Culver Lake 2012 Lake Monitoring Results

Weather Patterns Influence Summer Lake Conditions

During 2011 we had a late Spring following the "winter of snow". We also experienced significant late spring storm runoff episodes as well as a late snowpack melt and ice-out. Later, the 2011 Summer was cut abruptly short by Hurricane Irene (followed by a Halloween Snow Storm). After the October Snow Storm we had very little winter weather during the 2011-12 Winter. *Overall 2012 was the mildest year on record*, *July was the warmest*. That set up an early and robust Diatom bloom in many lakes and reservoirs. In some (especially where the availability of silica and nitrate was exhausted early) N-fixing Cyanobacteria gained advantage early and were very abundant in the Summer. In systems where nitrate and especially Silica remained available, Diatoms continued to thrive and Cyanobacteria densities remained relatively low. In more shallow systems, the lack of winter ice cover resulted in unusually abundant light intensity to the bottom; benthic algae became abundant. Many systems exhibited somewhat different water quality than usual due to the preceding weather patterns, especially the "Intense" vs "absent" winter conditions. The "growing season" has been very long, especially for Diatoms in many lakes and reservoirs (being cold water algae, the Diatoms in many lakes have experienced a growing season since April 2011).

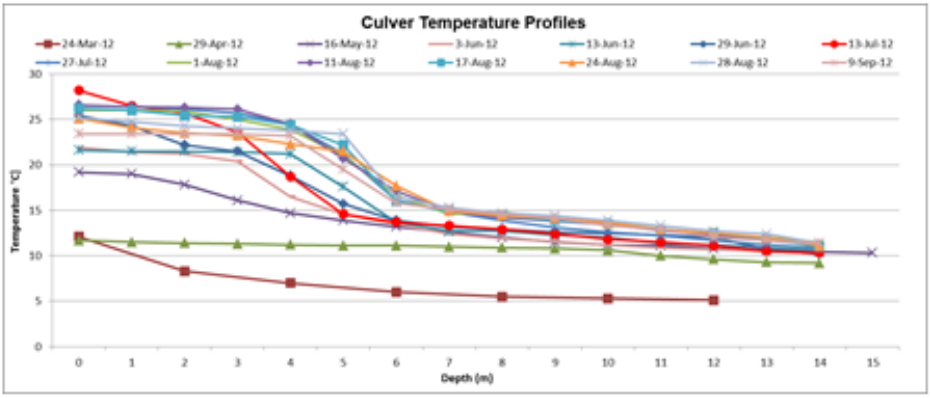
The Summer Stratification Season was indeed “unusual” at Culver Lake following the lack of 2011-12 winter conditions. The growing season was very long (if indeed it ever ended between 2011 and 2012). Nitrate and silica availability was exhausted very early. That inhibits more desirable phytoplankton (Diatoms and Greens) in Spring and early Summer. N-fixing Cyanobacteria gained a competitive advantage early and were very dominant at Culver Lake during the Summer of 2012. To compound that further, Culver Lake experienced unusually calm weather in June and early July. *“It is always windy at Culver Lake, which gives the Normanoch Swim Team its name.”* Not so during June and early July 2012…Culver Lake experienced an extended period of the “doldrums”. That is clearly seen in the temperature and RTRM profiles. Heat was retained in a very narrow layer, thermoclines were established at a more shallow depth that typical.

We have been experiencing very variable weather pattern extremes over the past few years and it has influenced lake conditions. That is especially true for Winter and conditions during the following Summer. Summer 2012 followed a very mild and dry Winter and Spring. The growing season, and thermal stratification, began very early. And that all followed the Summer of 2011 when Hurricane Irene abruptly mixed the lake downward before natural turnover had occurred. The surface water phosphorus concentration went from 22ppb before Irene, to 50ppb after.

Total Phosphorus as P (µg/L)	2011			
Depth (m)	14-Jun	22-Jul	15-Sep	18-Oct
1	30	22	50	
3	21	19	26	
5	16	26	11	
7	11	9	13	
9	10	17	19	
12	13	10	76	
14	56	24	108	190

