

Supplementary Information

Seasonal shifts in microbial diversity in the lakes of Fildes Peninsula, King George Island, Maritime Antarctica

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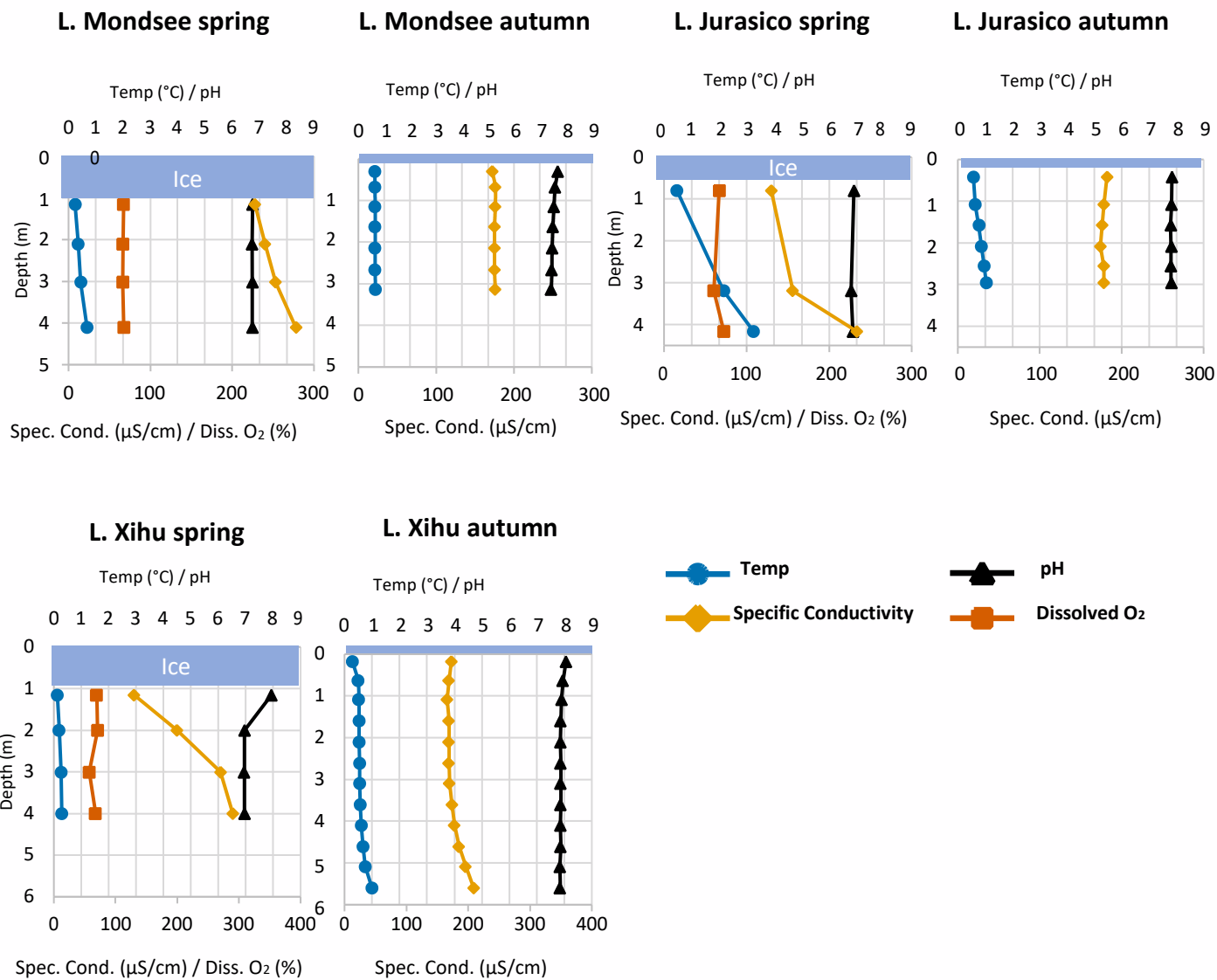


