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Relations between environmental gradients and diversity indices of benthic invertebrates in lotic systems of northern Italy

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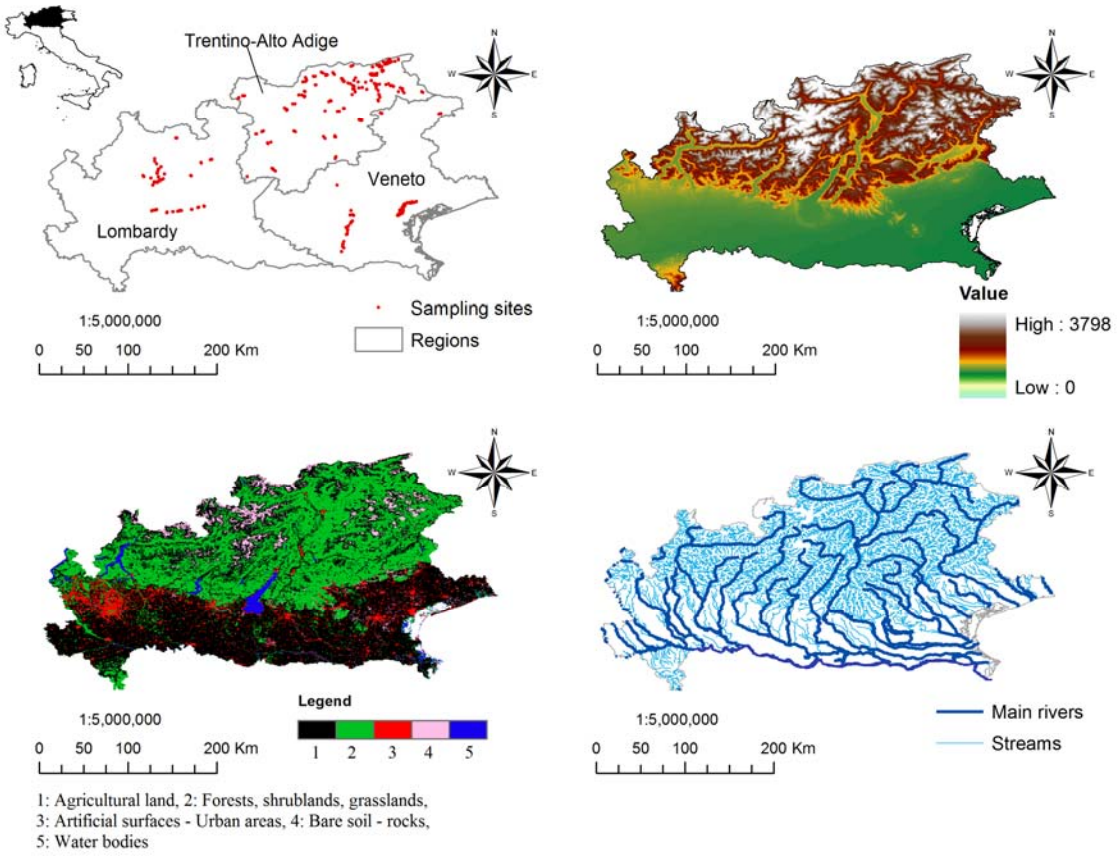

Figure S1 Study area and sampling stations (locations overlap), altitude, land uses and hydrographic network.

Table S1 Environmental parameters, abbreviations, units, type of variable transformation and statistics.

