2013 Report:

McCavanaugh Ponds

Aquatic Plant and Water Quality Report

Adirondack Watershed Institute

Paul Smith's College

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Cover Photo: Lower St. Regis Lake

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Executive Summary

The objective of this report is to describe the water quality status and aquatic plant communities of the water bodies of the McCavanaugh Pond Club currently being managed with grass carp to control aquatic vegetation. Water quality monitoring has occurred at the McCavanaugh Ponds for seven years. However, with the exception of 2006, only one sample is analyzed per year. Given the inherent variability in limnological data, we feel trend analysis on these single samples would be weak, if not invalid, and therefore we did not statistically analyze the time series data. The data and accompanying analysis provided in this report give insight into the water quality and plant community of the McCavanaugh Pond Club's water bodies, more detailed limnological studies may be necessary to produce management recommendations.

McCavanaugh Pond

1. Since 2006 the trophic status of McCavanaugh Pond has fluctuated between the eutrophic and mesotrophic boundary. In 2013 the Trophic Status Index of McCavanaugh Pond based on secchi disk transparency (63) and chlorophyll (59) suggests a eutrophic classification for the pond, while the TSI value for total phosphorus (46) suggests a mesotrophic classification for the pond. A disparity of this nature typically occurs when the water body is experiencing phosphorus limitation or has elevated levels of dissolved organic matter that reduce the secchi transparency.

2. Vertical profile analysis from September suggests that McCavanaugh Pond provides a suitable thermal environment and adequate dissolved oxygen for brook trout, whose optimal temperature is around 16°C, and optimal oxygen concentration is 5 mg/L and above. However this scenario may be quite different during the warm summer months when brook trout may be restricted to a narrow stratum where temperatures are cool and oxygen is still adequate.

3. McCavanaugh Pond is an acidic water body with a historical average of 6.3 pH units. We observed a decrease in alkalinity over the seven years of monitoring, ranging from values near 20 during the first several years to values below 10 mg/L for the past two years. Water bodies with alkalinity values less than 10 mg/L are classified as being sensitive to acidic deposition.

4. McCavanaugh Pond is a deeply colored water body with a historical average of 79 PtCo units. Elevated color levels are associated with high levels of dissolved organic material in the water. Elevated color values also result in a decrease in secchi transparency.

5. We observed 13 native aquatic plant species in McCavanaugh Pond, the most common being water shield, white water lily, spatterdock and purple bladderwort. The aquatic plant beds occupy a minimum area of 12 acres. We did not detect any change in plant bed area between 2011 and 2013. The slight difference in bed area (0.3 acres) is within the range of error expected when performing a visual survey from the surface.

6. The frequency of occurrence of white water lily and water shield captured by the rake decreased by 12% between 2011 and 2013; however, we found a greater percentage of rakes had dense coverage

of water lily in 2013. Lesser bladderwort and common bladderwort were ensnared by the rake in 2013 but not in 2011. The frequency of occurrence of purple bladderwort did not change between years; however greater density of purple bladderwort was captured on the rake in 2013.

Dickman Ponds

7. The trophic status of the Dickman ponds has fluctuated between eutrophic and mesotrophic characteristics since the study began in 2006. However, both ponds are deeply colored, averaging 102 PtCo units; this value is greater than any of the 67 lakes analyzed by the AWI in 2013. Elevated color levels are indicative of high concentrations of humic organic matter. The elevated color and relatively low concentrations of chlorophyll suggests the ponds maybe somewhat dystrophic. Phosphorus and chlorophyll concentrations in the ponds appear to be decreasing over the past several years. However, this cannot be statistically validated due to low sample size.

8. Vertical profile analysis from September suggests that the Dickman Ponds provides a suitable thermal environment and adequate dissolved oxygen for brook trout, whose optimal temperature is around 16°C, and optimal oxygen concentration is 5 mg/L and above. This scenario is likely quite different during the warm summer months when brook trout may be restricted to a narrow stratum where temperatures are cool and oxygen is still adequate; however, because the ponds are so shallow this type of refuge may not exist.

9. The Dickman ponds are acidic and have low acid buffering ability. The historical average pH is 5.8 for Dickman 1 and 5.9 for Dickman 2.

10. We observed 12 native plant species in the Dickman ponds, the most common being water shield, purple bladderwort, common bladderwort, and spatterdock. In 2011 the aquatic plant detected in the surface survey occupied a minimum area of 14.6 acres (84% of surface area), in 2013 we found the minimum surface are occupied to be 9.8 acres (67% of surface area).

11. The frequency of occurrence of water shield captured by the rake decreased by 16% between 2011 and 2013. We also observed that the density of the plants ensnared by the rake was less in 2013. The frequency of occurrence of purple bladderwort increased by 22% between 2011 and 2013 and the density of plants ensnared by the rake also increased.

In conclusion, we found the water quality of the McCavanaugh Pond Club's water bodies conducive to brook trout growth and survival. However, we surmise that warm summer water temperatures and bottom anoxia may greatly reduce the available habitat for the fish. The Dickman ponds are quite acidic. Although brook trout are the least acid sensitive salmonids, it is likely that the acidity of the Dickman Ponds has negative impacts on juvenile fish. We were unable to detect a substantial difference in the plant community of McCavanaugh Pond in 2013. The Dickman Ponds did see a reduction in water shield and the area occupied by plant beds. The final survey of the ponds will occur in September, 2014.

Introduction

In an effort to control the growth of aquatic plants and increase fishing opportunities for brook trout (*Salvelinus fontinalis*), the McCavanaugh Pond Club has stocked triploid crass carp (*Ctenopharyngodon idella*) into McCavanaugh Pond, Dickman Pond #1 and Dickman Pond #2 under APA permit 2004-216 (amended permit 2004-216A). To support the amended permit the Club is required to assess the water quality and aquatic plant communities of the ponds from 2011 to 2014. The objective of our study is to monitor water quality parameters of the ponds and provide information of the response of the aquatic plant communities to the introduction of the grass carp.

Methodology

Field Sampling and Lab analysis

Limnological data was collected from the deepest sections of the ponds on one occasion during September with the exception of year 2012, when the samples were collected in October. Transparency was observed using a 20 cm black and white Secchi disk from the shady side of the vessel. Temperature and dissolved oxygen were determined every meter from the surface to the bottom with a YSI 556a D.O./Temp meter. Water samples were collected using a 1 liter Kemmerer bottle from a depth of 1.5 meters. 250 mL of the surface water was immediately passed through a 0.7 µm cellulose membrane filter. The filter was collected, wrapped in foil and put on ice for chlorophyll-a analysis. All samples were kept on ice after collection and chemically preserved or stored at 4°C until analysis could be completed. Samples were analyzed for pH, conductivity, alkalinity, total phosphorus, chlorophyll-a, apparent color and conductivity at the AWI Environmental Research Lab following the analytical methods described in Table 1. Brief narrative descriptions of each water quality indicator are provided in the Appendix.

Table 1. Analytical techniques performed on the McCavanaugh Pond samples at the AWI Environmental Research Lab.

Analyte	Method Description	Reference
Lab pH	Mettler Toledo standard pH electrode	APHA
Conductivity	Conductivity at 25° C via Mettler Toledo conductivity cell	APHA 2510 B
Apparent Color	Single wavelength method with PtCO standards	APHA 2120 C
Chlorophyll-a	Trichromatic method uncorrected for phaeophyton	APHA 10200 H
Total Phosphorus	Acid-persulfate digestion, automated ascorbic acid reduction	APHA 4500-P H
Alkalinity	Automated methyl orange method	EPA 301.2

The aquatic plant surveys were carried out during early September of 2011 and 2013. The surface survey was performed by paddling a canoe through the entire littoral zone ponds in a zigzag fashion, starting at the shoreline and moving out to a depth where plants were no longer visible from the surface. An observer on the bow of the boat identified the visible plants and collected data on bed location, species composition, and estimate of percent surface cover with a Trimble Geo XT global positioning system. Plant specimens were periodically collected with a rake to ensure proper identification. After the littoral zone was delineated, the point intercept rake toss method was used to assess species distribution and relative abundance. Rake toss locations were evenly distributed throughout the littoral zone; 25 points were identified for McCavanaugh Pond and 30 points for the Dickman ponds combined (Figure 1). At each site a standard plant rake was tossed from the starboard side of the boat. All plants captured by the rake were identified to the species level and their relative abundance determined using the Cornell/US Army Corps Abundance Scale, where D = dense (difficult to bring on boat), M = medium (rakeful), S = sparse (handful), and T= trace (fingerful).

