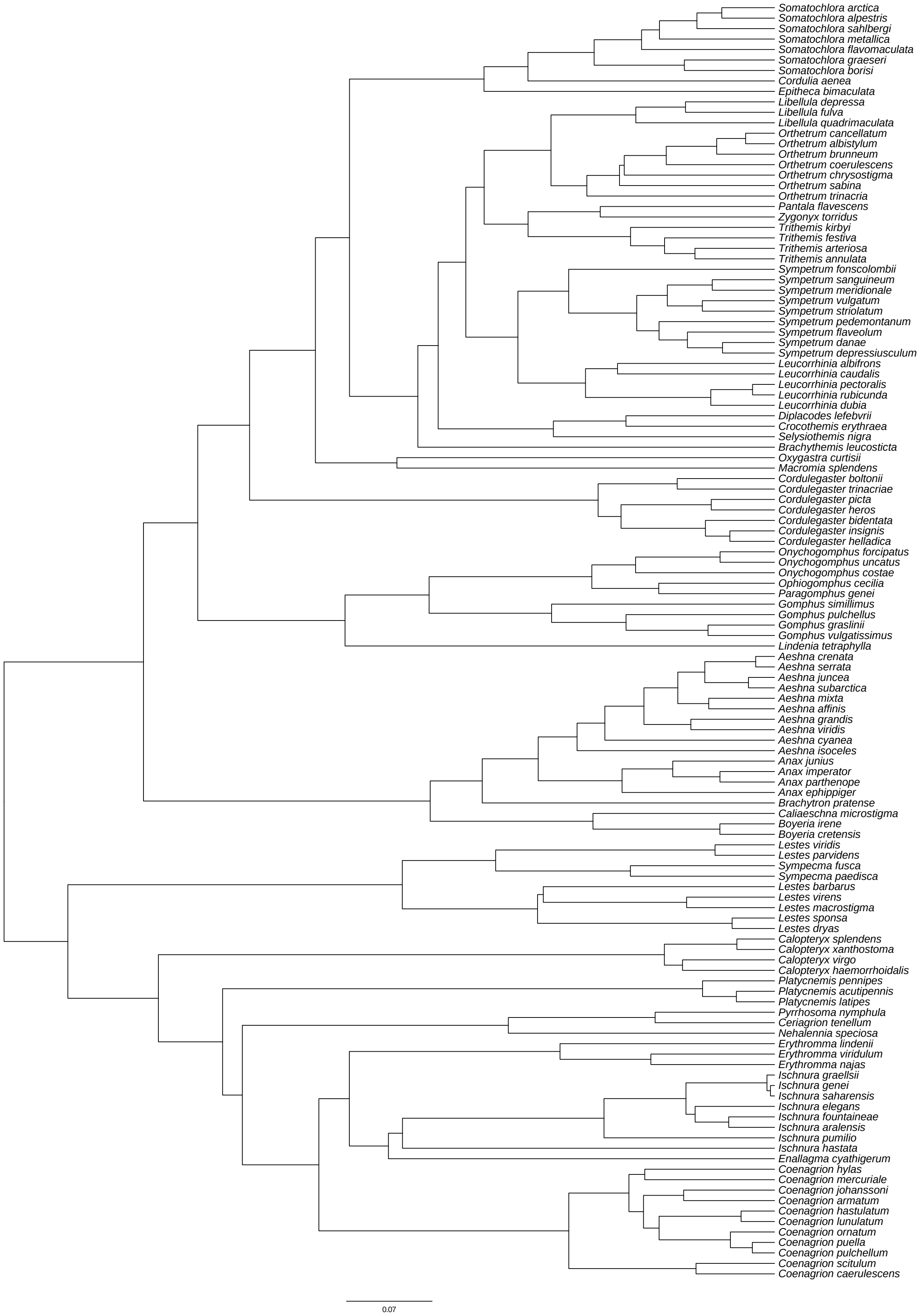

Figure A3. Phylogeny of 122 European dragonflies, representing the combination of available taxonomic information and molecular data for up to nine different loci. Branch-lengths were inferred with an estimated lognormal relaxed molecular clock for 50 million independent runs using a Bayesian approach. For details on the construction see the Appendix A1.

