Fungal communities in Scandinavian lakes along a longitudinal gradient

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Supplementary Information

Fig. S1. Correlation matrix of spatial (longitude, latitude and altitude) and environmental (TOC, TP and conductivity, all log transformed) predictors.

Fig. S2. NMDS ordination of Hellinger transformed relative abundance data for 10 samples that were sequenced twice. Each replicate is connected by a line with a respective sample (dark blue is actual sample, light blue is its replicate).

Fig. S3. The relationship between sequencing depth and OTU richness (both log transformed; $P < 0.001$, Pearson correlation coefficient = 0.40) for the whole set of Scandinavian lakes ($n = 77$).

Fig. S4. Assessment of similarity of NMDS ordinations based on different metrics (i.e. Raup-Crick, Jaccard, Bray-Curtis and Gower) on 8 data sets: all lakes (77 lakes); excluding one lake with min total reads (76 lakes); excluding one lake with min total reads and one lake with max total reads (75 lakes); excluding two lakes with both min and max total reads (73 lakes); only lakes with total reads > 50 (64 lakes); only lakes with total reads > 100 (43 lakes); only lakes with total reads > 150 and coverage > 10X (30 lakes); only lakes with total reads > 200 (27 lakes). Procrustes tests are based on 999 permutations.

Fig. S5. The relationship of minimum sequencing depth (reads/site) and Procrustes correlations with reference > 150 total reads/site.

Table S1. Location and environmental characteristics of sampling sites.

Table S2. Information on the fungal phyla and orders presented as % of total reads and total OTUs in *n* lakes of the whole set of Scandinavian lakes ($n = 77$).

Table S3. Taxonomic assignment of representative OTUs against NCBI v.2.2.29 and UNITE v.7. *Available online*

Table S4. Fitted environmental (TOC, TP, conductivity, all log transformed) and spatial (longitude, latitude, altitude) factors onto NMDS ordination (k = 2) for the subset of 30 lakes (with > 150 total reads and > 10X coverage; coverage = total reads/OTU richness per lake). Significant correlation between axes ($P < 0.05$) is indicated by bold font. Number of permutations for assessing significance of factors is 999. Stress = 0.24.

Appendix 1. Classification of the representative OTUs with RDP Bayesian Classifier against Warcup Fungal ITS trainset 2. *Available online*

Appendix 2. The representative sequences of OTUs. *Available online*

Appendix 3. OTU-table with read abundance for aquatic fungal communities. *Available online*

