Pike Lake Chain, Oneida and Vilas Counties, WI (Google Earth Map)

Using Lake Sediment Surveys to Evaluate Growth Potential of Curlyleaf Pondweed and Eurasian Watermilfoil and Sediment Phosphorus Release in the Pike Lake Chain, Price and Vilas Counties, Wisconsin

[Sediments Collected September 29, 2010]

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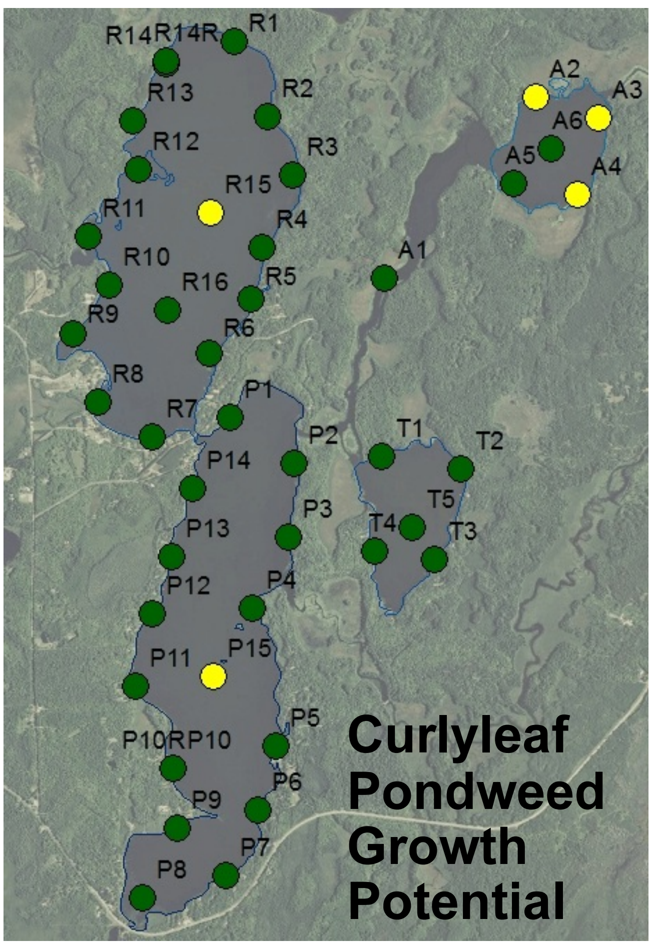
Summary

If the non-native aquatic plants, curlyleaf pondweed and Eurasian watermilfoil, should invade the Pike Lake Chain, the question is what would they do in the lakes. For managing non-native plants it is helpful to know where the plants have the potential to grow to nuisance conditions. A lake sediment sampling technique (McComas, unpublished) shows where curlyleaf pondweed and Eurasian watermilfoil have the potential to grow to heavy conditions based on lake sediment characteristics. This technique was applied to the Pike Lake Chain (Amik, Pike, Round and Turner). The sediment samples were collected from 42 sites around the Pike Lake Chain on September 29, 2010. The lake sediments were analyzed at the Soils Lab at the University of Minnesota.



Curlyleaf Pondweed Growth Potential: Lake sediment sampling results from 2010 have been used to predict lake bottom areas that have the potential to support three types of curlyleaf pondweed plant growth: light, moderate, or heavy based on the key sediment parameters of pH, the Fe:Mn ratio, sediment bulk density, and organic matter (McComas, unpublished). Curlyleaf pondweed growth potential is predicted to produce low growth and moderate growth (where plants may occasionally top out in a broken canopy) in the Pike Lake Chain. Currently, curlyleaf has not been found in the Pike Lake Chain.

Figure S1. The circle color indicates the type of curlyleaf pondweed growth predicted to occur at that site. Key: green = light; yellow = moderate; red = heavy.

Eurasian Watermilfoil Growth Potential: Lake sediment sampling results from 2010 have been used to predict lake bottom areas that have the potential to support heavy EWM growth. Based on the key sediment parameters of NH_4 and organic matter (McComas, unpublished), a table and map were prepared that predict what type of growth could be expected for milfoil growth in the Pike Lake Chain (Figure S2).

Conclusions: The Pike Lake Chain sediment survey results indicate a potential for low to moderate growth of curlyleaf and with a potential for mostly moderate growth of Eurasian watermilfoil. Definitions of light, moderate, and heavy growth are shown on the next two pages.

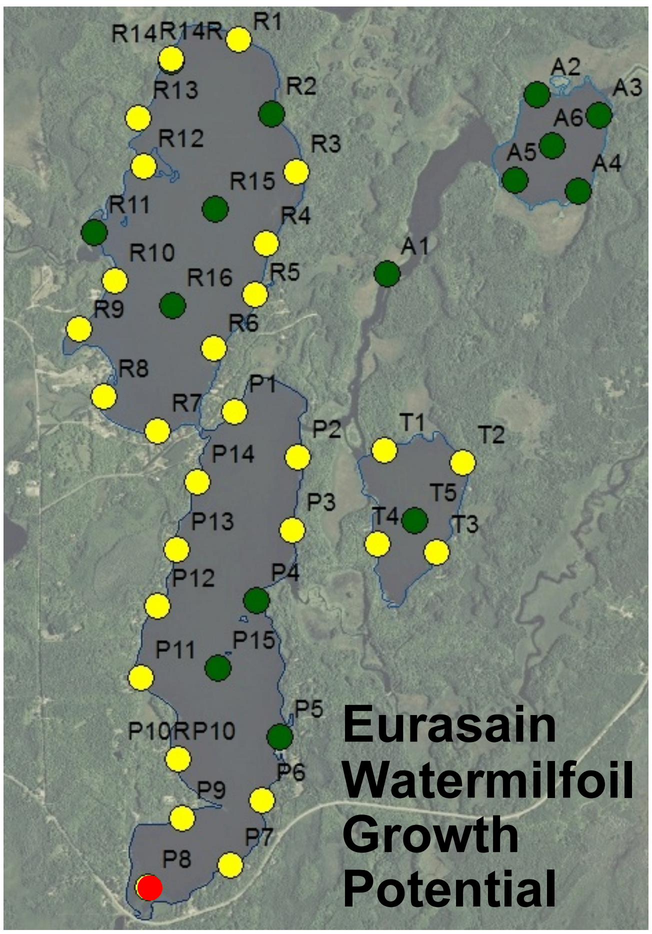


Figure S2. The circle color indicates the type of Eurasian watermilfoil growth predicted to occur at that site. Key: green = light; yellow = moderate; red = heavy.