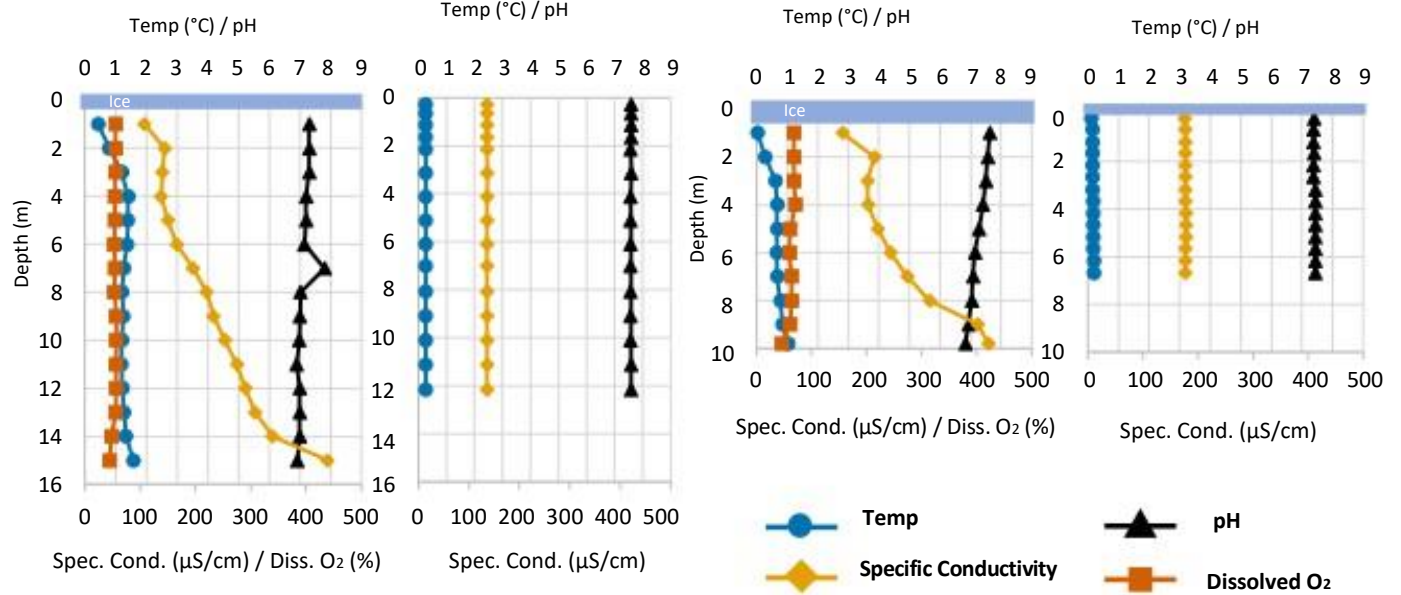
Fig. S1. Water column profiles of Fildes Peninsula lakes. Temp = temperature. Spec. cond. = specific conductivity. Diss. O₂ = dissolved oxygen. Note the differing x and y axis scales.

L. Uruguay spring

L. Uruguay autumn

L. Kitiash spring

L. Kitiash autumn



L. Hotel spring

L. Hotel autumn

L. Las Estrellas spring

L. Las Estrellas autumn

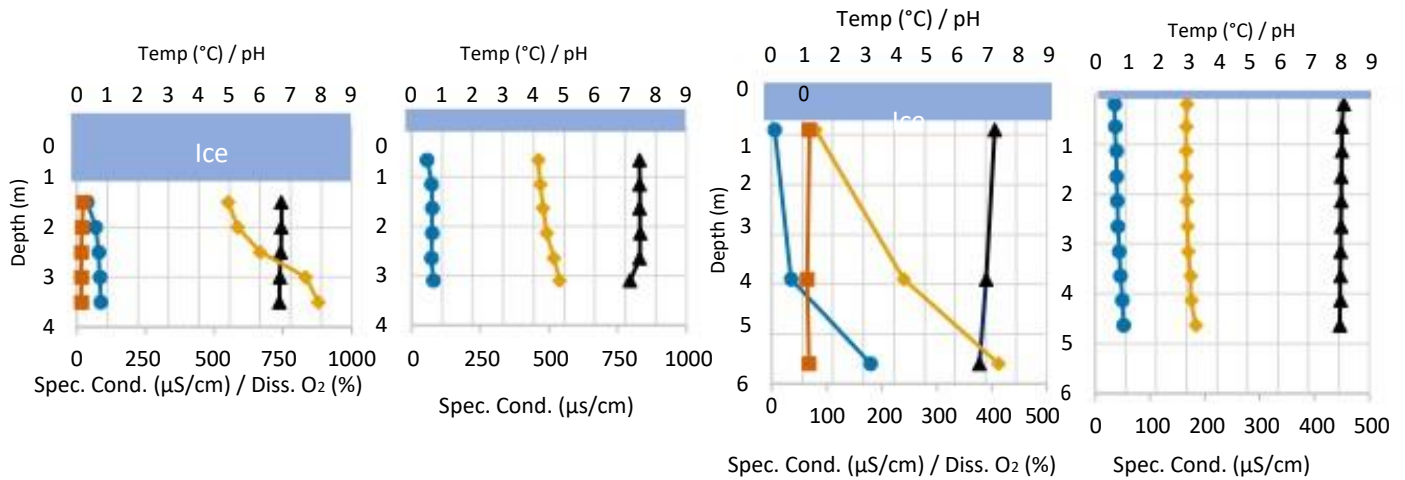


Fig. S1 cont'd. Water column profiles of Fildes Peninsula lakes. Temp = temperature. Spec. cond. = specific conductivity. Diss. O₂ = dissolved oxygen. Note the differing x and y axis scales.