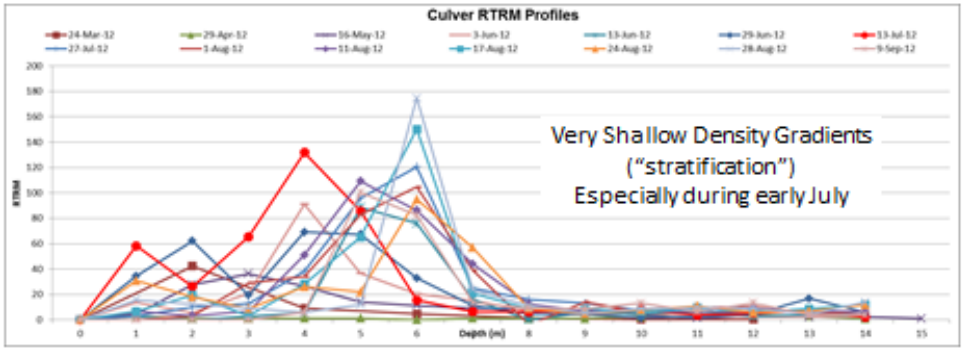
Temperature °C >25 °C

Depth (m)	24-Mar-12	29-Apr-12	16-May-12	3-Jun-12	13-Jun-12	29-Jun-12	13-Jul-12	27-Jul-12	1-Aug-12	11-Aug-12	17-Aug-12	24-Aug-12	28-Aug-12	9-Sep-12
0	12.1	11.7	19.2	21.9	21.6	25.6	28.2	26.5	26	26.6	26.2	25.1	25.2	23.6
1		11.5	19	21.6	21.5	26.3	26.5	26.6	26	26.6	26	26.1	24.7	23.6
2	8.2	11.6	17.8	21.2	21.5	22.2	25.7	26.1	25.9	26.3	25.6	23.5	24.3	23.6
3		11.3	16.1	20.6	21.4	21.5	23.6	25.7	25	26.1	25.3	23.2	24	23.6
4	7	11.2	14.7	16.5	21.2	18.8	18.7	24.5	23.9	24.5	24.4	23.3	23.8	23.2
5		11.1	13.9	14.6	17.6	15.7	14.6	21.2	21	20.7	22.2	21.5	23.6	19.5
6	6	11.1	13.2	13.6	13.7	13.9	13.7	16.1	16.6	17.1	16	17.7	16.5	15.8
7		11	12.6	12.6	12.7	13.2	13.3	14.8	14.6	14.9	14.9	14.9	15.3	15.1
8	5.5	10.9	12	11.9	12.7	12.9	12.9	13.9	14.8	14.2	14.4	14.6	14.7	14.6
9		10.8	11.5	11.6	12.3	12.6	12.4	13.1	14	13.8	13.9	14.1	14.6	14.1
10	5.2	10.6	11.2	11.2	12	12.5	11.8	12.6	13.6	13.4	13.5	13.6	13.9	13.3
11		10	11.1	10.9	11.4	12.2	11.5	12.2	13	12.8	12.9	12.9	13.2	12.9
12	5.1	9.6	10.8	10.7	11.2	12	11.1	11.7	12.9	12.2	12.5	12.5	12.7	12
13		9.3	10.6	10.5	10.9	10.7	10.5	11.2	12	11.7	11.9	12	12.6	11.7
14		9.2	10.4	10.3	10.6	10.2	10.3	10.9	11.5	11.2	11	11.1	11.4	11.4
15			10.2											