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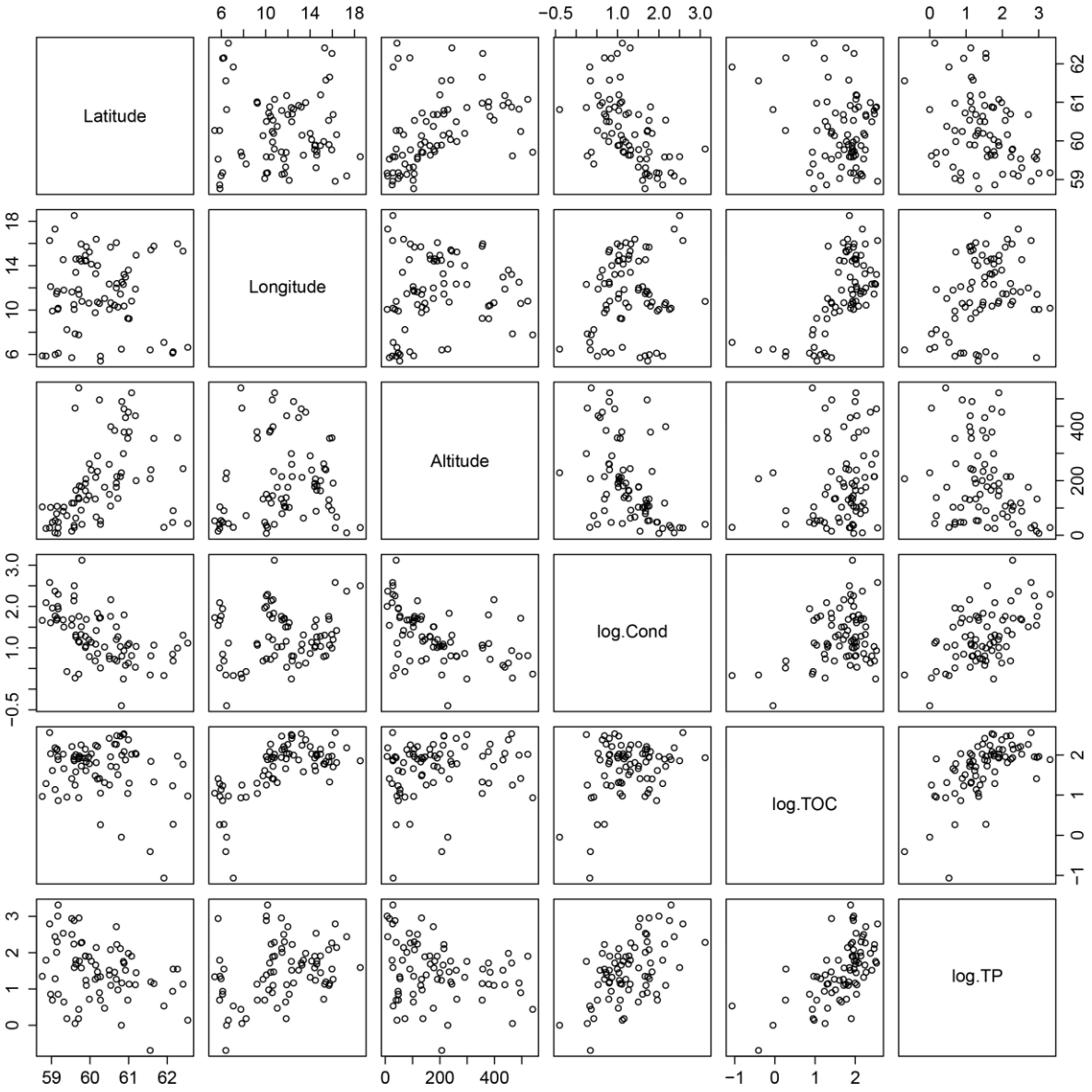

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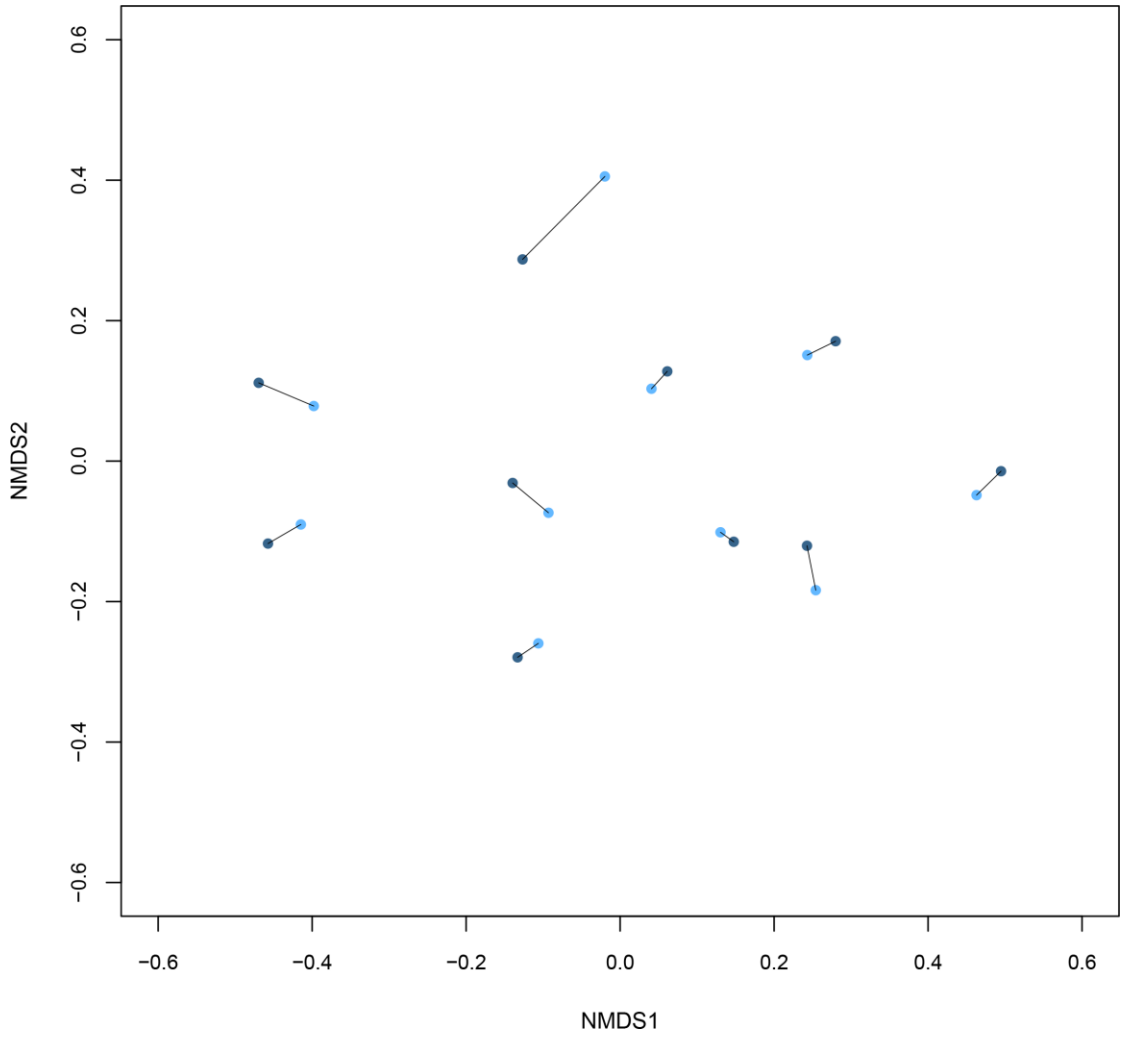

