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SUPPLEMENTARY MATERIAL

Diatom diversity in headwaters influenced by permafrost thawing: First evidence from the Central Italian Alps

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Supplementary Tab. 1. Water chemistry of the 16 sampled freshwater and median values.

ID	pH	EC	Alk	HCO ₃	SO ₄	Cl	Ca	Mg	Na	K	NO ₃	NH ₄	TN	PO ₄	TP	SiO ₂
		$\mu\text{ S cm}^{-1}$	meq L ⁻¹	mg L ⁻¹	mg L ⁻¹	mg L ⁻¹	mg L ⁻¹	mg L ⁻¹	mg L ⁻¹	mg L ⁻¹	$\mu\text{ g L}^{-1}$	$\mu\text{ g L}^{-1}$	$\mu\text{ g L}^{-1}$	$\mu\text{ g L}^{-1}$	$\mu\text{ g L}^{-1}$	mg L ⁻¹
SU-GL1	6.9	33	6.1	7.4	14.1	0.6	6.4	0.8	0.3	0.3	57	5	80	1	70	0.5
SU-RG1	7.2	118	24.5	29.9	34.0	0.8	18.0	2.6	2.0	1.0	186	16	297	1	2	2.2
SU-GL2	8.9	25	15.4	14.4	0.6	0.7	4.1	0.3	0.9	0.1	21	18	241	2	76	0.2
SU-RG2	7.8	437	85.0	103.7	157.6	1.1	74.7	12.4	1.3	1.1	148	9	142	5	5	2.3
MR-GL	4.7	36	0.6	0.7	12.1	0.6	3.4	0.7	0.8	0.3	14	27	3121	2	428	0.6
MR-RG1	6.5	192	3.7	4.5	71.0	0.7	21.0	7.1	1.5	0.2	960	9	1069	5	11	4.1
MR-RG2	6.9	507	9.4	11.4	245.0	2.8	72.0	18.0	3.6	0.4	234	5	300	3	4	4.7
MR-RG3	6.6	346	3.9	4.8	153.1	1.7	45.7	12.4	2.0	0.3	1400	5	1558	4	11	5.6
MR-RG4	7.0	516	17.9	21.8	230.0	2.0	60.6	25.9	3.6	1.0	319	5	422	2	14	7.8
MR-REF1	6.5	200	3.3	4.0	97.8	1.7	25.1	7.0	2.0	0.6	113	5	191	2	5	6.4
MR-REF2	5.3	99	1.2	1.4	38.8	1.0	11.9	2.9	1.8	0.4	173	5	239	3	5	3.9
AM-GL	6.6	11	5.7	7.0	1.4	0.4	2.3	0.1	0.2	0.1	101	5	4813	4	186	0.9
AM-RG1	6.6	18	8.0	9.7	1.7	0.7	2.3	0.1	0.9	0.4	397	8	444	2	4	3.9
AM-RG3	6.3	16	5.0	6.1	1.6	0.7	2.9	0.1	0.3	0.2	386	5	427	2	6	3.8
AM-RG4	6.6	19	7.6	9.3	1.6	0.7	2.4	0.1	1.4	0.5	318	9	379	3	6	3.9
AM-REF	6.5	15	5.6	6.8	1.6	0.6	2.8	0.1	0.2	0.2	304	5	335	2	4	3.9
Median	6.6	68	5.9	7.2	24.1	0.7	9.1	1.7	1.3	0.3	210	5	357	2	6	3.9
M GL	6.7	29	5.9	7.2	6.8	0.6	3.7	0.5	0.6	0.2	39	11	1681	2	131	0.6
M RG	6.6	192	8.0	9.7	71.0	0.8	21.0	7.1	1.5	0.4	319	8	422	3	6	3.9
M REF	6.5	99	3.3	4.0	38.8	1.0	11.9	2.9	1.8	0.4	173	5	239	2	5	3.9
M SU	7.5	76	20.0	22.2	24.1	0.7	12.2	1.7	1.1	0.7	102	12	191	2	38	1.3
M MR	6.5	200	3.7	4.5	97.8	1.7	25.1	7.1	2.0	0.4	234	5	422	3	11	4.7
M AM	6.6	16	5.7	7.0	1.6	0.7	2.4	0.1	0.3	0.2	318	5	427	2	6	3.9

ID = sample abbreviation, GL = glacier-fed samples, RG = permafrost-fed, REF = rhithral streams, SU = Sulden sub-catchment, MR = La Mare sub-catchment, AM = Amola sub-catchment, EC = electrical conductivity at 20°C, Alk = alkalinity, TN = total nitrogen, TP = total phosphorous, M = median.

