SUPPORTING INFORMATION FOR:

Acidification in the Adirondacks: Defining the Biota in Trophic Levels of 30 Chemically Diverse Acid-Impacted Lakes

by

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Supporting Information contains 11 pages with 1 figure, 7 tables and literature references pertaining to sampling and experimental methods.

Figure S1. Location within the southwestern Adirondack Park of the 30 lakes sampled during this study. All lakes are within a 50-kilometer radius of the red dot at 43.647067, -74.681566. See Table S1 for map code identification.

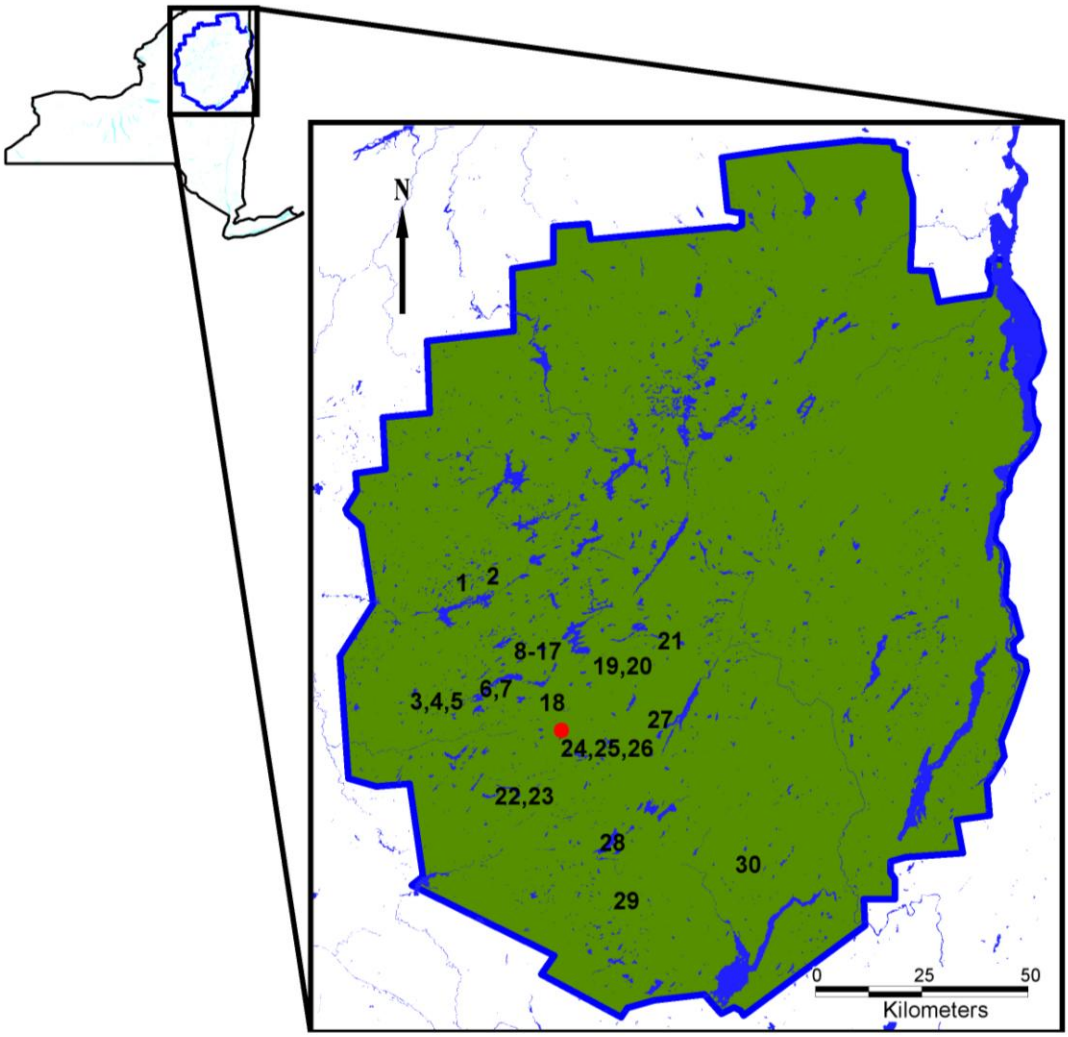

Table S1. Ponded waters sampled during the current study and their characteristics. The map code #s refer to the location on Figure S1. Mid-summer chemistry means are presented for the period 1994-1996.

