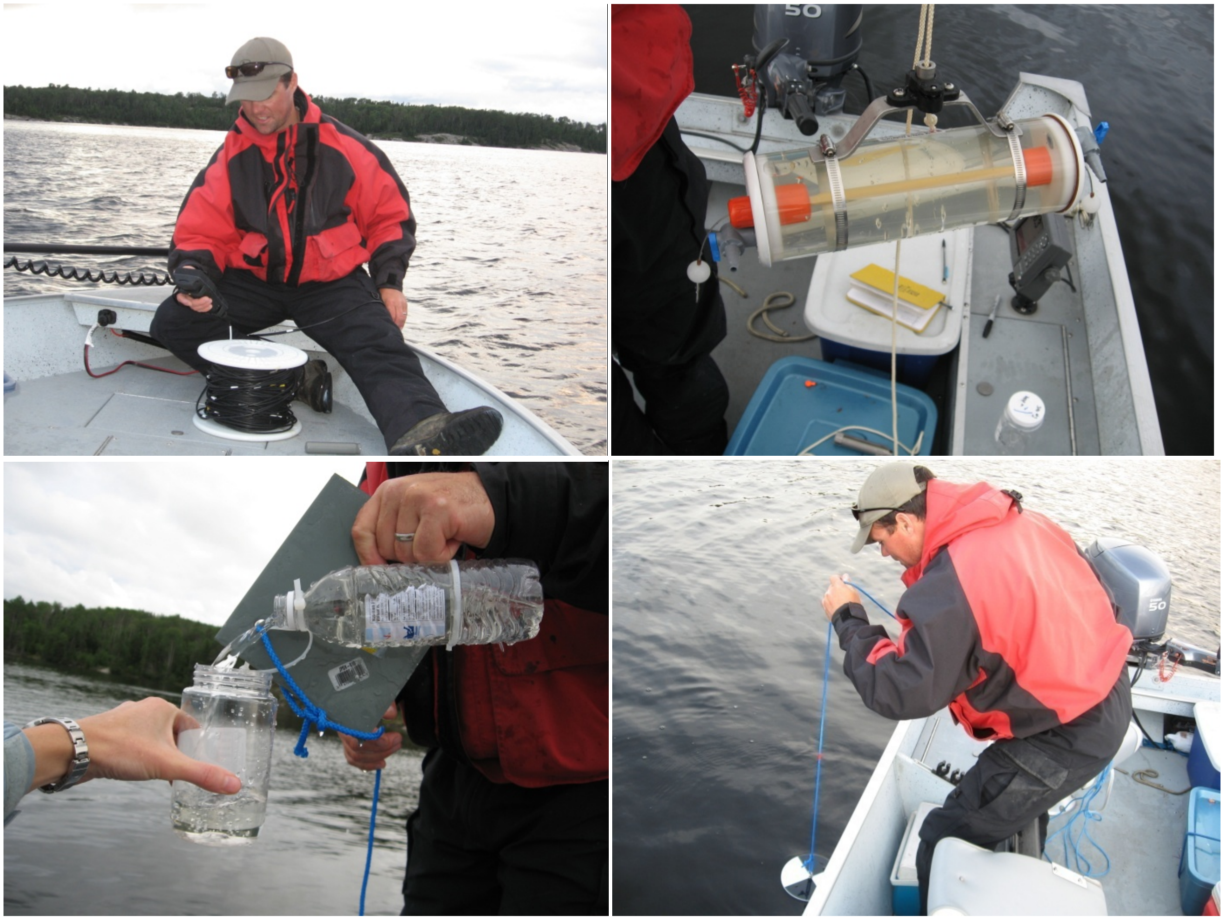
RYAN HAINES CONSULTING



BLACK STURGEON LAKES WATER QUALITY MONITORING

2010 REPORT

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1.0 BACKGROUND

In the fall of 2007, the City of Kenora was presented with the results of the *Lake Capacity and Management Study for Black Sturgeon Lake* (Gartner Lee Ltd. and Kelli Saunders Environmental Management, October 2007). One of the recommendations of this study was to conduct a water quality assessment on Lower Black Sturgeon Lake for two consecutive years to establish baseline data and then once every five years to monitor changes to the water quality in the lake.

In the spring of 2009, the City of Kenora awarded the contract to conduct the first year of water quality monitoring on Lower Black Sturgeon Lake to Ryan Haines Consulting. Following the 2009 sampling season, the City of Kenora extended the contract to Ryan Haines Consulting to continue water quality monitoring for the 2010 sampling season to establish two years of baseline data for the water body.

2.0 METHODOLOGY

Eight sampling sessions were conducted during the 2010 season between April and November with one sampling session each month. Water samples were taken at two locations on Lower Black Sturgeon Lake and one location at Upper Black Sturgeon during each sampling session (Figure 1). Sample locations on Lower Black Sturgeon correspond to sites identified in the *Lake Capacity and Management Study for Black Sturgeon Lake*. The site on Upper Black Sturgeon was added for the 2010 season to help to better understand the source of the higher nutrient levels at the upstream site on Lower Black Sturgeon during the 2009 sampling season. These sites provide the best data to determine the impacts of development on the water quality of Black Sturgeon Lakes as one of the sites is located at the closest location with sufficient depth to the outlet of Black Sturgeon Lakes into the Winnipeg River (site #2); one of the sites is located in the closest location with sufficient depth to the inlet of Black Sturgeon Creek into Lower Black Sturgeon Lake (site #3); and the site added for the 2010 sample season was located at the outlet of Upper Black Sturgeon Lake (site X) into Black Sturgeon Creek to determine the nutrient input from Upper Black Sturgeon Lake into the system. Site #2 was used to assess the impacts of development on water quality because the vast majority of new and proposed developments on Lower Black Sturgeon Lake are occurring upstream of this site. Information collected from sites #2 and #3 were compared to total phosphorous data collected by Ministry of the Environment (MOE) since 1997. These two sites have the largest dataset of all sites monitored on Lower Black Sturgeon Lake over the past decade (*Lake Capacity and Management Study for Black Sturgeon Lake*).

All field work was conducted from a small motorboat with a sonar unit mounted to the stern. At each sampling site, an anchor was used to keep the boat in a fixed location.

Temperature/oxygen profiles were obtained at sites #1, #2, #3, and X during each sampling session using an YSI 55 Dissolved Oxygen Meter. Site #1 was tested to determine the distribution of oxygen and temperature throughout the water column at one of the deepest sections in the center portion of the lake.

This For the purpose of this report, the thermocline is defined as a change in water temperature of equal to or greater than $1^{o}C$ per meter change in depth. For the purposes of this report anoxic conditions refer to dissolved oxygen levels lower than 0.5 mg/L.

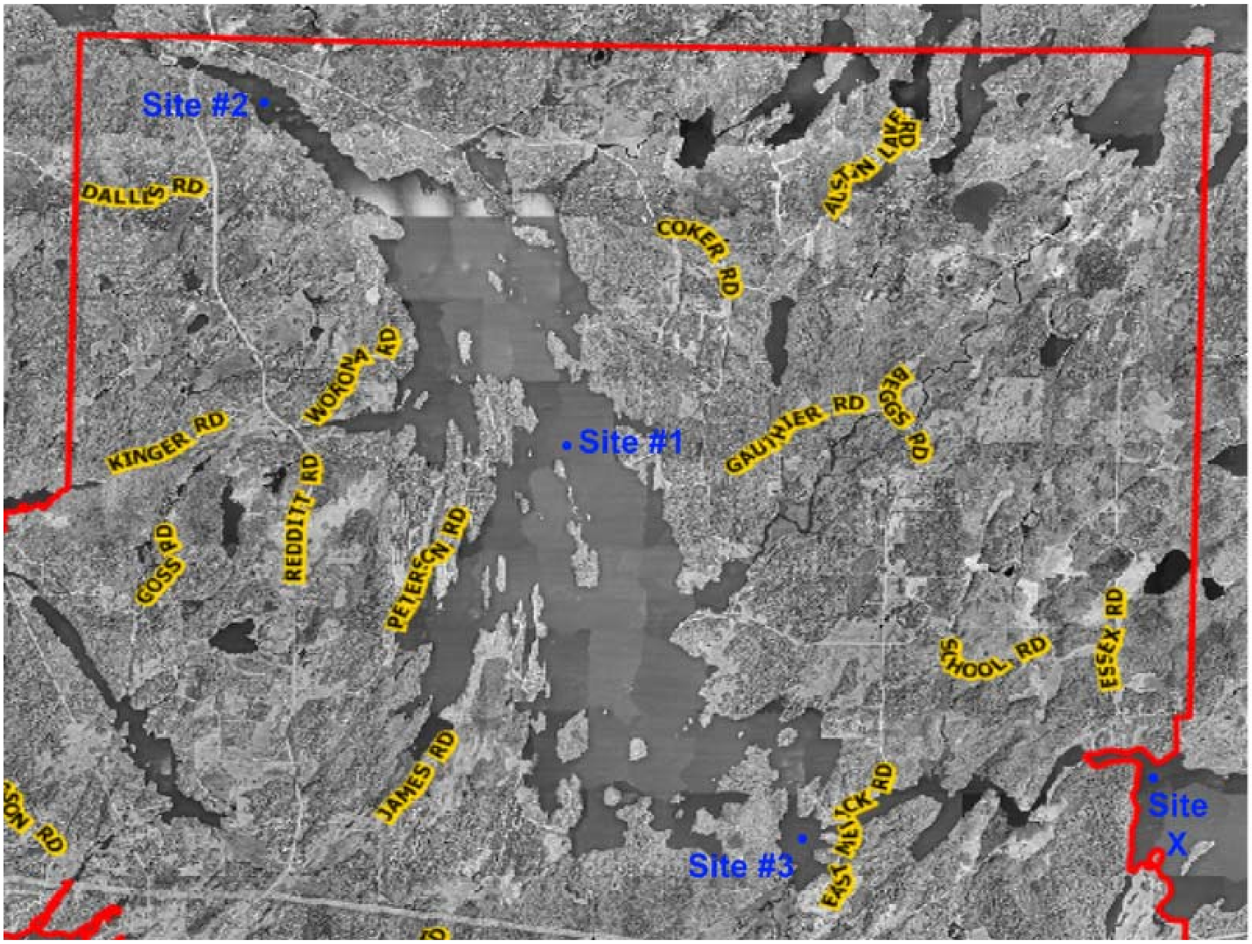


Figure 1 – Sampling Sites for Water Quality Monitoring on Black Sturgeon Lakes for 2010 sampling season

Secchi depth was determined at each site by lowering a Secchi disk (20-cm disk with alternating black and white quadrants) over the shady side of the boat (Figure 2). The disk was lowered until the observer could no longer distinguish between the white and black quadrants and then raised until the disk came back into view. This was repeated three times and then the depths at which the disk disappeared and then reappeared were averaged to give the Secchi depth.


Figure 2 – Lowering of Secchi disk

Lake productivity samples were collected both as a euphotic zone composite (i.e., a sample containing water representative of the entire euphotic zone) and at a depth of 1 m from the bottom. The euphotic zone is the section of the water column where enough light penetrates to facilitate algae growth (measured as 2X the Secchi depth). In order to obtain a water sample containing water from the surface to the bottom of the euphotic zone, a weighted, 500 mL, small neck bottle (Figure 3) was lowered with a rope in the water column to a depth of double the Secchi depth. A euphotic zone sample was taken at sites #2, 3, and X on April 18, 2010 for analysis of water quality characterization, including nutrients (phosphorous and nitrogen), dissolved organic carbon (DOC), colour, pH, alkalinity, turbidity, and scans for cations/anions and trace metals.

Figure 3 – Transferring water sample from euphotic zone composite into lab sample bottle

At sites #2, 3 and X, an additional water sample was taken approximately 1 m from the bottom of the lake using a Beta horizontal water sampler (Figure 4). Both ends of the water sampler were opened prior to lowering it (using a rope) to the desired water depth. At the desired depth, a small weight was sent down through the water column along the length of the rope triggering a release mechanism on the sampler and causing the sampler caps to close.

Figure 4 – Horizontal Beta Sampler prior to deployment

All euphotic zone samples and samples taken 1m from the bottom of the lake were transferred immediately upon collection to sample bottles for analysis at a laboratory. One euphotic zone sample and one bottom sample were taken at each site and analyzed for total phosphorous. One additional euphotic zone water sample was taken and tested for chlorophyll a at sites #2, 3 and X throughout the sampling period. Euphotic zone water samples were collected in July and August from all sites (one sample per site) and were analyzed for identification of the algal community. All water samples were shipped in ice-packed coolers via Greyhound bus to ALS Laboratory Group in Winnipeg, MB, for analysis.

Some genera of algae are more likely to be found in water bodies with high levels of organic pollution. Algal sample results obtained during this study were incorporated into the Algal Genera Pollution Index, which is an indicator of organic pollution. These results were then used to determine a pollution index value using the Genus Pollution Index scores found in Table 1. For each genera present in each sample, the corresponding Genus Pollution Index score was added to the pollution index value for that site. A pollution index value of >20 indicates high organic pollution. Midrange values (15-19) indicate that pollution is moderate. Low scores (<15) indicate the absence of organic pollution.