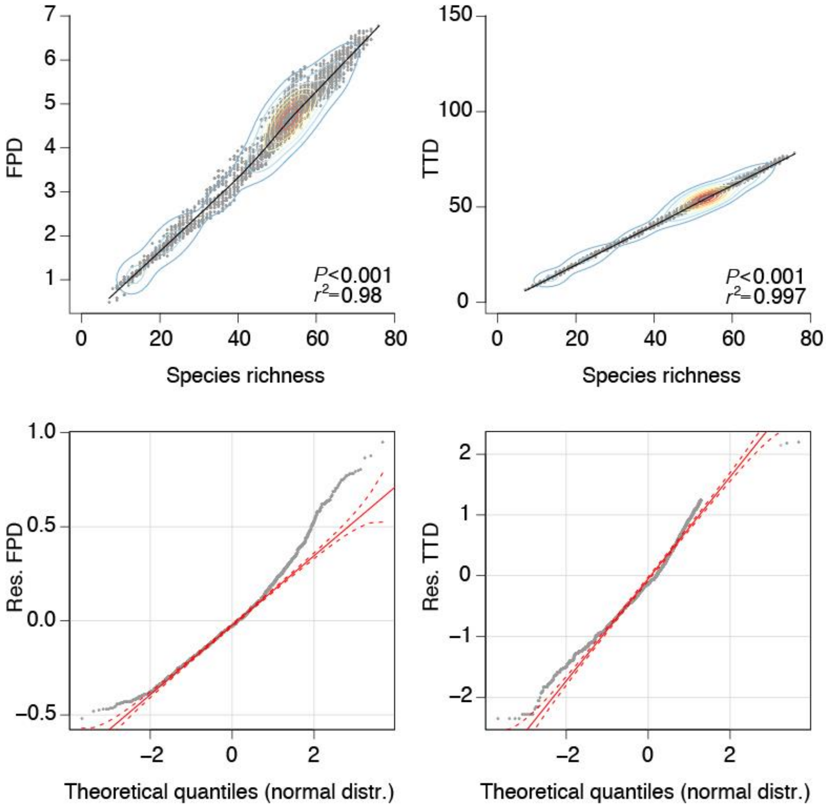

Figure A4. Correlations of Faith's phylogenetic diversity (FPD, i.e. the minimum spanning tree) and total taxonomic distinctiveness (TTD, i.e. sum of pairwise distances) against species richness and Quantile-Quantile-plot of the residuals from spline-based smoothed regressions of these relationships across 4,192 assemblages of European dragonflies. Black lines were fitted with spline-based smoothed regressions. Coloured contour lines indicate data density. Note that only the variance of TTD is independent from the respective species richness value, i.e. satisfies homoscedasticity, whereas the variance of FPD shows strong outliers at higher fitted values.

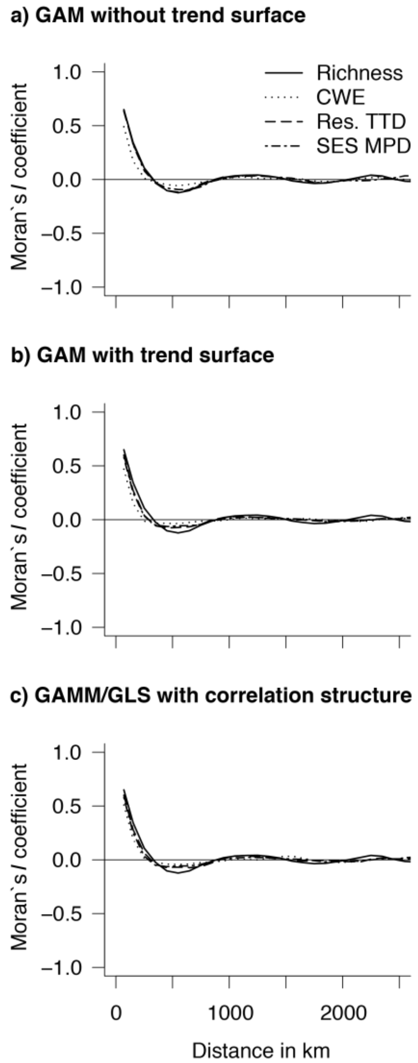

Figure A5. Spatial autocorrelation (Moran's *I* coefficient) in the residuals of multiple regressions of species richness (Richness), corrected weighted endemism (i.e. geometric mean of the inverse occupancy of co-occurring species, CWE), the residuals of spline-based smoothed regressions of total taxonomic distinctiveness (i.e. sum of pairwise distances) and species richness (Res. TTD) and effect-sizes of mean pairwise distances (SES MPD) against seven predictor variables. Predictor variables were species richness, four principal components that describe temperature and precipitation, the proportion of lentic to lotic species and the location of the 0°C isotherm at the last glacial of 4,192 assemblages of European dragonflies. Results are presented for regressions that were modelled **(a)** with and **(b)** without a trend surface (i.e. smoothed term) of geographical coordinates as an additional independent variable that accounts for spatial autocorrelation in the model residuals. In addition, autocorrelation was modelled using **(c)** a Gaussian spatial correlation structure of geographical coordinates in generalized additive mixed models (a generalized least squares model in the case of species richness). Note that spatial independence (i.e. the distance beyond which the effect of spatial similarity was no longer significant) was reached at about 500 km for the residuals of the regressions modelled without and with trend surface term or a Gaussian spatial correlation structure, indicating that the other environmental variables (e.g. temperature and precipitation) already reduced spatial autocorrelation to a minimum.

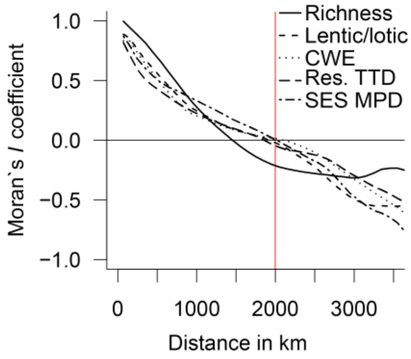

Figure A6. Spatial autocorrelation (Moran's *I* coefficient) of four different measures of diversity and the proportion of lentic to lotic species (lentic/ lotic) across 4,192 assemblages of European dragonflies. Variable abbreviations are Richness: total species number, CWE: corrected weighted endemism (i.e. geometric mean of the inverse occupancy of co-occurring species), Res. TTD: Residuals of spline-based smoothed regressions of total taxonomic distinctiveness (i.e. sum of pairwise distances) against species richness, SES MPD: standardised effect-sizes of mean pairwise distances. Note that in all measures except species richness, spatial independence (i.e. the distance beyond which the effect of spatial similarity was no longer significant) was reached at about 2,000 km (vertical red line), indicating large scale spatial autocorrelation.