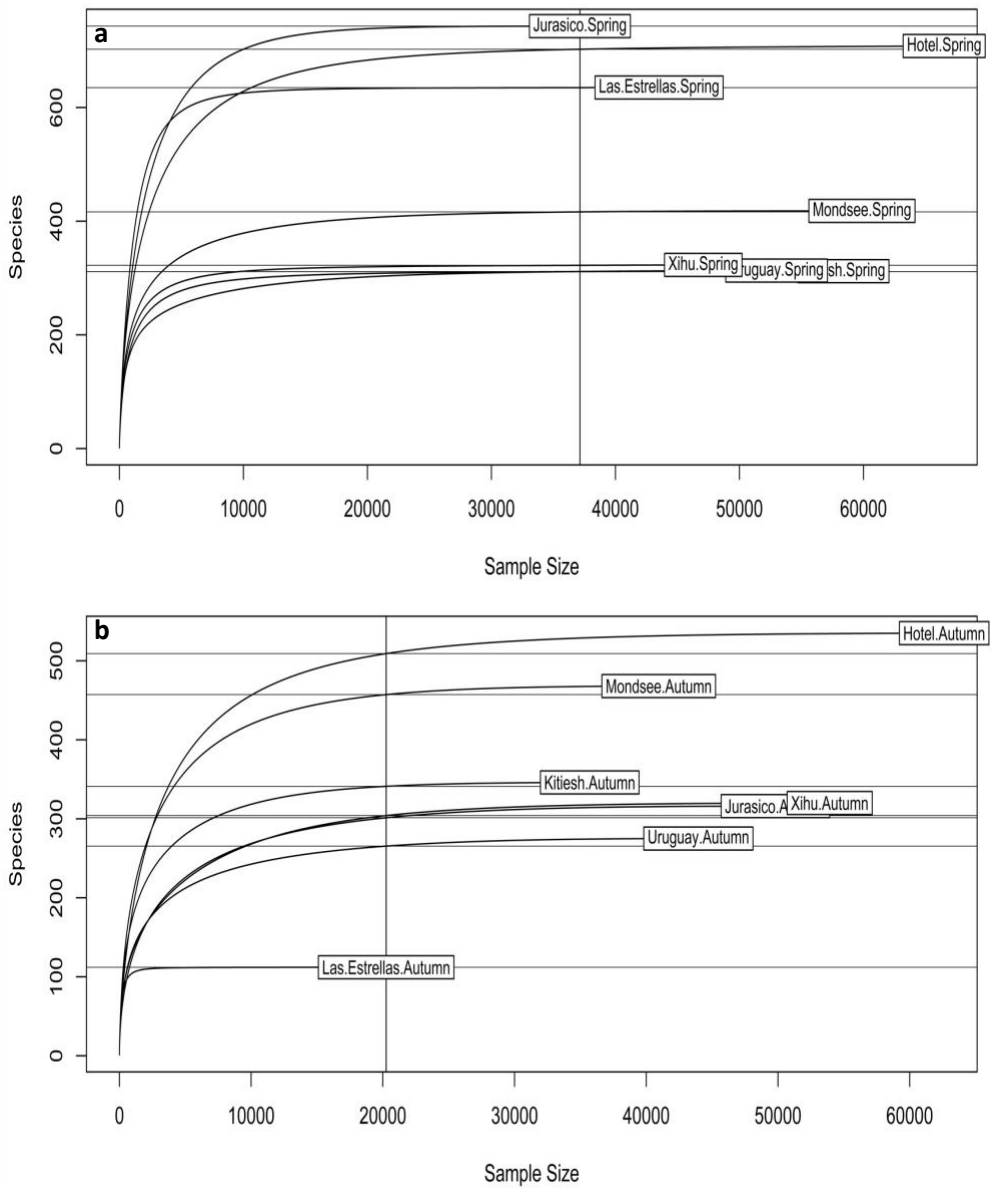


Fig. S2. Rarefaction curves for spring (a) and autumn (b).

Table S1. Volume of water filtered for pigment and DNA extraction. NA: not available.