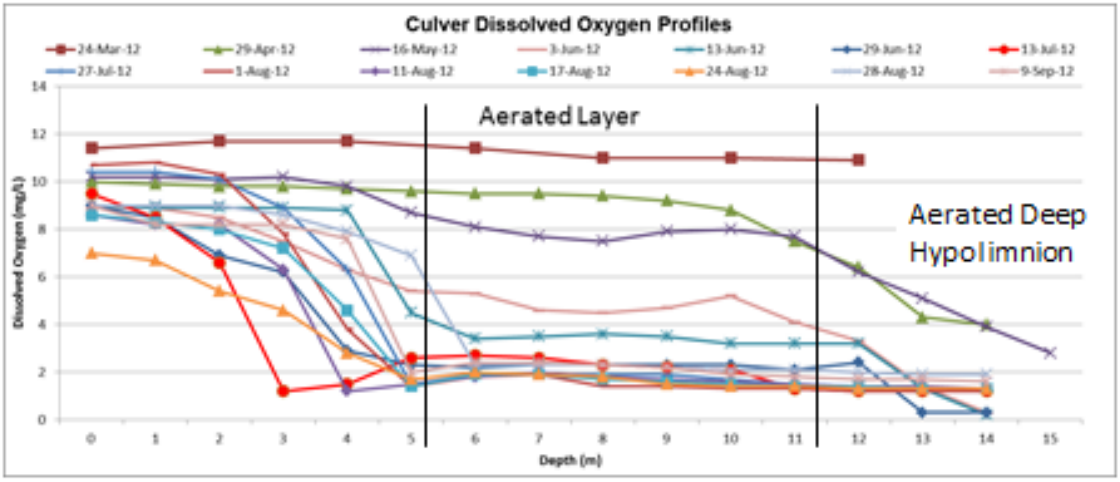
RTRM >50

Depth (m)	24-Mar-12	29-Apr-12	16-May-12	3-Jun-12	13-Jun-12	29-Jun-12	13-Jul-12	27-Jul-12	1-Aug-12	11-Aug-12	17-Aug-12	24-Aug-12	28-Aug-12	9-Sep-12
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1		2.7	5.0	13.7	2.7	34.6	58.4	3.3	0.0	6.7	6.7	31.0	1.58	0.0
2	42.4	1.3	27.9	5.5	0.0	82.1	26.4	10.0	3.2	3.3	19.3	18.0	1.26	0.0
3		1.3	36.3	21.1	2.7	19.4	65.6	13.0	29.0	6.7	3.2	9.0	9.3	0.0
4	9.1	1.3	28.7	91.2	5.5	69.3	121.8	28.1	34.1	51.1	28.3	26.0	6.0	6.0
5		1.3	14.1	36.8	88.7	67.4	85.7	95.9	82.9	109.2	65.2	22.0	11.9	100.5
6	6.8	0.0	11.5	20.6	76.1	33.0	15.6	120.6	106.7	86.6	15.03	95.0	176.7	82.6
7		1.3	9.2	15.5	15.9	11.5	6.6	25.0	28.9	66.0	21.1	57.0	2.39	13.5
8	1.5	1.2	8.9	7.2	0.0	6.8	6.4	15.9	-3.6	12.5	8.9	9.0	1.12	9.1
9		1.2	6.7	6.0	6.0	6.5	7.5	13.1	16.3	6.9	8.8	5.0	5.4	8.9
10	0.6	2.3	6.0	5.2	6.5	1.5	8.6	7.6	6.6	6.6	6.6	8.0	8.8	13.3
11		7.0	1.3	2.8	8.0	3.0	6.0	6.0	9.8	9.5	9.7	11.0	9.8	6.6
12	0.6	6.0	2.7	2.3	2.7	6.5	5.3	7.0	10.4	8.9	6.0	6.0	9.4	13.6
13		2.0	2.3	2.3	2.8	16.9	7.2	6.7	6.5	7.0	8.8	7.0	6.5	6.0
14		1.0	2.3	2.3	3.5	5.9	2.3	3.8	6.7	6.7	12.0	12.0	1.60	6.0
15			1.2											
SUM	58.9	29.1	161.3	231.8	220.1	398.2	431.6	366.0	341.5	365.5	254.8	316.0	317.0	261.6
MAX	42.4	7.0	36.3	91.2	88.7	69.3	121.8	120.6	106.7	109.2	150.3	95.0	176.7	100.5



Culver Lake became thermally stratified early in 2012, and almost all resistance to mixing and heat accumulation occurred in the top 4 meters in July. Waters deeper than 5m remained cold and well mixed (by aeration systems).

Dissolved Oxygen (mg/L)			<0.5mg/L	<1 mg/L										
Depth (m)	24-Mar-12	29-Apr-12	16-May-12	3-Jun-12	13-Jun-12	29-Jun-12	13-Jul-12	27-Jul-12	1-Aug-12	11-Aug-12	17-Aug-12	26-Aug-12	28-Aug-12	9-Sep-12
0	11.4	10	10.2	8.9	9	9	9.5	10.4	10.7	8.6	8.6	7	9	9
1		9.9	10.2	8.9	8.9	8.5	8.5	10.4	10.8	8.2	8.3	6.7	9	8.2
2	11.7	9.8	10.1	8.5	8.9	6.9	6.6	10.1	10.3	8.2	8	5.4	9	8.2
3		9.8	10.2	7.5	8.9	6.2	1.2	8.9	7.8	6.3	7.2	4.6	8.6	8.2
4	11.7	9.7	9.8	6.3	8.8	2.9	1.5	6.3	3.8	1.2	4.6	2.8	7.9	7.6
5		9.6	8.7	5.4	6.5	2.3	2.6	1.5	1.4	1.5	1.6	1.7	6.9	2
6	11.4	9.5	8.1	5.3	3.4	2.2	2.7	1.9	1.8	1.8	1.9	2	2.3	2.4
7		9.5	7.7	4.6	2.5	2.3	2.6	1.9	1.9	2	1.9	1.9	2.3	2.4
8	11	9.4	7.5	4.5	2.6	2.3	2.3	1.9	1.6	1.8	1.7	1.8	2.3	2.3
9		9.2	7.9	4.7	2.5	2.3	2.2	1.9	1.6	1.7	1.6	1.5	2.2	2.2
10	11	8.8	8	5.2	2.2	2.3	2.1	1.7	1.3	1.6	1.5	1.6	2.1	1.9
11		7.5	7.7	4.1	2.2	2.1	1.5	1.5	1.3	1.5	1.6	1.6	2.1	1.8
12	10.9	6.6	6.2	3.3	2.2	2.4	1.2	1.4	1.2	1.4	1.6	1.3	2	1.7
13		4.3	5.1	1.6	1.3	0.3	1.2	1.3	1.2	1.4	1.3	1.3	1.9	1.7
14		4	3.9	0.3	0.2	0.3	1.2	1.3	1.2	1.3	1.3	1.3	1.9	1.6
15			2.8											