Name	Map Code #	Hydrologic Type[1]	Surface Area (ha)	Max Depth (m)	pH air eq	ANC (ueq/L)	NH_4 (ueq/L)	DOC (mg/L)	NO_3 (ueq/L)	SO_4 (ueq/L)	Total P (ug/L)	Total Nitrogen (ugN/L)	Secchi depth (m)[2]	Chla (ug/L)	Ca (ueq/L)	Total Aluminum (ug/L)	Labile mono Al (ug/L)
Big Moose	13	TDL	512.1	21.3	5.3	1	2.3	4.2	19	88	5.0	586	4.7	0.9	62	225	83
Brooktrout	26	TDL	28.7	23.2	5.2	-5	1.9	1.8	12	90	1.8	283	8.2	0.9	56	148	90
Carry	27	MSL	2.8	4.6	4.9	-14	1.5	3	1	70	11.8	403	na	2.3	50	51	32
Cascade	17	MDL	40.0	6.1	6.5	44	1.3	3.8	22	97	4.3	439	na	1.1	125	92	24
Constable	14	TDH	20.6	4.0	5.0	-5	2.1	5.1	13	101	4.4	443	3.5	2	45	318	138
Dart	10	TDL	51.8	17.7	5.5	6	1.4	3.8	18	89	4.3	490	4.6	1.5	68	187	46
G	28	TDL	39.9	9.8	5.7	9	1.4	3.4	5	79	5.3	844	2.8	5.9	63	99	26
Grass	5	MDH	5.3	5.2	5.9	25	1.6	4.8	7	90	5.7	494	4.9	1.1	62	177	47
Indian	25	TDH	33.2	10.7	5.2	-2	1.3	5.4	4	74	5.3	337	3.1	2.3	60	243	75
Jockeybush	29	TDL	17.3	11.3	5.3	-2	1.1	2.6	15	93	3.5	409	8.6	1	61	120	63
Limekiln	18	MDL	186.9	21.9	6.1	20	1.6	2.8	17	83	3.9	405	9.1	0.9	89	77	10
Long	21	TDH	1.7	4.0	4.6	-18	1.9	10.7	1	79	10.6	553	1.5	3.8	40	290	104
Loon Hollow	1	TDL	5.7	11.6	4.7	-22	1.5	4.9	10	80	3.1	781	4.4	2.1	41	432	260
Middle Branch	3	MDL	17.0	5.2	6.4	54	0.9	4.5	3	79	6.4	363	2.8	4.7	95	76	12
Middle Settlement	4	TDL	15.8	11.0	5.1	-6	2.2	3.3	3	82	3.6	411	6.8	1.1	32	137	65
Moss	9	MDL	45.7	15.2	6.7	66	2	4.1	16	91	4.4	528	5.4	1.4	135	99	8
North	22	TDL	176.8	17.7	5.4	5	2	4.4	16	79	2.4	488	4.3	1.1	61	241	65
Queer	15	TDL	54.5	21.3	5.6	0	2.3	3.5	18	95	2.7	561	8.8	1.3	82	102	36
Raquette	19	MDH	1.5	3.0	6.2	60	1.6	8.3	5	104	7	489	2.4	4.5	95	320	51
Rondaxe	8	MDL	90.5	10.1	6.4	50	2.2	4	14	83	5.1	485	3.8	1.9	114	108	12
Round	6	MSL	2.6	6.4	4.7	-12	3.1	1.2	4	78	5.2	348	na	1	42	74	48
Sagamore	20	MDH	68.0	22.9	6.1	39	1.4	6.9	15	102	5.6	452	3.3	1.6	103	231	52
South	23	TDL	202.0	20.1	5.3	-3	1.2	2.5	23	74	3.8	595	8.1	0.9	57	148	64
Squash	12	TDH	3.3	5.8	4.5	-34	1.4	6.5	1	72	8.7	826	2.5	2.4	32	346	130
Squaw	24	TDL	36.4	6.7	6.0	13	1.3	3.6	9	91	6.2	501	3.6	3.2	101	72	11
West	11	TDH	10.4	5.2	5.2	5	4	6.5	2	85	9.5	549	2.1	8	43	195	36
Wheeler	7	MDH	5.2	18.0	6.3	41	1.8	6.2	3	79	8.2	489	2.9	2.8	90	117	6
Willis	30	MDL	14.6	2.7	6.6	56	1.6	4.3	2	80	10.4	436	na	4.7	112	44	5
Willy's	2	TDL	24.3	13.7	4.8	-16	1.1	2.9	27	100	2.5	619	8.3	0.6	47	388	224
Windfall	16	CD	2.4	6.1	6.9	119	1	4.1	20	107	7.8	748	4.1	3.8	205	59	11