TABLE 1 - Algal Genera Pollution Index (Palmer, 1969)

Genus	**Pollution Index**
Anacystis	**1**
Ankistrodesmus	**2**
Chlamydomonas	**4**
Chlorella	**3**
Cyclotella	**1**
Euglena	**5**
Gomphonema	**1**
Lepocinclis	**1**
Melosira	**1**
Micractinium	**1**
Navicula	**3**
Nitzshia	**3**
Oscillatoria	**5**
Pandorina	**1**
Phacus	**2**
Phormidium	**1**
Scenedesmus	**4**
Stigeoclonium	**2**
Synedra	**2**

3.0 RESULTS

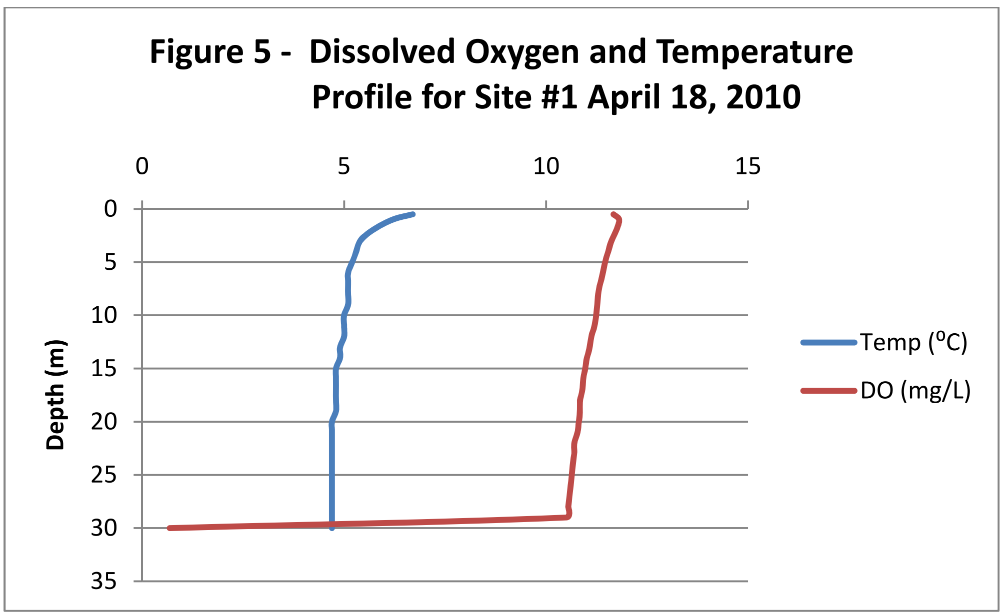
3.1 Sampling Session Dates and Locations

Sampling occurred on April 18th, May 9th, June 6th, July 5th, August 4th, September 1st, October 5th, and November 1st, 2010. The depth of the sampling sites varied depending upon the anchoring location for each site and fluctuating water levels. Site #1 depths varied from 30.0 to 30.5 m; the sampling depth at site #2 varied from 16.6 to 17.9 m; and sampling depths at site #3 varied from 9.9 to 10.7 m. Site X was the shallowest site, with sampling depths ranging from 6.8 to 7.8 m.

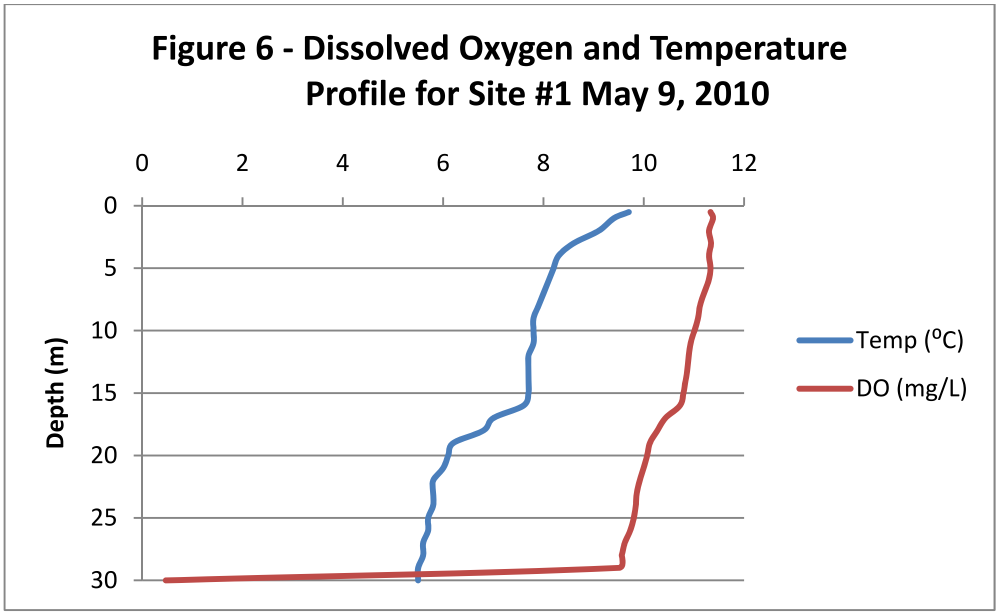
3.2 Dissolved Oxygen and Temperature Profiles

3.2.1 Profiles for Site #1 (Deep, Center Portion of Lower Black Sturgeon)

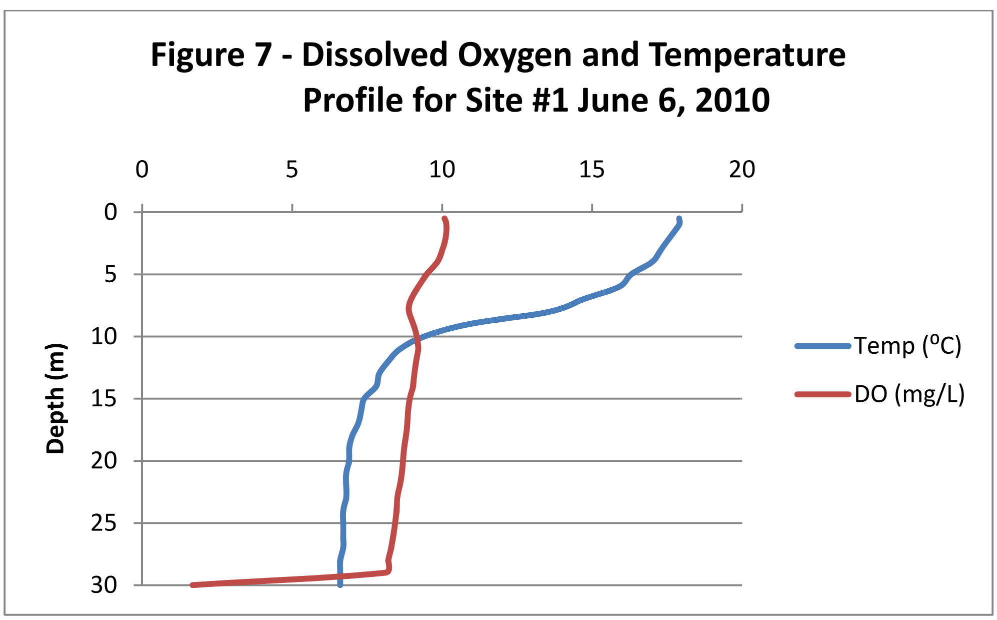
On April 18th, the temperature and dissolved oxygen(DO) values for site #1 were fairly uniform throughout the water column, with only a 1.17 mg/L variation in DO and a 2.0°C variation in temperature (Figure 5), with the exception of the lowest reading at 30 m, which recorded an approximately 10 mg/L drop in the DO reading.



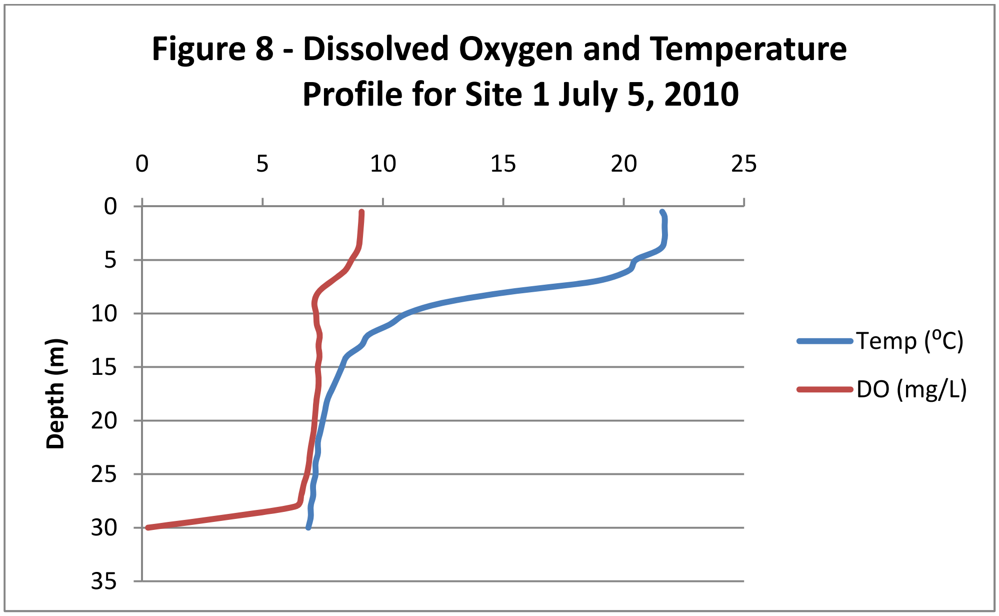
On May 9th, the surface waters began to warm to approach 10°C, but DO levels remained fairly uniform throughout the water column with only a 1.83 mg/L variation in oxygen concentration (Figure 6), again with the exception being the 30 m reading which recorded an approximately 10 mg/L drop in the DO reading.



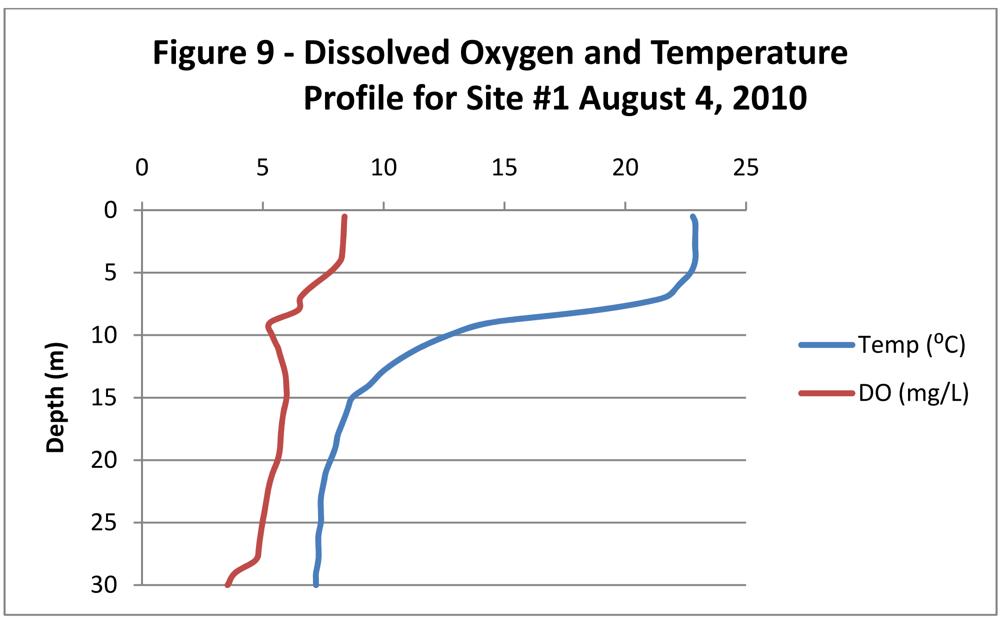
The profile for June 6th begins to demonstrate thermal stratification, but the DO concentrations throughout the water column remained largely unchanged. The surface waters had warmed to 17.9°C and a thermocline (greater than a 1°C change in temperature per meter change in depth) occurred from 6 to 10 m. Dissolved oxygen levels were fairly uniform from the surface to a depth of 29 m, but there was a significant drop in DO concentrations at the reading at 30 m (0.2 m from the bottom) with a DO value of 1.68 mg/L (Figure 7).



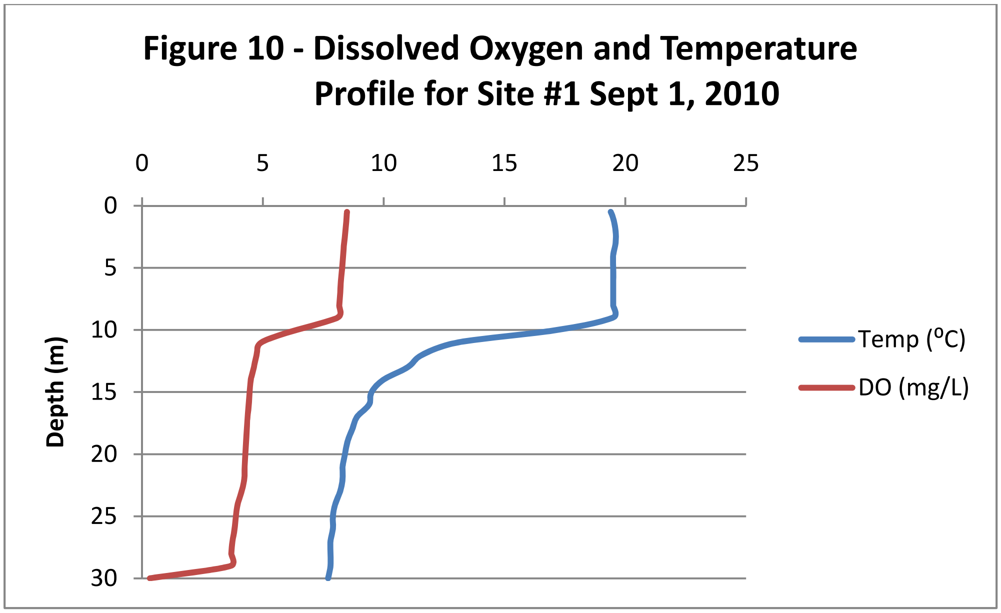
On July 5th, the surface temperatures warmed to greater than 20°C while the thermocline at site #1 was observed at the same depth as June 6, located between 6 and 10 m. The dissolved oxygen levels continued to decline as the waters warmed, but remained relatively consistent throughout the water column, varying from 9.11 to 6.38 mg/L, from the surface to 28 m, and then dropped quickly to anoxic conditions of 0.24 mg/L at the 30 m depth reading (Figure 8).