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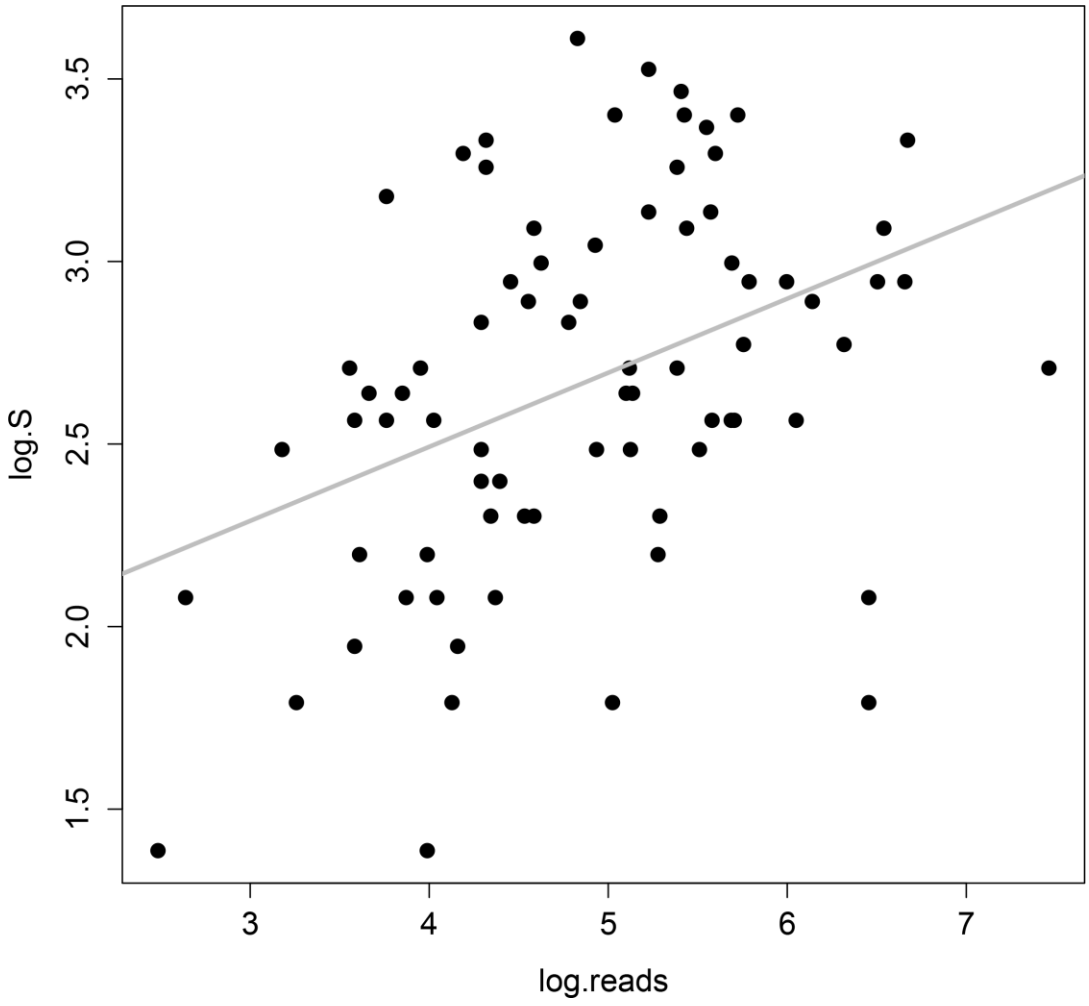