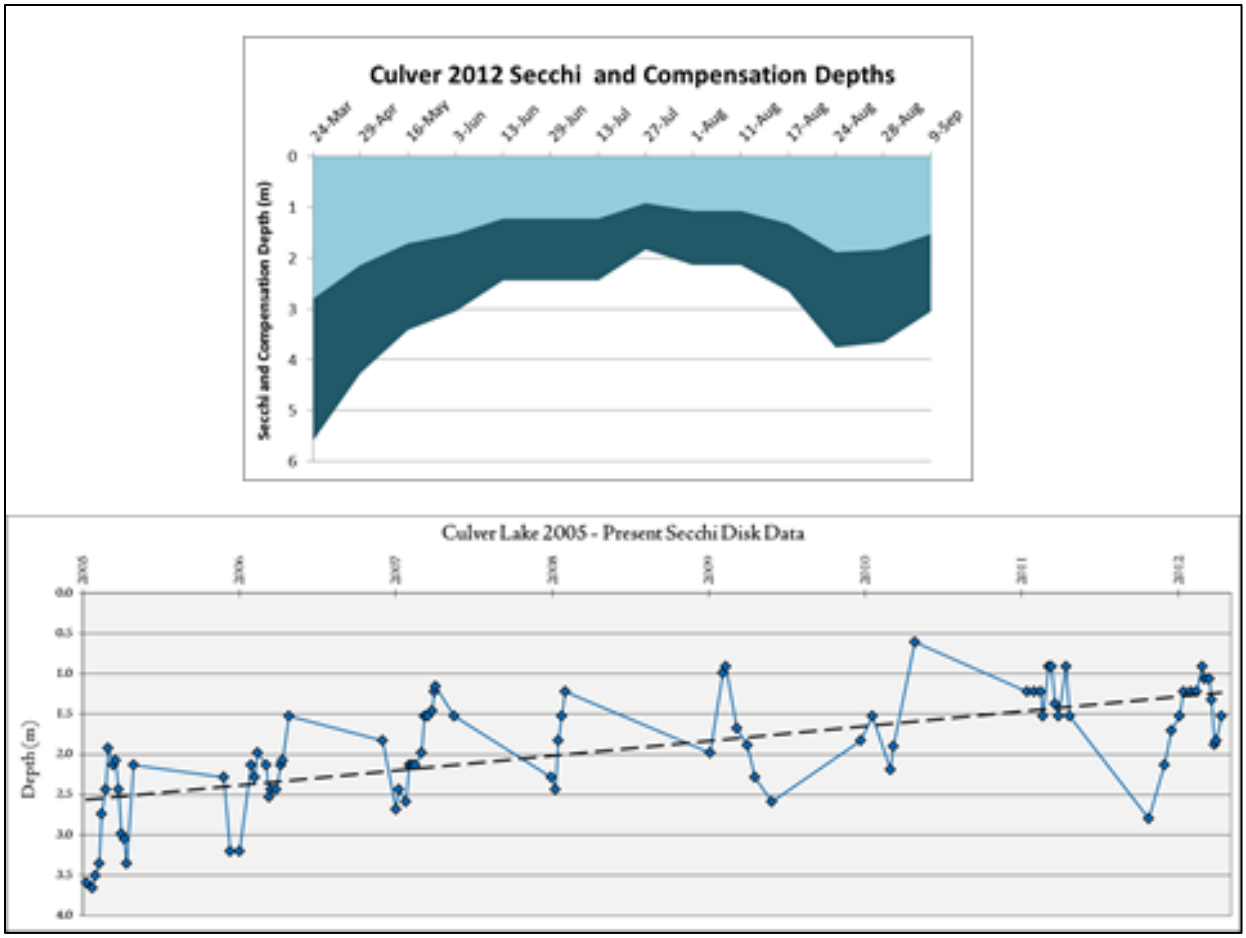


Despite the early onset of summer stratification conditions, the deep strata remained aerobic to very close to the deepest bottom.