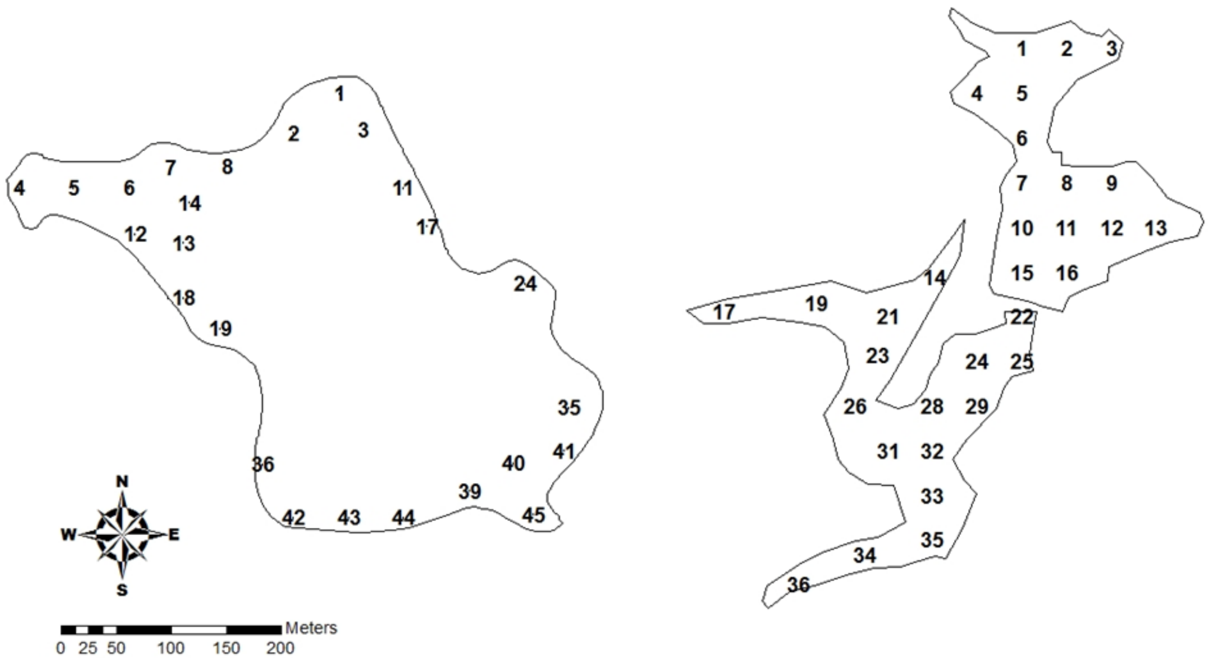

Figure 1. Locations for the point intercept rake toss on McCavanaugh Pond (left) and the DIckman Ponds (right).

Data Analysis

Average annual values for secchi disk transparency, total phosphorus, and chlorophyll-a in the pond were used to calculate Carlson's Trophic Status Index, (TSI), a commonly used quantitative index for classifying lakes based on trophic status (Carlson 1977). TSI values were calculated as follows:

- TSI (Secchi Disk) = 60 – 16.41xln[Secchi Disk (m)]
- TSI (Chlorophyll) = 30.6 + 9.81xln[Chlorophyll a(µg/L)]
- TSI (Total Phosphorus) = 4.15 + 14.42xln[Total Phosphorus (µg/L)]

Typically TSI values are between 0 and 100. Lakes with TSI values less than 40 are classified as oligotrophic, TSI values between 40 and 50 are classified as mesotrophic, and TSI values greater than 50 are classified as eutrophic. A detailed description of TSI values and likely lake attributes is found in Table 2. Time series charts were constructed for the water quality indicators of the study ponds; however trend analysis was not performed because only one sampling event occurred per year. Plant distribution map were produced using ArcGIS (ESRI Redlands, CA). Relative abundance and spatial distribution of plants between years were tabulated and compared.

Table 2. Trophic classification of lakes based on Carlson's Trophic State Index (TSI). Description of trophic classifications can be found in Appendix 2.

TSI Value	Trophic Classification*	Likely Attributes
<30	Oligotrophic	Clear water, high oxygen throughout hypolimnion during the entire year
30-40	Oligotrophic	Clear water, periods of hypolimnetic anoxia possible during the summer in relatively shallow lakes
40-50	Mesotrophic	Moderately clear, increasing probability of hypolimnetic anoxia during the summer
50-60	Eutrophic	Mildly eutrophic. Decreased transparency, hypolimnetic anoxia, and warm water fishery only. Supports all recreational / aesthetic uses but threatened.
60-70	Eutrophic	Dominance of blue-green algae, algal blooms likely, extensive macrophytes growth in shallow water
70-80	Eutrophic	Heavy algal blooms possible throughout summer, hyper eutrophic
>80	Eutrophic	Algal scum, summer fish kills, few macrophytes due to algal shading

Results – Water Quality

McCavanaugh Pond

On September 19th 2011 the temperature profile of McCavanaugh Pond ranged from 17°C on the surface to 13.5°C at the bottom. The epilimnion (surface strata of uniform temperature) was approximately 0.5 meters deep. Dissolved oxygen concentration in McCavanaugh pond was greater than 5 mg/L in the majority of the water column but rapidly decreased to as low as 2 mg/L after a depth of 3 meters (Figure 2).

Time series data on water quality parameters and trophic indicators for McCavanaugh are displayed in Figure 3. The transparency of McCavanaugh Pond in September 2013 was low, with a secchi depth of 0.8 meters, indicating a high amount of dissolved and particulate matter in the water. Over the past seven years of monitoring the transparency of McCavanaugh Pond has ranged from as low as 0.8 in 2013 to as high as 1.7 in 2006. Total phosphorus concentration on the sampling day was determined to be 18 µg/L. Historically, the total phosphorus concentration of the pond has ranged from 11 to 26 µg/L. Chlorophyll-a concentration in McCavanaugh Pond was 17.8 µg/L in the 2013 sample, and substantially higher than observed in previous years when it has ranged between 5 and 7 µg/L. The TSI for McCavanaugh Pond calculated with secchi transparency (63), chlorophyll (59), and total phosphorus (46) averaged to a TSI value of 56, suggesting a eutrophic classification for McCavanaugh Pond (Table 3). The trophic state of McCavanaugh has fluctuated around the Mesotrophic-eutrophic boundary.