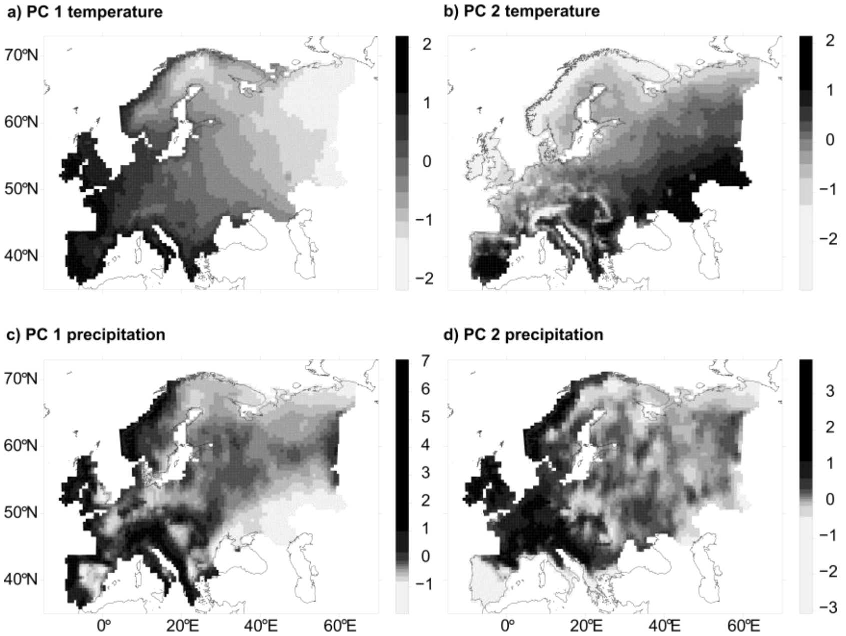

Figure A7. Spatial variation of four principal components that characterise major temperature and precipitation trends of a set of 19 biologically relevant variables. The data were downloaded at worldclim.org (BIOCLIM version 1.4). Colour class intervals are scaled according to equal frequencies (quantiles).

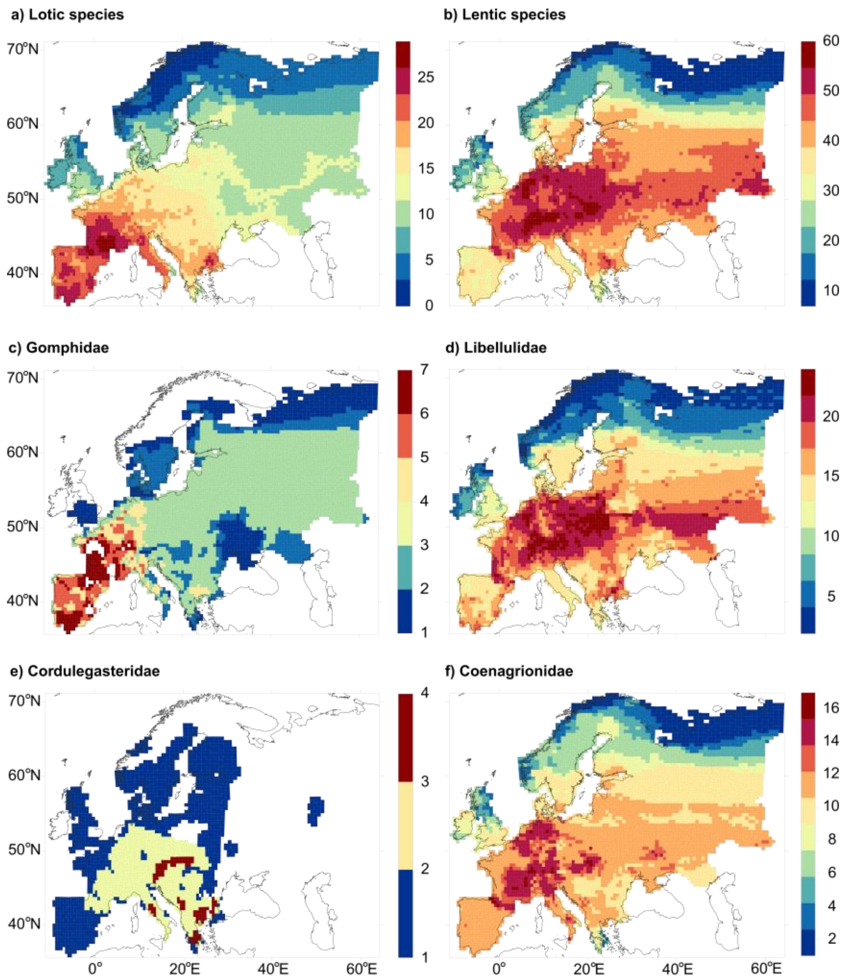

Figure A8. Geographic distribution of species **(a)** species developing in lotic and **(b)** lentic habitats, as well as of species that belong to the two biggest predominately **(c, e)** lotic and **(d, f)** lentic families across 4,192 assemblages of European dragonflies (EPSG: 4326; equal-area grid CGRS). Colour class intervals are scaled according to equal class breadth. Note that the richness of lotic species decreases gradually from south-west and south-east to north-east, whereas the richness of lentic families is highest in central Europe.