[1] First letter designates till depth, either thin (T) or medium (M); second letter designates drainage (D) or seepage (S) waters; third letter designates either low (L) or high (H) DOC concentration; CD = carbonate-influenced drainage

[2] '*na*' indicates that the secchi disc was visible on the bottom during all mid-summer sampling periods.

TABLE S2. Physical, chemical and biological parameters, collection protocols and laboratory methodology.

PARAMETER	COLLECTION TECHNIQUE AT LAKE SITE	ANALYTICAL METHODOLOGY	REFERENCES
Physical Characteristics: Light, dissolved oxygen, secchi, temperature	Vertical profiles at 1m intervals at deep site	Standard secchi protocol; YSI dissolved oxygen-temperature meter; Licor light meter	
Chemical Characteristics: pH, ANC, conductivity, NO_3, NH_4, TN, TP, PO_4, DOC, Ca, SO_4, Tot Al, labile mono-Al, chlorophyll	Integrated epilimnetic sample; hypolimnetic grab sample at least 1 m above the bottom sediment	Ion Chromatograph, Atomic Absorption, Autoanalyzer, Spectrophotometer, pH meter, DOC analyzer, Flow Injection Analysis, Inductively Coupled Plasma Emission	Analytes (S1) Chlorophyll (S2)
Biological Characteristics: Bacterioplankton	Integrated epilimnetic sample Hypolimnetic grab sample	16S ribosomal DNA, cloning, sequencing, phylogenetic analyses & 16S ribosomal RNA analysis (collected and stored for *in situ* hybridizations)	Nucleic acid techniques (11) Primers (S3)
Biological Characteristics: Phytoplankton	Integrated photic zone sample – in lakes more shallow than 2x the secchi depth, samples were collected from the surface to 1 m above the bottom Samples were stored in amber 250 mL PE bottles w 3% gluteraldeyyde:formaldehyde solution	Species identification and enumeration – The 1994-1995 samples were membrane filtered, cleaned, mounted, and examined at 625x magnification. One to three slides were prepared from each sample and 10-30 microscope fields were examined on each slide. The 1996 samples were concentrated by centrifugation (20 min @ 1000g) and Utermöhl sedimentation chambers (10mL), examination with an inverted compound microscope, identification to lowest possible taxon (at up to 1500x magnification) and enumeration of random fields. 500 natural units (colonies or individual cells) were identified and enumerated (at 645x) from each sample; large forms were identified and enumerated at low power (150x). Using common geometric shapes, the biovolume (um^3) was calculated for each taxon; percent biovolume and total biovolume (um^3/mL) in each sample were determined.	Inverted Microscopy (S4, S5) Taxonomy (S6, S7, S8, S9, S10, S11, S12, S13)
Biological Characteristics: Zooplankton	Constant flow pump, 64 µm mesh net, integrated to depth of photic zone or 15 m (or within 1 m of bottom); samples rinsed into 250 mL PE bottle; narcotized with CO_2; preserved with formalin	Species identification and enumeration	Rotifer taxonomy (S14, S15) Crustacean taxonomy (S16, S17, S18, S19, S20)
Biological Characteristics: Macrophytes	SCUBA transects	Species identification, density, diversity and dominance	Transects (S21) Taxonomy (S22)
Biological Characteristics: Fish	Trapnet, seine, gillnet, snorkeling	Net setting, tags, identification, enumeration, size, scales for age-growth estimates	Netting (S23) Tagging (S24) Population estimates (S25)