Curlyleaf Pondweed Growth Characteristics

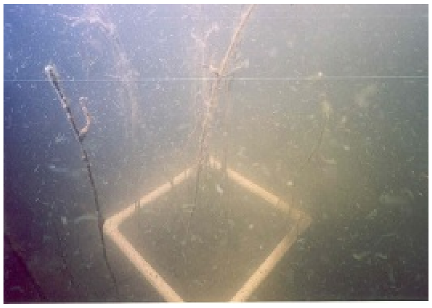
(source: Steve McComas, Blue Water Science, unpublished)

Light Growth Conditions

Plants rarely reach the surface.

Navigation and recreational activities are not generally hindered.

Stem density: 0 - 160 stems/m^2
Biomass: 0 - 50 g-dry wt/m^2
Estimated TP loading: <1.7 lbs/ac



MnDNR rake sample density equivalent for light growth conditions: 1, 2, or 3.

Moderate Growth Conditions

Broken surface canopy conditions.

Navigation and recreational activities may be hindered.

Lake users may opt for control.

Stem density: 100 - 280 stems/m^2
Biomass: 50 - 85 g-dry wt/m^2
Estimated TP loading: 2.2 - 3.8 lbs/ac

MnDNR rake sample density equivalent for moderate growth conditions: 2, 3 or sometimes, 4.

Heavy Growth Conditions

Solid or near solid surface canopy conditions.

Navigation and recreational activities are severely limited.

Control is necessary for navigation and/or recreation.

Stem density: 400+ stems/m^2
Biomass: >300 g-dry wt/m^2
Estimated TP loading: >6.7 lbs/ac

MnDNR rake sample density has a scale from 1 to 4. For certain growth conditions where plants top out at the surface, the scale has been extended: 4.5 is equivalent to a near solid surface canopy and a 5 is equivalent to a solid surface canopy. Heavy growth conditions have rake densities of a 4 (early to mid-season with the potential to reach the surface), 4.5, or 5.

Eurasian Watermilfoil Growth Characteristics

(source: Steve McComas, Blue Water Science, unpublished)

Light Growth Conditions

Plants rarely reach the surface.

Navigation and recreational activities generally are not hindered.

Stem density: 0 - 40 stems/m^2
Biomass: 0 - 51 g-dry wt/m^2

MnDNR rake sample density equivalent for light growth conditions: 1, 2, or 3.

Moderate Growth Conditions

Broken surface canopy conditions. However, stems are usually unbranched.

Navigation and recreational activities may be hindered.

Lake users may opt for control.

Stem density: 35 - 100 stems/m^2
Biomass: 30 - 90 g-dry wt/m^2

MnDNR rake sample density equivalent for moderate growth conditions: 3 or 4.

Heavy Growth Conditions

Solid or near solid surface canopy conditions. Stems typically are branched near the surface.

Navigation and recreational activities are severely limited.

Control is necessary for navigation and/or recreation.

Stem density: 250+ stems/m^2
Biomass: >285 g-dry wt/m^2

MnDNR rake sample density has a scale from 1 to 4. For heavy growth conditions where plants top out at the surface, the scale has been extended: 4.5 is equivalent to a near solid surface canopy and a 5 is equivalent to a solid surface canopy.

Pike Lake Chain Sediment Phosphorus Release Potential Based on Phosphorus Concentrations and Fe:P Ratios

A variety of factors contribute to internal phosphorus loading in lakes. Research by Jensen et al (1992) found when a total iron to total phosphorus ratio was greater than 15 to 1, phosphorus release from lake sediments was minor. That benchmark has been used to characterize the potential of the Pike Lake Chain lake sediments to release phosphorus. Results show a mix of sediment Fe:P ratios in shallow and deep water. Round Lake has the highest potential for phosphorus release and Amik has the lowest potential.

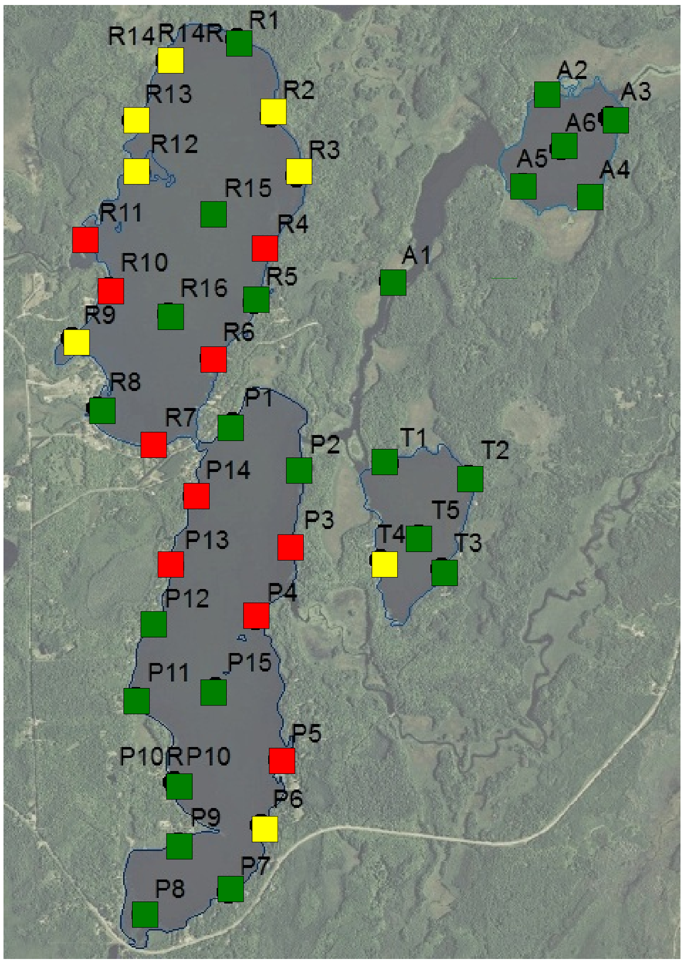


Figure S3. Lake sediment sample locations are shown with color squares. Colored squares represent phosphorus release potential at that site. Key: Green = low; Yellow = moderate; and Red = high.

Lake Water Quality Data (2010)

	Amik	Pike	Round	Turner
Total Phos (ug/l):	36	44	31	24
Secchi disc (ft):	4.6	3.3	4.6	6.6
Chlorophyll (ug/l):	18	14	8	7

Introduction

For managing non-native plants it is helpful to know where the plants have the potential to grow to nuisance conditions. A technique developed by Blue Water Science shows where nuisance growth of curlyleaf pondweed and Eurasian watermilfoil can occur in a lake based on lake sediment characteristics. This technique was applied to Lake Nokomis.

Pike Lake chain sediments were collected from 42 sites around the lake on September 29, 2010. The lake sediments were analyzed at the Soils lab at the University of Minnesota and results are presented in this report.

Methods

Lake Soil Collection: A total of 42 lake sediment samples were collected from the depth of 3 to 30 feet on September 29, 2010 by Steve McComas, Blue Water Science. Samples were collected using a modified soil auger, 5.2 inches in diameter (Figure 1) and soils were sampled to a depth of 6 inches. The lake soil from the sampler was transferred to 1-gallon zip-lock bags and delivered to the University of Minnesota soil testing laboratory.