Supplementary Tab. 2. Concentrations of trace metal in the 16 freshwater samples and median values (abbreviations as in Supplementary Tab. 1). Values indicated in the raw data as < than a given concentration were replaced by the half of the value.

ID	Al µg L ⁻¹	As µg L ⁻¹	Ba µg L ⁻¹	Co µg L ⁻¹	Cu µg L ⁻¹	Fe µg L ⁻¹	Li µg L ⁻¹	Mn µg L ⁻¹	Ni µg L ⁻¹	Sr µg L ⁻¹	Zn µg L ⁻¹
SU-GL1	36.0	2.0	0.4	0.2	0.5	17.0	3.0	3.1	0.2	9.0	4.0
SU-RG1	12.0	6.0	1.7	0.2	0.5	4.0	7.0	0.2	0.5	41.0	6.0
SU-GL2	19.0	2.0	0.5	0.2	0.5	17.0	1.5	8.9	0.3	4.0	2.0
SU-RG2	12.0	31.0	15.4	0.4	0.5	1.0	3.0	0.2	0.2	410.0	4.0
MR-GL	255.0	2.0	4.0	6.7	6.0	157.0	1.5	80.0	26.0	22.0	560.0
MR-RG1	15.0	2.0	3.6	0.6	1.0	4.0	1.5	0.2	11.0	82.0	14.0
MR-RG2	45.0	2.0	8.1	1.1	1.0	15.0	1.5	0.2	5.8	315.0	9.0
MR-RG3	30.0	2.0	5.9	0.9	2.0	9.0	3.0	4.8	60.0	148.0	28.0
MR-RG4	117.0	2.0	6.4	1.0	2.0	16.0	6.0	6.2	42.0	230.0	16.0
MR-REF1	31.0	2.0	3.6	1.9	2.0	4.0	3.0	12.1	31.0	82.0	45.0
MR-REF2	111.0	2.0	4.3	2.6	5.0	4.0	5.0	31.0	19.0	56.0	30.0
AM-GL	211.0	2.0	2.2	0.2	0.5	250.0	1.5	6.0	0.2	1.0	8.0
AM-RG1	8.0	2.0	0.1	0.2	0.5	2.0	1.5	0.2	0.3	1.0	3.0
AM-RG3	6.0	2.0	0.1	0.2	0.5	3.0	1.5	0.2	0.4	1.0	2.0
AM-RG4	25.0	2.0	0.5	0.2	0.5	30.0	1.5	0.7	0.3	1.0	8.0
AM-REF	7.0	2.0	0.6	0.2	0.5	3.0	1.5	0.2	0.4	2.0	2.0
EU 83/1998	n.a.	10.0	n.a.	n.a.	2.0	n.a.	n.a.	n.a.	20.0	n.a.	n.a.
Median	27.5	2.0	2.9	0.3	0.5	6.5	1.5	1.9	0.5	31.5	8.0
Median GL	123.5	2.0	1.4	0.2	0.5	87.0	1.5	7.5	0.3	6.5	6.0
Median RG	15.0	2.0	3.6	0.4	0.5	4.0	1.5	0.2	0.5	82.0	8.0
Median REF	31.0	2.0	3.6	1.9	2.0	4.0	3.0	12.1	19.0	56.0	30.0
Median SU	15.5	4.0	1.1	0.2	0.5	10.5	3.0	1.6	0.3	25.0	4.0
Median MR	45.0	2.0	4.3	1.1	2.0	9.0	3.0	6.2	26.0	82.0	28.0
Median AM	8.0	2.0	0.5	0.2	0.5	3.0	1.5	0.2	0.3	1.0	3.0

EU 83/1998 = European limits for drinking waters as in the Council Directive 98/83/EC on the quality of water intended for human consumption.

Supplementary Tab. 3. List of the 12 taxa identified in the four glacial streams surveyed in the present study, and number of valvae for each taxon observed by scanning the whole area of permanent slides. Sample codes as in Supplementary Tab. 1.