TABLE S3. Chemical parameters and analytical methods.

PARAMETER	ANALYTICAL METHOD
pH	Electrometric (US EPA Method 150.1)
ANC	Gran Titration (US EPA Method 310.1)
Specific Conductance	Wheatstone Bridge type meter (US EPA Method 120.1)
Dissolved Oxygen	Membrane Electrode (US EPA Method 360.1)
Inorganic Anions (NO_3, SO_4)	Ion Chromatography (US EPA Method 300.0)
Total Nitrogen	Persulfate Oxidation
Total Phosphorus	Colorimetric (US EPA Method 365.2)
Dissolved Organic/Inorganic Carbon	IR Spectroscopy (US EPA Method 415.2)
Ammonium	Flow Injection Analysis (Lachat)
Total Metals	Atomic Absorption (US EPA Method 200)
Aluminum (total)	Inductively Coupled Plasma Emission
Aluminum (labile monomeric)	Flow Injection

Table S4. Characteristics for the 50 most common phytoplankton species identified in the 30 study lakes, including major taxonomic group, the lowest pH at which the species occurred, acidification category, the percent occurrence of each species (# of lakes in which the species occurred divided by the total of 30 lakes) and the number of lakes with the specified relative densities of each phytoplankton species. For Acidification Category, AT = acid tolerant, AR = acid resistant, AS = acid sensitive; see text for explanation. Widespread means the species comprised 5 – 25% of the phytoplankton community density; Abundant means the species comprised 25 – 50% of the phytoplankton community density.