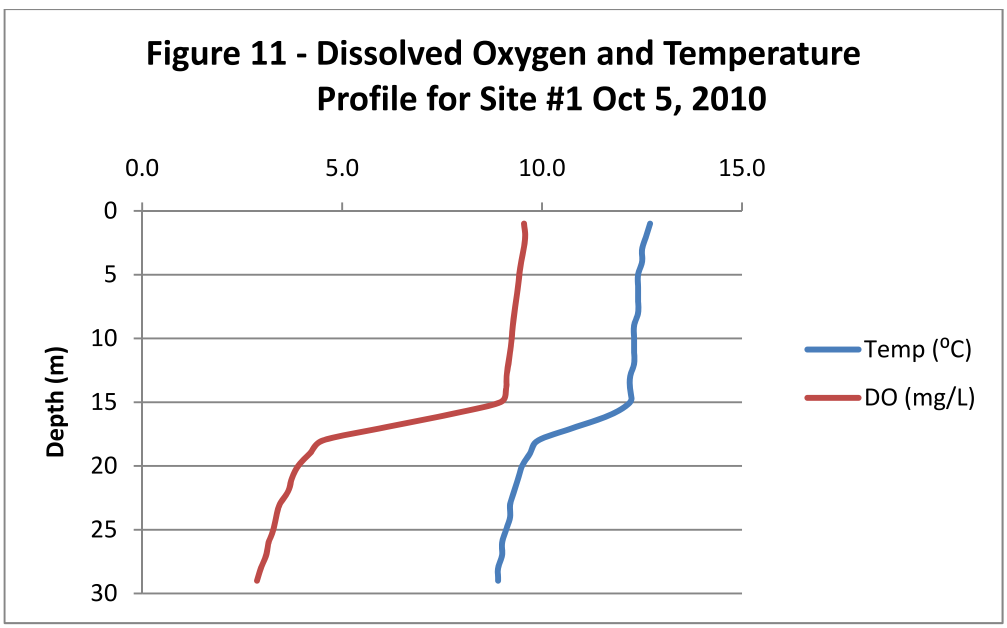
During the August 4th sampling session, the DO and temperature profiles were beginning to show more of a direct relationship, with a decrease in DO of over 1.17 mg/L recorded over the thermocline depth of 7 to 11 m (Figure 9).



On September 1st, the DO readings showed a decline with depth, with a decrease continuing to reflect the drop in temperature associated with the thermocline. The thermocline was located between 9 and 12 m, where a 3.36 mg/L drop in DO concentration was observed (Figure 10).



On October 5th, the surface temperatures had dropped below 13°C, and, while there was a drop in temperature between 15 and 18 m, the decrease did not meet the definition of a thermocline. A decrease in DO levels was also observed between the depths of 15 and 18 m, with all of the water above 15 m having oxygen concentrations over 9 mg/L and all of the water below 18 m depth having concentrations below 5 mg/L (Figure 11).



On November 1st, temperature profiles were uniform throughout the water column, with a temperature variation of 0.3°C from top to bottom. A variation in DO values of 0.97 mg/L were observed from the surface to 1.5 m from the bottom. There was a drop in dissolved oxygen concentrations to 6.57 mg/L at a depth of 30 m (0.5 m from the bottom) (Figure 12).

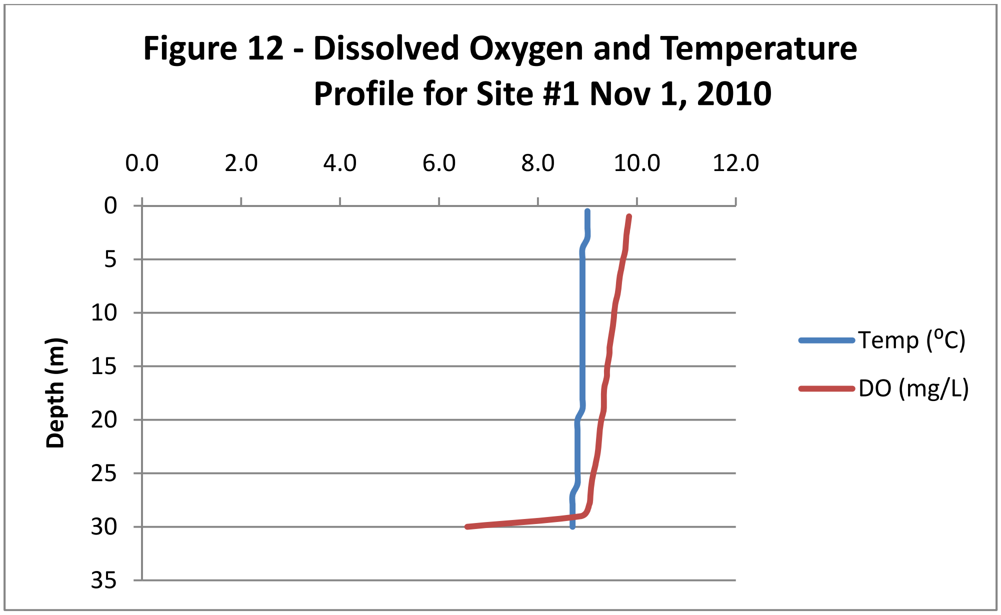


Figure 12 - Dissolved Oxygen and Temperature Profile for Site #1 Nov 1, 2010

3.2.2 Profiles for Site #2 (Outlet of Lower Black Sturgeon Lake)

On April 18th, the temperature and dissolved oxygen (DO) values for site #2 were fairly uniform, with only a 2.0°C variation in temperature and a 0.96 mg/L variation in DO (Figure 13).

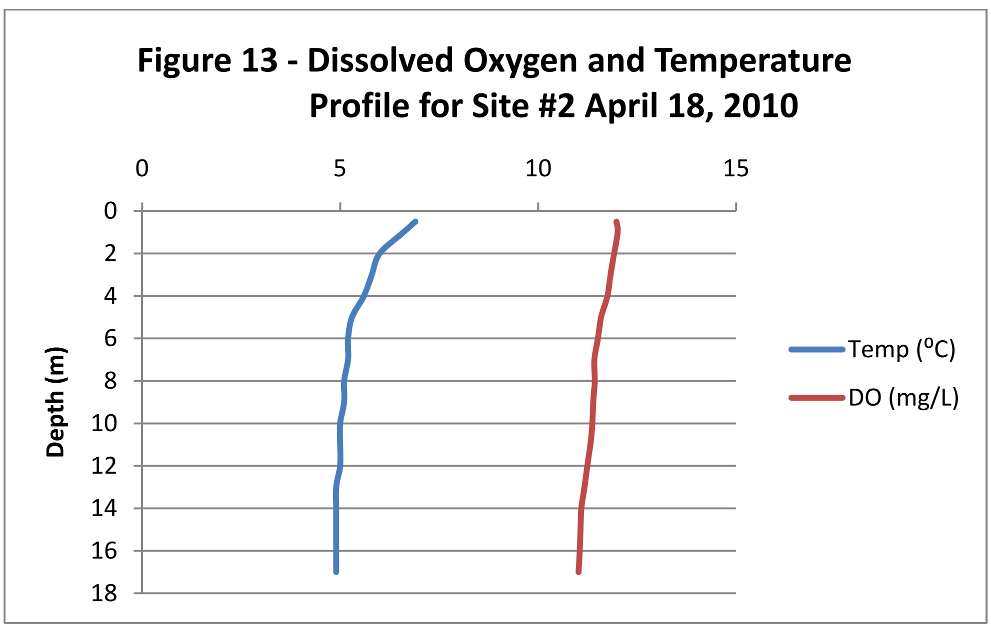


Figure 13 - Dissolved Oxygen and Temperature Profile for Site #2 April 18, 2010

Although a thermocline was not present, the temperature and DO profiles recorded at site #2 on May 9th, demonstrated a larger variation than shown on April 18th. Temperatures varied by 2.9°C and DO concentrations varied by a 1.33 mg/L (Figure 14).

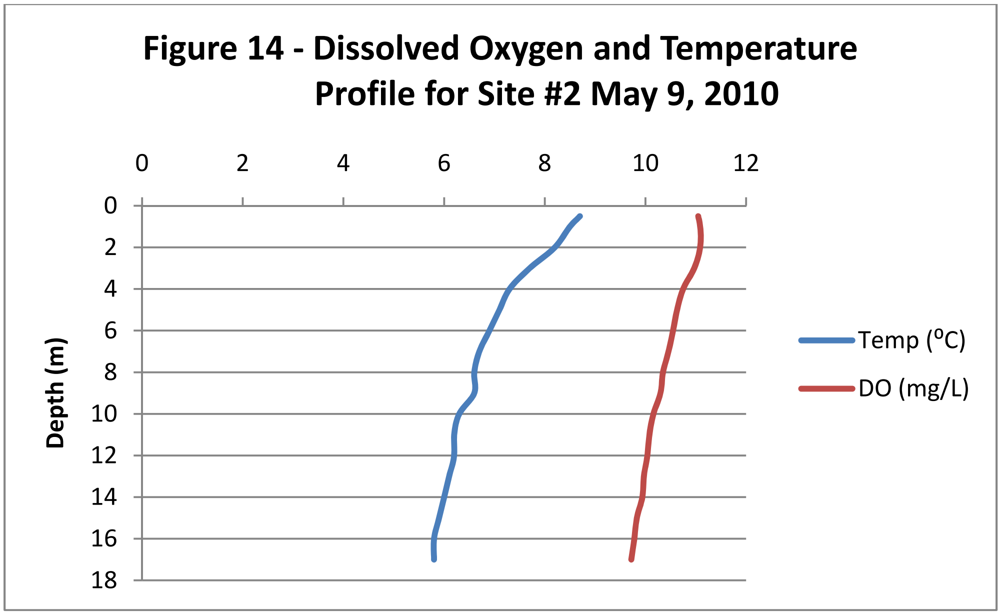


Figure 14 - Dissolved Oxygen and Temperature Profile for Site #2 May 9, 2010

Figure 15 shows a warming of the surface waters on June 6th to 18.6°C and a thermocline at depths of 5 to 9 m below the surface. The dissolved oxygen concentration decreased gradually from 10.16 to 7.84 mg/L throughout the water column (Figure 15).