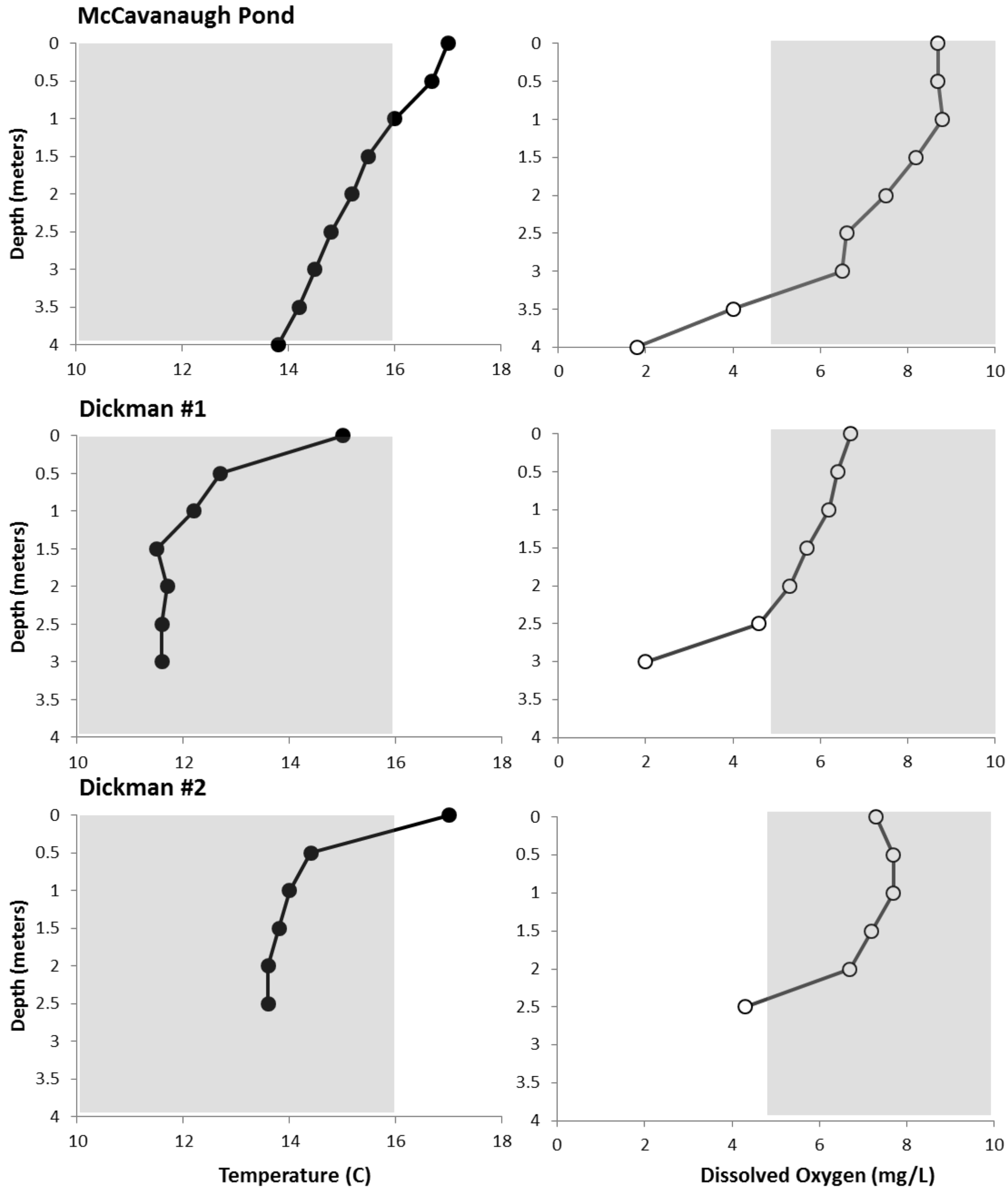

Figure 2. Temperature and dissolved oxygen profiles for McCavanaugh and Dickman Ponds on September 19th, 2013. Shaded boxes represent the optimal temperature and dissolved oxygen ranges for brook trout (Coutant 1977; Spoor 1990).

McCavanaugh is a slightly acidic pond. Historically the pH of the pond has ranged from as low as 5.6 in 2011 to as high as 6.7 in 2013. The alkalinity of the 2013 sample was 9.2 mg/L $CaCO_3$ indicating that the pond is weakly buffered against acid deposition. However, the alkalinity observed between 2006 and 2009 was nearly twice as high as observed the past two years. McCavanaugh pond is deeply colored with an apparent color value that has ranged from 54 PtCo units to a high of 97 PtCo units in the 2013 sample.

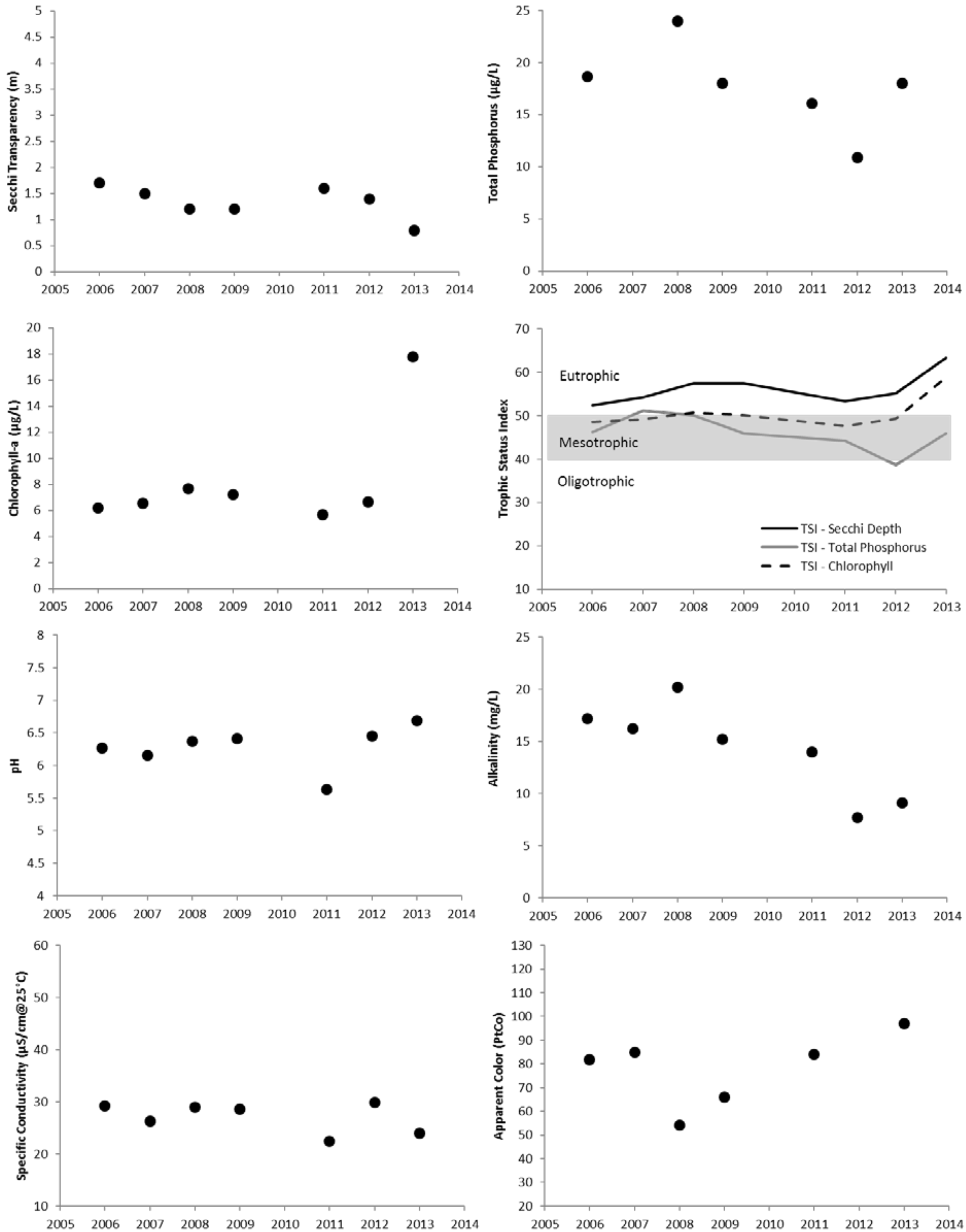

Figure 3. Annual snapshot of epilimnetic water quality and trophic indicators of McCavanaugh Pond, 2006-2013. Samples were collected during the month of September with the exception of 2006 (June and August average) and 2012 (October).

Dickman #1

On September 19th 2011 the temperature profile of Dickman #1 ranged from 15°C on the surface to 11.6°C at the bottom. Dissolved oxygen concentration in Dickman #1 pond was greater than 5 mg/L in the majority of the water column but rapidly decreased to as low as 2 mg/L in the last meter of depth (Figure 2).