Lake Soil Analysis: At the lab, sediment samples were air dried at room temperature, crushed and sieved through a 2 mm mesh sieve. Sediment samples were analyzed using standard agricultural soil testing methods. Fifteen parameters were tested for each soil sample. A summary of extractants and procedures is shown in Table 1. Routine soil test results are given on a weight per volume basis.

Table 1. Soil testing extractants used by University of Minnesota Crop Research Laboratory. These are standard extractants used for routine soil tests by most Midwestern soil testing laboratories (reference: Western States Laboratory Proficiency Testing Program: Soil and Plant Analytical Methods, 1996-Version 3).

Parameter	Full Name	Extractant
P-Bray	Phosphorus - Bray	0.025M HCL in 0.03M NH_4F
P-Olsen	Phosphorus - Olsen	0.5M $NaHCO_3$
NH_4-N	Ammonium - nitrogen	2N KCL
K, Ca, Mg	Potassium, Calcium, Magnesium	1N NH_4OA_c (ammonium acetate)
Fe, Mn, Zn, Cu	Iron, Manganese, Zinc, Copper	DTPA (diethylenetriamine pentaacetic acid)
B	Boron	Hot water
SO_4-S	Sulfate - sulfur	$Ca(H_2PO_4)_2$
pH		water
Organic matter		Loss on ignition at 360^{o}C

Figure 1. Soil auger used to collect lake sediments.

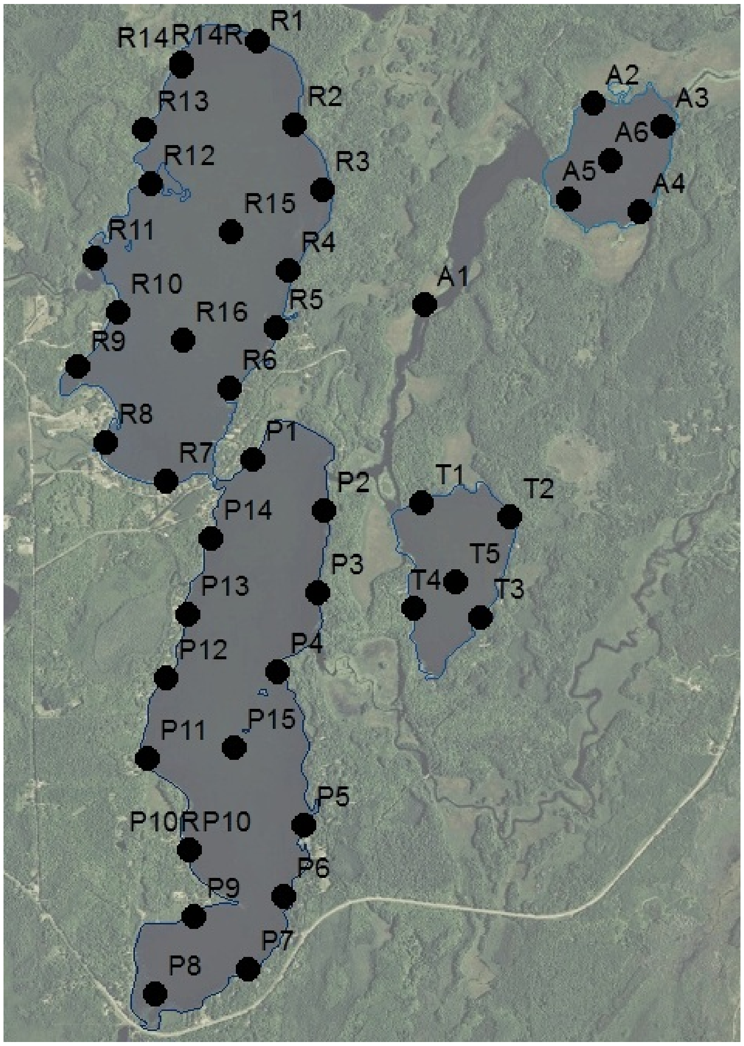


Figure 2. lake sediment sample locations are shown with black circles.

Reporting Lake Soil Analysis Results: Lake soils and terrestrial soils are similar from the standpoint that both provide a medium for rooting and supply nutrients to the plant.

However, lake soils are also different from terrestrial soils. Lake soils (or sediments) are water logged, generally anaerobic and their bulk density ranges from being very light to very dense compared to terrestrial soils.

There has been discussion for a long time on how to express analytical results from soil sampling. Lake sediment research results are often expressed as grams of a substance per kilogram of lake sediment, commonly referred to as a weight basis (mg/kg). However, in the terrestrial sector, to relate plant production and potential fertilizer applications to better crop yields, soil results typically are expressed as grams of a substance per cubic foot of soil, commonly referred to as a weight per volume basis. Because plants grow in a volume of soil and not a weight of soil, farmers and producers typically work with results on a weight per volume basis.

That is the approach used here for lake sediment results: they are reported on a weight per volume basis or $\mu g/cm^3$.

A bulk density adjustment was applied to lake sediment results as well. For agricultural purposes, in order to standardize soil test results throughout the Midwest, a standard scoop volume of soil has been used. The standard scoop is approximately a 10-gram soil sample. Assuming an average bulk density for an agricultural soil, a standard volume of a scoop has been a quick way to prepare soils for analysis, which is convenient when a farmer is waiting for results to prepare for a fertilizer program. It is assumed a typical silt loam and clay texture soil has a bulk density of 1.18 grams per cm^3. Therefore a scoop size of 8.51 cm^3 has been used to generate a 10-gram sample. It is assumed a sandy soil has a bulk density of 1.25 grams per cm^3 and therefore a 8.00 cm^3 scoop has been used to generate a 10-gram sample. Using this type of standard weight-volume measurement, the lab can use standard volumes of extractants and results are reported in ppm which is close to $\mu g/cm^3$. For all sediment results reported here a scoop volume of 8.51 cm^3 was used.

However lake sediment bulk density has wide variations but only a single scoop volume of 8.51 cm^3 was used for all lake sediment samples. This would not necessarily produce a consistent 10-gram sample. Therefore, for our reporting, we have used corrected weight volume measurements and results have been adjusted based on the actual lake sediment bulk density. We used a standard scoop volume of 8.51 cm^3, but sediment samples were weighed. Because test results are based on the premise of a 10 gram sample, if our sediment sample was less than 10 grams, then the reported concentrations were adjusted down to account for the less dense bulk density. If a scoop volume weighed greater than 10.0 grams than the reported concentrations were adjusted up. For example, if a 10-gram scoop of lake sediment weighed 4.0 grams, then the correction factor is 4.00 g/ 10.00 g = 0.40. If the analytical result was 10 ppm based on 10 grams, then it should be 0.40 x 10 ppm = 4 ppm based on 4 grams. The results could be written as 4 ppm or 4 $\mu g/cm^3$. Likewise, if a 10-gram scoop of lake sediment weighed 12 grams, then the correction factor is 12.00 g / 10.00 g = 1.20. If the analytical result was 10 ppm based on a 10 gram scoop, then it should be 1.20 x 10 ppm = 12 ppm based on 12 grams. The result could be written as 12 ppm or 12 $\mu g/cm^3$. These are all dry weight determinations.