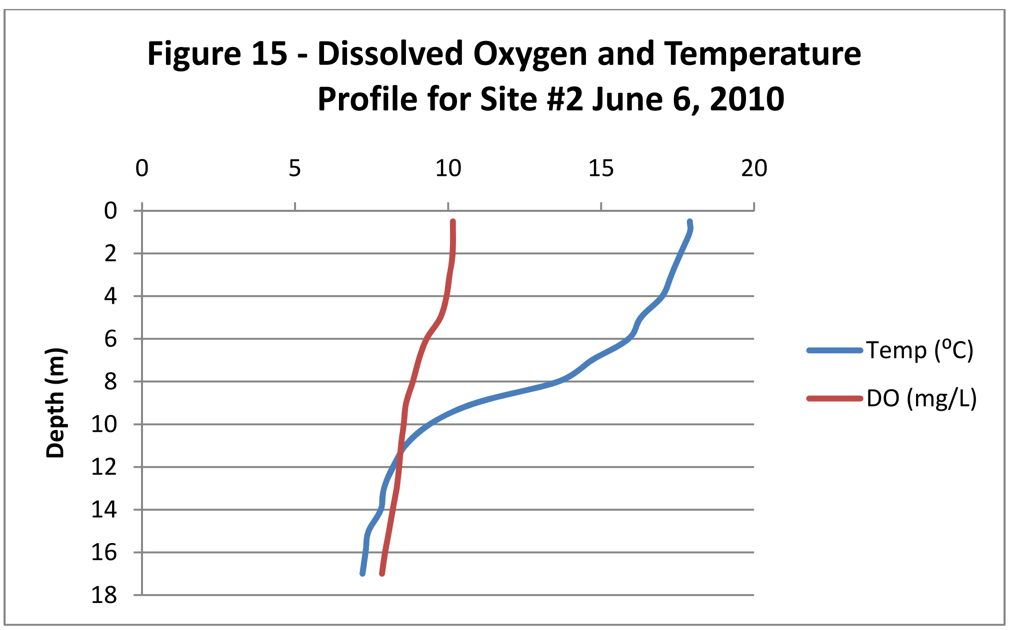
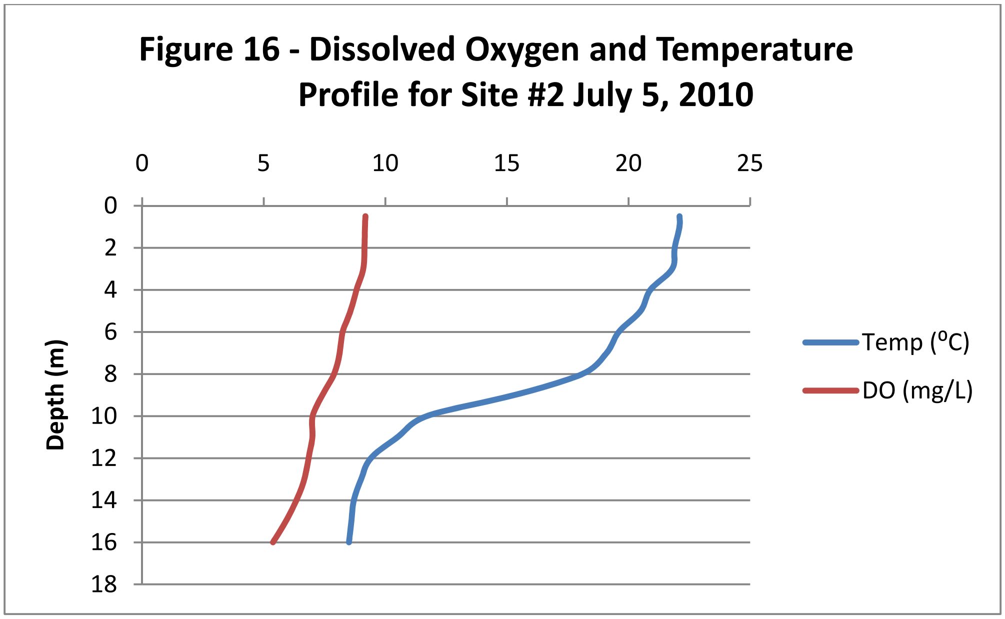
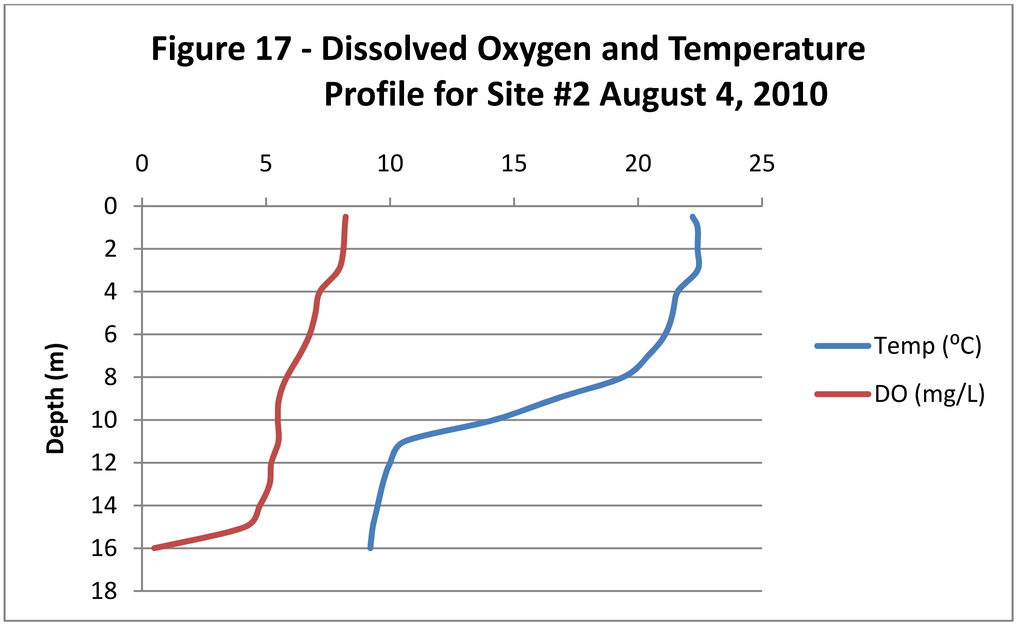


Figure 15 - Dissolved Oxygen and Temperature Profile for Site #2 June 6, 2010

On July 5th, the thermocline had moved deeper and was present between 7 and 12 m depths. The highest temperature recorded in the water column was 22.1°C. The dissolved oxygen profile continued to demonstrate a gradual decline in levels with readings from 9.18 to 5.38 mg/L (Figure 16).

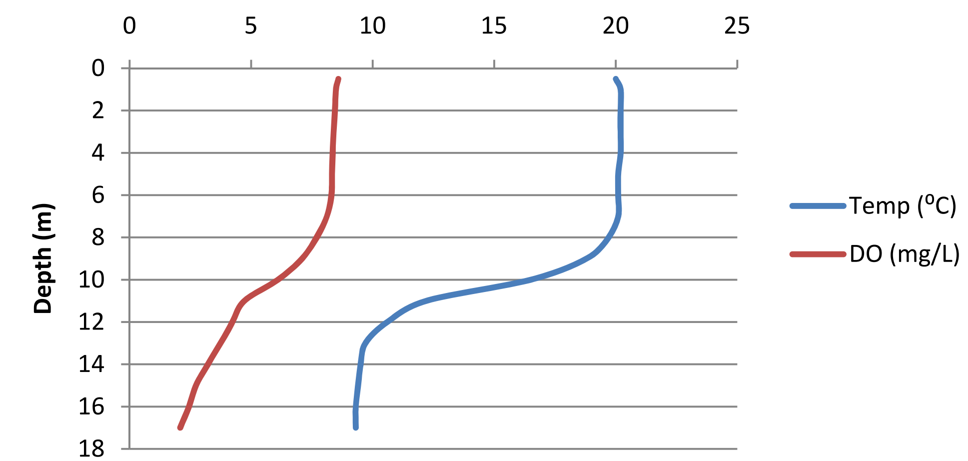


On August 4th, the thermocline at site #2 was present from 7 to 11 m. The dissolved oxygen concentration mirrored the temperature profile with a drop from 8.21 to 4.16 mg/L from the surface to 15 m. The DO reading 0.6 m from the bottom was anoxic at 0.49 mg/L (Figure 17).



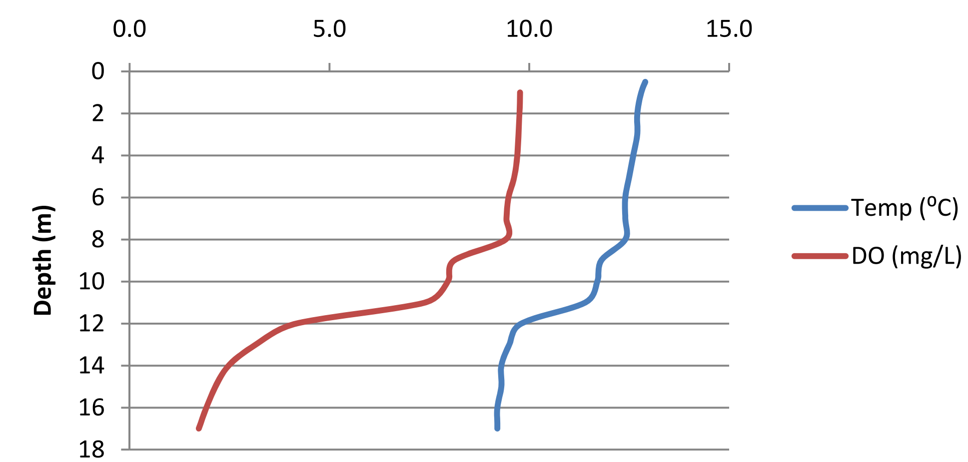
The depth and temperature variation of the thermocline was greater on September 1st, with temperature varying from 18.8 to 10.6°C over the 9 to 12 m depths of the thermocline. The temperature decline was accompanied with a similar decline in dissolved oxygen levels. Between depths of 9 m to 12 m, the DO readings dropped from 7.10 to 4.23 mg/L (Figure 18).

Figure 18 - Dissolved Oxygen and Temperature Profile for Site #2 Sept 1, 2010

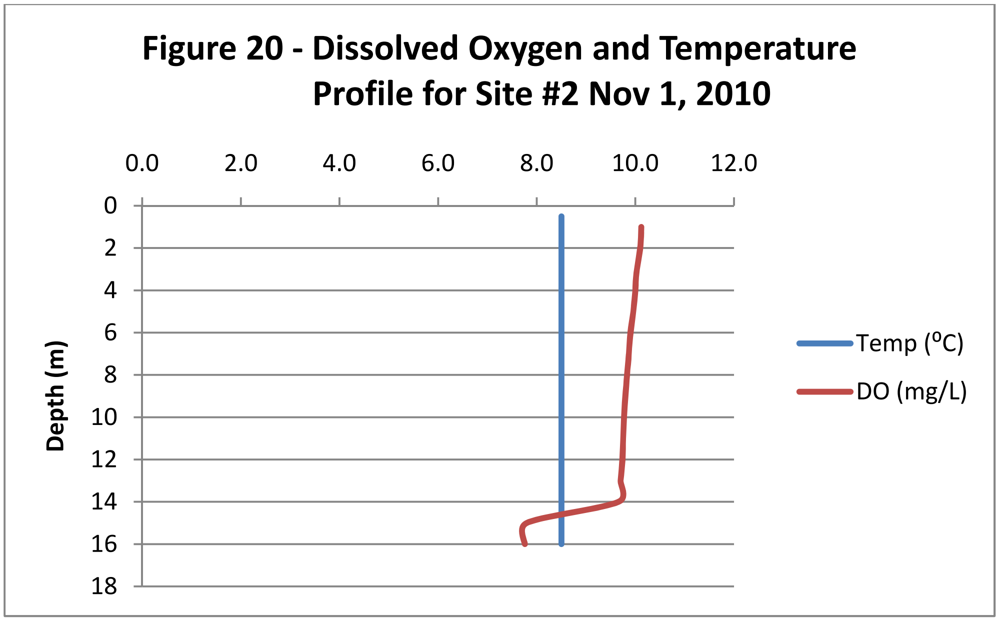


On October 5th, the dissolved oxygen and temperature profiles for section #2 closely mirrored each other with the greatest decline in both focussed on the well-defined thermocline between 11 and 12 m (Figure 19).

Figure 19 - Dissolved Oxygen and Temperature Profile for Site #2 Oct 5, 2010

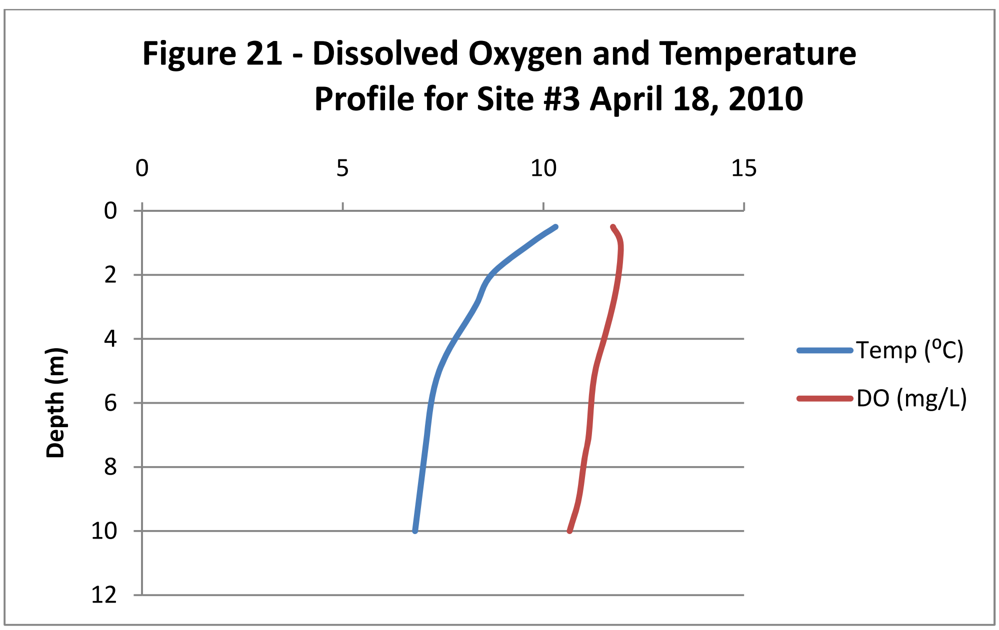


On November 1st, the temperature profile at site #2 was completely uniform with every reading being 8.5°C from the surface to the bottom. The dissolved oxygen profile was almost uniform from the surface to the bottom with the values varying from 10.13 to 9.66 mg/L. The DO readings between 14 and 15 m are marked by a decline from 9.66 to 7.80 mg/L which stabilizes for the deepest reading at 16 m (7.76 mg/L) (Figure 20).