Time series data on water quality parameters and trophic indicators for Dickman #1 are displayed in Figure 4. The transparency of Dickman #1 in September 2013 was 1.5 meters. Over the past seven years of monitoring the transparency of Dickman #1 has ranged from a low 1.1 meters in 2006 to as high as 2.4 meters in 2012. Total phosphorus concentration on the sampling day was determined to be 9.2 µg/L. Historically the total phosphorus concentration of the pond has ranged from 6.6 to 22 µg/L. Chlorophyll-a concentration in McCavanaugh Pond was 2.2 µg/L in the 2013 sample, and has historically ranged from 2.2 to 9.8 µg/L. The TSI for McCavanaugh Pond calculated with secchi transparency (54.1), chlorophyll (38.2), and total phosphorus (36.1) averaged to a TSI value of 43, suggesting a mesotrophic classification for Dickman #1 (Table 3). The trophic state of Dickman #1 has fluctuated around the Mesotrophic-eutrophic boundary. Dickman #1 is an acidic pond. Historically the pH of the pond has ranged from as low as 5.6 in 2007 to as high as 6.4 in 2012. The alkalinity of the 2013 sample was 8.5 mg/L $CaCO_3$ indicating that the pond is weakly buffered against acid deposition. Historically the alkalinity has ranged between 7 to 14 mg/L . Dickman #1 is deeply colored with an apparent color value that has ranged from 61 PtCo units to a high of 125 PtCo units in the 2011 sample.

Dickman #2

On September 19th 2011 the temperature profile of Dickman #2 ranged from 17°C on the surface to 13.8°C at the bottom. Dissolved oxygen concentration in Dickman #2 pond was greater than 5 mg/L in the majority of the water column but rapidly decreased to as low as 2 mg/L in the last meter of depth (Figure 2).

Time series data on water quality parameters and trophic indicators for Dickman #2 are displayed in Figure 5. The transparency of Dickman #2 in September 2013 was very low, with a secchi depth of only 0.5 meters. Over the past seven years of monitoring the transparency of Dickman #2 has ranged from a low 0.5 meters in 2013 to as high as 1.8 meters in 2012. Total phosphorus concentration on the sampling day was determined to be 10 µg/L. Historically the total phosphorus concentration of the pond has ranged from 8.8 to 21.2 µg/L. Chlorophyll-a concentration in McCavanaugh Pond was 3.0 µg/L in the 2013 sample, and has historically ranged from 3.0 to 10.3 µg/L. The TSI for McCavanaugh Pond calculated with secchi transparency (70), chlorophyll (41), and total phosphorus (39) averaged to a TSI value of 50, suggesting a eutrophic classification for Dickman #2 (Table 3). The trophic state of Dickman #2 has fluctuated around the Mesotrophic-eutrophic boundary. Dickman #2 is also an acidic pond. Historically the pH of the pond has ranged from as low as 5.3 pH units in 2011 to as high as 6.4 in 2009. The alkalinity of the 2013 sample was 4.4 mg/L $CaCO_3$ indicating that the pond is also weakly buffered against acid deposition. Historically the alkalinity has ranged between 2.6 to 22.2 mg/L . Dickman #2 is also deeply colored with an apparent color value that has ranged from 88 PtCo units to a high of 114 PtCo units in the 2013 sample.

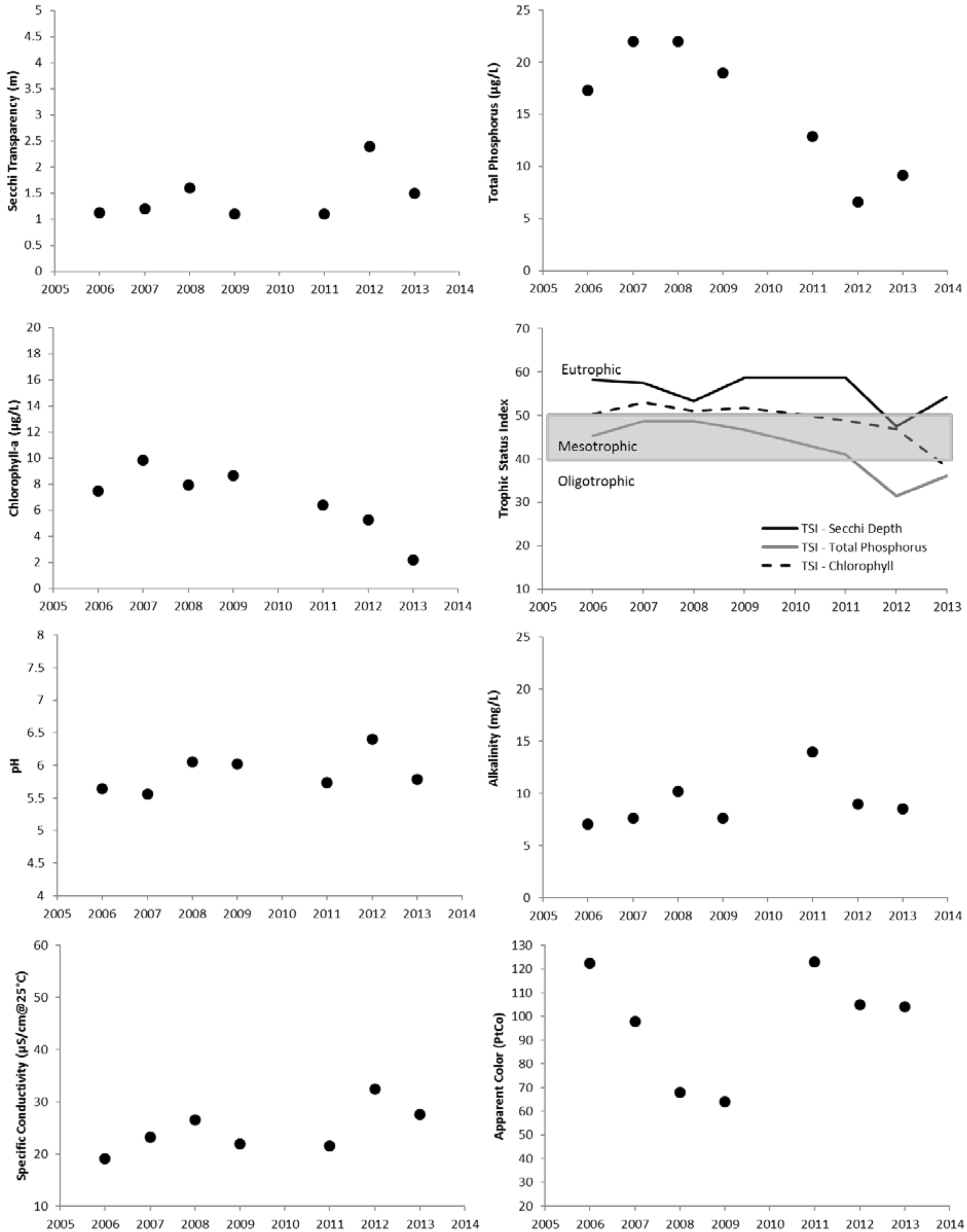

Figure 4. Annual snapshot of epilimnetic water quality and trophic indicators of Dickman Pond #1, 2006-2013. Samples were collected during the month of September, with the exception of 2006 (June and August average) and 2012 (October).