This correction factor is important for evaluating the ammonium-nitrogen raw data. There appears to be a threshold nitrogen concentration at 10 ppm. If nitrogen is greater than 10 ppm, heavy milfoil growth can occur. If the correction factor is not applied, light, fluffy sediments may produce a high nitrogen reading, but would not support heavy milfoil growth. When the correction factor is applied, and if the nitrogen concentration falls below 10 ppm, light or moderate growth of milfoil is predicted rather than heavy growth.

Delineating Areas of Potential Heavy Curlyleaf and Milfoil Growth: Delineating an area of potential heavy plant growth is based on conventional soil survey techniques. For this report, a zone sampling method rather than a grid sampling method was used for collecting lake sediments. For example, if sediment results show a potential for heavy growth collected in a cove, typically, the water depth in the cove from 5 to 7 feet would be designated as having a potential for heavy growth. If samples found along a stretch of shoreline had a potential for heavy growth, a designated heavy growth area would be delineated until there was a shoreline break or change in sediment texture. In other cases, if the next site down the shoreline showed a potential for light growth, then the designated heavy growth area would extend midway between a heavy and light potential growth sample sites.

Results

Potential for Heavy Growth of Non-native Invasive Plants Based on Lake Sediment Characteristics

A total of 42 sediment sites were sampled around the Pike Lake Chain (Amik, Pike, Round, Turner). Sediment depths, locations, and physical characteristics are shown in Table 2. Sample locations are shown in Figure 2. Aquatic plants were found growing out to 10 feet of water.

Table 2. Pike Chain of lakes sediment sample locations and field observations on Sept 29, 2010.

	E	N	Depth	Notes
A1	728758	5089850	7	fern pondweed, mucky sediments
A2	729870	5091178	7	fern dominates plants
A3	730322	5091193	7.5	muck, fern
A4	730166	5090463	11	fern, soft sediments
A5	729700	5090546	7	very soft sediments
A6	729976	5090800	6	
P1	727630	5088834	7	sandy
P2	728080	5088500	7.5	
P3	728050	5087961	5	sand-soft
P4	727787	5087446	4	
P5	727960	5086440	5.5	sand
P6	727829	5085963	5	sand
P7	727594	5085490	7	silty sand
P8	726983	5085323	5	soft fine grained sand muck
P9	727236	5085838	6	silty sand-wood slabs
P10	727212	5086277	7	fine sand
P10R	727212	5086277	6	
P11	726935	5086876	7	course sand
P12	727058	5087400	4	
P13	727200	5087824	4	by bulrush
P14	727355	5088316	7	
P15	727500	5086940	16	
R1	727656	5091580	7	sand darker
R2	727900	5091031	4	
R3	728088	5090609	5	
R4	727856	5090075	4	sand
R5	727775	5089700	6	sand
R6	727475	5089308	5	sand
R7	727055	5088691	5	
R8	726665	5088949	5	
R9	726481	5089450	7	
R10	726738	5089800	6	
R11	726590	5090156	7.5	sand
R12	726951	5090649	7	
R13	726917	5091007	7.5	sand
R14	727157	5091423	7	
R14r	727160	5091445	7	
R15	727483	5090331	25	
R16	727166	5089619	22	
T1	728740	5088550	7	NWM, mostly sand
T2	729315	5088459	7.5	NWM, claspingleaf, water celery, sand
T3	729124	5087800	6.5	sand gravel muck, NWM
T4	728690	5087855	8	sand, gravel
T5	728962	5088030	13.5	

The Pike Chain sediment results are shown in Table 3. A total of 15 parameters were analyzed for each sediment sample. Most of the samples had a bulk density of 1.4 g/cm^3 or less, indicating a mix of sand and muck. For other parameters, like phosphorus and nitrogen, concentrations were variable and ranged from low to high. Two deep water samples were analyzed and were found to have higher concentrations of most of the parameters compared to the littoral zone samples.

Table 3. Pike Chain soil data. Sample were collected on September 29, 2010. Soil chemistry results are reported as µg/cm^3-dry which is equivalent to ppm except for organic matter (%) and pH (standard units).