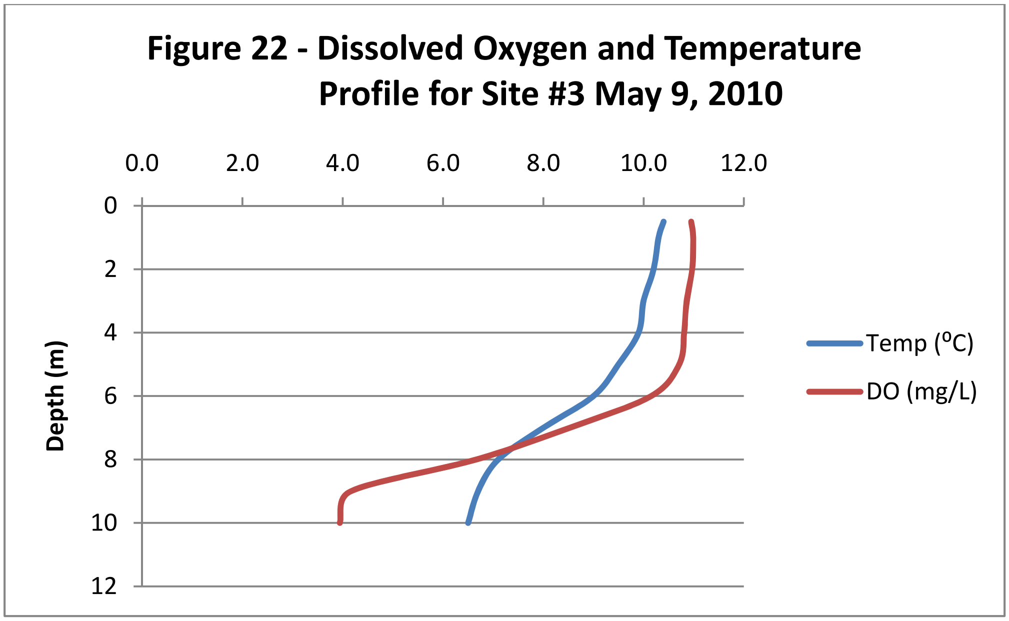


3.2.3 Profiles for Site #3 (Inlet of Lower Black Sturgeon)

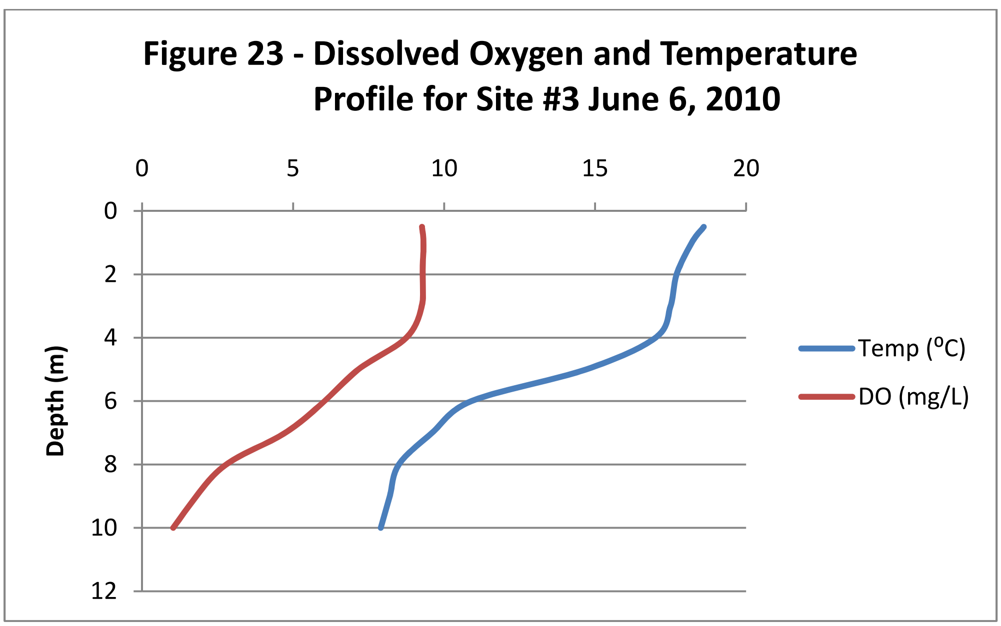
The dissolved oxygen (DO) profile and temperature readings for site #3 on April 18th were relatively uniform throughout the water column. The recorded DO readings varied between 11.73 and 10.65 mg/L. The temperature profile results dropped from 10.3 to 6.8°C between the surface and the bottom (Figure 21).



The thermocline was present at depths of 6 to 7 m on May 9th at site #3. The DO profile demonstrates a reduction in oxygen concentration beginning at the upper boundary of the thermocline, and ending at the deepest measurement, with values declining from 10.15 mg/L at 6 m to 3.94 mg/L at 10 m (Figure 22).

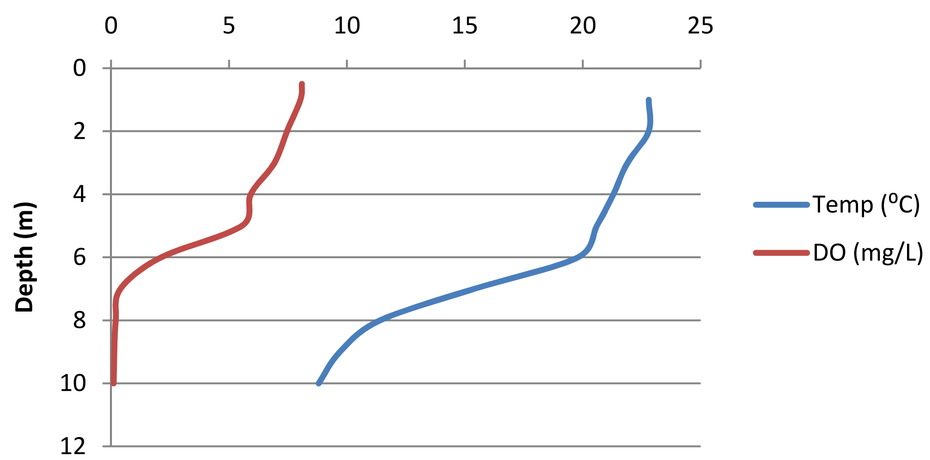


The June 6th recorded temperatures created a profile that shows a fairly steady decline in temperatures from 18.6 to 7.9°C with a thermocline present between the 4 and 8 m readings. The DO profile shows a more pronounced decline in DO readings from 4 m to 10 m of 8.75 and 1.03 mg/L, respectively (Figure 23).



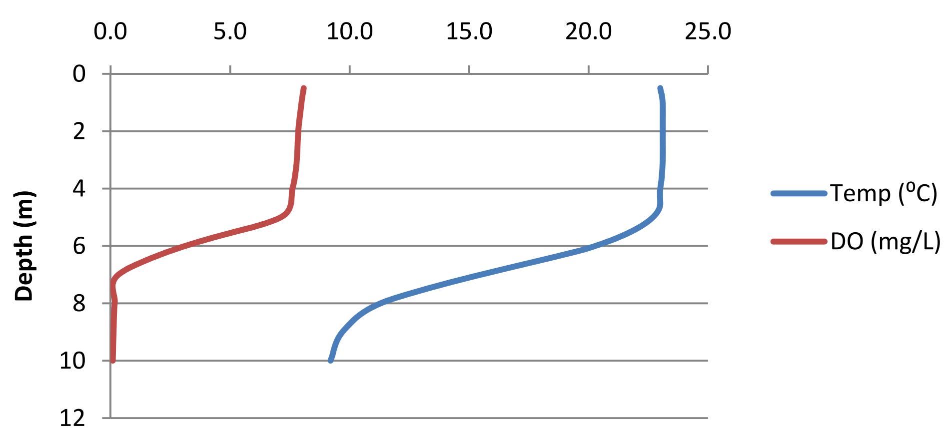
The DO and temperature profiles roughly mirrored each other on July 5th. The temperature profile ranged from 22.8°C at the 0.5 m depth reading to 8.6°C at the 10 m depth with the thermocline present at the 3 to 8 m depth readings. The DO readings declined from 8.09 to 6.93 mg/L from the 0.5 m to 3 m depths followed by a rapid reduction to 2.13 mg/L at 6 m and then anoxic conditions of 0.40 to 0.11 mg/L throughout the remaining depths (Figure 24).

Figure 24 - Dissolved Oxygen and Temperature Profile for Site #3 July 5, 2010

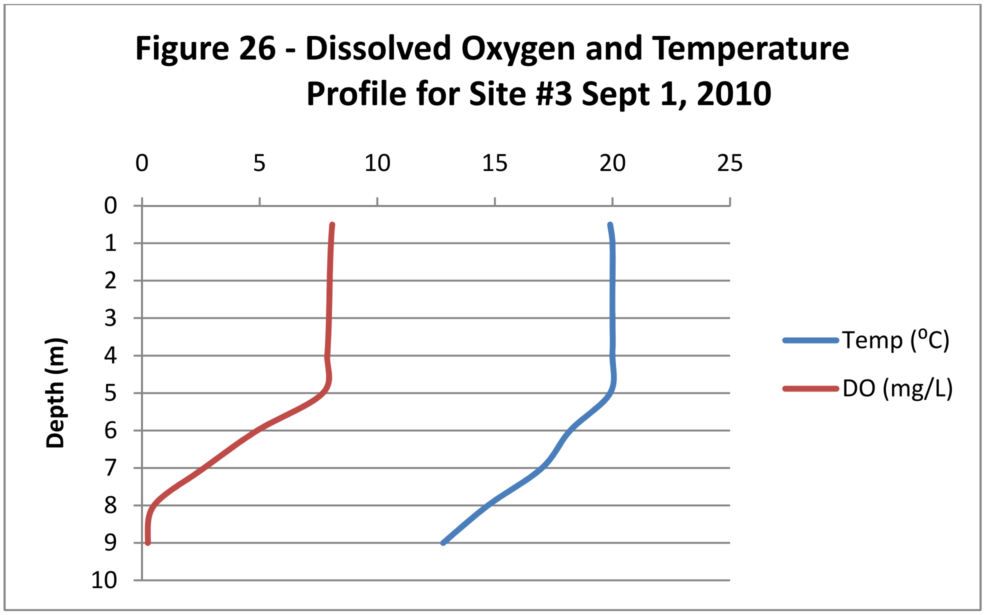


The temperature and dissolved oxygen profiles for August 4th were similar to those shown for July 5th, with the thermocline present from 5 to 9 m and anoxic conditions present in the readings from 7 to 10 m depths (Figure 25).

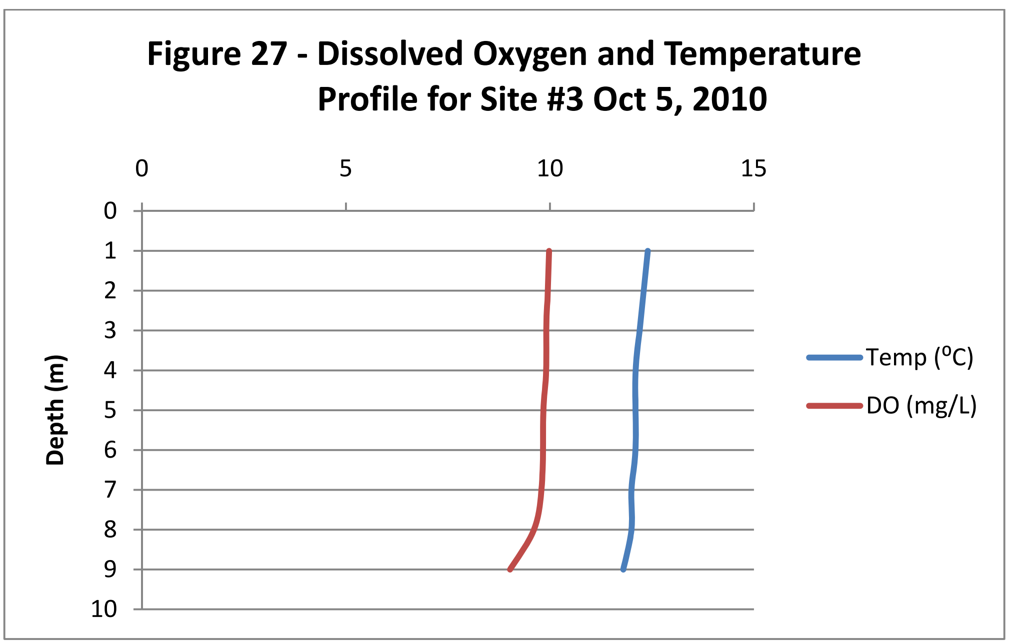
Figure 25 - Dissolved Oxygen and Temperature Profile for Site #3 August 4, 2010



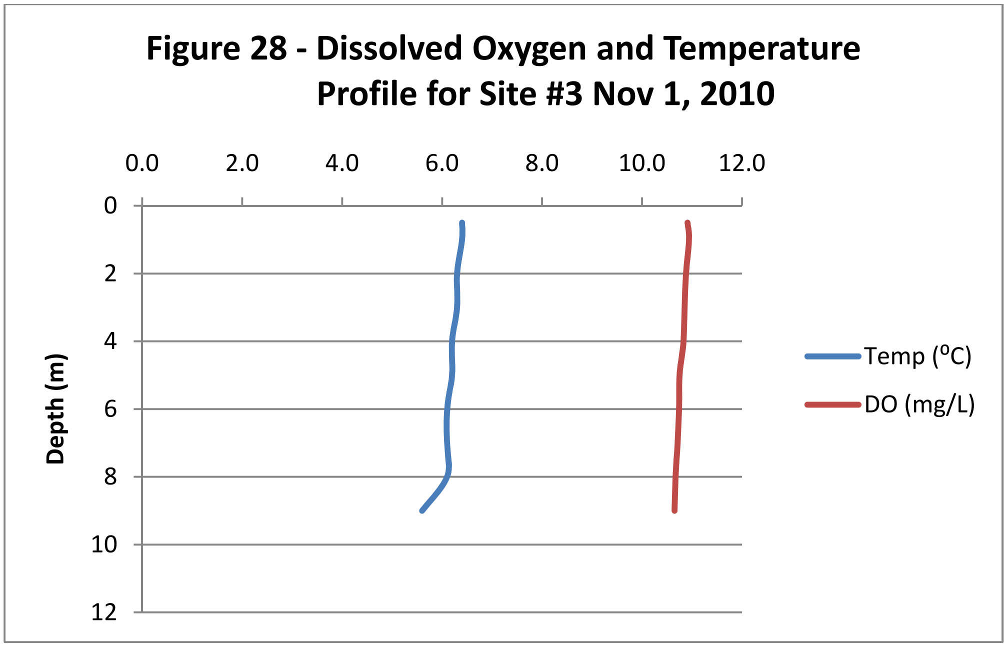
Data collected on September 1st indicate a compression of the anoxic conditions into the water column from 8 to 9 m depths (DO readings ranging from 0.5 to 0.24 mg/L). The temperature profile shows relatively uniform temperatures of 19.9 to 20.0ºC for the first 5 m of depth, with the thermocline present from 5 to 9 m (Figure 26).