Lake	Season	Volume filtered for phytoplankton (ml)	Volume filtered for bacterioplankton (ml)
Mondsee	Spring	700	1000
	Autumn	345	588
Jurasico	Spring	700	1000
	Autumn	1000	1000
Uruguay	Spring	700	1000
	Autumn	690	1000
Kitiesh	Spring	NA	1000
	Autumn	420	725
Hotel	Spring	250	750
	Autumn	215	250
Las Estrellas	Spring	500	1000
	Autumn	950	1000
Xihu	Spring	500	750
	Autumn	500	1000

Table S2. Chlorophyll concentration (ng L⁻¹). Chl-a: Chlorophyll a, Chl-b: Chlorophyll b, Chl-c₁: Chlorophyll c₁, MgDVP: Mg-3,8-divinyl-pheoporphyrin a₅ monomethyl ester. NA: not available.

Lake	Season	Chl-a	Chlorophyllide a	Chl-b	Chlorophyllide b	Chl-c ₁	MgDVP	Pheophorbide a	Pheophytin a
Mondsee	Spring	649.97	179.78	48.87	4.10	0.00	0.00	0.00	128.58
	Autumn	657.06	71.63	44.72	0.00	0.00	2.41	87.47	150.03
Jurasico	Spring	132.24	17.50	5.92	0.00	0.00	0.00	0.00	45.91
	Autumn	433.82	60.43	40.31	3.38	7.44	0.90	0.00	42.44
Uruguay	Spring	213.69	72.02	18.33	0.00	0.00	0.00	0.00	38.49
	Autumn	440.85	87.86	32.61	7.12	0.00	0.00	0.00	64.91
Kitiesh	Spring	NA	NA	NA	NA	NA	NA	NA	NA
	Autumn	783.40	83.93	45.18	0.00	0.00	10.78	0.00	205.74
Hotel	Spring	45.85	3.28	13.80	0.00	0.00	0.00	0.00	29.29
	Autumn	9606.82	246.37	202.62	0.00	0.00	0.00	1943.87	1454.68
Las Estrellas	Spring	199.27	0.00	9.05	0.00	0.00	0.00	0.00	0.00
	Autumn	700.96	0.00	28.99	0.00	0.00	0.00	0.00	26.38
Xihu	Spring	117.97	43.38	18.28	0.00	0.00	0.97	0.00	18.77
	Autumn	579.74	51.99	37.65	0.00	0.00	7.77	0.00	94.89

Table S3. Unknown carotenoid concentrations with the absorption maxima and retention times (ng L⁻¹). NA: not available, ND: not detectable.

Lake	Season	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.	Unk.
		carotenoid 455, 480 nm 8.43 min	carotenoid 470 nm 11.80 min	carotenoid 460 nm 12.00 min	carotenoid 475 nm 15.90 min	carotenoid 475 nm 17.80 min	carotenoid 450 nm 19.30 min	carotenoid 470 nm 20.90 min	carotenoid 500 nm 27.30 min	carotenoid 440, 470 nm 28.40 min	carotenoid 416, 440, 470 nm 29.60 min	carotenoid 475 nm 30.90 min
Mondsee	Spring	0.00	0.00	9.60	0.00	12.76	0.00	0.00	0.00	1.63	0.00	0.00
	Autumn	0.00	3.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jurasico	Spring	3.78	8.16	0.00	0.00	2.90	0.00	0.00	0.00	0.00	0.00	0.00
	Autumn	4.88	4.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uruguay	Spring	0.00	0.00	9.57	0.00	10.00	0.00	0.00	0.00	0.97	2.55	0.00
	Autumn	0.00	4.42	0.00	0.00	0.00	1.38	0.54	0.00	0.00	0.00	0.00
Kitiesh	Spring	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Autumn	0.00	6.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hotel	Spring	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Autumn	0.00	0.00	29.69	0.00	20.46	0.00	0.00	0.00	0.00	0.00	0.00
Las Estrellas	Spring	0.00	5.90	0.00	5.55	0.00	0.00	3.16	24.56	1.34	3.02	4.92
	Autumn	0.00	4.27	0.00	3.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xihu	Spring	0.00	13.65	0.00	0.00	5.17	0.00	0.00	0.00	0.59	0.00	0.00
	Autumn	0.00	5.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table S4. Carotenoid concentrations (ng L⁻¹). NA: not available, ND: not detectable.