Percent Saturation DO			>120											
Depth (m)	24-Mar-12	29-Apr-12	16-May-12	3-Jun-12	13-Jun-12	29-Jun-12	13-Jul-12	27-Jul-12	1-Aug-12	11-Aug-12	17-Aug-12	26-Aug-12	28-Aug-12	9-Sep-12
0	108.0	92.1	110.4	101.6	102.1	109.7	121.8	129.3	131.9	107.2	106.4	85.0	109.3	105.7
1		90.8	110.0	100.6	100.8	101.5	105.7	129.1	123.1	101.8	102.3	80.0	108.3	96.3
2	102.0	89.7	106.2	95.7	100.8	79.2	80.9	126.7	123.7	101.6	97.5	66.0	107.5	96.3
3		89.5	103.6	83.1	100.6	70.2	14.1	109.1	94.6	77.8	87.6	56.0	102.2	96.3
4	100.0	88.4	96.5	66.5	99.1	31.1	16.1	75.5	45.1	14.4	55.1	32.0	93.5	88.9
5		87.3	84.2	53.1	67.1	23.2	25.6	16.9	15.7	16.7	16.1	19.0	81.0	21.8
6	92.0	87.3	82.9	51.7	43.6	22.3	25.1	15.2	14.6	15.6	14.2	18.0	70.6	20.2
7		86.2	76.2	49.6	32.0	21.0	25.8	14.8	17.7	17.8	18.8	20.0	23.0	23.9
8	88.2	85.9	71.4	42.6	33.0	21.8	26.6	18.4	18.8	19.5	18.6	19.0	22.7	22.6
9		84.8	68.8	41.4	33.6	21.6	21.5	18.1	13.6	17.4	16.5	18.0	22.5	22.4
10	89.0	82.6	72.0	42.8	32.5	21.6	20.3	17.9	12.5	16.3	15.4	14.0	21.3	21.0
11		78.0	72.7	47.0	29.3	21.5	19.3	15.8	12.3	15.1	14.2	13.0	20.1	18.0
12	88.0	65.8	69.5	36.9	29.2	19.5	11.8	13.8	12.1	14.0	12.1	13.0	19.8	16.7
13		55.8	55.7	29.6	29.0	21.6	10.8	12.8	11.1	12.9	12.0	12.0	18.7	15.7
14		34.8	34.9	2.7	1.8	2.7	10.7	11.8	11.0	11.8	11.8	12.0	17.4	14.6
15			25.0											

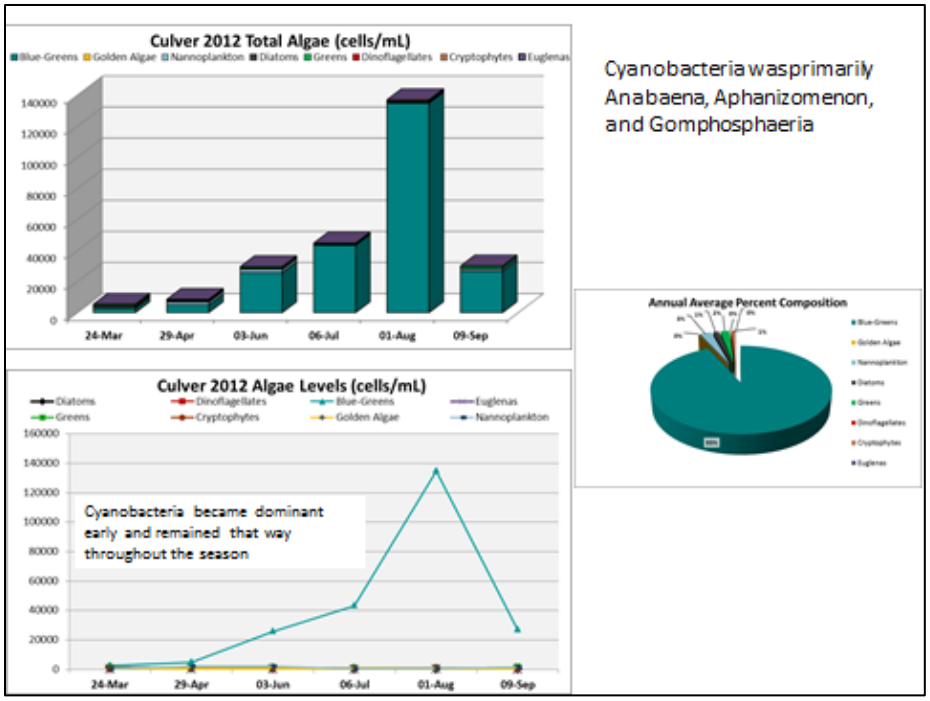
% Dissolved Oxygen saturation in excess of 120% indicates periods of relatively intense photosynthetic activity.