Uniform temperature and dissolved oxygen profiles were documented on October 5th at site #3. The temperature readings varied with a decrease in temperature from 12.5 to 11.8°C with depth. The DO profile demonstrates a nearly straight vertical line with the readings being between 10.0 and 9.0 mg/L (Figure 27).

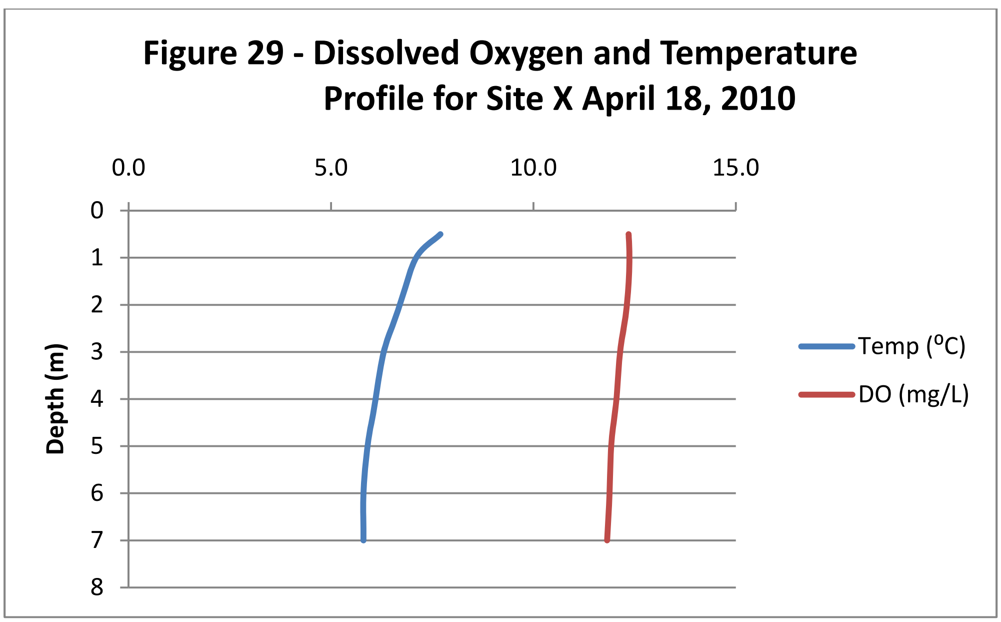


Similar to the profile for October 5th, the November 1st profiles are virtually straight vertical lines for both temperature and dissolved oxygen. The only difference between this profile and the one collected on October 5th is a decrease in temperature (range 6.4 to 5.6°C) and an increase in DO (range 10.91 to 10.65 mg/L) (Figure 28).

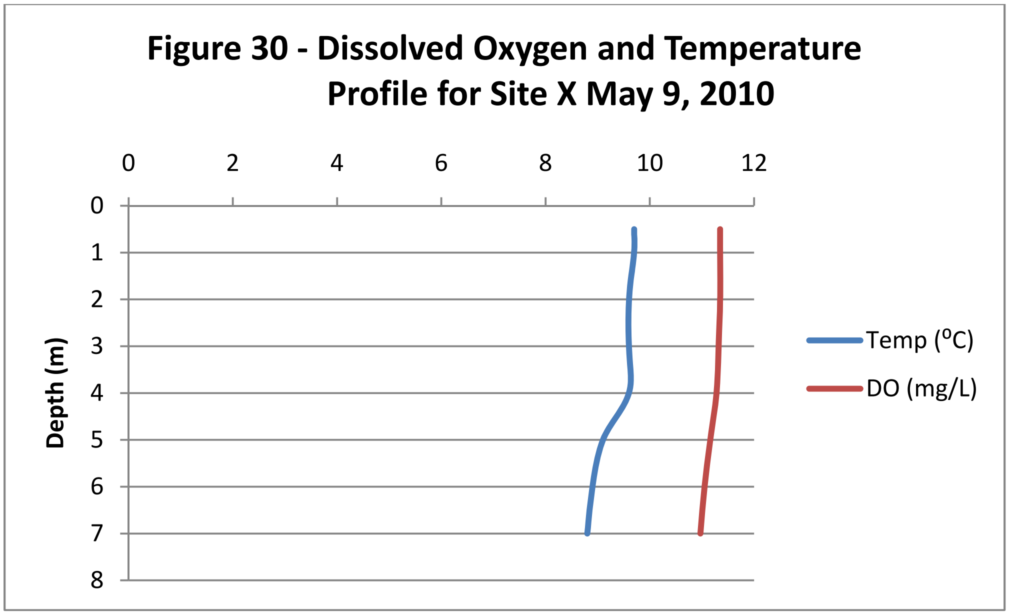


3.2.4 Profiles for Site X (Outlet of Upper Black Sturgeon)

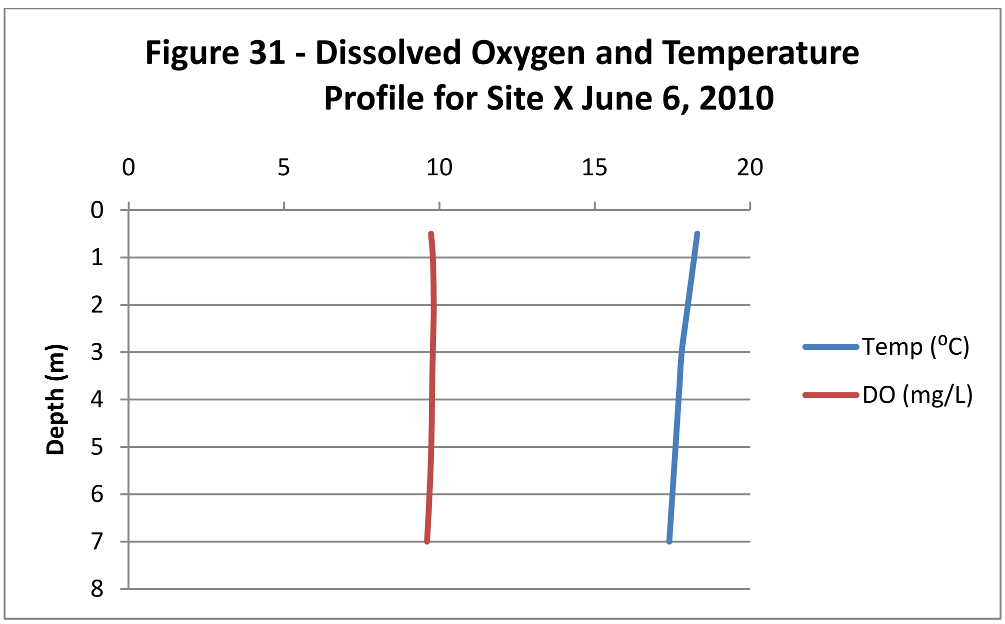
On April 18th, the temperature and oxygen profiles for site X showed relatively uniform profiles throughout the water column. Temperatures varied from 7.7 to 5.8°C and DO concentrations from 12.35 to 11.82 mg/L from the surface to the deepest reading (Figure 29).



On May 9th, the temperature and oxygen profiles remained relatively uniform for site X. Temperature varied from 9.7 to 8.8°C and oxygen concentration from 11.35 to 10.97 mg/L from the surface to deepest reading (Figure 30).

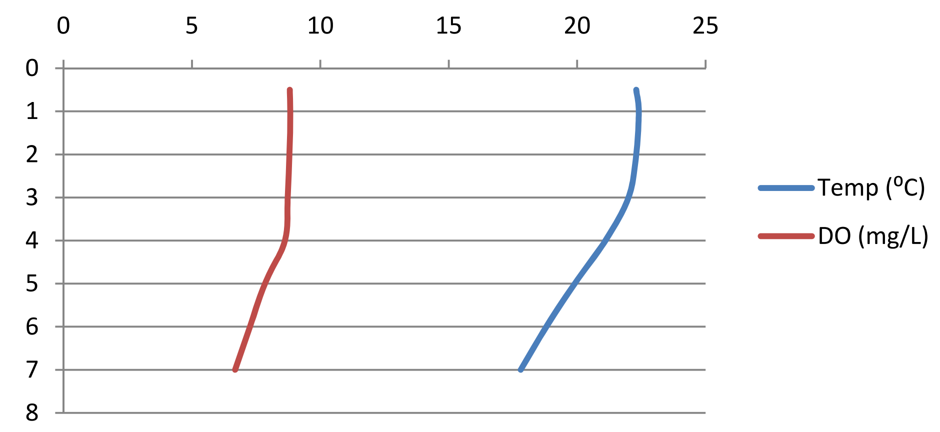


The temperature and oxygen profiles remained uniform throughout the water column of site X on June 6th. The temperature ranged from 18.3 to 17.4°C and the dissolved oxygen concentration ranged from 9.73 to 9.60 mg/L (Figure 31).



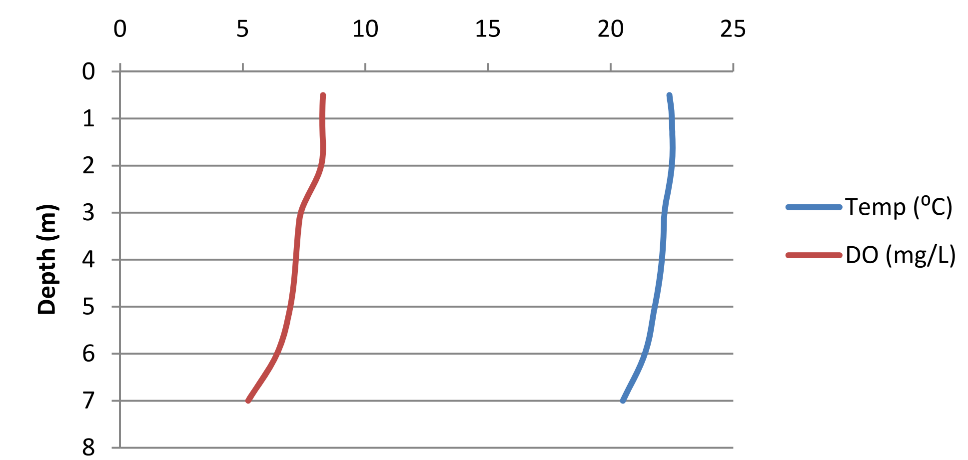
On July 5th, the dissolved oxygen and temperature profiles showed a parallel decline from depths of 3 to 4 m to the bottom. The dissolved oxygen was relatively uniform from 8.83 to 8.62 mg/L for the 0.5 to 4.0 m depths, and then dropped steadily to 6.68 mg/L at 7.0 m. The temperature profile was similar, with temperatures of 22.3 to 21.1°C from 0.5 to 0.4 m depths, with a steady decline to 17.8°C at 7.0 m (Figure 32).

Figure 32 - Dissolved Oxygen and Temperature Profile for Site X July 5, 2010

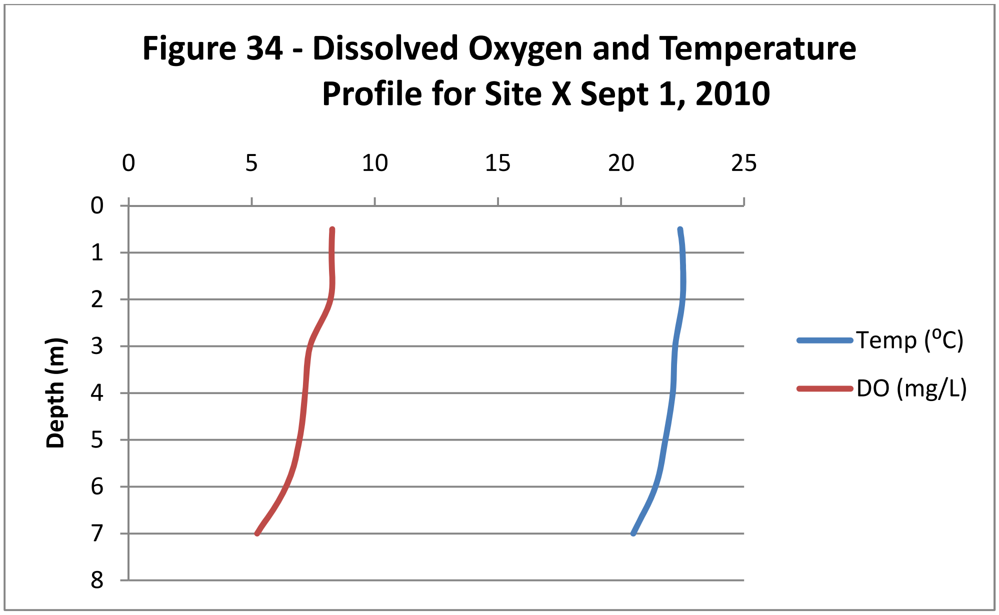


The temperature and oxygen profiles showed slight decreases with depth on August 4th. The temperature profile ranged from 22.5°C at the 1.0 and 2.0 m depth readings to a low of 20.5°C at the deepest measurement recorded at 7.0 m. The dissolved oxygen profile declined from 8.27mg/L at 0.5 m to 5.22 mg/L at 7.0 m (Figure 33).