Lake	Season	Antheraxanthin	Astaxanthin	β,β-carotene	β,ε-carotene	9-cis-neoxanthin	Diadinoxanthin	Dinoxanthin	Fucoxanthin	19-hex-fucoxanthin	Lutein	Peridinin	Zeaxanthin	Violaxanthin
Mondsee	Spring	0.00	8.47	6.76	1.41	13.50	6.52	0.00	27.57	3.60	56.24	7.38	5.12	14.28
	Autumn	0.00	0.00	4.11	0.31	8.42	2.78	0.00	9.37	5.91	48.37	0.00	3.40	9.14
Jurasico	Spring	0.00	0.00	2.99	0.00	1.62	0.73	0.00	13.43	10.00	5.28	0.00	3.07	7.86
	Autumn	0.00	13.28	4.57	0.00	12.53	0.64	0.00	24.44	2.59	26.30	0.00	3.83	7.64
Uruguay	Spring	0.00	5.31	5.22	0.00	2.64	4.77	3.03	17.94	4.16	13.66	7.36	2.56	6.79
	Autumn	0.00	20.02	2.74	0.00	9.93	3.48	1.89	8.30	4.27	46.51	2.03	1.95	8.78
Kitiesh	Spring	0.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Autumn	0.00	4.43	8.66	0.00	11.76	8.94	4.41	29.73	4.36	58.61	0.00	5.39	22.96
Hotel	Spring	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Autumn	15.89	98.75	90.48	0.00	171.61	81.00	0.00	0.00	39.81	932.34	0.00	54.08	186.37
Las Estrellas	Spring	0.00	24.29	1.38	0.00	0.00	0.00	0.00	3.12	0.00	2.99	8.48	1.75	5.61
	Autumn	0.00	13.80	0.00	0.00	13.44	0.00	0.00	17.61	12.33	51.55	0.00	2.84	9.32
Xihu	Spring	0.00	1.14	1.60	0.00	2.32	1.62	0.00	2.40	0.00	10.51	4.09	1.75	15.83
	Autumn	0.00	0.00	2.80	0.00	9.00	0.60	0.00	14.47	4.11	31.98	0.00	1.98	6.78

Table S5. LCBD: Local contribution to beta diversity. Values in bold are significant prior to Holm's correction for multiple testing ($p < 0.05$), and those in bold and with an asterisk are still significant after correction. NA: Not available, ND: Not detectable.

Lake	Season	LCBD Pigments	LCBD Bacterioplankton
Mondsee	Spring	0.072	0.102
Jurasico	Spring	0.311	0.129
Uruguay	Spring	0.066	0.124
Kitiesh	Spring	NA	0.095
Hotel Las Estrellas	Spring	ND	0.212*
Xihu	Spring	0.395*	0.228*
Mondsee	Autumn	0.156	0.11
Mondsee	Autumn	0.095	0.115
Jurasico	Autumn	0.169	0.119
Uruguay	Autumn	0.117	0.143
Kitiesh	Autumn	0.085	0.081
Hotel Las Estrellas	Autumn	0.255	0.297*
Xihu	Autumn	0.112	0.161
Xihu	Autumn	0.167	0.084

Table S6. Spearman correlation matrix with the R^2 values between unknown and identified pigments. Values in bold are significant prior to Holm's correction for multiple testing ($p < 0.05$), and the one in bold and with an asterisk are still significant after correction.

	Unk. carotenoid 455, 480 nm 8.43 min	Unk. carotenoid 470 nm 11.80 min	Unk carotenoid 460 nm 12.00 min	Unk. carotenoid 475 nm 15.90 min	Unk. carotenoid 475 nm 17.80 min	Unk. carotenoid 450 nm 19.30 min	Unk. carotenoid 470 nm 20.90 min	Unk. carotenoid 500 nm 27.30 min	Unk carotenoid 440, 470 nm 28.40 min	Unk. carotenoid 416, 440, 470 nm 29.60 min	Unk. carotenoid 475 nm 30.90 min
MgDVP	0.11	0.42	-0.46	-0.36	-0.35	-0.24	-0.36	-0.24	-0.39	-0.36	-0.24
Chl-c1	0.74	-0.32	-0.17	-0.13	-0.21	-0.09	-0.13	-0.09	-0.21	-0.13	-0.09
Peridinin	-0.36	0.13	0.28	0.26	0.12	0.15	0.53	0.54	0.93*	0.66	0.54
Fucoxanthin	0.22	-0.21	0.01	-0.16	-0.32	-0.22	-0.39	-0.31	0.04	-0.10	-0.31
9-cis-neoxanthin	-0.09	-0.36	0.49	-0.18	0.26	0.04	-0.35	-0.48	-0.26	-0.53	-0.48
Violaxanthin	-0.26	0.05	0.33	-0.30	0.58	-0.04	-0.41	-0.48	-0.17	-0.59	-0.48
19-hex-fucoxanthin	-0.04	-0.36	0.19	-0.08	0.11	0.04	-0.32	-0.44	-0.64	-0.38	-0.44
Astaxanthin	-0.16	-0.12	0.36	0.47	0.09	0.31	0.53	0.40	0.16	0.29	0.40
Diadinoxanthin	0.12	-0.50	0.66	-0.65	0.48	-0.04	-0.38	-0.44	-0.03	-0.20	-0.44
Dinoxanthin	-0.25	0.17	0.04	-0.25	-0.39	0.40	0.13	-0.17	-0.03	0.21	-0.17
Antheraxanthin	-0.13	-0.32	0.63	-0.13	0.57	-0.09	-0.13	-0.09	-0.21	-0.13	-0.09
Alloxanthin	-0.37	-0.44	0.67	0.18	0.21	-0.22	-0.11	0.04	0.21	0.12	0.04
Zeaxanthin	0.20	-0.54	0.48	-0.34	0.30	-0.31	-0.52	-0.39	-0.30	-0.40	-0.39
Lutein	-0.37	-0.15	0.43	-0.24	0.20	0.04	-0.35	-0.48	-0.32	-0.53	-0.48
β , ϵ -carotene	-0.20	-0.28	0.30	-0.20	0.23	-0.13	-0.20	-0.13	0.32	-0.20	-0.13
β , β -carotene	0.08	-0.50	0.66	-0.64	0.35	-0.22	-0.46	-0.39	-0.04	-0.17	-0.39
Chl-b	-0.22	-0.24	0.49	-0.40	0.22	-0.04	-0.34	-0.39	-0.21	-0.46	-0.39
Chl-a	-0.43	-0.11	0.43	-0.16	0.12	-0.04	-0.27	-0.31	-0.25	-0.39	-0.31