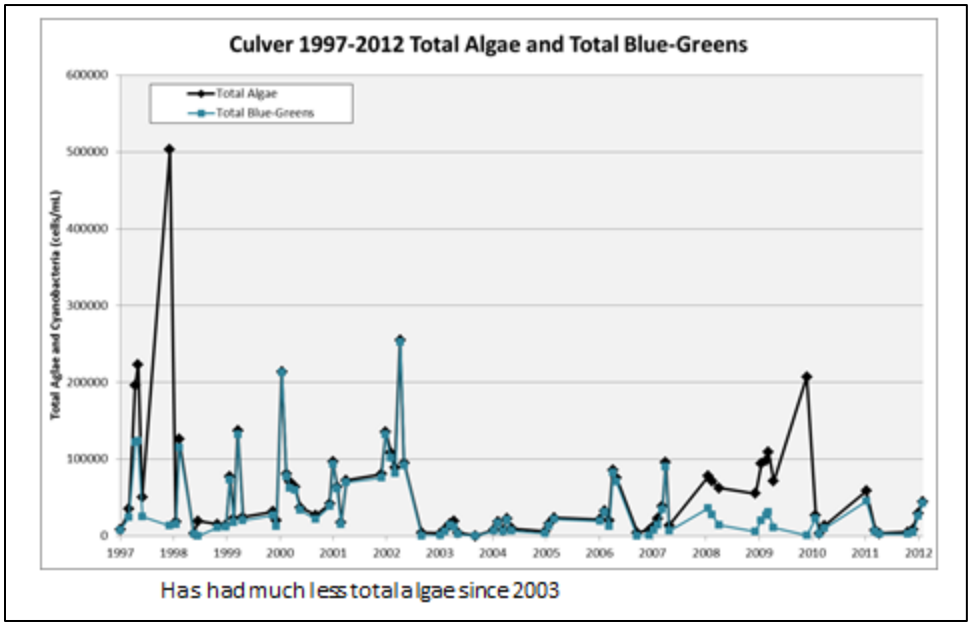
The % oxygen saturation only reached 130%, and only in the very surface layer. That doesn't indicate intense photosynthetic activity (rapid algae *growth*). Rather it suggests *accumulation* of Cyanobacteria near the surface.



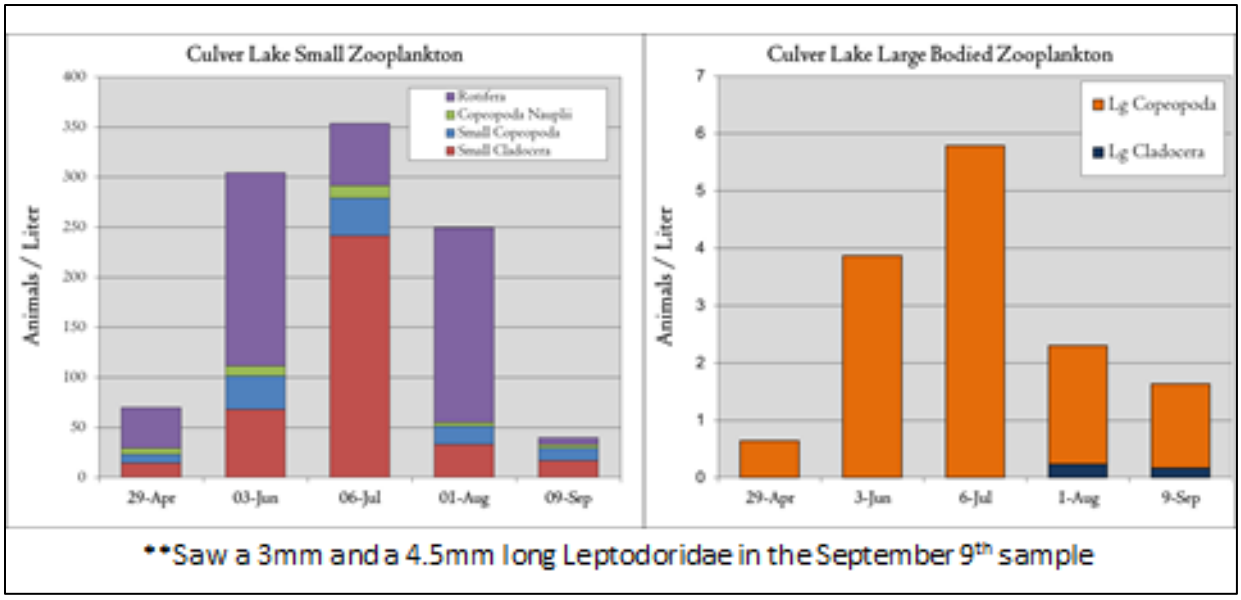
Secchi disk transparency (an indicator of water clarity) appears to be declining again since 2005.

The compensation depth (depth where adequate light is available for oxygen production by photosynthesis to balance respiration needs) was very shallow in 2012. Aeration maintained aerobic conditions well, despite the shallow compensation depth.





N-fixing Cyanobacteria became dominant early in the year, and steadily increased through August. However, total phytoplankton cell densities have been lower in the lake since 2003. Although there has been less algae, what there has been has been very concentrated near the lake surface.