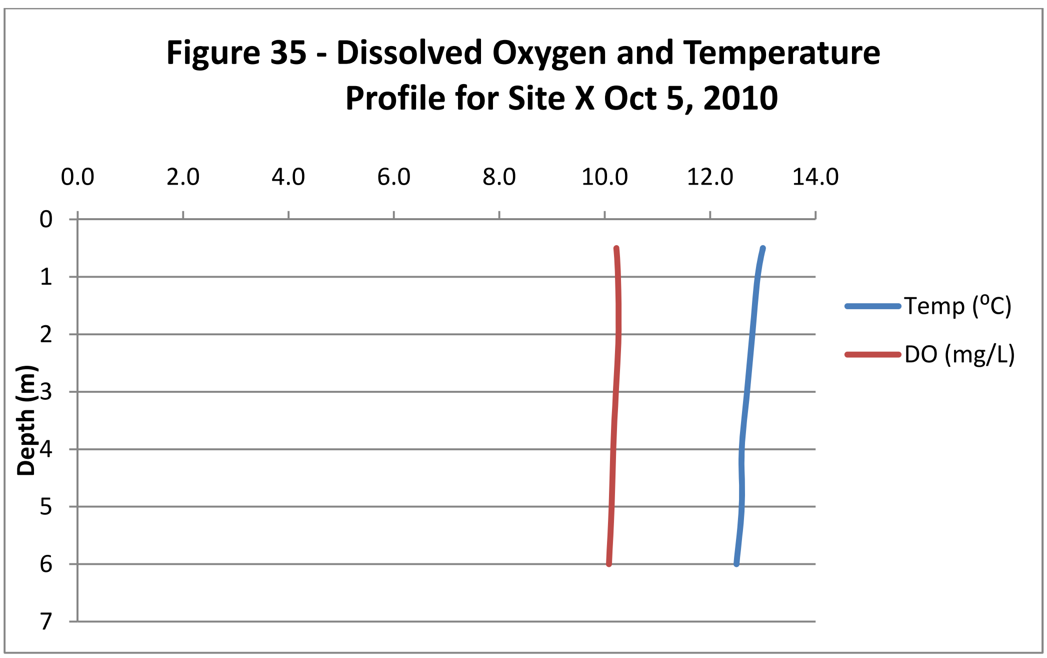
Figure 33 - Dissolved Oxygen and Temperature Profile for Site X August 4, 2010



The temperature and oxygen profiles showed slight decreases with depth on September 1st. The temperature profile ranged from 19.2°C at the 2.0, 3.0, and 4.0 m depth readings to a low of 18.6°C at the deepest measurement recorded at 7.0 m. The dissolved oxygen profile declined from 7.84 mg/L at 0.5 m to 6.26 mg/L at 7.0 m (Figure 34).

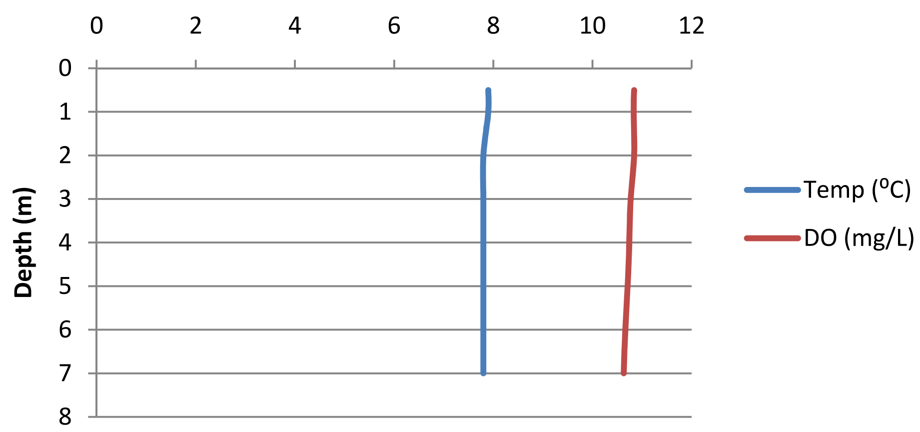


The October 5th DO and temperature profiles for site X are almost completely uniform. The dissolved oxygen profile ranged from 10.26 mg/L at 2.0 m to 10.08 mg/L at 6.0 m. The temperature profile ranged from 13.0°C at 0.5 m to 12.5°C at 6.0 m (Figure 35).



The November 1st DO and temperature profiles for site X are almost completely uniform. The dissolved oxygen profile ranged from 10.84 mg/L at 0.5 and 2.0 m to 10.63 mg/L at 7.0 m. The temperature profile ranged from 7.9°C to 7.8°C (Figure 36).

Figure 36 - Dissolved Oxygen and Temperature Profile for Site X Nov 1, 2010

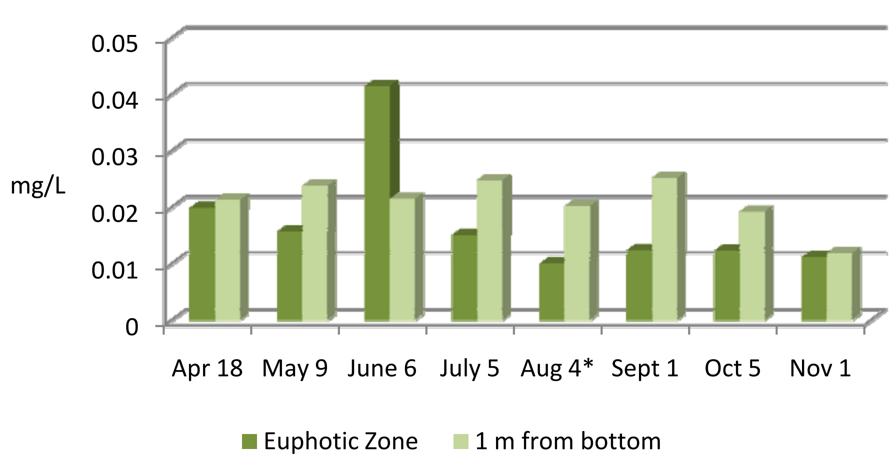


3.3 Total Phosphorous

3.3.1 Total Phosphorous for Site #2 (Outlet of Lower Black Sturgeon)

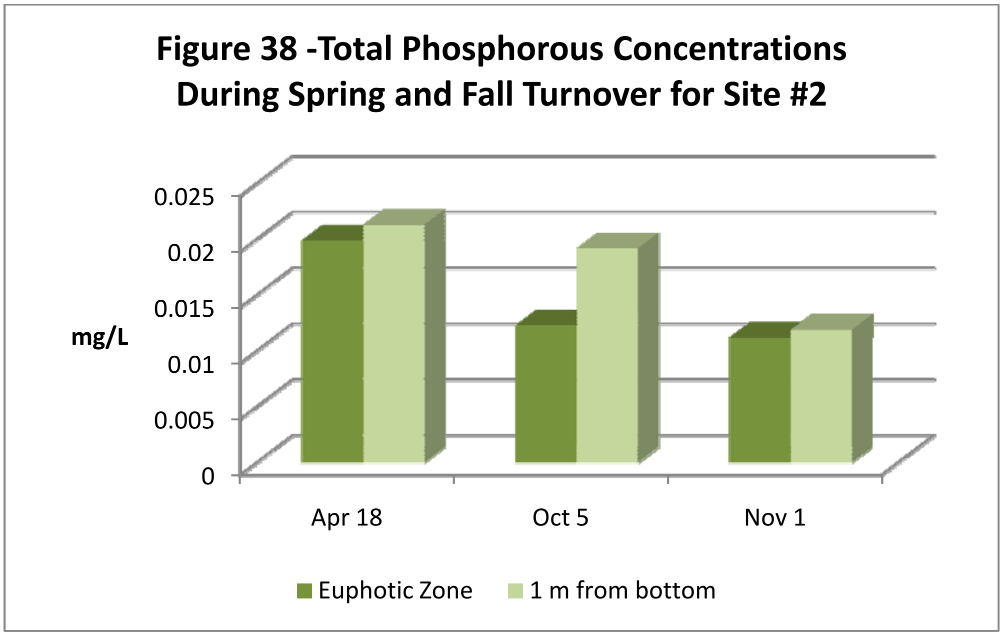
The total phosphorous concentrations for site #2 demonstrated higher phosphorous levels in samples collected from a depth of 1 m from the lake bottom when compared with those taken from the euphotic zone for all of the sample dates with the exception of June 6th (Figure 37). The ratio of phosphorous concentrations in bottom to euphotic zone water samples for the seven dates with higher bottom concentrations varied from 1.06:1 to 2.03:1.

Figure 37 - Phosphorous Concentrations for Site #2



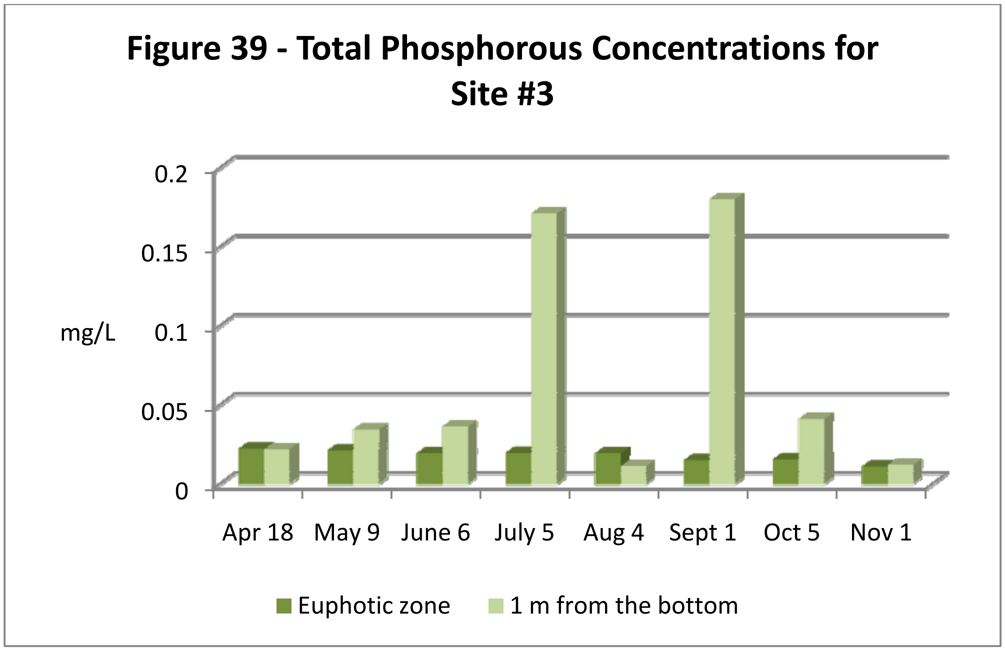
*August 4th euphotic zone result was below detection limit of 0.01 mg/L

The spring and fall turnover results for the total phosphorous concentrations for site #2 were all below the provincial water quality objective of 0.0200 mg/L with the exception of the concentration 1 m from the bottom on April 18 (i.e., 0.0213 mg/L). The lowest concentration found at site #2 was the euphotic zone sample taken on November 1 of 0.0112 mg/L (Figure 38).

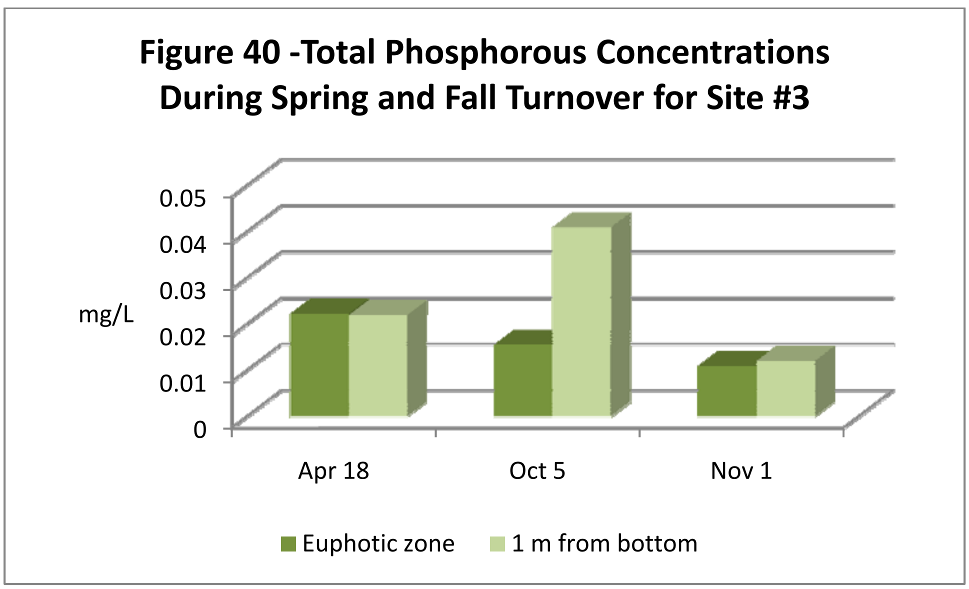


3.3.2 Total Phosphorous for Site #3 (Inlet of Lower Black Sturgeon)

Total phosphorous concentrations for site #3 were relatively consistent throughout the sampling season for euphotic zone analyses, but varied considerably for analysis of samples taken 1 m from the bottom. The euphotic zone concentrations varied from 0.0109 mg/L (November 1) to 0.0222 mg/L (April 18). The samples taken at 1 m from the bottom showed a large variation in phosphorous concentrations of almost tenfold from the lowest values of 0.0111 mg/L and 0.0120 mg/L on August 4th and November 1st, respectively, to the highest values of 0.171 mg/L and 0.180 mg/L on July 5th and September 1st, respectively (Figure 39). On August 4th and September 1st the deep water samples exhibited a sulphur smell.