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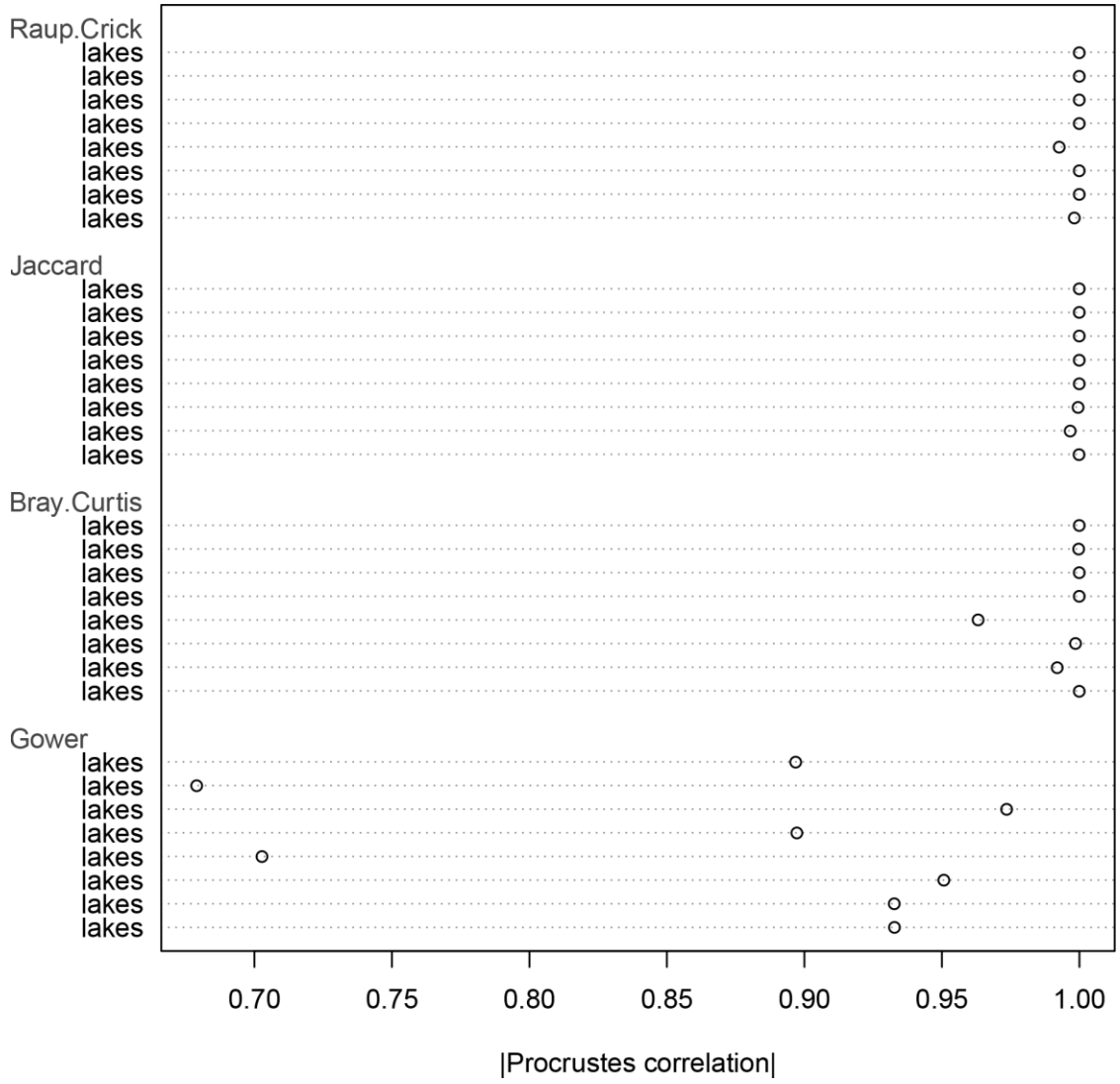