Table A1. List of 17 of in total 138 European dragonfly species for which no phylogenetic information was available. One of them, *Orthetrum cancellatum*, was added to the phylogeny according to taxonomic information. However, sixteen species were not considered because it lacked either taxonomic information, distribution data or because their ranges were outside the study area (number of occupied grid cells is provided).

Species	Taxonomic information	Phylogenetic information	Occupied grid cells	Geographic Distribution	Comments
Aeshna caerulea	-	-	1867	Northern Europe	
Anax immaculifrons	-	-	52	Balkan	
Ceriagrion georgifreyi	-	-	0	Greek archipelagos	Range is outside of study area. Species was **not considered**.
Coenagrion ecornutum	-	-	14	Southern Ural	
Coenagrion intermedium	-	-	0	Crete	Range is outside of study area. Species was **not considered**.
Epallage fatime	Dijkstra & Kalkman, 2012	-	153	Greece	Only member of the Eupaedidae in Europe. The next relatives in Europe are probably the Calopterygidae, but Dijkstra & Kalkman (2012) and an analysis by Dumont suggest that several other tropical families are between them. The species was therefore **not considered**.
Gomphus flavipes	Dijkstra & Kalkman, 2012	-	2207	Central Europe	According to Dijkstra & Kalkman (2012) controvert status: Stylurus/ Gomphus. Species was **not considered**.
Gomphus schneiderii	-	-	-	-	Data deficient
Onychogomphus ubadschii	-	-	-	-	Data deficient
Orthetrum cancellatum	Dijkstra & Kalkman, 2012	-	3777	Europe, except most northern parts	Species was **added** according to taxonomic information.
Orthetrum nitidinerve	-	-	284	Iberian peninsular & southern Italy	
Orthetrum taeniolatum	-	-	175	Greece	
Platycnemis subdilatata	-	Yes	0	Gran Canaria	Range is outside of study area. Species was **not considered**.
Pyrrhosoma elisabethae	-	-	14	Greece	
Sympetrum nigrifemur	-	-	0	Canaries	Range is outside of study area. Species was **not considered**.
Sympetrum sinaiticum	-	-	61	Spain	

Table A2. Taxon sampling, GenBank accession numbers and total number of base pairs for nine loci of 121 European dragonfly species.