Algal Taxon	Algal Group	Lowest pH of Occurrence	Acidification Category	% Occurrence	Widespread (5% to 25%)	Abundant (25% to 50%)
Cryptomonas ovata Ehrenberg	crypto	4.5	AT	100.0	18	1
Dinobryon divergens Imhof	chryso	4.5	AT	43.3	2	0
Dinobryon sertularia Ehrenberg	chryso	4.5	AT	80.0	5	1
Eunotia sp.	bacillario	4.5	AT	36.7	2	0
Gloeocystis sp.	chloro	4.5	AT	50.0	0	0
Mallomonas sp.	chryso	4.5	AT	93.3	17	4
Microcystis incerta Lemmermann	cyano	4.5	AT	26.7	0	0
Oocystis parva West et West	chloro	4.5	AT	83.3	0	0
Tabellaria fenestrata (Lyngbye) Kützing	bacillario	4.5	AT	73.3	1	0
Undetermined Green (coccoid)	chloro	4.5	AT	100.0	0	0
Undetermined Chrysophyte sp. 1 ANS FWA	chryso	4.5	AT	100.0	12	0
Chrysococcus rufescens Klebs	chryso	4.6	AT	56.7	0	0
Gonyostomum semen (Ehrenberg) Diesing	chloro	4.6	AT	33.3	7	1
Oocystis pusilla Hansgirg	chloro	4.6	AT	86.7	1	0
Oocystis submarina Lagerheim	chloro	4.6	AT	46.7	0	0
Peridinium inconspicuum Lemmermann	pyrrho	4.6	AT	86.7	7	1
Sphaerocystis schroeteri Chodat	chloro	4.6	AT	70.0	5	0
Undetermined Cyanobacteria (colonial	cyano	4.6	AT	50.0	1	0
Unk. Dinoflagellate sp. 1 ANS FWA	pyrrho	4.6	AT	16.7	3	0
Chroococcus sp.	cyano	4.7	AT	96.7	9	1
Cosmarium sp.	chloro	4.7	AT	30.0	4	1
Dinobryon bavaricum Imhof	chryso	4.7	AT	96.7	12	2
Gymnodinium sp.	pyrrho	4.7	AT	50.0	1	0
Merismopedia tenuissima Lemmermann	cyano	4.7	AT	90.0	15	3
Mougeotia sp.	chloro	4.7	AT	43.3	4	1
Nitzschia sigmoidea (Nitzsch) Ehrenberg	bacillario	4.7	AT	36.7	0	0
Peridinium limbatum Lemmermann	pyrrho	4.7	AT	36.7	5	1
Peridinium wisconsinense Eddy	pyrrho	4.7	AT	50.0	4	1
Cymbella sp.	bacillario	4.8	AT	16.7	0	0
Phormidium sp.	cyano	4.8	AT	83.3	0	0
Botryococcus braunii Kützing	chloro	4.9	AT	26.7	2	0
Dictyosphaerium pulchellum Wood	chloro	4.9	AT	63.3	0	0
Melosira varians Agardh	bacillario	4.9	AT	10.0	1	0
Pinnularia sp.	bacillario	4.9	AT	43.3	0	0
Selenastrum minutum (Nägeli) Collins	chloro	4.9	AT	66.7	1	0
Rhodomonas minuta Skuja	crypto	5.0	AR	86.7	0	0
Tabellaria flocculosa (Roth) Kützing	bacillario	5.1	AR	86.7	0	0
Arthrodesmus incus (Brébisson) Hassall	chloro	5.2	AR	50.0	0	0
Chrysosphaerella longispina Lauterborn	chryso	5.2	AR	50.0	0	0
Cyclotella sp.	bacillario	5.3	AR	43.3	0	0
Peridinium sp.	pyrrho	5.3	AR	33.3	1	0
Rhabdogloea smithii (Chodat) Komárek	cyano	5.4	AR	23.3	1	0
Staurastrum pentacerum Smith	chloro	5.4	AR	26.7	0	0
Aulacoseira ambigua (Grunow) Simonsen	bacillario	6.0	AS	33.3	0	0
Aulacoseira sp.	bacillario	6.0	AS	20.0	0	0
Staurastrum curvatum West	chloro	6.0	AS	10.0	0	0
Synedra sp.	bacillario	6.0	AS	26.7	0	0
Cylindrocapsa geminella Wolle	chloro	6.2	AS	13.3	0	0
Synura sp.	chryso	6.2	AS	30.0	0	0
Scenedesmus serratus (Corda) Bohlin	chloro	6.7	AS	16.7	0	0

Table S5. Characteristics for 27 rotifer species identified in the 30 study lakes, including the lowest pH at which the species occurred, acidification category, the percent occurrence of the species and the number of lakes with the specified relative densities of the rotifer species. For Acidification Category, AT = acid tolerant, AR = acid resistant, AS = acid sensitive; see text for explanation. Widespread means the species comprised 5 – 25% of the rotifer community density; Abundant, the species comprised 25 – 50%; and Dominant, the species comprised greater than 50% of the community density.