Although some large-bodied zooplankton were observed during 2012 the populations of herbivorous "algae-eating" zooplankton continues to be low. Small-bodied Cladocera and rotifers continue to be most abundant.

Total Phosphorus as P (µg/L)

Depth (m)	24-Mar	29-Apr	3-Jun	6-Jul	2-Aug	9-Sep	22-Oct	9-Nov	22-Nov
1	14	22	33	34	23	25	28	28	29
3		24	29	30		15			
5		29	33	16	15	16			
7		24	18	15		27			
9		24	18	12	11	35			
12		25	22	14		99			
14		53	54	21	253	360			

Total Phosphorus was "moderate" during 2012; concentrations were not "high". TP concentrations in the middle aerated layer were lower than in the surface layer. Internal loading due to *deep* anoxic sediment release is not indicated. However, we continue to see a significant increase in TP of surface water between March and June (the source needs to be identified). Unlike following Hurricane Irene, surface TP did not increase dramatically in October and November as in 2011 (a bit of good news!).

Nitrite / Nitrate (µg/L)

Depth (m)	24-Mar	29-Apr	3-Jun	6-Jul	2-Aug	9-Sep	22-Oct	9-Nov	22-Nov
1	105	<10				<10	14	124	203
3		<10							
5		<10			<10	<10			
7		<10							
9		<10				<10			
12		<10							
14		<10			<10	<10			

Silica (mg/L)

Depth (m)	24-Mar	29-Apr	3-Jun	6-Jul	2-Aug	9-Sep	22-Oct	9-Nov	22-Nov
1	0.07	0.12	0.28	0.53	1.3		1.8	2.1	1.9
5					1.20				
9					1.25				
14					3.3				

Nitrate availability was exhausted very early, and silica decreased below the 0.5 mg/L generally considered necessary to sustain Diatoms. That sets the stage for Cyanobacteria to out-compete more desirable phytoplankton. The "focusing" of TP near the surface during Summer may be the result of the buoyancy of the Cyanobacteria (they brought their P up with them).

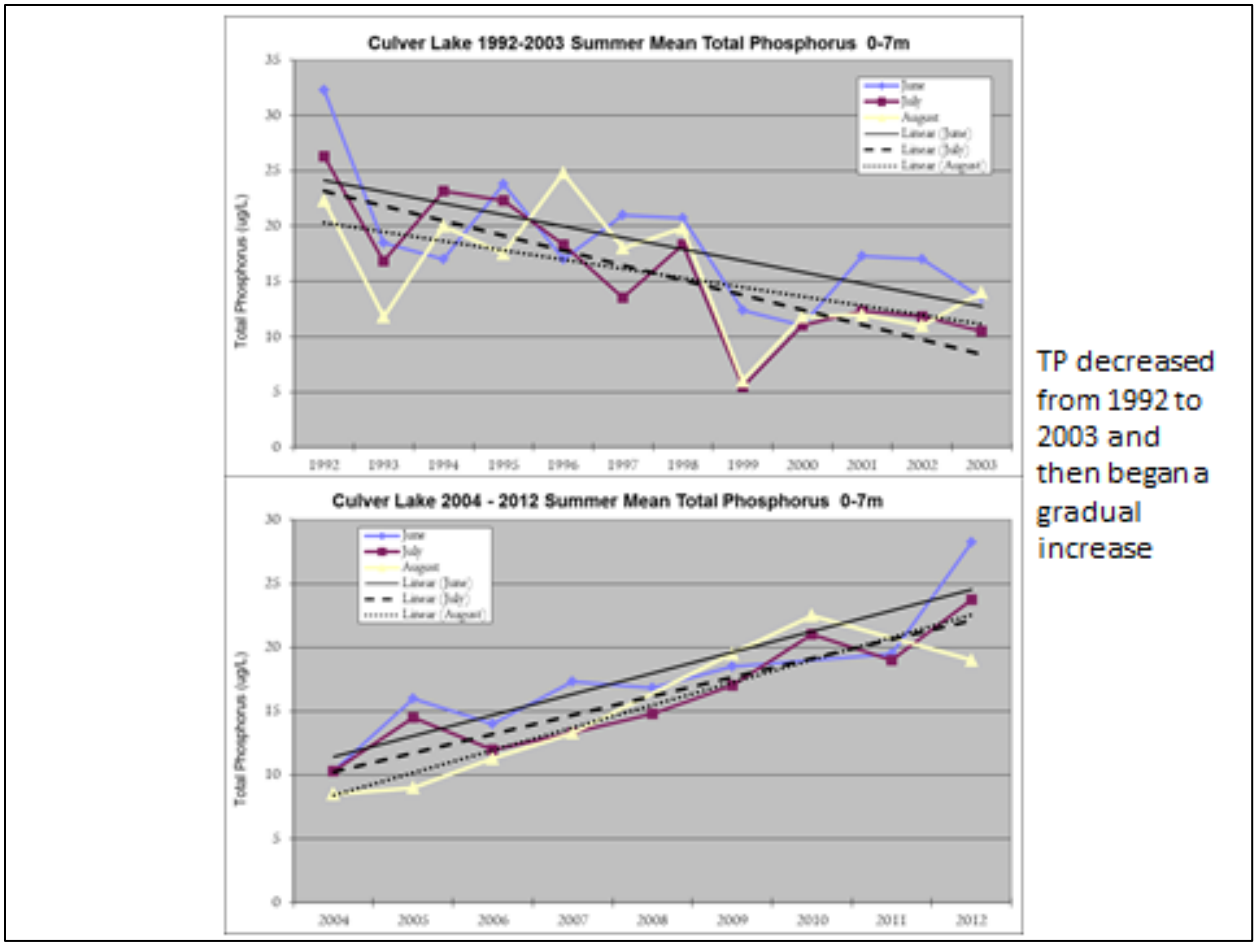
Iron (mg/L)