Species	5.8S	12S	16S	18S	28S	ITS1	ITS2	COI	COII	Number of bp
Aeshna affinis	-	EU477647	EU477647	-	FJ596629	-	-	-	-	3680
Aeshna crenata	AB711407	-	KF256875	AB706685	AB711402	AB706679	AB706685	AB711455	-	5311
Aeshna cyanea	FN356031	-	AF037177	X89481	FN356031	FN356031	FN356031	AF195739	-	12588
Aeshna grandis	-	EU477645	EU477645	-	FJ596630	-	-	KC912203	-	7402
Aeshna isoceles	FN356032	EU477649	EU183249	DQ008199	FN356032	FN356032	FN356032	-	-	13026
Aeshna juncea	AB706693	EU477646	AB707642	AB706693	AB706694	AB711414	AB711415	AB708586	-	6606
Aeshna mixta	AB706697	EU477648	KF256878	AB706697	AB706697	AB706697	AB706697	KC912204	-	7163
Aeshna serrata	AB706699	-	AB707650	AB706698	AB706698	AB706699	AB706699	AB708594	-	4192
Aeshna subarctica	AB711410	-	AB707651	AB711410	AB706700	AB711413	AB711411	AB711460	-	4082
Aeshna viridis	KU180366	-	-	-	KU180366	KU180366	KU180366	KU180301	-	1319
Anax (Hemianax) ephippiger	FN356093	EU477650	AB707654	FN356093	FN356093	FN356093	FN356093	AB708598	-	4083
Anax imperator	FN356035	EU477652	EU183256	FN356035	FN356035	FN356035	FN356035	KC912221	-	12639
Anax junius	-	AY282557	AB707656	AY338719	FJ009959	-	-	AB708600	EU055328	7238
Anax parthenope	AB706712	EU477651	KF256853	AB706718	KF256926	AB706720	AB706713	AB708611	DQ166787	7379
Boyeria cretensis	-	-	-	-	-	-	-	KM518217	-	447
Boyeria irene	FN356042	EU477640	EU477640	FN356042	FJ596627	FN356042	FN356042	KM518220	-	6472
Brachythemis leucostricta	-	EF640412	EF631573	-	-	-	-	-	-	1669
Brachytron pratense	FN356043	EU477641	EU055106	FN356043	EF631258	FN356043	FN356043	KC912235	-	9231
Caliaeschna microstigma	-	EU477639	EU477639	DQ008197	EU055297	-	-	-	-	9192
Calopteryx haemorrhoidalis	FN356047	-	KC912444	AJ458975	FJ596626	AJ308348	AJ308350	-	-	8600
Calopteryx splendens	AJ308366	EU477612	AF170955	AJ458965	AJ308362	AJ308365	AJ308363	DQ411707	-	10389
Calopteryx virgo	AJ308357	-	EU183237	AJ458970	AJ308363	AJ308359	AJ308356	DQ411708	-	8536
Calopteryx xanthostoma	AJ308353	-	AF170954	AJ458971	AJ459196	AJ308352	AJ308353	-	-	6727
Ceriagrion tenellum	FN356055	-	-	FN356055	AJ308352	FN356055	FN356055	KC912308	-	12240
Coenagrion armatum	KM660063	-	KM660002	KM660063	FN356055	KM660064	KM660063	-	KM659949	4076
Coenagrion caerulescens	FN356062	-	KM660007	FN356062	KM660038	FN356062	FN356062	-	KM659953	9524
Coenagrion hastulatum	FN356063	-	KM660019	KM660076	KM660037	FN356063	FN356063	-	-	8253
Coenagrion hylas	FN356064	-	AB707539	AB706589	FN356063	AB706588	AB706589	AB708483	KM659959	7849
Coenagrion johanssoni	KM660064	-	KF256885	KM660068	KF256958	FN356067	KM660068	KF257103	KM659950	5619
Coenagrion lunulatum	KM660072	-	-	FN356067	FN356067	FN356068	FN356067	-	-	10464
Coenagrion mercuriale	KM660065	-	KM660018	KM660075	KM660034	AJ621059	FN356068	-	KM659963	9466
Coenagrion ornatum	KM660071	-	KM660015	AJ621059	KM660045	AJ488546	AJ621059	-	KM659960	9409
Coenagrion puella	AJ488546	AF232897	KM660000	KM660061	KM660030	AJ488547	AJ488546	-	KM659947	9713
Coenagrion pulchellum	KM660067	-	KF369677	KM660067	AJ488547	FN356070	AJ488547	KF369350	KM659957	7572
Coenagrion scitulum	KM660066	-	KM660005	KM660073	KM660035	-	FN356070	-	KM659948	7768
Cordulegaster bidentata	KF584980	-	-	KF584984	FN356071	FN356071	FN356071	KF584963	EF155432	3122
Cordulegaster boltonii	KF584981	EU477688	EU477688	KF584987	FJ596634	FN356072	FN356072	KF584953	-	7321
Cordulegaster helladica	-	-	-	KF584983	-	-	-	KF584939	-	950
Cordulegaster heros	KF584991	-	-	KF584991	-	-	-	KF584940	-	985
Cordulegaster insignis	FN356073	-	-	FN356073	FN356073	FN356073	FN356073	KF584942	-	12935
Cordulegaster picta	KF584993	EU477685	EU477685	KF584992	FJ596637	AB706952	AB706952	KF584944	-	8447
Cordulegaster trinacriae	KF584994	-	-	KF584994	-	-	-	KF584946	-	1215
Cordulia aenea	FN356074	EU477707	EU477707	AF461236	EU424326	FN356074	FN356074	NOT_USED	NOT_USED	12608
Crocothemis erythraea	-	-	JQ964135	DQ008200	EF631321	-	-	KC912238	-	2311
Diplacodes lefebvrii	FN356080	EF640419	EF640419	FN356080	FN356080	FN356080	FN356080	-	-	15915
Enallagma cyathigerum	AJ420945	KF855787	KF855858	AJ420942	AF461201	FN356085	FN356085	KC912313	KF855908	13081
Epitheca bimaculata	FN356087	EU477708	EU477708	AB707002	FN356087	AB707004	AB707004	AB708897	-	7236
Erythromma (Cercion) lindenii	FN356089	EU477628	EU477628	AJ488550	FN356089	AJ488550	AJ488550	-	-	16145
Erythromma najas	AJ621054	EU055009	EU055105	AJ621054	AJ621054	AJ621055	AJ621054	EF176762	EF176767	12993
Erythromma viridulum	AJ621058	-	-	AJ621058	AJ621058	AJ621058	AJ621058	-	-	12220
Gomphus graslinii	-	EU477661	EU477661	-	-	-	-	-	KM222699	3700
Gomphus pulchellus	-	EU477663	EU477663	-	-	-	-	-	KM222700	2584
Gomphus simillimus	-	-	EU477660	-	-	-	-	-	KM222702	2548
Gomphus vulgatissimus	FN356091	EU477660	EU477650	FN356091	FN356091	FN356091	FN356091	-	-	6395
Ischnura aralensis	FN356099	-	-	FN356099	FN356099	FN356099	FN356099	-	-	2441
Ischnura elegans	KC430218	HQ834795	KF256901	KC413851	KM660022	AB706611	AB706609	KF257118	KM659940	10234
Ischnura fountaineae	FN356105	-	-	FN356105	FN356105	FN356105	FN356105	-	KC430124	12868
Ischnura genei	KC430200	-	-	JQ911511	JQ911511	-	KC430212	-	KC430116	4266
Ischnura graellsii	KC430208	HQ834798	-	KC430208	AJ488545	AJ488545	AJ488545	KC912315	KC430117	11347