Table S7. Spearman correlation matrix with the R^2 values between unknown pigments. Values in bold are significant prior to Holm's correction for multiple testing ($p < 0.05$), and those in bold and with an asterisk are still significant after correction.

	Unk. carotenoid 455, 480 nm 8.43 min	Unk. carotenoid 470 nm 11.80 min	Unk. carotenoid 460 nm 12.00 min	Unk. carotenoid 475 nm 15.90 min	Unk. carotenoid 475 nm 17.80 min	Unk. carotenoid 450 nm 19.30 min	Unk. carotenoid 470 nm 20.90 min	Unk. carotenoid 500 nm 27.30 min	Unk. carotenoid 440, 470 nm 28.40 min	Unk. carotenoid 416, 440, 470 nm 29.60 min	Unk. carotenoid 475 nm 30.90 min
Unk. carotenoid 455, 480 nm 8.43 min	1.00	-0.47	-0.25	-0.20	0.01	-0.13	-0.20	-0.13	-0.31	-0.20	-0.13
Unk. carotenoid 470 nm 11.80 min	-0.47	1.00	-0.60	0.28	-0.30	0.14	0.35	0.32	0.02	0.04	0.32
Unk. carotenoid 460 nm 12.00 min	-0.25	-0.60*	1.00	-0.25	0.61	-0.17	-0.25	-0.17	0.40	0.13	-0.17
Unk. carotenoid 475 nm 15.90 min	-0.20	0.28	-0.25	1.00	-0.31	-0.13	0.50	0.74	0.23	0.50	0.74
Unk. carotenoid 475 nm 17.80 min	0.01	-0.30	0.61*	-0.31	1.00	-0.21	-0.31	-0.21	0.25	-0.31	-0.21
Unk. carotenoid 450 nm 19.30 min	-0.13	0.14	-0.17	-0.13	-0.21	1.00	0.60	-0.09	-0.21	-0.13	-0.09
Unk. carotenoid 470 nm 20.90 min	-0.20	0.35	-0.25	0.50	-0.31	0.60*	1.00	0.74	0.23	0.50	0.74
Unk. carotenoid 500 nm 27.30 min	-0.13	0.32	-0.17	0.74*	-0.21	-0.09	0.74*	1.00	0.47	0.74	1.00
Unk. carotenoid 440, 470 nm 28.40 min	-0.31	0.02	0.40	0.23	0.25	-0.21	0.23	0.47	1.00	0.62	0.47
Unk. carotenoid 416, 440, 470 nm 29.60 min	-0.20	0.04	0.13	0.50	-0.31	-0.13	0.50	0.74*	0.62*	1.00	0.74
Unk. carotenoid 475 nm 30.90 min	-0.13	0.32	-0.17	0.74*	-0.21	-0.09	0.74*	1.00*	0.47	0.74	1.00

Table S8. Bacteria indicator species for spring. The closest relative in GeneBank, the environment where it was found, the identity percentage and the accession number is indicated.