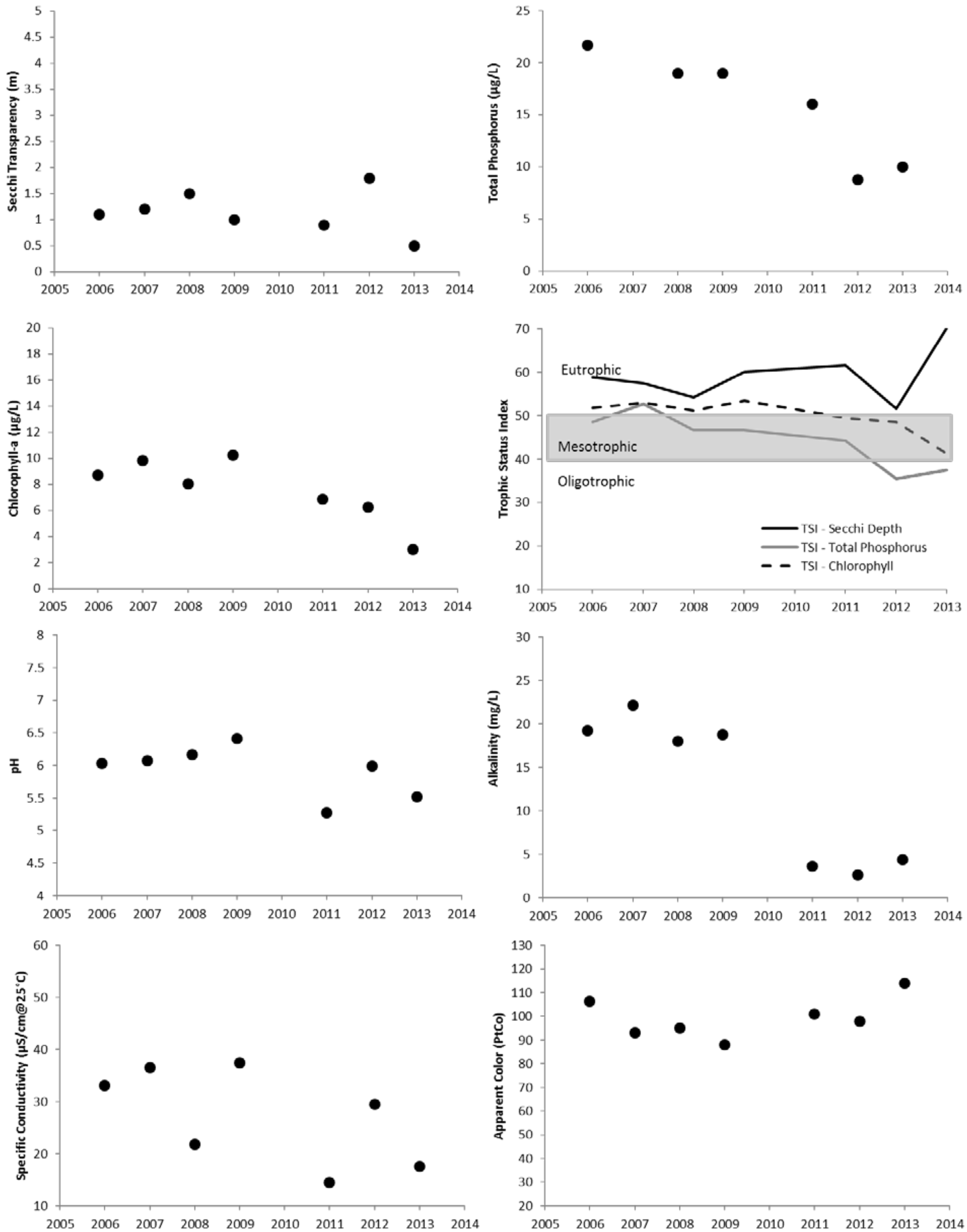

Figure 5. Annual snapshot of epilimnetic water quality and trophic indicators of Dickman Pond #2, 2006-2013. Samples were collected during the month of September, with the exception of 2006 (June and August average) and 2012 (October).

Results – Aquatic Plants

McCavanaugh Pond

During our visual surveys we identified 13 native aquatic plant species occurring in four distinct plant beds in McCavanaugh, not including several emergent and semi-aquatic species that fringe the pond margin. In 2011 the aquatic plant beds of McCavanaugh occupied a minimum area of 12.1 acres (43% of surface area). We found no detectable difference in the 2013, when the minimum occupied area of aquatic plant beds was 11.8 acres (Figure 6). The observed difference between years is well within the error expected with this type of visual survey. Using the percent cover estimates in Table 3, the most common plants to occur in these beds are water shield, white water lily, spatterdock, and purple bladderwort. Other plants such as Canada waterweed, water naiad and the pondweeds occur in the pond but are much less abundant (Table 4).

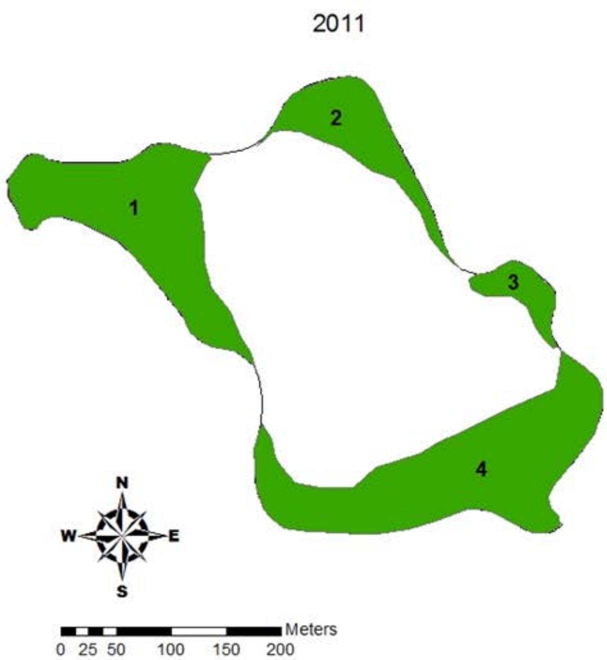

Figure 6. Results of the surface survey of aquatic plant beds on McCavanaugh and Dickman Ponds from September 2011 (left) and 2013 (right). Species and percent cover in each numbered bed can be found in Table 3.

A total of 6 species of aquatic plants were encountered on the 25 plant rakes deployments in McCavanaugh Pond (Appendix 2). We captured plants on 88% of rake deployments in 2011, and 84 % of rakes in 2013. The percent frequency of occurrence and density of aquatic plants on rakes is outlined in Table 4. The white water lily was the most common plant encountered on the rake. In 2011 it occurred on 72% of the rake deployments, and was found to be dense or medium on 12 % of the rakes. We ensnared 12% less water lily in 2013 when the plant occurred on 60% of the rake deployments. The density of water lily captured on the rake was greater in 2013, when 24 % of the deployments had dense or medium coverage. The water shield was also common on the rakes, occurring on 48% of the deployments in 2011 and 36% in 2013. Although the water shield was common throughout the shallow water it was not found to be particularly abundant on the rakes. We observed greater amounts bladderworts on the rakes in 2013. Lesser bladderwort and common bladderwort were not ensnared by the rakes in 2011 but were found on 12% and 16% of rake deployments in 2013 respectively. The frequency of occurrence of the purple bladderwort did not change between years (28% of rakes); however we did observe greater densities of the plant on the rakes in 2013 (Table 4).

Table 3. Distribution and percent cover of aquatic plant species detected in the surface survey of McCavanaugh Pond in 2011 and 2013. Bed numbers correspond to Figure 6. R = rare (<5% cover), O = occasional (5-15%), P = present (15-25%), C = common (25 – 50%), and A = abundant (>50%).

		September 2011				September 2013			
Scientific Name	**Common Name**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Brasenia schreberi	water shield	C	P	O	R	C	C	A	P
Eriocaulon aquaticum	pipewort	R	O			R	R		
Elodea Canadensis	common water weed			R	R			P	
Najas species	water naiad	R				R		R	
Nuphar variegate	spatterdock	P	R	R	O	P	R	R	O
Nymphaea odorata	white water lily	A	C	C	A	A	A	C	A
Potamogeton amplifolius	large- leaved pondweed	R			R		R		
Potamogeton epihydrus	ribbon-leaved pondweed					R			
Potamogeton natans	floating pondweed	R				R			
Sparganium species	bur-reed	R		R		R	R		R
Utricularia minor	lesser bladderwort					R			
Utricularia vulgaris	common bladderwort	R				R	R		
Utricularia purpurea	purple bladderwort	A	R	R		A	P		C

Dickman Ponds

We observed 12 native aquatic plant species occurring in four distinct plant beds during our surface surveys of the Dickman Ponds (both ponds combined) In 2011 the aquatic plant beds of the ponds occupied a minimum area of 14.6 acres (84% of surface area). We observed fewer plants from the surface in 2013, when the minimum occupied area of aquatic plant beds was 9.8 acres (67% of the surface area; Figure 7). Although the area occupied by plants was less in 2013, we did not detect any substantial difference on percent cover within the beds. Using the percent cover estimates in Table 5, the most common plants to occur in these beds are water shield, purple bladderwort, common bladderwort, white water lily, and spatterdock. Similar to McCavanaugh Pond, other plants such as Canada waterweed, water naiad, and the pondweeds (*Potamogeton species*) occur but are much less abundant (Table 5).