Rotifers	Lowest pH of Occurrence	% Occurrence	Acidification Category	Widespread 5-25%	Abundant 25-50%	Dominant > 50%
Keratella taurocephala Meyers 1938	4.5	100.0	AT	4	5	18
Polyarthra vulgaris Carlin 1943	4.5	100.0	AT	15	1	1
Polyarthra major Burckhardt 1900	4.5	56.7	AT	1	0	0
Conochiloides dossuarius Hudson 1885	4.5	43.3	AT	3	0	0
Monostyla lunaris Ehrbg. 1882	4.5	26.7	AT	0	0	0
Lecane mira Murray 1913	4.6	50.0	AT	0	0	0
Ascomorpha ecaudis Perty 1850	4.6	93.3	AT	0	0	0
Gastropus stylifer Imhoff 1891	4.7	96.7	AT	14	2	1
Synchaeta pectinata Ehrbg. 1892	4.7	40.0	AT	0	0	0
Collotheca mutabilis Hudson 1885	4.7	73.3	AT	1	0	0
Trichocerca multicrinnis Kelicott 1897	4.7	86.7	AT	0	0	0
Monostyla closterocerca Schmarda 1895	4.7	3.3	AT	0	0	0
Trichotria tetrarchis Ehrbg. 1889	4.8	3.3	AT	0	0	0
Microcodon clavus	4.8	33.0	AT	0	0	0
Conochilus unicornis Rousselet 1892	4.9	56.7	AT	4	2	0
Unknown one toe	5.0	13.3	AT	0	0	0
Asplanchna priodonta Gosse 1850	5.1	33.3	AR	0	0	0
Keratella hiemalis Carlin 1943	5.1	43.3	AR	2	0	0
Kellicottia bostoniensis Rousselet 1892	5.1	60.0	AR	7	1	0
Kellicottia longispina Kelicott 1879	5.1	53.3	AR	5	2	0
Ascomorpha saltans Bartsch 1870	5.2	26.7	AR	0	0	0
Keratella crassa Ahlstrom 1943	5.2	63.3	AR	6	0	0
Trichocerca rousselet Voigt 1901	5.3	26.7	AR	0	0	0
Ploesoma truncatum Levander 1894	5.3	46.7	AR	0	0	0
Trichocerca cyclindrica Imhoff 1981	5.5	33.3	AR	0	0	0
Keratella cochlearis Gosse 1851	5.9	50.0	AS	5	2	0
Hexarthra mira Hudson 1871	6.6	3.3	AS	0	0	0

Table S6. Characteristics for 19 crustacean species identified in the 30 study lakes, including the lowest pH at which the species occurred, acidification category, the percent occurrence of the species and the number of lakes with the specified relative densities of crustacean species. For Acidification Category, AT = acid tolerant, AR = acid resistant, AS = acid sensitive; see text for explanation. Widespread means the species comprised 5 – 25% of the crustacean community density; Abundant, the species comprised 25 – 50%; and Dominant, the species comprised greater than 50% of the community density.

Crustaceans	Lowest pH of Occurrence	% Occurrence	Acidification Category	Widespread 5-25%	Abundant 25-50%	Dominant > 50%
Orthocyclops modestus Forbes 1881	4.5	6.7	AT	1	0	0
Diaphanosoma branchyurum Lieven 1848	4.5	40.0	AT	2	0	0
Holopedium gibberum Zaddach 1855	4.5	73.3	AT	7	0	0
Daphnia pulex Forbes 1882	4.5	6.7	AT	0	0	0
Sinobosmina freyi De Melo 1994	4.5	86.7	AT	8	5	3
Agalodiaptomus leptopus Lilljeborg 1889	4.5	20.0	AT	0	0	3
Mesocyclops edax Forbes 1891	4.7	83.3	AT	17	0	0
Tropocyclops extensus Kiefer 1931	4.7	60.0	AT	6	2	1
Leptodiaptomus minutus Herrick 1893	4.7	86.7	AT	2	7	15
Polyphemus pediculum Linneaus 1761	4.7	66.7	AT	0	0	0
Alona spp.	4.7	10.0	AT	0	0	0
Daphnia catawba Coker 1926	4.7	90.0	AT	10	1	0
Cyclops scutifer Sars 1863	5.1	36.7	AR	5	0	0
Eubosmina maritima De Melo 1994	5.5	43.3	AR	8	1	0
Daphnia ambigua Scourfield 1947	5.7	6.7	AS	0	0	0
Diaphanosoma birgei Korinek 1981	6.0	26.7	AS	0	0	0
Epischura lacustris Forbes 1882	6.1	26.7	AS	1	0	0
Skistodiaptomus oregonensis Lilljeborg 1889	6.3	3.3	AS	0	0	1
Daphnia parvula Fordyce 1901	6.4	3.3	AS	0	0	0

Table S7. Characteristics for 52 aquatic macrophyte species identified in the study lakes, including the lowest pH at which the species occurred, the acidification category and the percent occurrence of the species. For Acidification Category, AT = acid tolerant, AR = acid resistant, AS = acid sensitive; see text for explanation.