Parameter	Unit	Transformation	Abbrev.	Min	Max	Mean	St.dev.	[1]Case
Longitude (WGS84 ellipsoid)	Dec. degrees	log(x+1)	long	9.51	12.53	11.66	0.8	*
Latitude (WGS84 ellipsoid)	Dec. degrees	log(x+1)	lat	45.45	47.04	45.96	0.55	*
Altitude	m a.s.l.	log(x+1)	alt	1	2027	411	532	-
Stream width	m	log(x+1)	width	0.5	55	7.6	8.2	*
Mean depth of the riverbed	cm	log(x+1)	meandep	5	150	34	21.1	*
Maximum depth of the riverbed	cm	log(x+1)	maxdep	7	220	56.9	36.6	-
[2]Pool area	%	$\arcsin(x/100)^{0.5}$	pool	0	90	9.4	15.7	-
[2]Riffle area	%	$\arcsin(x/100)^{0.5}$	riffle	0	100	20	28.5	-
[2]Run area	%	$\arcsin(x/100)^{0.5}$	run	0	100	70.6	38.1	-
[3]Rock cover (>350 mm)	%	$\arcsin(x/100)^{0.5}$	rock	0	80	7.7	15.1	-
[3]Boulders cover (350-100 mm)	%	$\arcsin(x/100)^{0.5}$	boulder	0	80	13	16.8	-
[3]Cobbles cover (100-35 mm)	%	$\arcsin(x/100)^{0.5}$	cobble	0	80	15.2	15.9	*
[3]Gravel cover (35-2 mm)	%	$\arcsin(x/100)^{0.5}$	gravel	0	70	9.5	12.5	*
[3]Sand cover (2-1 mm)	%	$\arcsin(x/100)^{0.5}$	sand	0	90	24.7	22.2	-
[3]Silt+clay cover (<1mm)	%	$\arcsin(x/100)^{0.5}$	siltc	0	100	29.8	33.5	*
[4]Water velocity - flow conditions	Ordinal	none	flow	1	7	3.5	1.7	*
[5]Retention of detritus	Ordinal	none	detritus	1	3	1.9	0.6	*
[6]Shading of the riverbed	%	$\arcsin(x/100)^{0.5}$	shade	0	100	12.1	24.4	-
[7]Type of riparian vegetation	Ordinal	none	rip_veg	1	7	3.4	2.04	*
[8]Aquatic vegetation cover	%	$\arcsin(x/100)^{0.5}$	veg_cov	0	100	17.2	27	*
[9]Anthropization	Ordinal	none	anthropi	1	4	2.5	0.9	-
COD	O_2 mg L^{-1}	log(x+1)	COD	0.5	96	10.2	11.5	*
BOD_5	O_2 mg L^{-1}	log(x+1)	BOD	0	22	1.9	2.1	*
Nitrate nitrogen	N mg L^{-1}	log(x+1)	NO3N	0	5	1.1	0.9	*
Ammonia nitrogen	N mg L^{-1}	log(x+1)	NH4N	0	15.3	0.4	1.1	*
Phosphorus	P mg L^{-1}	log(x+1)	PHOSP	0	2.7	0.1	0.2	*
Escherichia coli	UFC/100 mL	log(x+1)	COLI	0	260000	6911	26474	*
Water temperature	°C	log(x+1)	TEMP	0.1	32	13.1	7.4	*
pH	-	none	PH	5.2	10	7.9	0.6	-
Dissolved oxygen	mg L^{-1}	log(x+1)	DO	0.4	20.3	10	2.8	*
Electrical conductivity	µs cm^{-1}	log(x+1)	EC	12	1616	422	232	-

[1]Variables coded "-" were not used in the final RDA analysis due to collinearity.

[2]Characterization of the watercourse surface (total sum of pool, riffle and run areas percentages equal to 100%).

[3]Substrate grain sizes (total sum of rocks, boulders, cobbles, gravels, sand and silt+clay percentages equal to 100%).

[4]Ordination according to: 1=undetectable/very slow, 2=slow, 3=medium and laminar flow, 4=medium and turbulent flow, 5=high velocity and laminar flow, 6=high velocity and turbulent flow, 7=very high velocity very turbulent flow.

[5]Ordination according to: 1=poor, 2=moderate and 3=high retention of detritus.

[6]The percentage ratio between the distance of trees canopy covering the stream from both sides versus stream width.

[7]Ordination according to: 1=absent, 2=herbaceous, 3=shrub-herbaceous, 4=shrub, 5=forest-herbaceous, 6=forest-shrub, 7=forest.

[8]The percentage coverage of macrophytes in the river bed.

[9]Ordination according to: 1=natural environment with no human presence, 2=natural environment with anthropogenic activities, 3=agricultural land and urbanized areas, 4=fully urbanized areas.

Table S2 Observed taxa of macroinvertebrate groups and taxonomic level.