A total of 8 species of aquatic plants were encountered on the 31 plant rakes deployments in the Dickman Ponds (Appendix 2). We captured plants on 84% of rake deployments in 2011, and 81 % of rakes in 2013. The percent frequency of occurrence and density of aquatic plants on rakes is outlined in Table 6. The water shield was the most common plant encountered on the rake. In 2011 it occurred on 81% of the rake deployments, and was found to be abundant on 48% of the rakes. We ensnared 16% less water shield in 2013 when the plant occurred on 65% of the rake deployments. The density of water shield captured on the rake was greater in 2013, when 48 % of the deployments had dense or medium coverage. The purple bladderwort *was* also very common on the rakes, occurring on 55% of the rakes in 2011 and 77% of the rakes in 2013. The number of rakes with dense or medium coverage of the purple bladderwort also increased from 23% in 2011 to 65% in 2013.

Table 4. Percent frequency of occurrence and density of aquatic plants species ensnared by the plant rake in McCavanaugh Pond in 2011 and 2013. %FO represents the number of rakes the species occurred on out of the 25 total rakes deployed in the pond. %D or M represents the percentage of rakes that ensnared dense plants (D = difficult to bring into boat) or medium amount of plants (M = a rakeful).

	2011		2013		Change in plant community	
	% F.O.	% D or M	% F.O	% D or M	Δ %F.O	Δ % D or M
Water shield	48	0	36	0	-12	0
Spatterdock	20	8	20	4	0	0
White water lily	72	12	60	24	-12	+12
Lesser bladderwort	0	0	12	0	+12	0
Common bladderwort	0	0	16	0	+16	0
Purple bladderwort	28	16	28	57	0	41

Figure 7. Results of the surface survey of aquatic plant beds on McCavanaugh and Dickman Ponds from September 2011 (left) and 2013 (right). Species and percent cover in each numbered bed can be found in Table 5.

Table 5. Distribution and percent cover of aquatic plant species detected in the surface survey of the Dickman Ponds in 2011 and 2013. Bed numbers correspond to Figure 7. R = rare (<5% cover), O = occasional (5-15%), P = present (15-25%), C = common (25 – 50%), and A = abundant (>50%).

		September 2011				September 2013			
Scientific Name	**Common Name**	**5**	**6**	**7**	**8**	**5**	**6**	**7**	**8**
Brasenia schreberi	water shield	A	C	A	A	A	p	A	A
Eleocharis acicularis	dwarf hair grass		R				R		
Najas species	water naiad	R	R	R	R	R	R	R	R
Nuphar variegata	spatterdock	O	P	O	O	O	P	P	C
Nymphaea odorata	white water lily	P	P	O	P	P	P	P	P
Potamogeton amplifolius	large- leaved pondweed		R			R	R		
Potamogeton epihydrus	ribbon-leaved pondweed	R				R			
Potamogeton natans	floating pondweed			R	C	R		R	R
Sparganium species	bur-reed			R			R	R	
Utricularia minor	lesser bladderwort	O	P	O	C	O	O	O	O
Utricularia vulgaris	common bladderwort	P	C	P	C	P	C	P	P
Utricularia purpurea	purple bladderwort	C	C	C	C	C	C	C	C

Table 6. Percent frequency of occurrence and density of aquatic plants species ensnared by the plant rake in the Dickman ponds in 2011 and 2013. %FO represents the number of rakes the species occurred on out of the 25 total rakes deployed in the pond. %D or M represents the percentage of rakes that ensnared dense plants (D = difficult to bring into boat) or medium amount of plants (M = a rakeful).

	2011		2013		Change in plant community	
	% F.O.	% D or M	% F.O	% D or M	Δ %F.O	Δ % D or M
Water shield	81	48	65	29.0	-16	-19
Hairgrass	3	0.0	0.0	0.0	-3	0
Spatterdock	16	3	13	3	-3	0
White water lily	0.0	0.0	3	3	+3	+3
Floating pondweed	0.0	0.0	7	0.0	+7	0
Lesser bladderwort	26	0.0	13	0.0	-13	0
Common bladderwort	16	0.0	19	0.0	+3	0
Purple bladderwort	55	23	77	65	+22	+42

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Appendix 1: Brief Review of Water Quality Indicators

Alkalinity - Alkalinity measures the buffering capacity of a lake, which is the ability of the lake to resist a change in pH. High alkalinity lakes are well buffered against changes in pH, while low alkalinity lakes are poorly buffered against changes in pH. Thus, a high alkalinity lake would have a more stable pH compared to a low alkalinity lake, and a more stable pH is less stressful to aquatic life. Alkalinity largely depends on the concentration of calcium carbonate in the water, and lakes with less than 10 ppm calcium carbonate are highly sensitive to acidification, while lakes with greater than 20 ppm calcium carbonate are not sensitive to acidification (Godfrey et al. 1996).

Calcium, Magnesium, Potassium, Sodium – all essential elements for plant growth, but generally not limiting in aquatic systems and thus do not contribute to algae blooms. Calcium, Magnesium, and Potassium are macronutrients, and Sodium is a micronutrient. All are naturally occurring elements that are released through rock weathering plus smaller quantities from atmospheric deposition. Though, the rocks of most Adirondack watershed have low concentrations of these elements, so they are found in low concentrations in lakes under natural conditions. Road salting has elevated the sodium concentration in Adirondack lakes and perhaps the concentrations of the other elements through exchange processes occurring within the soil (Kelting et al. 2012). High concentrations of sodium in drinking water may cause health problems for people with hypertension (Corsi et al. 2010), and thus the US EPA has set a drinking water standard of 20 ppm for sodium, though there is debate over the validity of this standard (it may be too low). Lake calcium concentration also relates to habitat suitability for zebra mussels, as researchers have reported minimum calcium concentrations ranging for 8 to 20 ppm to support a viable population (Cohen 2004). So, calcium is an important indicator to track to assess the risk for zebra mussel infestation. Calcium may also be important to understand internal P loading, Ca-P (Pollman and James 2011).

Carlsons Trophic Status Index (TSI) – a numerical trophic state index that incorporates most lakes into a scale of 0-100. Each major division (10, 20, 30 etc.) represents a doubling of algal biomass. The index can be calculated from Secchi disk transparency, chlorophyll-a, or total phosphorus concentrations.

Chloride – an anion that can have negative effects on aquatic life when at high concentrations (Corsi et al. 2010), and can impart an undesirable taste to drinking water, also when at high concentrations. The US EPA has a drinking water guideline of 250 ppm for salty taste, but this is not an enforceable standard. The principal source of chloride in lakes in our region is road salt (Kelting et al. 2012).

Chlorophyll a – the primary photosynthetic pigment found in all species of algae that is used as an index of algal biomass (Wetzel 2001). Chlorophyll *a* is not a direct measure of algal biomass as the concentration of chlorophyll varies somewhat by species and environmental conditions. This said, increases in chlorophyll *a* are generally associated with increased algal production, and the concentration of chlorophyll *a* is widely considered as the most direct measure of the trophic state of lakes. Algal biomass is affected by nutrient availability, water temperature, and light, so there can be considerable variation in chlorophyll *a* concentrations throughout the year depending on which of these three factors is limiting growth at a particular time. Though, major changes in algal biomass (e.g. a bloom) and thus chlorophyll *a* are usually related to changes in the availability of phosphorus, nitrogen, and silica (Wetzel 2001).

Color – can limit light penetration and plant productivity and reduces water clarity. Color is influenced by the types and concentrations of suspended and dissolved particles in the water. Sources of these particles include dissolved organic carbon, algae, minerals and soils. Tannins produced from decomposition of plant and animal matter give water a tea color, particularly when associated with wetlands. Algae produce a variety of colors that range from red to green, depending on the type. Dissolved iron produces red to brown colors and dissolved manganese produces black, both of these metals are abundant in Adirondack waters. True Color, measured on filtered water samples, is used by the NYS DEC when interpreting total phosphorus concentrations in relation to eutrophication. A greater percentage of the total phosphorus is bound to organic matter in darker colored waters, and thus is less available compared to the total phosphorus measured in lighter colored waters.