Sample Number	Depth (ft)	Bulk Density (wt/8.51)	Water pH	Bray-P (ppm)	Olsen-P (ppm)	Exch K (ppm)	LOI OM (%)	Zinc (ppm)	Iron (ppm)	Copper (ppm)	Manganese (ppm)	Calcium (ppm)	Mg (ppm)	Boron (ppm)	NH4-N (ppm)	SO4-S (ppm)	Fe/Mn (%)	Fe/P
AMIK																		
A1	7	0.32	5.7	1	1	8	88.1	0	143	0	10	450	63	0	15	1.622	14.3	143
A2	7	0.64	6.4	1.6	0.5	13	30.9	2.8	121.6	1.1	7.1	1520	194	0.7	8.0	42	17.1	76
A3	7.5	0.38	6.6	0.6	0.3	12	47.1	1.3	310.0	0.4	30.7	1120	69	0.2	41.1	4	10.1	516
A4	11	0.33	6.1	2.3	0.6	10	40.7	0.5	169.0	0.2	9.5	370	34	0.3	59.0	5	17.8	73.4
A5	7	0.35	5.9	2.4	0.3	13	35.2	0.6	170.7	0.2	9.1	360	36	0.2	25.9	6	18.8	71.1
A6	6	0.53	5.9	2.7	3.6	37	43.0	5.1	436.0	0.6	10.5	1273	178	0.6	17.8	37	41.4	21.1
PIKE																		
P1	7	1.35	5.9	12.7	3.5	18	1.1	2.2	221.0	0.3	22.5	478	43	0.7	5.0	44	9.8	17.4
P2	7.5	1.30	6.1	6.7	2.2	28	1.7	2.0	245.8	1.4	23.2	760	84	0.4	6.8	38	10.6	36.7
P3	5	1.35	6.1	34.6	11.5	21	1.2	1.7	151.9	0.8	14.4	431	48	0.2	3.7	23	10.6	4.4
P4	4	1.29	6.2	21.9	5.5	14	1.3	1.5	110.7	0.4	5.9	376	42	0.1	4.1	23	18.7	5
P5	5.5	1.29	6.4	12.1	3.3	21	0.7	2.2	103.2	0.2	9.0	282	33	0.2	22.4	24	11.5	8.5
P6	5	1.28	5.8	12.0	3.3	12	1.0	3.3	161.1	0.3	8.8	259	27	0.3	5.2	37	18.2	13.4
P7	7	0.87	5.9	5.9	2.2	10	2.7	2.1	260.1	0.3	20.4	422	45	0.4	6.1	25	12.8	44.1
P8	5	0.56	6.1	3.1	3.3	16	13.4	1.4	401.7	0.4	30.9	594	55	0.1	10.8	8	13.0	121.7
P9	6	1.00	6.2	3.4	0.8	11	2.9	2.0	119.7	0.3	9.3	642	68	0.3	4.5	68	12.9	35.2
P10	7	1.30	6.0	8.8	2.2	17	0.9	2.2	174.4	0.2	14.9	471	43	0.3	6.2	79	11.7	19.8
P10-R	6	1.34	7.0	5.7	1.1	18	1.0	1.0	79.7	1.8	8.5	599	87	0.6	4.2	34	9.3	13.9
P11	7	1.04	6.4	4.4	1.8	11	3.7	2.4	165.2	0.9	9.2	1063	134	0.4	8.9	99	18.0	37.5
P12	4	1.21	6.9	10.3	3.1	14	1.5	2.1	196.0	0.3	19.3	502	61	0.4	7.2	60	10.2	19
P13	4	1.39	6.7	22.4	3.5	20	0.9	0.7	108.0	0.5	9.7	404	45	0.1	4.6	19	11.2	4.8
P14	7	1.38	6.1	19.9	4.7	20	0.8	2.5	191.3	0.5	14.2	280	36	0.2	4.6	52	13.5	9.6
P15	16	0.63	6.1	1.1	4.8	33	31.5	3.1	575.2	0.2	13.5	1306	159	0.7	6.2	32	42.7	119.8
ROUND																		
R1	7	1.36	6.5	8.1	3.5	23	0.7	1.3	171.4	0.3	11.2	314	43	0.2	4.9	49	15.2	21.2
R2	4	1.47	6.3	12.5	3.8	24	0.4	1.1	112.8	0.1	13.0	134	18	0.3	8.5	20	8.6	9
R3	5	0.94	6.7	10.4	4.8	15	4.4	0.5	193.5	0.4	24.5	498	58	0.1	5.4	8	7.9	10.6
R4	4	1.29	7.0	18.7	3.3	14	0.6	1.3	90.9	0.2	7.4	330	23	0.1	6.3	11	12.3	4.9
R5	6	1.05	6.6	13.4	2.7	20	3.8	1.2	225.9	0.4	25.8	471	57	0.3	6.9	14	8.8	16.8
R6	5	1.29	6.8	16.5	4.4	20	1.0	0.7	86.2	0.2	13.4	459	20	0.1	7.3	13	6.4	5.2
R7	5	1.37	6.4	31.6	4.7	33	0.6	1.1	105.3	0.6	15.6	412	60	0.1	6.4	35	6.8	3.3
R8	5	0.95	6.4	11.3	3.2	27	4.1	1.3	216.1	0.9	32.8	562	69	0.1	6.1	26	6.6	19.1
R9	7	1.30	6.6	17.7	4.4	27	1.2	2.4	242.8	0.4	27.5	481	61	0.2	8.3	42	8.8	13.7
R10	6	1.36	6.2	33.6	4.6	17	0.8	1.3	172.3	0.3	18.5	336	42	0.2	5.9	37	9.3	5.1
R11	7.5	1.49	6.2	16.4	3.8	25	0.5	1.4	146.1	0.3	22.8	175	23	0.1	9.7	18	6.4	8.9
R12	7	1.36	6.2	15.0	4.6	28	0.8	1.4	183.2	0.3	35.0	287	37	0.2	5.4	21	5.2	12.2
R13	7.5	1.41	6.3	15.6	4.8	36	0.6	1.2	161.8	0.2	20.6	371	43	0.1	6.0	17	7.9	10.3
R14	7	1.40	6.8	7.1	2.4	17	0.5	1.1	104.2	0.2	7.5	252	29	0.2	7.0	26	13.9	14.6
R14R	7	1.38	6.8	7.1	2.4	19	0.6	1.1	130.2	0.2	10.7	225	29	0.9	4.4	33	12.1	19.5
R15	25	0.72	6.2	1.9	4.9	48	32.4	3.2	598.1	0.4	47.5	1495	212	1.2	27.4	20	12.6	122.1
R16 (Deep)	22	0.68	6.0	1.2	5.2	37	33.3	2.6	588.6	0.3	26.0	1549	215	1.2	29.2	37	22.7	113.2
TURNER																		
T1	7	1.25	6.9	5.3	2.1	21	1.5	1.6	236.9	0.4	12.7	247	31	0.2	5.2	32	18.6	44.6
T2	7.5	1.28	6.9	4.4	1.1	25	1.2	1.1	132.3	1.1	7.6	664	95	0.4	4.0	151	17.3	30.1
T3	6.5	1.04	6.5	7.1	2.7	30	3.5	1.2	268.6	0.4	15.1	443	47	0.4	7.3	18	17.8	37.8
T4	8	1.19	6.3	16.2	5.1	16	2.0	1.4	179.5	0.4	8.9	584	86	0.2	7.2	43	20.1	11.1
T5	13.5	0.48	6.2	3.7	2.5	19	38.6	4.0	404.7	0.6	12.1	614	93	0.4	23.1	25	33.5	109.4

Curlyleaf Pondweed Growth Potential for the Pike Lake Chain

Lake sediment sampling results from 2010 have been used to predict lake bottom areas that have the potential to support three types of curlyleaf pondweed plant growth: light, moderate, or heavy. Based on the key sediment parameters of pH, the Fe:Mn ratio, sediment bulk density, and organic matter (McComas, unpublished), the predicted growth characteristics of curlyleaf pondweed are shown in Table 4 and Figure 3.

In the Pike Chain of Lakes, curlyleaf pondweed growth is predicted to produce either light growth or moderate growth (where plants may occasionally top out in a broken canopy) . The moderate growth is predicted to occur in Amik Lake.

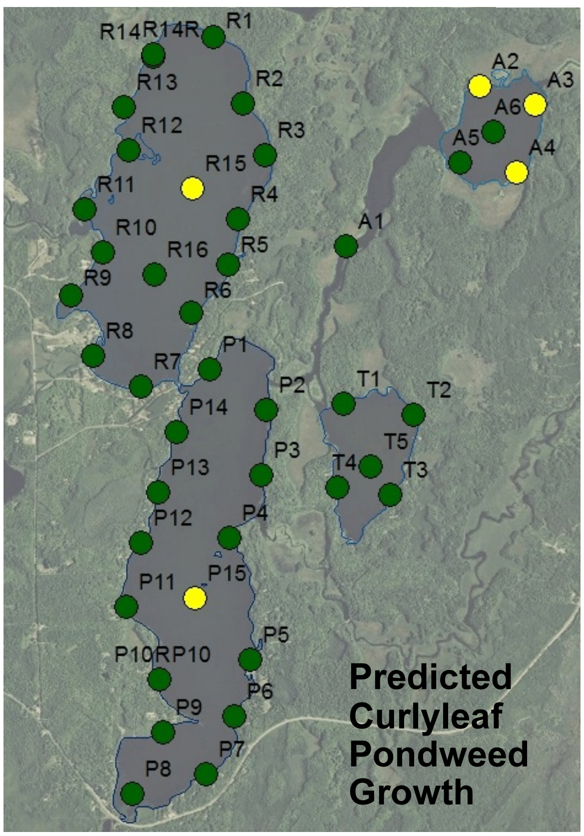


Figure 3. Sediment sample locations are shown with a circle. The circle color indicates the type of curlyleaf pondweed growth predicted to occur at that site. Key: green = light; yellow = moderate; red = heavy.