Ischnura hastata	-	AF067713	-	-	-	NOT_USED	-	JN578213	AF067673	1242
Ischnura pumilio	KC430231	-	-	KC430231	FN356107	FN356107	FN356107	-	KC430148	9130
Ischnura saharensis	JQ911512	-	-	KC430211	JQ911512	-	-	-	KC430122	5519
Lestes barbarus	HQ830289	EU477616	EU477616	FN356110	FN356110	FN356110	FN356110	HQ830316	-	8551
Lestes dryas	HQ830291	EU477621	AB707358	AB706407	AB706408	AB706407	AB706407	AB708302	-	3904
Lestes macrostigma	FN356112	EU477620	EU477620	FN356112	AJ421950	FN356112	FN356112	HQ830317	-	8548
Lestes (Chalcolestes) parvidens	FN356057	-	-	FN356057	NOT_USED	FN356057	FN356057	HQ830299	-	2245
Lestes sponsa	AB706416	-	AB707368	AB706412	AB706415	AB706417	AB706413	AB708312	-	6166
Lestes virens	FN356117	EU477619	EU477619	FN356117	FN356117	FN356117	FN356117	HQ830318	-	3847
Lestes (Chalcolestes) viridis	HQ830276	EU477618	EU477617	AJ421949	AJ421949	AJ421949	FN356058	HQ830312	-	14594
Leucorrhinia albifrons	AF549594	-	-	-	-	-	HQ830272	-	-	2159
Leucorrhinia caudalis	FN356118	-	-	FN356118	FN356118	FN356118	FN356118	-	-	8588
Leucorrhinia dubia	AF549551	EU477718	AB708030	AB707079	AB707084	AB707084	AB707081	AB708974	-	5182
Leucorrhinia pectoralis	AF549562	EU477752	EU477752	AF461240	AF461206	-	AF549549	JN991193	-	6804
Leucorrhinia rubicunda	AF549559	-	-	-	-	-	AF549562	-	-	1406
Libellula depressa	-	EU477730	JQ964136	DQ008204	FJ596598	-	-	AF195741	DQ166795	4703
Libellula fulva	-	EU477728	EU477728	DQ008205	FJ596602	-	-	AF195745	-	9166
Libellula quadrimaculata	AB707092	DQ021418	KF256841	AB707092	AB707092	AB707093	FN356119	AB708986	-	10803
Lindenia tetraphylla	FN356120	EU477674	EU477674	DQ008196	FN356120	FN356120	FN356120	-	KM222704	8166
Macromia splendens	FN356128	EU477696	EU477698	FN356128	FJ712329	FN356128	FN356128	-	-	14419
Nehalennia speciosa	HM598674	-	JF746958	HM598673	FN356135	AB706623	FN356135	FN252228	JF746942	8424
Onychogomphus costae	FN356137	-	-	FN356137	FN356137	FN356137	FN356137	-	KM222698	12425
Onychogomphus forcipatus	FN356138	EU477670	EU477670	FN356138	FJ596620	FN356138	FN356138	KF584975	KM222679	14740
Onychogomphus uncatus	-	EU477671	EU477671	-	FJ712321	-	-	-	KM222691	3730
Ophiogomphus cecilia	FN356139	-	-	FN356139	FN356139	FN356139	FN356139	-	-	12435
Orthetrum albistylum	AB707122	DQ021412	KF256851	AB781475	AB127411	AB707118	AB707120	AB709013	DQ166806	7714
Orthetrum brunneum	-	DQ021414	DQ021416	-	-	-	-	-	-	3638
Orthetrum chrysostigma	FN356140	-	EU183261	FN356140	FN356140	FN356140	FN356140	KC912259	-	13274
Orthetrum coerulescens	-	DQ021445	DQ021445	-	-	-	-	KC912263	-	2282
Orthetrum sabina	AB781490	EF640404	AB708149	AB707199	AB781490	AB707198	AB707199	AB709092	DQ166788	5787
Orthetrum trinacria	-	-	EU183258	-	-	-	-	KC912286	-	3599
Oxygastra curtisii	-	EU477701	EU477701	DQ008194	EF631413	-	-	-	-	4679
Pantala flavescens	GU323034	EF640450	KF256865	AB707210	AB707210	AB707210	AB707211	AB709104	DQ166791	6694
Paragomphus genei	-	-	EU183242	-	-	-	-	-	-	471
Platycnemis acutipennis	FN356147	EU477626	KF369847	FN356147	GU563595	FN356147	FN356147	GU644640	-	11501
Platycnemis latipes	FN356150	EU477625	EU477625	FN356150	-	FN356150	FN356150	-	-	13484
Platycnemis pennipes	AJ459230	EU055010	KF369849	EU055200	EU055298	AJ459230	AJ459230	KF369498	EU055397	14350
Pyrrhosoma nymphula	FN356160	-	-	FN356160	AF461202	FN356160	FN356160	-	-	12882
Selysiothemis nigra	FN356162	-	-	FN356162	FN356162	FN356162	FN356162	-	-	12315
Somatochlora alpestris	AB707017	EU477700	EU477700	AB707014	AB707017	AB707014	FN356163	AB708909	-	11202
Somatochlora arctica	FN356164	-	AB707969	AB707019	FN356164	AB707019	FN356164	AB708913	-	9291
Somatochlora borisi	FN356165	-	-	FN356165	FN356165	FN356165	FN356165	-	-	12560
Somatochlora flavomaculata	-	EU055008	EU477704	AF461242	AF461212	-	-	-	EU055395	6695
Somatochlora graeseri	FN356166		AB707982	FN356166	KF256935	FN356166	FN356166	AB708930		3797
Somatochlora metallica	AB707038	EU477702	AB707987	AB707038	AB707038	AB707037	AB707038	AB708932	-	5620
Somatochlora sahlbergi	FN356167	-	-	FN356167	FN356167	FN356167	FN356167	-	-	12600
Sympecma fusca	HQ830287	EU477630	KF369913	AJ421948	KF370312	AJ421948	FN356170	KF369553	-	16478
Sympecma paedisca (annulata)	AB706422	EU055000	KF256890	AB706424	AB706423	AB706424	AB706424	AB708319	EU055387	7432
Sympetrum danae	EU243988	JQ772598	JQ772599	EU243994	EU243986	AB707227	AB707228	EU243910	-	5969
Sympetrum depressiusculum	AB707244	JQ772601	AB708189	AB707235	AB707242	AB707246	AB707246	AB709143	-	5265
Sympetrum flaveolum	AB707261	JQ772603	AB708211	JQ772553	AB707261	AB707261	AB707260	AB709154	-	6284
Sympetrum fonscolombii	AB707263	EF640440	KF256880	AB707263	JQ964125	AB707262	AB707262	AB709156	-	5605
Sympetrum meridionale	JQ772561	JQ772609	EU477742	JQ772561	FJ712328	-	JQ772554	EF636213	-	6361
Sympetrum pedemontanum	AB707287	EF640444	KF256877	AB707288	KF256950	AB707286	AB707287	AB709182	-	5418
Sympetrum sanguineum	AF549604	EF640445	EU477743	AF461245	FJ596607	-	JQ772563	-	-	6034
Sympetrum striolatum	EF636358	JQ772615	KF256868	EF636357	EF636366	AB707296	AB707297	EF636234	M83962	7405
Sympetrum vulgatum	AF549605	JQ772619	AB708251	AF461246	AF461216	AB707301	AB707301	EF636247	-	7071
Trithemis annulata	GU323055	-	GU323102	-	-	GU323055	GU323055	-	-	2118
Trithemis arteriosa	FN356177	EF640456	FJ471469	FN356177	FN356177	FN356177	FN356177	KC912287	-	12551
Trithemis festiva	GU323051	EF640458	KC197051	-	-	GU323051	GU323051	JN817429	DQ166786	4627
Trithemis kirbyi	GU323035	-	GU323130	-	-	GU323035	GU323035	KC912297	-	2269
Zygonyx torridus	-	EU477724	EF631535	-	EF631422	-	-	-	-	2619