Species	Common Name	Lowest pH of Occurrence	Acidification Category	% Occurrence
Eriocaulon aquaticum	Pipewort	4.74	AT	74
Utricularia resupinata	Lavender bladderwort	4.74	AT	68
Nuphar variegata	Yellow pond lily	4.74	AT	65
Isoetes echinospora	Quillwort	4.74	AT	48
Juncus pelocarpus	Bog rush	4.74	AT	45
Potamogeton epihydrus	Ribbon-leaf pondweed	4.74	AT	35
Dulichium arundinaceum	Threesquare	4.74	AT	26
Ranunculus reptans	Creeping spearwort	4.74	AT	3
Subularia aquatica	Awlwort	4.74	AT	3
Utricularia purpurea	Purple bladderwort	4.80	AT	71
Utricularia geminiscapa	Hidden flower bladderwort	4.80	AT	45
Scirpus subterminalis	Bulrush	4.80	AT	39
Nymphaea odorata	White waterlily	4.80	AT	29
Sphagnum sp.	Sphagnum moss	4.80	AT	6
Lobelia dortmanna	Water lobelia	4.87	AT	55
Potamogeton confervoides	Pondweed	4.87	AT	52
Myriophyllum tenellum	Leafless milfoil	4.87	AT	45
Fontinalis sp.	Moss	4.87	AT	23
Utricularia intermedia	Bladderwort	4.87	AT	19
Isoetes sp.	Quillwort	4.87	AT	10
Sparganium sp.	Sparganium	4.94	AT	65
Carex sp.	Sedge	4.94	AT	10
Utricularia vulgaris	Great bladderwort	5.25	AR	35
Eleocharis sp.	Spikerush	5.25	AR	19
Vallisneria americana	Wild celery	5.25	AR	13
Myriophyllum humile	Low watermilfoil	5.25	AR	10
Elodea sp.	Waterweed	5.25	AR	6
Nymphoides cordatum	Floating heart	5.32	AR	23
Isoetes lacustris	Large spored quillwort	5.32	AR	16
Brasenia schreberi	Watershield	5.36	AR	29
Eleocharis acicularis	Needle spikerush	5.36	AR	19
Sagittaria graminea	Grassy arrowhead	5.51	AR	19
Potamogeton pusillus	Narrowleaf pondweed	5.51	AR	16
Utricularia minor	Little bladderwort	5.51	AR	16
Stuckenia pectinatus	Sago pondweed	5.51	AR	10
Pontederia cordata	Pickerelweed	5.66	AS	10
Myriophyllum verticillatum	Whorl-leaf watermilfoil	5.70	AS	3
Chara spp.	Muskgrass	5.88	AS	19
Najas flexilis	Water naiad	5.88	AS	10
Iris versicolor	Blue flag iris	5.88	AS	6
Sagittaria latifolia	Arrowhead	5.88	AS	3
Equisetum sp.	Horsetail	6.19	AS	6
Potamogeton spirillus	Little pondweed	6.19	AS	6
Sagittaria cuneata	Arumleaf arrowhead	6.35	AS	10
Megalodonta beckii	Water marigold	6.35	AS	3
Nitella spp.	Muskgrass	6.57	AS	6
Elatine minima	Little elatine	6.57	AS	3
Ceratophyllum demersum	Coontail	6.60	AS	6
Elodea canadensis	Waterweed	6.60	AS	3
Potamogeton amplifolius	Broad-leaf pondweed	6.60	AS	3
Potamogeton vaseyi	Vaseys pondweed	6.60	AS	3
Potamogeton natans	Floating-leaf pondweed	6.80	AS	3

Supplemental references that deal with techniques and taxonomy

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