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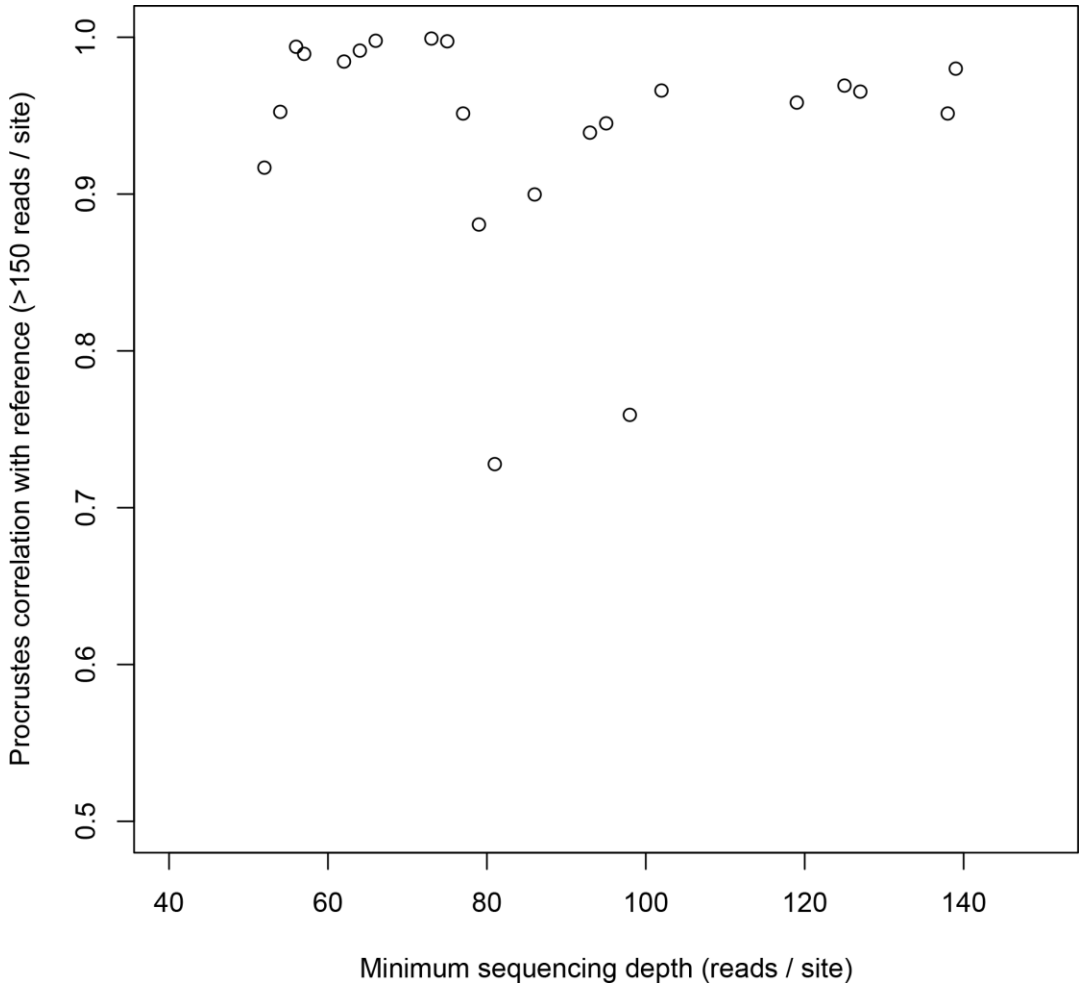

Table S1. Location and environmental characteristics of sampling sites.