Class	Order	Family	Genus	Closest relative	Environmental source	% identity	GenBank Accession
Actinobacteria	Micrococcales	<i>Microbacteriaceae</i>	<i>Parafriporibacterium</i>	Uncultured bacterium	Soil near a sulfidic pond in Greenland	99.26	MT362452
Actinobacteria	Micrococcales	<i>Microbacteriaceae</i>	<i>Cryobacterium</i>	<i>Cryobacterium</i> sp. L11	Permafrost of Victoria Valley (Antarctica)	99.63	KT965167
Actinobacteriota	Actinobacteria	<i>Micrococcales</i>	<i>Cryobacterium</i>	<i>Cryobacterium</i> sp. L11	Permafrost of Victoria Valley (Antarctica)	100	KT965167
Acidobacteriae	Paludibaculum	NA	NA	uncultured bacterium	Benthic sediments from oligotrophic Andean lake	99.63	KY691677
Alphaproteobacteria	Rhodobacterales	<i>Rhodobacteraceae</i>	<i>Pseudorhodobacter</i>	<i>Pseudorhodobacter</i> sp	Antarctic soils	99.63	KY476581
Alphaproteobacteria	Sphingomonadales	<i>Sphingomonadaceae</i>	<i>Polymorphobacter</i>	<i>Polymorphobacter</i> sp. PAMC 29334	Antarctic lichen	98.53	CP080243
Alphaproteobacteria	Sphingomonadales	<i>Sphingomonadaceae</i>	<i>Polymorphobacter</i>	<i>Polymorphobacter</i> sp	Antarctic lichen	98.16	MW507628
Alphaproteobacteria	Reyranellales	<i>Reyranellaceae</i>	<i>Reyranella</i>	Uncultured bacterium	Benthic sediments from oligotrophic Andean lake	100	KY691029
Alphaproteobacteria	Acetobacteriales	<i>Acetobacteraceae</i>	<i>Rhodovastum</i>	Uncultured bacterium	Soil environments under mosses on Anchorage Island (Antarctica)	99.26	EF219762
Bacteroidia	Flavobacteriales	<i>Flavobacteriaceae</i>	<i>Flavobacterium</i>	<i>Flavobacterium</i> sp	Antarctic soil	99.63	KY476592
Bacteroidia	Flavobacteriales	<i>Flavobacteriaceae</i>	<i>Flavobacterium</i>	Uncultured bacterium	Baltic Sea thick ice	100	LM651934
Bacteroidia	Flavobacteriales	<i>Flavobacteriaceae</i>	<i>Flavobacterium</i>	<i>Flavobacterium</i> sp.	Cryoconite hole sediment	100	MT473233
Bacteroidia	Chitinophagales	NA	NA	Uncultured bacterium	Baltic Sea thick ice	100	LM651944
Bacteroidia	Chitinophagales	NA	NA	Uncultured bacterium	Lake Nahuel Huapi	100	KM127806
Bacteroidia	Cytophagales	<i>Cyclobacteriaceae</i>	<i>Algoriphagus</i>	<i>Algoriphagus</i> sp. R-36727	Transantarctic Mountains, Forlidas Pond (Antarctica)	100	FR691439
Gammaproteobacteria	Burkholderiales	NA	NA	Uncultured bacterium	Microbial mats from King George Island	100	KX704294
Gammaproteobacteria	Burkholderiales	NA	NA	Uncultured bacterium	Biofilm attached on the membrane surfaces	95.59	GU257829
Gammaproteobacteria	Burkholderiales	<i>Alcaligenaceae</i>	GKS98 freshwater group	Uncultured Alcaligenaceae bacterium	Lake Michigan	100	EU641811
Gammaproteobacteria	Burkholderiales	<i>Comamonadaceae</i>	<i>Rhodoferax</i>	Uncultured bacterium	Arctic lake sediment	99.63	MN788553
Gammaproteobacteria	Burkholderiales	<i>Comamonadaceae</i>	<i>Rhodoferax</i>	<i>Rhodoferax</i> sp.	Fresh water	100	KC759436
Gammaproteobacteria	Burkholderiales	<i>Comamonadaceae</i>	<i>Rhodoferax</i>	<i>Rhodoferax</i> saidenbachensis	Sea-ice melt pool	99.63	KU179847
Gammaproteobacteria	Burkholderiales	<i>Comamonadaceae</i>	<i>Polaromonas</i>	<i>Polaromonas</i> sp.	Cryoconite hole (Antarctica)	100	MG098813
Gammaproteobacteria	Burkholderiales	<i>Oxalobacteraceae</i>	<i>Aquaspirillum</i> , arcticum group	Uncultured <i>Aquaspirillum</i> sp.	Glacier ice	100	KT752942
Gammaproteobacteria	Burkholderiales	<i>Oxalobacteraceae</i>	<i>Aquaspirillum</i> , arcticum group	Uncultured <i>Aquaspirillum</i> sp.	Glacier ice	100	KT752934
Gammaproteobacteria	Burkholderiales	<i>Oxalobacteraceae</i>	<i>Aquaspirillum</i> , arcticum group	Uncultured <i>Aquaspirillum</i> sp.	Glacier ice	99.26	KT752942
Gammaproteobacteria	Burkholderiales	<i>Oxalobacteraceae</i>	<i>Undibacterium</i>	<i>Undibacterium</i> sp.	Glacier ice	98.90	MN334244
Gammaproteobacteria	Burkholderiales	<i>Oxalobacteraceae</i>	<i>Undibacterium</i>	<i>Undibacterium</i> sp.	Glacier ice	99.26	MN334243
Planctomycetes	Gemmatales	<i>Gemmataceae</i>	NA	Uncultured bacterium	Lake Taihu	98.53	JN868815
Planctomycetes	Gemmatales	<i>Gemmataceae</i>	NA	Uncultured Planctomycetaceae bacterium	Stratified ferrous lake	98.17	MG740937
Thermoleophilia	Gaiellales	NA	NA	Uncultured bacterium	Lake water (Ontario)	97.33	KY515625
Thermoleophilia	Gaiellales	NA	NA	Uncultured bacterium	High-altitude Pyrenean lakes	96.34	HE858024