Depth (m)	24-Mar	29-Apr	3-Jun	6-Jul	2-Aug	9-Sep	22-Oct	9-Nov	22-Nov
1						0.03			
5						0.03			
9			0.060	0.04		0.24			
12			0.100	0.048	0.11	0.36			
14			0.130	0.041	0.83	1.8			

Manganese (mg/L)

Depth (m)	24-Mar	29-Apr	3-Jun	6-Jul	2-Aug	9-Sep	22-Oct	9-Nov	22-Nov
1						0.05			
5						0.07			
9				0.13		0.87			
12				0.16	0.98	0.85			
14			1.26	0.55	1.85	2.6			

The availability of iron as an alternate terminal electron acceptor at the deep sediment-water interface continues to be low. The concentrations of manganese consistently exceed that of total iron in deep over-bottom water. The low iron in deep water may have been related to more aerobic conditions maintained during 2012. However, iron flux has continued to be low over recent years as well, and sulfide odors have again become more apparent. A sediment amendment with iron would increase the phosphorus binding capacity, and provide a desirable ATEA for anaerobic respiration (reducing sulfide production that causes adverse impacts including permanent removal of iron as ferrous sulfide and organism toxicity). Iron addition to the surficial sediments is one management action to be considered.



Culver Lake was strongly influenced by one of the harshest winters (2010-11) followed by the mildest winter on record (2011-12) back-to-back. Climate variability, especially winter conditions, may be the "new reality". That needs to be considered in management strategies. Regardless of the weather patterns, the trends are not encouraging. Between 1992 and 2003 TP concentrations decreased and lake conditions improved. Since 2003 TP has again increased in surface waters. The TP increase occurs in the surface water layer; it is not due to anoxic sediment release from deep water sediments (aerobic conditions have been maintained thru much of the water column and deep/middle layer TP is lower than in surface water) .

Some Possible Management Actions to consider:

- The cause of surface water TP increase between early Spring and early Summer needs to be determined. Is that increase due to Buoyant Cyanobacteria carrying TP from deep strata to the surface? Is that increase due to sediment release in more shallow areas (3-6m, anoxic or aerobic)? Is theTP increase in surface waters related to sediment

disturbance during plant harvesting activities? Is the increase related to external loading from the watershed, perhaps from marsh areas? Some additional monitoring during key times (April-June; during harvesting, etc.) is warranted.

- Expansion of the epilimnion to a deeper elevation and enhanced Spring circulation may help shift phytoplankton away from buoyant N-fixing Cyanobacteria to Greens and Diatoms. If the same amount of algae that occurred in the top 3 meters in 2012 were mixed through 6m transparency would improve (approximately doubling water clarity with the same algae biomass). That would also deepen the compensation depth, light would reach more of the lake bottom.
- The sediment P-binding capacity continues to be very limited. Iron is what gives sediment its P-binding capacity in a lake like Culver. A sediment amendment with iron can increase the binding capacity for phosphorus. Several materials could be considered, including Iron-based coagulants used in the drinking water treatment industry, iron oxide solids (natural iron oxide powder), Siderite (a powdered or granular natural iron carbonate used as a livestock iron supplement and being studied for remediating sediment flux in lakes), ferric nitrate (nitrate provides several additional benefits in deep anaerobic sediments), iron filings, etc.
    - If a sediment amendment with iron is performed, several depths/areas should be evaluated- the bottom area between 3-7m may be a significant P release source- in 2012 the sediments in the deepest area did not appear to be the major P source to surface water (as it was in the late 1980s).