Sample ID	Lake ID	Lake	Country	Latitude	Longitude	Altitude	TOC	TP	Cond	Area.km^2
ITS.1	170	Gjersjøen	N	59,7897	10,7749	40	6,898	9,80	22,6	2,64
ITS.2	180	Øgderen	N	59,7139	11,4130	133	6,944	19,20	5,82	12,66
ITS.3	189	Krøderen	N	60,1349	9,7586	133	4,395	3,55	1,98	43,91
ITS.4	191	Rødbyvatnet	N	59,5818	10,4872	118	6,652	9,35	8,48	1,16
ITS.5	194	Sperillen	N	60,5040	10,0584	150	3,500	4,00	2,08	37,28
ITS.6	214	Gjesåssjøen	N	60,6817	11,9924	176	9,613	15,10	4,52	3,98
ITS.7	233	Osensjøen	N	61,1758	11,8877	438	7,689	3,05	1,7	43,64
ITS.8	236	Rokossjøen	N	60,7869	11,4407	215	11,810	8,25	2,8	3,77
ITS.9	242	Sør Mesna	N	61,0764	10,8000	522	7,514	6,70	2,25	6,93
ITS.10	252	Vermundsjøen	N	60,6951	12,3870	215	11,945	9,25	1,98	3,34
ITS.11	258	Gjønvatnet	N	60,2697	5,8410	40	1,300	2,00	1,67	2,89
ITS.12	261	Kalandsvatnet	N	60,2709	5,4022	53	2,854	3,80	5,64	3,37
ITS.13	264	Myrkdalsvatnet	N	60,8117	6,4709	229	0,954	1,00	0,67	1,56
ITS.14	277	Engsetdalsvatnet	N	62,5333	6,6328	43	2,656	1,15	3,05	4,40
ITS.15	285	Rotevatnet	N	62,1405	6,1185	47	3,427	2,55	2,33	1,40
ITS.16	288	Vatnevatnet	N	62,1531	6,2286	90	1,314	4,70	1,98	2,05
ITS.17	326	Einavatnet	N	60,5381	10,6530	398	5,572	3,00	8,7	13,74
ITS.18	328	Randsfjorden	N	60,7230	10,2677	135	4,514	2,65	3,55	140,09
ITS.19	339	Ringsjøen	N	60,8824	10,3547	378	8,022	5,55	6,03	1,22
ITS.20	340	Sæbufjorden	N	61,0126	9,2151	379	3,659	3,10	3,01	1,53
ITS.21	344	Strondafjorden	N	60,9775	9,2486	355	2,833	2,00	2,9	13,36
ITS.22	345	Trevatna	N	60,6388	10,4353	384	9,680	4,30	2,06	4,80
ITS.23	349	Bogstadvannet	N	59,9705	10,6185	145	7,026	6,60	3,31	1,09

Sample ID	Lake ID	Lake	Country	Latitude	Longitude	Altitude	TOC	TP	Cond	Area.km^2
ITS.24	353	Aspern	N	59,1471	11,6844	106	8,539	9,95	5,56	6,59
ITS.25	361	Rødenessjøen	N	59,5320	11,6260	118	9,115	12,20	5,49	15,95
ITS.26	363	Rømsjøen	N	59,7011	11,8438	138	6,695	1,20	3,18	13,66
ITS.27	374	Edlandsvatnet	N	58,7626	5,8705	104	2,631	3,85	5,28	2,11
ITS.28	378	Hetlandsvatn	N	59,1752	6,1092	48	2,370	2,35	6,99	2,06
ITS.29	380	Lutsivatn	N	58,8601	5,8478	25	3,622	6,00	8,1	2,83
ITS.30	394	Vatsvatnet	N	59,5267	5,7042	15	4,092	18,90	4,68	2,17
ITS.31	395	Vostervatnet	N	59,0958	5,9754	54	3,122	3,60	5,87	2,66
ITS.32	404	Jølstravatnet	N	61,5579	6,4005	207	0,665	0,50	1,41	39,25
ITS.33	405	Oppstrynvatnet	N	61,9146	7,0767	29	0,344	1,70	1,39	22,97
ITS.34	433	Bandak	N	59,4016	8,2300	72	2,588	1,20	1,53	26,67
ITS.35	436	Grungevatnet	N	59,7071	7,7592	540	2,542	1,55	1,44	1,62
ITS.36	453	Vinjevatn	N	59,6123	7,8522	466	3,490	1,05	1,31	3,23
ITS.37	481	Åsrumvatnet	N	59,1633	10,0578	7	7,111	20,20	7,4	1,14
ITS.38	482	Bergsvannet	N	59,5884	10,0527	36	7,070	17,85	9,55	3,01
ITS.39	486	Goksjø	N	59,1725	10,1650	28	6,576	27,45	9,91	3,40
ITS.40	487	Hallevatnet	N	59,0253	9,9092	48	5,013	2,00	7,12	3,66
ITS.41	498	Dagarn	S	59,9037	15,7029	130	6,217	3,00	5,4	1,67
ITS.42	519	Langen	S	59,5911	18,5215	28	6,392	4,90	12,2	1,38
ITS.43	2252	Rotnessjøen	N	60,4969	12,3412	260	11,175	4,55	2,23	1,09
ITS.44	2268	Mylla	N	60,2443	10,5911	496	4,114	2,45	5,56	1,69
ITS.45	2312	Femsjøen	N	59,1332	11,4707	79	8,420	7,45	5,32	10,66
ITS.46	2374	Klämmingen	S	59,0920	17,2983	9	8,832	11,45	10,7	9,99
ITS.47	2678	Torrsjøn	S	58,9783	12,1139	102	7,619	2,35	4,98	1,76
ITS.48	2870	Visten	S	59,6299	13,3968	63	4,859	6,00	3,71	32,03