Table S9. Bacteria indicator species for autumn. The closest relative in GeneBank, the environment where it was found, the identity percentage and the accession number is indicated.

Class	Order	Family	Genera	Closest relative	Environmental source	% identity	GenBank Accession
Actinobacteria	Frankiales	Sporichthyaceae	NA	Uncultured bacterium	Argentina: Lake Espejo	100	KM169310
Actinobacteria	Frankiales	Sporichthyaceae	NA	Uncultured bacterium	Argentina: Lake Espejo	99.63	KM169127
Actinobacteria	Frankiales	Sporichthyaceae	Candidatus Planktophila	Uncultured bacterium	Stratified freshwater lake	98.90	AB753916
Actinobacteria	Micrococcales	Intrasporangiaceae	<i>Oryzihumus</i>	Uncultured <i>Oryzihumus</i> sp.	Roopkund Glacier Himalaya (India)	99.63	GQ421037
Bacteroidia	Cytophagales	Spirosomaceae	<i>Pseudarcicella</i>	Uncultured <i>Arcicella</i> sp.	High-altitude lakes (Tibetan plateau)	99.63	EU703221
Bacteroidia	Cytophagales	Spirosomaceae	<i>Pseudarcicella</i>	Uncultured bacterium	Argentina: Lake Espejo	100	KM169218
Bacteroidia	Cytophagales	Spirosomaceae	<i>Pseudarcicella</i>	Uncultured bacterium	Argentina: Lake Espejo	99.63	KM155089
Bacteroidia	Cytophagales	Spirosomaceae	<i>Pseudarcicella</i>	Uncultured bacterium	Antarctica: Lake Limnopolar	100	KF928869
Bacteroidia	Chitinophagales	Chitinophagaceae	<i>Sediminibacterium</i>	Uncultured Chitinophagaceae bacterium	Lake Constancelake (Germany)	100	MG740845
Bacteroidia	Chitinophagales	Chitinophagaceae	<i>Sediminibacterium</i>	Uncultured bacterium	High-altitude Pyrenean lakes	99.63	HE857031
Bacteroidia	Sphingobacteriales	env.OPS 17	NA	Uncultured bacterium	Argentina: Lake Espejo	98.9	KM185189
Bacteroidia	Sphingobacteriales	env.OPS 17	NA	Uncultured bacterium	Argentina: Lake Espejo	99.26	KM185593
Verrucomicrobiae	Chthoniobacterales	Terrimicrobiaceae	FukuN18 freshwater group	Uncultured bacterium group	Acidic high-Arctic wetland active layer soil	98.53	GU047442
Verrucomicrobiae	NA	NA	NA	Uncultured bacterium	Argentina: Lake Nahuel Huapi	100	KM156398
Verrucomicrobiae	NA	NA	NA	Uncultured bacterium	Permafrost thaw pond (Nunavik)	98.16	JN656765
Verrucomicrobiae	NA	NA	NA	Uncultured bacterium	Permafrost thaw pond (Nunavik)	98.53	JN656911
Verrucomicrobiae	NA	NA	NA	Uncultured bacterium	Limnopolar Lake (Antarctic)	99.63	FR848702