Conductivity – pure water is a poor conductor of electricity. The ability of water to conduct electricity increases as the concentration of dissolved ions in the water increases. Thus, conductivity is measured as an indicator of dissolved ions and is a very useful surrogate when the relationships between ion concentrations and conductivity are known. For example, conductivity can be used to estimate sodium and chloride concentrations (Daley et al. 2009).

Dissolved Organic Carbon – a food source for aquatic biota, plays a significant role in lake chemistry, imparts color to the water (e.g. tea colored water is from humic substances), and affects water clarity. Dissolved organic carbon enters streams and lakes from uplands or is produced in lakes and streams. Forested watersheds in particular have been shown to export a significant amount of dissolved organic carbon to lakes (Dillon and Molot 1997). Dissolved organic carbon concentrations in Adirondack lakes have increased over the last 20 years, and this increase may relate to changes in acid deposition (Monteith et al. 2007).

Dissolved Oxygen – needed for survival and health of many forms of aquatic life, as well as affects the availability of phosphorus. Dissolved oxygen is consumed during respiration and decomposition and replenished by photosynthesis and diffusion from the atmosphere. The lack of cycling during summer stratification inhibits the replenishment of dissolved oxygen to bottom waters in the summer, resulting in depletion of dissolved oxygen as previously mentioned. Depletion of dissolved oxygen in bottom waters may result in increased release of phosphorus from the dissolution of iron-phosphates contained in the sediment (Katsev et al. 2006).

Eutrophic – From the Greek words *Eu*, meaning good and *trophi*, meaning nourishment; eutrophic lakes have abundant levels of nutrients. As a result of high nutrient availability eutrophic lakes are typified by high algal productivity, low transparency, high organic matter in the sediments, and periods of anoxia in the bottom of the water column (hypolimnion). Eutrophic lakes tend to support dense aquatic plant growth in the littoral zone. Eutrophic lakes are unlikely to support a viable cold water fishery (Wetzel 2001).

Mesotrophic - From the Greek words *Meso*, meaning the middle and *trophi*, meaning nourishment. Mesotrophic lakes and an intermediate trophic classification on the continuum between oligotrophy and eutrophy.

Nitrogen – a macronutrient that can be the limiting nutrient for algae growth in lakes, but it is generally the second most limiting nutrient after phosphorus. Nitrogen enters our watersheds through biological fixation, atmospheric deposition, fertilizers, and human waste. Nitric acid, a component of acid rain produced by the combustion of fossil fuels, has contributed significantly to lake acidification (reduced pH) in our region (Driscoll et al. 2003). The plant available forms of nitrogen are ammonium and nitrate, which are generally present in very small quantities as they are rapidly assimilated into biomass. Most of the nitrogen is bound in organic matter and is released as ammonium by microbial activity and further converted to nitrate by microbes under aerobic conditions. Total nitrogen is all of the organically bound nitrogen plus the ammonium and nitrate. Under nitrogen limiting conditions, which may occur in lakes with high concentrations of phosphorus, nitrogen fixing cyanobacteria may proliferate (Wetzel 2001). Cyanobacteria are the largest group of toxin producing algae, though not all cyanobacteria produce toxins, and those that do produce toxins don't do so all of the time (Carmichael 2008).

Oligotrophic – From the Greek words *oligo,* meaning few and *trophi,* meaning nourishment; oligotrophic lakes have low levels of available nutrients. As a result of low nutrients, oligotrophic lakes have high transparency, low algal abundance, low organic matter in the sediments, sparse aquatic plant growth, and abundant dissolved oxygen throughout the water column the entire year. Oligotrophic lakes are most likely to support a cold water fishery (Wetzel 2001).

pH– pH measures the concentration of hydrogen ions in solution, and is considered a master variable for its influence on chemical processes and aquatic life. Neutral waters have a pH of 7, pH's less than 7 are acidic and pHs greater than 7 are basic. The optimum pH range for most aquatic life is between 6.5 and 8.

Phosphorus – a macronutrient that is often the limiting nutrient for algae growth in lakes and widely considered as the most important contributor to reduced water quality in lakes (Søndergaard et al. 2003). Natural weathering releases phosphorus from rocks and soils, and it also enters our watersheds in fertilizers, human waste, and atmospheric deposition. The plant available form is ortho-phosphate, which is generally present in very small quantities as it is rapidly assimilated into biomass. High ortho-phosphate concentrations are indicative of waste inputs (e.g. failing septic systems) or release of bound phosphorus from sediments (internal loading). Soluble total phosphorus is the fraction of total phosphorus that passes through a 0.45 micron filter. Total phosphorus is all of the inorganically and organically bound phosphorus combined, so it represents phosphorus in living tissues, detritus, and ortho-phosphate. The total phosphorus concentration in the surface waters is used as an indicator of lake trophic or productivity status; lakes with less than 10 ppb are considered oligotrophic or low productivity, lakes with 10 to 20 ppb are considered mesotrophic or moderate productivity, and lakes with greater than 20 ppb are considered eutrophic or high productivity. Total phosphorus near the lake bottom (Hypolimnion) is monitored to understand the importance of internal loading, the release of phosphorus accumulated in sediments which replenishes surface water phosphorus when lakes turn over.

Secchi Transparency – widely used measurement of water clarity used as an index of lake trophic state and is important to our perception of water quality. Secchi transparency is influenced by several factors beyond algal productivity, including the eyesight of the reader, time of day of the reading, suspended sediments, and dissolved organic carbon. Increases in suspended sediments from watershed runoff, shoreline erosion, or mixing will reduce Secchi transparency, as will increases in dissolved organic carbon from these same processes. Thus, the potential effects of suspended sediments and dissolved organic carbon should also be considered when interpreting Secchi transparency data.

Trophic Indicators- Lakes are typically assigned into one of three trophic or productivity classes (oligotrophic, Mesotrophic, eutrophic) based on total phosphorus, total nitrogen, chlorophyll *a*, and Secchi transparency (Table 7). These four indicators are known as trophic indicators. Under conditions when water clarity is largely a function of algae biomass, there should be good correlations between chlorophyll *a*, Secchi transparency, and total phosphorus and/or total nitrogen, depending on which of these two nutrients is limiting productivity. For example, Bachmann et al. (1996) reported strong positive correlations between chlorophyll *a* and both total phosphorus and total nitrogen, and strong negative correlations between Secchi transparency and chlorophyll *a*, total phosphorus, and total nitrogen in a study of 65 lakes in Florida. But, if other factors, such as suspended sediments (Davies-Colley and Smith 2001), dissolved organic carbon (Dillon and Molot 1997), or complex food web interactions (Carpenter et al. 1985) are affecting water clarity, then the correlations between trophic indicators can be diminished to non-existent. Thus, it is important to measure all four trophic indicators to assess the trophic state of lakes and to interpret them with full consideration of other factors that can affect water clarity, otherwise the interpretations may be misleading. The NYS DEC uses a true color threshold of 30 Ptu for interpreting total phosphorus and Secchi transparency. The classification thresholds listed in Table 4 are only applied to lakes with true color less than 30 Ptu, in recognition of the relationship between true color and phosphorus availability and between true color and water clarity. The NYS DEC uses chlorophyll *a* to classify lakes with greater than 30 Ptu true color.

Total Suspended Solids (TSS) – Total Suspended Solids is measured as the amount of material retained on a glass fiber filter disk after a known volume of water is filtered. Because turbidity and TSS both measure particles in water, they are related and have been shown to be highly correlated (Bertrand-Krajewski 2004). These particles include silt, clay, organic matter, plankton, and other organisms. Sources of turbidity and TSS include soil erosion in the watershed, algae production, and decomposition of organic matter.

Turbidity – turbidity is a measure of water clarity that is based on the scattering of light by particles in the water.