Light growth (left) refers to light nuisance growth that is mostly below the surface and is not a recreational or ecological problem. Heavy growth (right) refers to nuisance matting curlyleaf pondweed. This is the kind of nuisance growth predicted by high sediment pH and a sediment bulk density less than 0.51.

Table 4. The Pike Chain of Lakes sediment data and ratings for potential heavy curlyleaf pondweed growth.

Site	Depth (ft)	pH (su)	Organic Matter (%)	Fe:Mn Ratio	Potential for Heavy Curlyleaf Pondweed Growth
Light Growth		**6.8**	**5**	**4.6**	**Light (green)**
Moderate Growth		**6.2**	**11**	**5.9**	**Moderate (yellow)**
Heavy growth		**>7.7**	**>20**	**<1.6**	**Heavy (red)**
A1	7	5.7	88.1	14.3	Light
A2	7	6.4	30.9	17.1	Moderate
A3	7.5	6.6	47.1	10.1	Moderate
A4	11	6.1	40.7	17.8	Moderate
A5	7	5.9	35.2	18.8	Light
A6	6	5.9	43.0	41.4	Light
P1	7	5.9	1.1	9.8	Light
P2	7.5	6.1	1.7	10.6	Light
P3	5	6.1	1.2	10.6	Light
P4	4	6.2	1.3	18.7	Light
P5	5.5	6.4	0.7	11.5	Light
P6	5	5.8	1.0	18.2	Light
P7	7	5.9	2.7	12.8	Light
P8	5	6.1	13.4	13.0	Light
P9	6	6.2	2.9	12.9	Light
P10	7	6.0	0.9	11.7	Light
P10-R	6	7.0	1.0	9.3	Light
P11	7	6.4	3.7	18.0	Light
P12	4	6.9	1.5	10.2	Light
P13	4	6.7	0.9	11.2	Light
P14	7	6.1	0.8	13.5	Light
P15	16	6.1	31.5	42.7	Moderate
R1	7	6.5	0.7	15.2	Light
R2	4	6.3	0.4	8.6	Light
R3	5	6.7	4.4	7.9	Light
R4	4	7.0	0.6	12.3	Light
R5	6	6.6	3.8	8.8	Light
R6	5	6.8	1.0	6.4	Light
R7	5	6.4	0.6	6.8	Light
R8	5	6.4	4.1	6.6	Light
R9	7	6.6	1.2	8.8	Light
R10	6	6.2	0.8	9.3	Light
R11	7.5	6.2	0.5	6.4	Light
R12	7	6.2	0.8	5.2	Light
R13	7.5	6.3	0.6	7.9	Light
R14	7	6.8	0.5	13.9	Light
R14R	7	6.8	0.6	12.1	Light
R15	25	6.2	32.4	12.6	Moderate
R16 (Deep)	22	6.0	33.3	22.7	Light
T1	7	6.9	1.5	18.6	Light
T2	7.5	6.9	1.2	17.3	Light
T3	6.5	6.5	3.5	17.8	Light
T4	8	6.3	2.0	20.1	Light
T5	13.5	6.2	38.6	33.5	Light

Eurasian Watermilfoil Growth Potential in the Pike Chain

Lake sediment sampling results from 2010 have been used to predict lake bottom areas that have the potential to support three types of EWM growth: light, moderate, or heavy. Eurasian watermilfoil is not currently in Amik, Pike, Round or Turner. Based on the key sediment parameters of NH_4 and organic matter (McComas, unpublished), a table and map were prepared that predict what type of milfoil growth could be expected in the future (Table 5 and Figure 4). The sediment nitrogen conditions in the Pike Chain range from low to high with lake sediments areas over 10 ppm of nitrogen as candidates for heavy milfoil growth. However, it has been found that milfoil does not grow well in sediments with organic matter less than 0.6% or greater than 20%. Under current sediment conditions, it is predicted that in the Pike Chain most growth will be low to moderate. Eurasian watermilfoil may grow widely through the Pike Chain in the future, but it is predicted that it will produce limited growth.

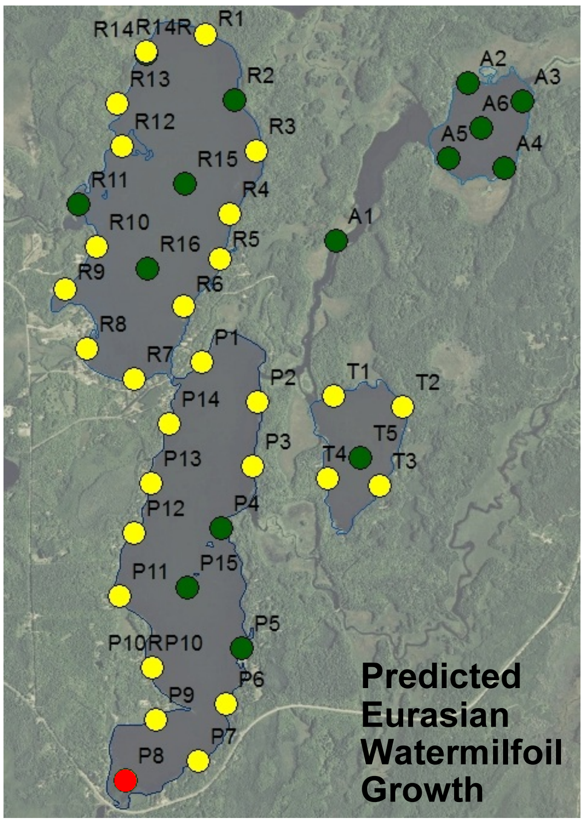


Figure 4. Sediment sample locations are shown with a circle. The circle color indicates the type of Eurasian watermilfoil growth predicted to occur at that site. Key: green = light; yellow = moderate; red = heavy.

Light growth (left) refers to light nuisance growth that is mostly below the surface and is not a recreational or ecological problem. Heavy growth (right) refers to nuisance matting Eurasian watermilfoil. This is the kind of nuisance growth predicted by high sediment nitrogen values and a sediment organic matter content less than 20%.