Table A3. Model-test results for 11 alignments, representing compiled molecular data for 9 different loci of 121 European dragonfly species. Best-fitting nucleotide substitution models, as selected by highest Bayesian Information Criterion (BIC) scores, are in bold. In addition, scores of the corrected Aikaike Information Criterion (AICc), the log-Likelihood (lnL), as well as the proportions of invariant sites and site rates with discretised gamma distribution of each model are presented.

Loci/ Alignment	Model	BIC	AICc	lnL	Invariant	Gamma
5.8S	**K2+G**	**2125**	895	-252	n/a	0.301
5.8S	JC+G	2125	902	-256	n/a	0.301
5.8S	K2+G+I	2129	893	-250	0.089	0.050
12S	**GTR+G**	**11731**	10718	-5236	n/a	0.241
12S	GTR+G+I	11740	10719	-5236	011	0.291
12S	HKY+G	11755	10776	-5269	n/a	0.239
16S	**T92+G+I**	**6728**	5492	-2586	0.493	0.667
16S	T92+G	6730	5502	-2592	n/a	0.203
16S	GTR+G+I	6734	5452	-2559	0.500	0.678
18S part 1	**K2+G**	**8469**	7451	-3616	n/a	0.050
18S part 1	TN93+G+I	8472	7408	-3590	0.578	0.072
18S part 1	K2+G+I	8475	7448	-3614	0.040	0.050
18S part 2	**K2+G**	**3408**	2848	-1338	n/a	0.264
18S part 2	K2+G+I	3415	2848	-1337	0.411	0.819
18S part 2	T92+G	3415	2849	-1337	n/a	0.263
28S part 1	**K2+G**	**2277**	1440	-602	n/a	0.036
28S part 1	K2+G+I	2277	1433	-597	0.614	0.461
28S part 1	JC+G	2281	1451	-608	n/a	0.037
28S part 2	**GTR+G+I**	**21820**	21290	-10586	0.625	0.474
28S part 2	TN93+G+I	21837	21333	-10611	0.629	0.490
28S part 2	GTR+G	21867	21345	-10615	n/a	0.056
ITS1	**T92**	**2188**	1034	-349	n/a	n/a
ITS1	K2	2190	1043	-354	n/a	n/a
ITS1	JC	2196	1056	-362	n/a	n/a
ITS2	**GTR+G+I**	**97217**	95515	-47586	0.030	0.259
ITS2	K2+G	97217	95595	-47634	n/a	0.252
ITS2	T92+G	97217	95585	-47628	n/a	0.250
COI	**GTR+G+I**	**7525**	6434	-3066	0.522	0.804
COI	GTR+G	7563	6479	-3090	n/a	0.202
COI	TN93+G+I	7585	6516	-3110	0.531	1.055
COII	**GTR+G+I**	**24140**	23443	-11636	0.419	0.739
COII	GTR+G	24207	23518	-11675	n/a	0.245
COII	TN93+G+I	24351	23679	-11757	0.425	1.015