Table 7. General trophic classification of lakes (adapted from Wetzel 2001) and NYS DEC assessment criteria.

Indicator	Oligotrophic	Mesotrophic	Eutrophic
Total phosphorus (ppb)			
Mean	8.0	26.7	84.4
Range	3.0 - 17.7	10.9 - 95.6	16 – 386
NYS DEC	< 10	10 - 20	> 20
Total nitrogen (ppb)			
Mean	661	753	1875
Range	307 - 1630	361 - 1387	393 - 6100
Chlorophyll a (ppb)			
Mean	1.7	4.7	14.3
Range	0.3 - 4.5	3 – 11	3 – 78
NYS DEC	< 2	2 - 8	> 8
Secchi transparency (m)			
Mean	9.9	4.2	2.45
Range	5.4 - 28.3	1.5 - 8.1	0.8 - 7.0
NYS DEC	> 5	2 - 5	< 2

Appendix 2: Rake Toss Data

YEAR	POND	X	Y		*Brasenia schreberi*	*Eleocharis acicularis*	*Nuphar variegata*	*Nymphaea odorata*	*Potamogeton natans*	*Utricularia minor*	*Utricularia vulgaris*	*Utricularia pupurea*
2011	Dickman	539595	4930825	1	M							M
2011	Dickman	539635	4930825	2	M		T			T	T	T
2011	Dickman	539675	4930825	3	D							M
2011	Dickman	539555	4930785	4	M		T			T		T
2011	Dickman	539595	4930785	5	D					S		
2011	Dickman	539595	4930745	6								
2011	Dickman	539595	4930705	7	S		M			S		
2011	Dickman	539635	4930705	8	S						S	
2011	Dickman	539675	4930705	9	M							M
2011	Dickman	539595	4930665	10	S					S		S
2011	Dickman	539635	4930665	11	S							S
2011	Dickman	539675	4930665	12								
2011	Dickman	539715	4930665	13	S							S
2011	Dickman	539517	4930621	14								
2011	Dickman	539595	4930625	15								
2011	Dickman	539635	4930625	16								
2011	Dickman	539329	4930590	17	M						T	S
2011	Dickman	539411	4930597	19	D						S	
2011	Dickman	539475	4930585	21	S							T
2011	Dickman	539595	4930585	22	T		S					M
2011	Dickman	539466	4930551	23	T							T
2011	Dickman	539555	4930545	24	M					S		S
2011	Dickman	539595	4930545	25	M	T						
2011	Dickman	539446	4930505	26	T					T		M
2011	Dickman	539515	4930505	28	T							
2011	Dickman	539555	4930505	29	M						S	
2011	Dickman	539475	4930465	31	T					T		M
2011	Dickman	539515	4930465	32	M							M
2011	Dickman	539515	4930425	33	M							
2011	Dickman	539454	4930372	34	M							
2011	Dickman	539515	4930385	35								
2011	Dickman	539395	4930345	36	M		T					T
2013	Dickman	539595	4930825	1	M				S	T	S	D
2013	Dickman	539635	4930825	2	M						S	M
2013	Dickman	539675	4930825	3	M		T					S
2013	Dickman	539555	4930785	4	M		S					M
2013	Dickman	539595	4930785	5	S		T					M
2013	Dickman	539595	4930745	6								
2013	Dickman	539595	4930705	7	T							S
2013	Dickman	539635	4930705	8	S					T		M
2013	Dickman	539675	4930705	9			T					D
2013	Dickman	539595	4930665	10								
2013	Dickman	539635	4930665	11	T							

YEAR	POND	X	Y		*Brasenia schreberi*	*Eleocharis acicularis*	*Nuphar variegata*	*Nymphaea odorata*	*Potamogeton natans*	*Utricularia minor*	*Utricularia vulgaris*	*Utricularia pupurea*
2013	Dickman	539675	4930665	12								
2013	Dickman	539715	4930665	13	S							M
2013	Dickman	539517	4930621	14	D				T			D
2013	Dickman	539595	4930625	15								
2013	Dickman	539635	4930625	16						S	S	
2013	Dickman	539329	4930590	17	T						T	T
2013	Dickman	539411	4930597	19	T							T
2013	Dickman	539475	4930585	21	T							D
2013	Dickman	539595	4930585	22							S	D
2013	Dickman	539466	4930551	23				M				M
2013	Dickman	539555	4930545	24	S						T	M
2013	Dickman	539595	4930545	25								D
2013	Dickman	539446	4930505	26	S							D
2013	Dickman	539515	4930505	28	M							M
2013	Dickman	539555	4930505	29								T
2013	Dickman	539475	4930465	31	S					T		D
2013	Dickman	539515	4930465	32	M							D
2013	Dickman	539515	4930425	33								
2013	Dickman	539454	4930372	34	M							M
2013	Dickman	539515	4930385	35	S							M
2013	Dickman	539395	4930345	36	M							M
2011	McCavanaugh	536864	4932620	1	S			T				
2011	McCavanaugh	536822	4932584	2								
2011	McCavanaugh	536884	4932587	3				T				
2011	McCavanaugh	536572	4932534	4	T			M				M
2011	McCavanaugh	536622	4932534	5	S			M				M
2011	McCavanaugh	536672	4932534	6	S			S				M
2011	McCavanaugh	536710	4932552	7				S				S
2011	McCavanaugh	536761	4932554	8								
2011	McCavanaugh	536922	4932534	11	T			T				
2011	McCavanaugh	536677	4932492	12				T				M
2011	McCavanaugh	536722	4932484	13				S				
2011	McCavanaugh	536726	4932520	14	T			S				D
2011	McCavanaugh	536943	4932499	17	T							
2011	McCavanaugh	536722	4932434	18				M				
2011	McCavanaugh	536755	4932406	19								
2011	McCavanaugh	537032	4932447	24				S				
2011	McCavanaugh	537072	4932334	35	S		S	S				
2011	McCavanaugh	536794	4932282	36	S		M					
2011	McCavanaugh	536981	4932259	39	S		T					
2011	McCavanaugh	537022	4932284	40	S			S				
2011	McCavanaugh	537068	4932295	41			M					
2011	McCavanaugh	536822	4932234	42				S				
2011	McCavanaugh	536872	4932234	43				S				

YEAR	POND	X	Y		*Brasenia schreberi*	*Eleocharis acicularis*	*Nuphar variegata*	*Nymphaea odorata*	*Potamogeton natans*	*Utricularia minor*	*Utricularia vulgaris*	*Utricularia pupurea*
2011	McCavanaugh	536922	4932234	44				S				
2011	McCavanaugh	537039	4932237	45	S		S	S				T
2013	McCavanaugh	536864	4932620	1	T			T				
2013	McCavanaugh	536822	4932584	2								
2013	McCavanaugh	536884	4932587	3				S				
2013	McCavanaugh	536572	4932534	4	S		S					M
2013	McCavanaugh	536622	4932534	5				M				M
2013	McCavanaugh	536672	4932534	6	S			M				M
2013	McCavanaugh	536710	4932552	7								S
2013	McCavanaugh	536761	4932554	8								
2013	McCavanaugh	536922	4932534	11	S							
2013	McCavanaugh	536677	4932492	12								M
2013	McCavanaugh	536722	4932484	13				T				
2013	McCavanaugh	536726	4932520	14				S				D
2013	McCavanaugh	536943	4932499	17								
2013	McCavanaugh	536722	4932434	18				M				
2013	McCavanaugh	536755	4932406	19				M		T		
2013	McCavanaugh	537032	4932447	24				M			T	
2013	McCavanaugh	537072	4932334	35	T		S	S		S	S	
2013	McCavanaugh	536794	4932282	36			M					
2013	McCavanaugh	536981	4932259	39	S			M				
2013	McCavanaugh	537022	4932284	40	T			T				
2013	McCavanaugh	537068	4932295	41	T		S				S	
2013	McCavanaugh	536822	4932234	42				T				
2013	McCavanaugh	536872	4932234	43								
2013	McCavanaugh	536922	4932234	44				T		T	S	
2013	McCavanaugh	537039	4932237	45	S		S	S				T