Sample ID	Lake ID	Lake	Country	Latitude	Longitude	Altitude	TOC	TP	Cond	Area.km^2
ITS.49	2872	Stora Le	S	59,3222	11,7941	103	5,253	1,90	4,49	84,88
ITS.50	2875	Näsrämmen	S	60,0339	14,1374	239	7,602	5,85	3,11	2,73
ITS.51	2878	Rangsjön	S	60,8236	12,5075	490	7,365	3,20	2,22	2,74
ITS.52	2887	Tisjön	S	60,9188	12,9657	431	6,525	4,55	1,78	27,05
ITS.53	2888	Halsjøen	S	60,8640	12,3111	299	12,275	5,80	1,28	5,18
ITS.54	2899	Jangen	S	60,1463	13,2715	212	9,409	5,25	2,97	4,51
ITS.55	3017	Sör-älgen	S	59,7243	14,6065	181	7,219	5,85	3,11	15,54
ITS.56	3019	Möckeln	S	59,3039	14,5383	88	7,538	12,60	5,34	17,99
ITS.57	3020	Ljusnaren	S	59,8792	14,9342	163	8,522	6,75	3,59	9,60
ITS.58	3025	Halvarsnoren	S	59,6318	14,5964	165	7,441	5,40	3,54	16,88
ITS.59	3027	Nätsjön	S	59,8913	14,4809	206	4,993	3,45	2,84	2,92
ITS.60	3029	Örlingen	S	59,8790	14,4200	190	6,836	6,70	2,74	1,40
ITS.61	3031	Saxen	S	59,7738	14,4097	178	5,612	4,85	4,53	7,02
ITS.62	3106	Långbjörken	S	59,7680	15,9521	92	9,503	9,65	3,75	1,67
ITS.63	3160	Skattungen	S	61,1941	14,9452	200	7,553	4,25	2,81	19,50
ITS.64	3165	Bäsingen	S	60,1606	16,3895	67	6,107	8,50	4,13	12,74
ITS.65	3167	Tisken	S	60,5309	15,6727	107	7,063	8,00	5,82	63,50
ITS.66	3185	Stora Almsjön	S	60,8784	13,2081	463	12,545	5,55	2,54	2,04
ITS.67	3189	Dragsjön	S	60,9927	13,5987	451	10,780	7,25	1,88	1,44
ITS.68	3201	Milsjön	S	60,1946	14,0086	291	9,118	3,75	2,37	3,29
ITS.69	3220	Stora Korslängen	S	59,9829	15,2304	262	5,943	2,05	2,2	3,45
ITS.70	3384	Hinsen	S	60,6821	16,0743	191	5,492	3,55	3,32	11,90
ITS.71	3397	Storsjön	S	61,6539	15,7592	355	3,768	3,15	2,9	1,89
ITS.72	3399	Grycken	S	61,5760	15,4245	240	6,299	3,30	2,24	3,17
ITS.73	3516	Holmsjön	S	62,4103	15,3132	244	5,856	3,10	3,69	50,73