Table 5. Pike Chain sediment data and ratings for potential heavy EWM growth.

Site	Depth (ft)	NH_4 Conc (ppm)	Organic Matter (%)	Potential for Heavy EWM Growth
Light Growth		**<10**	**>20**	**Light (green) to Moderate (yellow)**
Heavy Growth		**>10**	**<20**	**Heavy (red)**
A1	7	15	88.1	Light
A2	7	8	30.9	Light
A3	7.5	41.1	47.1	Light
A4	11	59	40.7	Light
A5	7	25.9	35.2	Light
A6	6	17.8	43.0	Light
P1	7	5.0	1.1	Moderate
P2	7.5	6.8	1.7	Moderate
P3	5	3.7	1.2	Moderate
P4	4	4.1	1.3	Moderate
P5	5.5	22.4	0.7	Moderate
P6	5	5.2	1.0	Moderate
P7	7	6.1	2.7	Moderate
P8	5	10.8	13.4	Heavy
P9	6	4.5	2.9	Moderate
P10	7	6.2	0.9	Moderate
P10-R	6	4.2	1.0	Moderate
P11	7	8.9	3.7	Moderate
P12	4	7.2	1.5	Moderate
P13	4	4.6	0.9	Moderate
P14	7	4.6	0.8	Moderate
P15	16	6.2	31.5	Light
R1	7	4.9	0.7	Moderate
R2	4	8.5	0.4	Light
R3	5	5.4	4.4	Moderate
R4	4	6.3	0.6	Moderate
R5	6	6.9	3.8	Moderate
R6	5	7.3	1.0	Moderate
R7	5	6.4	0.6	Moderate
R8	5	6.1	4.1	Moderate
R9	7	8.3	1.2	Moderate
R10	6	5.9	0.8	Moderate
R11	7.5	9.7	0.5	Light
R12	7	5.4	0.8	Moderate
R13	7.5	6.0	0.6	Moderate
R14	7	7.0	0.5	Light
R14-R	7	4.4	0.6	Moderate
R15	25	27.4	32.4	Light
R16	22	29.2	33.3	Light
T1	7	5.2	1.5	Moderate
T2	7.5	4.0	1.2	Moderate
T3	6.5	7.3	3.5	Moderate
T4	8	7.2	2.0	Moderate
T5	13.5	23.1	38.6	Light

Discussion

The Pike Lake Chain sediments: A number of sample sites were found with a brown, mucky sediment containing numerous snail shells (none were alive), found in water depths from 3 to 8 feet deep.

Curlyleaf Pondweed: In 2010, curlyleaf pondweed had not been found. Typical growth pattern, if curlyleaf pondweed were found in the Pike Lake Chain, would be light growth with a few areas of moderate growth.

Eurasian Watermilfoil: In 2010, milfoil was not found in the Pike Lake Chain Light to moderate growth would be a the typical growth condition if Eurasian watermilfoil were found in the lakes.

Overview of Role of Soil Nutrients for Plant Growth

The fertility of lake sediments may influence the type of aquatic plant growth in lakes. The role of sediment nutrients in mineral nutrition of land plants is shown in the box below. Aquatic plants have the same basic requirements as land plants .

Role of Soil Nutrients for the Mineral Nutrition in Plants (**from** Gardner, F.P., R.B. Pearce, and R.L. Mitchell. 1985. Physiology of Crop Plants and Foth, H.D. and B.G. Ellis. 1997. Soil Fertility 2nd Edition.)

N: Nitrogen is a constituent in amino acids, amides, proteins and nucleoprotein. It is essential to cell division, expansion and growth. Nitrogen is generally the most limiting nutrient in crop production (except for legumes).

P: Phosphorus is essential as a component of the energy transfer compound - ATP, for genetic information system (DNR & RNA), for cell membranes and phosphoprotein. Phosphorus is generally second to nitrogen as the most limiting nutrient for plant growth. Some phosphorus deficiency symptoms include dark green to blue-green leaves, and stunted plants. Phosphorus in soil solutions is usually present in low concentrations.

K: Potassium is essential to plants because it acts as enzyme activators for certain enzymes is aids in the maintenance of osmotic potential and water uptake. Most soils are buffered for potassium so yearly fluctuations are minor

Ca: Calcium is a component of the cell wall and is essential for cell division and elongation.

Mg: Magnesium is the center of the chlorophyll molecule. Magnesium also binds with ADP, ATP, and organic acids and therefore is essential for hundreds of enzymatic reactions. Magnesium is a cofactor for many enzymes. Nitrogen metabolism and protein synthesis are also dependent on the presence of Mg.

Fe: Iron is a constituent of the electron transport enzymes. Although Fe is not a part of the chlorophyll molecule, it affects chlorophyll levels because it must be present for chloroplast ultrastructure formation. Iron deficiencies can reduce the number and size of chloroplast.

Mn: Manganese is an activator of several enzymes, especially those involved in fatty acid and nucleotide synthesis and is essential in respiration and photosynthesis.

S: Sulfur is a constituent of the amino acids eystine, cysteine, and methionine. It also activities certain proteolytic enzymes and is a constituent of coenzyme A, glutathione, and certain vitamins. Sulfur deficiency can cause stunting and general plant yellowing: stems are thin. Sulfur is primarily absorbed as the SO_4 ion.

Zn: Zinc is essential for the enzymes in the synthesis of tryptophan. Zinc levels are positively correlated with increasing organic matter and negatively correlated with increasing pH.

B: Boron may influence cell development by controlling sugar transport and polysaccharide formation. Requirements for B and Ca often go hand in hand in hand; this has suggested that B, may be needed for cell wall formation and for metabolism of pectic compounds.

Cu: Copper is part of the chloroplast enzyme plastocyanin in the electron transport system between photoslystmes I and II. It is present as an exchange ion on soil particles and minutely in the soil solution. Copper may become toxic in soils with a use of copper sprays.

Na: Sodium is the most soluble of the salts. It may be a micronutrient, but generally is so abundant, is rarely limiting. It is leachable and its concentration gradually decreases over time.

CEC: Cation exchange capacity is the sum of exchangeable cations that a soil or other material can adsorb at a specific pH. CEC is determined at a pH of 7.0.

pH: pH has little or no direct effect on plant growth, however indirect effects are numerous and potent. In optimum pH is somewhere between 6.0 and 7.5.

Organic matter: Organic matter exerts a profound influence on almost every facet of the nature of soil. Most A horizons contain about 1 to 6 percent organic matter. A soil with greater than 20% organic matter is an organic soil and is classified as either peat or muck.

Pike Lake Chain Sediment Phosphorus Release Potential Based on Phosphorus Concentrations and Fe:P Ratios

Table 6. Pike Lake chain sediment samples were collected on .