Group	Taxonomic level	Group	Taxonomic level	Group	Taxonomic level
Bivalvia	F Pisidiidae	Ephemeroptera	G *Caenis**	Hirudinea	G *Batracobdella**
	F Sphaeriidae*		G *Habrophlebia**		G *Dina*
	F Unionidae		G *Paraleptophlebia**		G *Erpobdella*
Coleoptera	F Helodidae*		G *Baetis*		G *Glossiphonia*
	F Dytiscidae		G *Ephemerella*		G *Helobdella*
	F Elmidae		G *Habroleptoides**		G *Piscicola*
	F Hydraenidae		G *Cloeon*	Odonata	G *Calopteryx*
	F Hydrophilidae*		G *Epeorus*		G *Cercion**
	F Haliplidae		G *Rhithrogena*		G *Coenagrion*
Crustacea	F Asellidae		G *Ecdyonurus*		G *Ischnura*
	F Gammaridae	Gastropoda	F Bithyniidae		G *Orthetrum*
	F Palaemonidae		F Valvatidae		G *Platycnemis*
	F Niphargidae		F Ancylidae	Oligochaeta	F Enchytraeidae
Diptera	F Dixidae*		F Lymnaeidae		F Haplotaxidae
	F Simuliidae		F Neritidae*		F Lumbriculidae
	F Stratiomyidae*		F Physidae		F Tubificidae
	F Chironomidae		F Planorbidae		F Lumbricidae
	F Anthomyiidae		F Viviparidae*		F Naididae
	F Athericidae*		F Acroloxidae	Plecoptera	G *Leuctra*
	F Ceratopogonidae	Trichoptera	F Brachycentridae*		G *Chloroperla**
	F Empididae		F Hydropsychidae		G *Dinocras**
	F Tabanidae*		F Philopotamidae		G *Dyctiogenus*
	F Limoniidae		F Hydroptilidae		G *Isoperla*
	F Blephariceridae		F Odontoceridae*		G *Perla*
	F Psychodidae		F Ecnomidae*		G *Perlodes*
	F Tipulidae		F Rhyacophilidae		G *Amphinemura*
Gordioida	F Gordiidae		F Polycentropodidae*		G *Brachyptera*
Heteroptera	F Corixidae		F Beraeidae*		G *Nemoura*
	F Naucoridae		F Glossosomatidae*		G *Protonemura*
	F Nepidae*		F Goeridae*		G *Rhabdiopteryx**
Tricladida	G *Crenobia*		F Psychomyiidae*		
	G *Dendrocoelum**		F Leptoceridae*		
	G *Dugesia*		F Limnephilidae		
	G *Polycelis**		F Sericostomatidae		

† F corresponds to Family and G corresponds to Genus.

*Rare taxa occurring in <1% of all sampling stations were not used in RDA.

Table S3 Results of the RDA analysis based on the first four ordination axes (in the paper only the first and the second axes are used to interprete the results).

RDA with all variables (without co-variables)	4 ordination axes[1,2,3,4]			
No. taxa	68*			
No. environmental variables	19			
No. of co-variables	0			
No. sampling stations	585			
Eigenvalues (four major axes)	0.266[1]	0.035[2]	0.014[3]	0.011[4]
taxa-environment correlations	0.958	0.723	0.604	0.611
Cumulative % variance of taxa data	26.6	30.0	31.5	32.6
Cumulative % variance of taxa-environment relation	72.7	82.2	86.1	89.2
Total variance	1.000			
Sum of all eigenvalues	1.000			
Sum of all canonical eigenvalues	0.365			

*Rare taxa occurring in <1% of all sampling stations were not used in RDA.

Table S4 Marginal effects (Lambda-1), conditional effects (Lambda-A), statistical significance (*P*,*F*) and variance inflation factors for the selected parameters which are used in the RDA analysis of Table S3.

Variable	λ-1	λ-A	*P*	*F*	VIF
lat	0.23	0.23	0.002	173.17	7.19
long	0.09	0.05	0.002	44.61	2.40
rip_veg	0.17	0.00	0.002	2.62	2.37
veg_cov	0.07	0.00	0.002	4.40	1.57
detritus	0.01	0.00	0.008	1.74	1.30
TEMP	0.12	0.01	0.002	4.90	2.32
meandep	0.01	0.00	0.018	1.67	1.83
width	0.04	0.01	0.002	7.90	2.13
cobble	0.14	0.01	0.002	8.51	2.82
gravel	0.12	0.00	0.002	4.01	2.20
siltc	0.21	0.00	0.004	2.02	5.76
flow	0.16	0.01	0.002	6.39	2.66
COLI	0.13	0.01	0.002	6.77	2.44
COD	0.10	0.00	0.002	2.50	2.58
BOD	0.05	0.01	0.002	4.41	1.73
NO3N	0.09	0.01	0.002	3.38	1.96
NH4N	0.05	0.01	0.002	2.71	2.21
PHOSP	0.06	0.01	0.004	1.85	1.59
DO	0.04	0.00	0.002	4.13	1.45