Sample ID	Lake ID	Lake	Country	Latitude	Longitude	Altitude	TOC	TP	Cond	Area.km^2
ITS.74	3541	Stornaggen	S	62,2666	15,9710	357	7,174	4,70	2,7	3,04
ITS.75	5000	Forsjösjön	S	58,9535	16,2635	27	12,895	16,30	13,2	1,87
ITS.76	10000	Hurdalsjøen	N	60,3765	11,0408	176	3,711	1,60	2,77	32,81
ITS.77	10001	Harestuvatnet	N	60,1932	10,7121	234	4,060	4,35	6,27	1,98

Basic characteristics of lakes sampled

Lake ID	Project lake identifier
Lake	Lake name
Country	Country of lake's location (N = Norway, S = Sweden)
Latitude	Latitude of sampling site (decimal degrees, WGS84, from airplane GPS)
Longitude	Longitude of sampling site (decimal degrees, WGS84, from airplane GPS)
Altitude	Lake altitude (m)
TOC	Total Organic Carbon (mg/L; NIVA/UiO), Shimadzu TOC analyzer
TP	Total Phosphorus (µg/L: below detection limit (= <1) coded as -1; NIVA/UiO), molybdate-blue method (auto-analyzer) on persulfate digested sample
Cond	Specific conductivity (mS/m)
Area.km^2	Lake surface area (km²)

Table S2. Information on the fungal phyla and orders presented as % of total reads and total OTUs in *n* lakes of the whole set of Scandinavian lakes (*n* = 77).

Phylum	Order	% of total reads	% of total OTUs	Occurrence, *n* lakes
Ascomycota		**5.43**	**25.86**	
	Capnodiales	1.27	0.86	54
	Chaetothyriales	0.15	2.16	9
	Dothideales	0.31	0.43	19
	Erysiphales	0.08	0.86	8
	Helotiales	0.53	3.45	35
	Hypocreales	0.13	2.59	11
	Incertae sedis	0.02	0.86	4
	Lecanorales	0.07	0.86	8
	Pezizales	0.08	0.43	6
	Pleosporales	2.22	8.62	61
	Saccharomycetales	0.21	1.29	12
	Taphrinales	0.25	1.72	9
	Xylariales	0.13	1.72	12
Basidiomycota		**15.21**	**44.83**	
	Agaricales	1.22	9.91	35
	Atheliales	0.02	0.43	2
	Auriculariales	0.28	1.72	11
	Boletales	0.15	2.16	11
	Cantharellales	0.20	2.59	13
	Cystofilobasidiales	0.29	1.29	16
	Entylomatales	0.03	0.43	2
	Filobasidiales	0.07	0.43	4
	Hymenochaetales	0.22	2.59	14
	Incertae sedis	0.20	0.86	14
	Leucosporidiales	0.12	1.29	9

Phylum	Order	% of total reads	% of total OTUs	Occurrence, *n* lakes
	Malasseziales	0.62	0.86	31
	Phallales	0.02	0.43	2
	Polyporales	1.02	3.88	40
	Pucciniales	0.58	1.72	23
	Russulales	0.59	3.88	24
	Sporidiobolales	1.21	3.02	34
	Thelephorales	0.22	0.86	18
	Tremellales	7.52	4.31	49
	Trichosporonales	0.55	0.86	6
	Unassigned	0.05	0.86	5
	Ustilaginales	0.03	0.43	3
Chytridiomycota		**63.37**	**20.26**	
	Chytridiales	0.05	0.86	4
	Rhizophydiales	1.94	1.29	9
	Spizellomycetales	0.06	0.43	2
	Unassigned	61.32	17.67	72
Zygomycota		**0.19**	**2.16**	
	Mortierellales	0.19	2.16	9
Unassigned		**15.81**	**6.90**	42

Table S4. Fitted environmental (TOC, TP, conductivity, all log transformed) and spatial (longitude, latitude, altitude) factors onto NMDS ordination (k = 2) for the subset of 30 lakes (with > 150 total reads and > 10X coverage; coverage = total reads/OTU richness per lake). Significant correlation between axes ($P < 0.05$) is indicated by bold font. Number of permutations for assessing significance of factors is 999. Stress = 0.24.

Parameter	NMDS1	NMDS2	R^2	Pr(>r)
Latitude	-0.28394	0.95884	0.1486	0.117
Longitude	0.72591	-0.68778	0.495	0.001
Altitude	-0.98358	-0.18047	0.099	0.234
Conductivity	0.97807	-0.20826	0.3625	0.002
TOC	0.50257	-0.86454	0.3281	0.005
TP	0.64451	-0.76459	0.4128	0.001