Sample Number	Depth (ft)	Iron (ppm)	Bray-P (ppm)	Olsen-P (ppm)	Fe:P Ratio	P Release Potential
AMIK						
A1	7	143	1	1	143	Low
A2	7	121.6	1.6	0.5	76	Low
A3	7.5	310.0	0.6	0.3	516	Low
A4	11	169.0	2.3	0.6	73.4	Low
A5	7	170.7	2.4	0.3	71.1	Low
A6	6	436.0	2.7	3.6	21.1	Low
PIKE						
P1	7	221.0	12.7	3.5	17.4	Low
P2	7.5	245.8	6.7	2.2	36.7	Low
P3	5	151.9	34.6	11.5	4.4	High
P4	4	110.7	21.9	5.5	5	High
P5	5.5	103.2	12.1	3.3	8.5	High
P6	5	161.1	12.0	3.3	13.4	Moderate
P7	7	260.1	5.9	2.2	44.1	Low
P8	5	401.7	3.1	3.3	121.7	Low
P9	6	119.7	3.4	0.8	35.2	Low
P10	7	174.4	8.8	2.2	19.8	Low
P10-R	6	79.7	5.7	1.1	13.9	Moderate
P11	7	165.2	4.4	1.8	37.5	Low
P12	4	196.0	10.3	3.1	19	Low
P13	4	108.0	22.4	3.5	4.8	High
P14	7	191.3	19.9	4.7	9.6	High
P15	16	575.2	1.1	4.8	119.8	Low
ROUND						
R1	7	171.4	8.1	3.5	21.2	Low
R2	4	112.8	12.5	3.8	9	Moderate
R3	5	193.5	10.4	4.8	10.6	Moderate
R4	4	90.9	18.7	3.3	4.9	High
R5	6	225.9	13.4	2.7	16.8	Low
R6	5	86.2	16.5	4.4	5.2	High
R7	5	105.3	31.6	4.7	3.3	High
R8	5	216.1	11.3	3.2	19.1	Low
R9	7	242.8	17.7	4.4	13.7	Moderate
R10	6	172.3	33.6	4.6	5.1	High
R11	7.5	146.1	16.4	3.8	8.9	High
R12	7	183.2	15.0	4.6	12.2	Moderate
R13	7.5	161.8	15.6	4.8	10.3	Moderate
R14	7	104.2	7.1	2.4	14.6	Moderate
R14R	7	130.2	7.1	2.4	19.5	Low
R15	25	598.1	1.9	4.9	122.1	Low
R16 (Deep)	22	588.6	1.2	5.2	113.2	Low
TURNER						
T1	7	236.9	5.3	2.1	44.6	Low
T2	7.5	132.3	4.4	1.1	30.1	Low
T3	6.5	268.6	7.1	2.7	37.8	Low
T4	8	179.5	16.2	5.1	11.1	Moderate
T5	13.5	404.7	3.7	2.5	109.4	Low

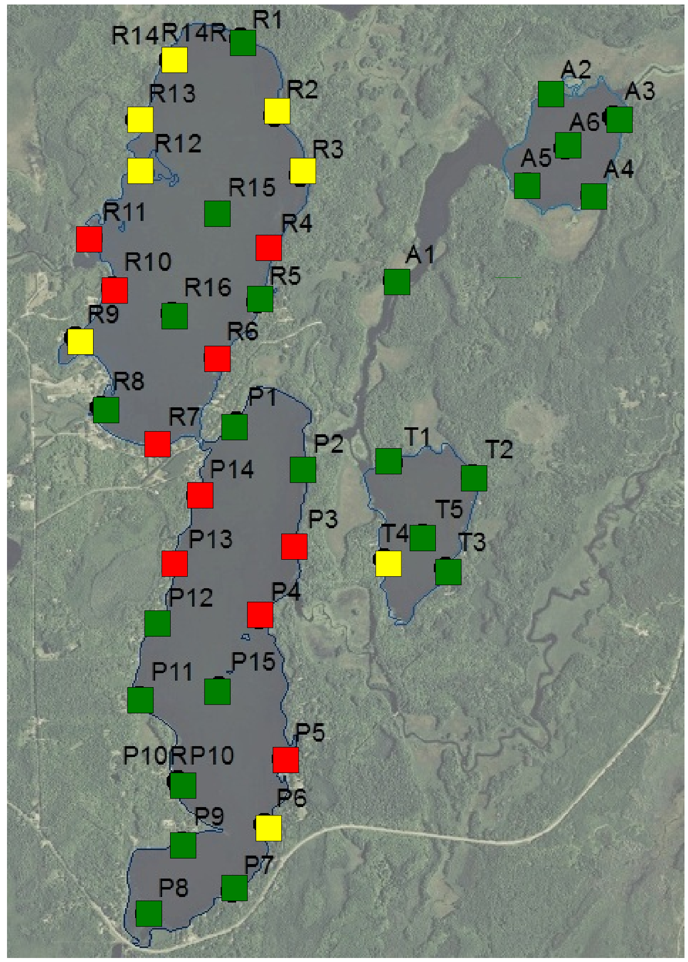


Figure 5. Lake sediment sample locations are shown with color squares. Colored squares represent phosphorus release potential at that site. Key: Green = low; Yellow = moderate; and Red = high.

Lake Water Quality Data (2010)

	Amik	Pike	Round	Turner
Total Phos (ug/l):	36	44	31	24
Secchi disc (ft):	4.6	3.3	4.6	6.6
Chlorophyll (ug/l):	18	14	8	7

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Iron:phosphorus ratio in surface sediment as an indicator of phosphate release from aerobic sediments in shallow lakes

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Key words: Lakes, sediments, iron, phosphorus, phosphate release

Abstract

Analysis of Danish lakes showed that both mean winter and mean summer concentrations of lake water total phosphorus in the trophogenic zone correlated negatively with the total iron to total phosphorus ratio (Fe:P) in surface sediments. No correlation was found between the water total phosphorus concentration and either the sediment phosphorus concentration alone or with sediment calcium concentration. The increase in total phosphorus from winter to summer, which is partly a function of net internal P-loading, was lowest in lakes with high Fe:P ratios in the surface sediment.

A study of aerobic sediments from fifteen lakes, selected as representative of Danish lakes with respect to the sediment Fe and phosphorus content, showed that the release of soluble reactive phosphorus was negatively correlated with the surface sediment Fe:P ratio. Analysis of phosphate adsorption properties of surface sediment from 12 lakes revealed that the capability of aerobic sediments to buffer phosphate concentration correlated with the Fe:P ratio while the maximum adsorption capacity correlated with total iron. Thus, the Fe:P ratio may provide a measure of free sorption sites for orthophosphate ions on iron hydroxyoxide surfaces.

The results indicate that provided the Fe:P ratio is above 15 (by weight) it may be possible to control internal P-loading by keeping the surface sediment oxidized. Since the Fe:P ratio is easy to measure, it may be a useful tool in the management of shallow lakes.

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