Table A4. Total sums of squares loadings, proportion of explained variance and cumulative explained variance of four principal components that characterise major temperature and precipitation trends of a set of 19 biologically relevant variables (highest contributions are in bold). The data were downloaded at worldclim.org (BIOCLIM version 1.4).

Variable	PC 1 temperature	PC 2 temperature	PC 1 precipitation	PC 2 precipitation
Annual Mean Temperature	**0.867**	0.472	-	-
Mean Diurnal Range	-	**0.717**	-	-
Isothermality	**0.893**	-	-	-
Temperature Seasonality	**-0.920**	0.359	-	-
Max Temperature of Warmest Month	0.352	**0.924**	-	-
Min Temperature of Coldest Month	**0.981**	0.119	-	-
Temperature Annual Range	**-0.875**	0.439	-	-
Mean Temperature of Wettest Quarter	-0.313	**0.645**	-	-
Mean Temperature of Driest Quarter	**0.918**	0.221	-	-
Mean Temperature of Warmest Quarter	0.490	**0.836**	-	-
Mean Temperature of Coldest Quarter	**0.979**	0.176	-	-
Annual Mean Precipitation	-	-	**0.858**	0.502
Precipitation of Wettest Month	-	-	**0.975**	0.146
Precipitation of Driest Month	-	-	0.421	**0.887**
Precipitation Seasonality	-	-	0.361	**-0.872**
Precipitation of Wettest Quarter	-	-	**0.973**	0.182
Precipitation of Driest Quarter	-	-	0.469	**0.867**
Precipitation of Warmest Quarter	-	-	0.224	**0.823**
Precipitation of Coldest Quarter	-	-	**0.931**	-
SS loadings	6.390	3.127	4.078	3.284
Proportion of Variance	0.581	0.284	0.510	0.410
Cumulative Variance	0.581	0.865	0.510	0.920

Table A5. Beta coefficients, per cent explained deviance (D) and generalized cross validation scores (GCV) from multiple regressions (gam) of five different measures of diversity against seven predictor variables. Predictors were z-standardized species richness, the four temperature and precipitation variables with the highest contribution to one of the four principal components (see loadings in Tab. A4, above), the proportion of lentic to lotic species and the location of the 0°C isotherm at the Last Glacial Maximum (LGM; 21 ka; unglaciated areas south of it = 1, glaciated areas north of it = 0) of 4,192 assemblages of European dragonflies. Except those models with species richness as dependent variable, models were corrected for species richness using a smoothing term; only effective degrees of freedom (edf) and per cent explained deviance from single regressions are presented. Positive or negative values indicate the positive or negative tendency of the relationship; n.s., not significant at $p > 0.001$. Variable abbreviations: Richness, total species richness; CWE, corrected weighted endemism (i.e. geometric mean of the inverse occupancy of co-occurring species); TTD, total taxonomic distinctiveness (i.e. sum of pairwise distances); SES MPD, standardized effect sizes of mean pairwise distances; Bio5, Maximum temperature of warmest month; Bio6, Minimum temperature of coldest month; Bio13, Precipitation of wettest month; Bio14, Precipitation of driest month. The proportion of lentic to lotic species and the 0°C isotherm at LGM are consistently strong predictors of patterns in all measures of diversity.

Model	edf	D	Standardized beta coefficients						D	GCV
	Richness (smoothed)		Bio5	Bio6	Bio13	Bio14	Lentic/ lotic	LGM iso.		
Richness	-	-	-1.9×10^{-03}	-2.4×10^{-04}	1.6×10^{-05}	-2.2×10^{-04}	-5.1×10^{-04}	2.7×10^{-03}	39.0	1.1×10^{-01}
CWE	8.7	12.0	n.s.	5.9×10^{-03}	1.1×10^{-03}	-5.0×10^{-03}	-1.1×10^{-01}	3.0×10^{-02}	81.2	3.3×10^{-06}
TTD	9.0	99.8	-1.6×10^{-05}	-1.7×10^{-05}	n.s.	-2.9×10^{-06}	1.1×10^{-04}	-5.5×10^{-05}	99.9	2.1×10^{-04}
SES MPD	8.9	35.7	n.s.	3.8×10^{-02}	n.s.	n.s.	-2.9×10^{-01}	2.8×10^{-01}	77.2	2.3×10^{-01}

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