Taxa	SU-GL1-E	SU-GL2-E	MR-GL-E	AM-GL-E
<i>Achnantheidium minutissimum</i> var. <i>minutissimum</i> (Kütz.) Czarnecki	18	1	7	
<i>Amphora pediculus</i> (Kützing) Grunow	1			
<i>Aulacoseira</i> cf. <i>islandica</i> (O.Müller) Simonsen		4		
<i>Cyclotella comensis</i> Grunow	1			
<i>Denticula tenuis</i> Kützing	2			
<i>Encyonopsis microcephala</i> (Grunow) Krammer	13			
<i>Hannaea arcus</i> (Ehrenberg) R.M.Patrick				1
<i>Naviculadicta schmassmannii</i> (Hustedt) Wermer & L.-Bertalot	2			
<i>Undetermined pennate</i>	4			
<i>Psammothidium bioretii</i> (H.Germain) Bukhtiyarova & Round				1
<i>Rossithidium petersenii</i> (Hustedt) Round & Bukhtiyarova	1			
<i>Stephanodiscus minutulus</i> (Kützing) Cleve & Möller			2	
Total	42	5	9	2

Supplementary Tab. 4. List of the 33 diatom taxa excluded from NMDS analysis as present with a relative abundance $\geq 0.5\%$ in only one sample. Rare taxa (N =42) only occurring with R.A. $< 0.5\%$ in the samples analysed are not included in the table.

Taxa	RA%	Sample
<i>Encyonema reichartii</i> (Krammer) D.G.Mann	7.18	SU-RG1-E
<i>Eunotia cisalpina</i> Lange-Bertalot & Cantonati	6.04	AM-RG1-M
<i>Karayevia laterostrata</i> (Hustedt) Bukhtiyarova	4.78	SU-RG1-E
<i>Caloneis vasileyevae</i> Lange-Bertalot, Genkal & Vekhov	2.64	SU-RG2-M
<i>Nitzschia alpinobacillum</i> Lange-Bertalot	2.04	SU-RG1-M
<i>Pinnularia microstauron</i> (Ehrenberg) Cleve	1.89	MR-REF2-M
<i>Nitzschia hantzschiana</i> Rabenhorst	1.82	MR-RG2-M
<i>Naviculadicta schmassmannii</i> (Hustedt) Wermer & Lange-Bertalot	1.82	AM-RG4-M
<i>Psammothidium curtissimum</i> (J.R.Carter) Aboal	1.82	AM-RG4-M
<i>Psammothidium grischunum</i> (Wuthrich) Bukhtiyarova & Round	1.67	SU-RG1-E
<i>Caloneis</i> sp. Cleve in MR-REF1-E	1.65	MR-REF1-E
<i>Nitzschia hamburugiensis</i> Lange-Bertalot	1.37	MR-RG2-M
<i>Nitzschia acidoclinata</i> Lange-Bertalot	1.14	MR-RG2-M
<i>Gomphonema</i> cf. <i>micropus</i> Kützing	1.10	AM-RG4-E
<i>Nitzschia</i> cf. <i>dealpina</i> Lange-Bertalot & G.Hofmann	1.02	SU-RG1-M
<i>Eunotia neofallax</i> Nörpel-Schempp & Lange-Bertalot	0.97	AM-RG1-M
<i>Brachysira neoexilis</i> Lange-Bertalot	0.96	MR-REF1-M
<i>Pinnularia</i> sp. Ehrenberg MR-REF1-M	0.96	MR-REF1-M
<i>Aulacoseira alpigena</i> (Grunow) Krammer	0.94	MR-REF1-E
<i>Encyonopsis cesatii</i> (Rabenhorst) Krammer	0.94	MR-REF1-E
<i>Psammothidium acidoclinatum</i> (Lange-Bertalot) Lange-Bertalot	0.94	MR-REF1-E
<i>Surirella roba</i> Leclercq	0.94	MR-REF2-M
<i>Gomphonema amoenum</i> Lange-Bertalot	0.92	AM-REF-E
<i>Naviculadicta digitulus</i> (Hustedt) Lange-Bertalot & Metzeltin	0.91	AM-RG4-M
<i>Fragilaria pinnata</i> Ehrenberg	0.81	SU-RG1-M
<i>Psammothidium</i> sp. Bukhtiyarova & Round sp. in AM-RG3-M	0.75	AM-RG3-M
<i>Navicula criptocephala</i> Kützing	0.72	MR-REF1-M
<i>Pinnularia borealis</i> Ehrenberg	0.72	SU-RG2-M
<i>Pinnularia sinistra</i> Krammer	0.71	MR-REF1-E
<i>Nupela lapidosa</i> (Krasske) Lange-Bertalot	0.69	AM-REF-E
<i>Gomphonema</i> sp. Ehrenberg in SU-RG2-E	0.65	SU-RG2-E
<i>Achnanthes distincta</i> Messikommer	0.55	AM-RG4-M
<i>Nitzschia</i> sp. Hassall in AM-RG4-M	0.55	AM-RG4-M

RA% = relative abundance in the data set, Sample = sample where each taxon has been identified with RA $\geq 0.5\%$. Sample codes as in Supplementary Tab. 1.