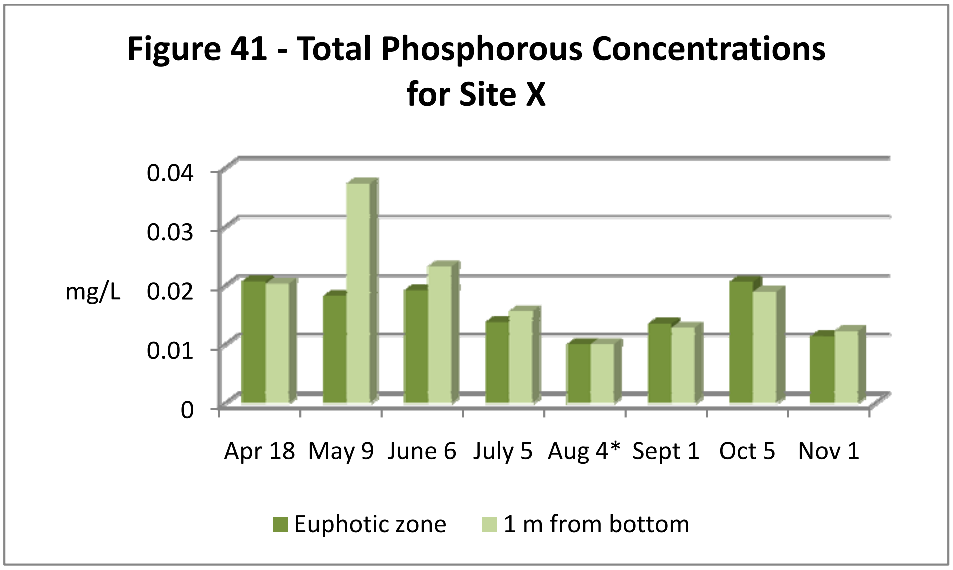


Half of the spring and fall turnover results for the total phosphorous concentrations for site #3 were above the provincial water quality objective of 0.0200 mg/L, with the lowest concentration found in the euphotic zone sample taken on November 1st (0.0109 mg/L) and the highest found during turnover events in the sample taken 1 m from the bottom on October 5th (0.0409 mg/L) (Figure 40).



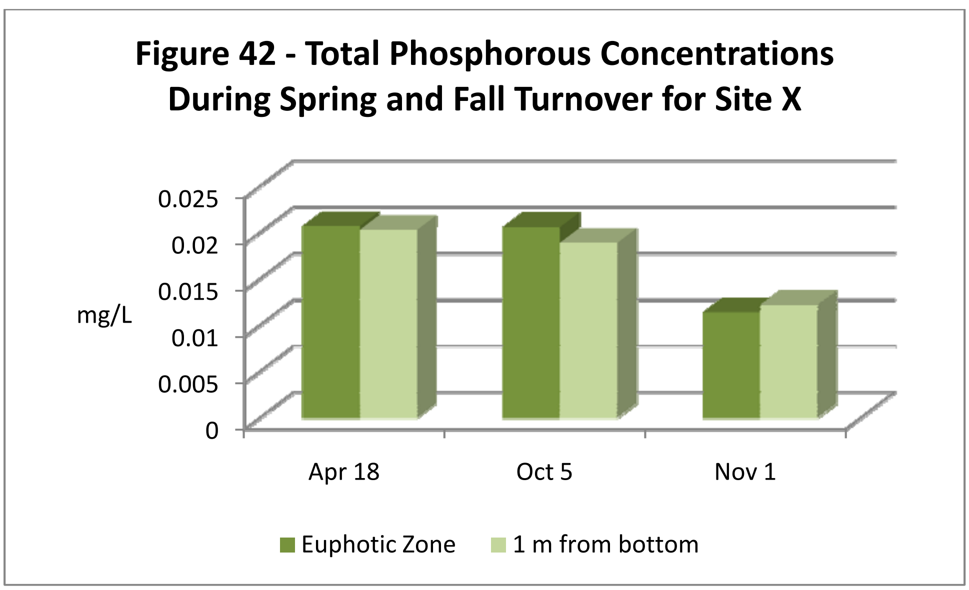
3.3.3 Total Phosphorous for Site X (Outlet of Upper Black Sturgeon)

With the exception of the sample results from May 9th, all of the euphotic zone and bottom samples for site X had relatively similar results for each date, and most of them were below the provincial water quality objective of 0.0200 mg/L. The highest concentration of phosphorous from site X was 0.0373 mg/L taken 1m from the bottom on May 9th and the lowest concentration was less than 0.0100 (the lowest measurable amount for the lab analysis equipment) for the euphotic zone and bottom samples taken on August 4th.



*August 4th euphotic zone and 1 m from botom results were below detection limit of 0.01 mg/L

The spring turnover results were slightly higher than the provincial water quality objective and fall turnover results for the total phosphorous concentrations for site X were all below the provincial water quality objective of 0.0200 mg/L. The lowest concentration found at site X was the euphotic zone sample taken on November 1st of 0.0114 mg/L and the highest concentration was the euphotic zone sample taken on April 18th of 0.0207 mg/L (Figure 42).



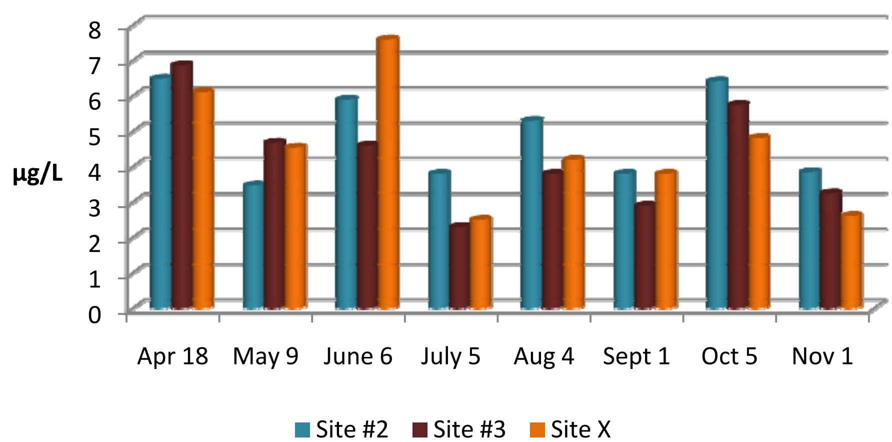
3.3.4 Lake Partner Program Phosphorous Results

With the cooperation of area residents and cottage owners, the Ministry of the Environment Lake Partner Program has been collecting phosphorous data during spring turnover on Black Sturgeon Lakes since 1997. While the use of volunteers does result in varying sampling methods and locations, it is felt that the information collected provides important information on the range of phosphorous levels in the system. The range of phosphorous concentrations analyzed through the Lake Partner Program over the past 14 years has ranged from 0.012 mg/L (1997-1999) to 0.0229 mg/L (2008). The average spring turnover concentrations for information collected by Ryan Haines Consulting in 2009 (0.0124 mg/L) and 2010 (19.65 mg/L) were within the range of values collected by the Lake Partner Program.

3.4 Chlorophyll a

The chlorophyll a concentrations for sites #2, #3, and X varied considerably between sampling dates. In addition, there was no noticeable relationship between the samples taken at the three different sites. Site #2 had the highest chlorophyll a concentration on four of the sample dates; site #3 had the highest concentration on two of the sample dates; and site X had the highest concentration on June 6th. The concentration measured at site X on June 6th was the highest concentration measured during the season (7.6 µg/L).

Figure 43 - Chlorophyll a Concentrations for 2010 Black Sturgeon Water Quality Sampling

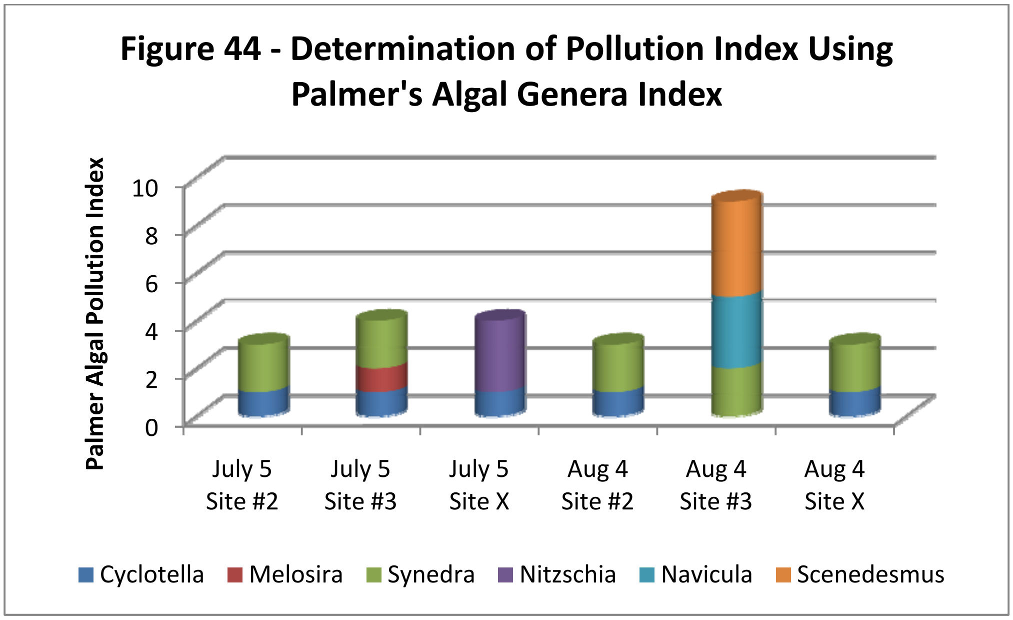


3.5 Algal Community

Samples for algal analysis were collected during the two sampling dates when the water column was the warmest (July 5th and August 4th). In these samples, 6 genera of algae found in the Palmer Pollution Index were identified. The Palmer Pollution Index (Palmer 1969) calculations for each of the samples were as follows (shown in Figure 44):

- site #2 on July 5th had an index of 3 (Cyclotella [1] and Synedra [2] present)
- site #3 on July 5th had an index of 4 (Cyclotella [1], Synedra [2], and Melosira [1] present)
- site X on July 5th had an index of 4 (Cyclotella [1] and Nitzschia [3] present)
- site #2 on August 4th had an index of 3 (Cyclotella [1] and Synedra [2] present)
- site #3 on August 4th had an index of 9 (Navicula [3], Synedra [2], and Scenedesmus [4])

- site X on August 4th had an index of 3 (Cyclotella [1] and Synedra [2] present)



3.6 Secchi Depths

The Secchi depths for site #2 ranged from 2.5 m to 3.5 m with an average of 2.88 m. The Secchi depths for site #3 ranged from 1.75 m to 2.75 m with an average of 2.44 m. Secchi depths for site X ranged from 2.5 m to 3.0 m with an average of 2.63 m. Secchi depths were often taken in the early morning or in the evening on overcast days, which would result in a reduction in visibility (and thus, Secchi depth) when compared to mid-day measurements with sunny conditions.

3.7 Water Quality Characterization

The provincial water quality objectives were not exceeded for any of the parameters analyzed for the water quality characterization sample collected on April 18th.

4.0 DISCUSSION

4.1 Dissolved Oxygen and Temperature Profiles

The dissolved oxygen and temperature profiles for sites #1, #2, and #3 were all typical for dimictic lakes, with turnover occurring in the spring and fall and the establishment of a thermocline within the water column during the summer months. Site X did not have sufficient depth to produce a thermocline, as for the bulk of the summer the thermocline in upper Black Sturgeon Lakes would have been deeper than the 7 m depth found at the site. Due to the typical profiles found at all four sites, it is felt that a detailed analysis of each profile is not warranted. This discussion will focus on the profiles that provide important indicators of the health of the lake.

4.1.2 Dissolved Oxygen, Anoxia, and Internal Loading

One of the reasons that dissolved oxygen concentration readings throughout the water column are important is that they can determine when anoxia (DO readings of less than 0.5 mg/L) is occurring. An oxygen layer at the sediment-water interface will prevent the release of phosphorous stored in the sediment. The lack of oxygen due the decomposition of organics in the hypolimnion can result in the removal of this oxygen barrier and the release of phosphorous from the sediments, thereby increasing the amount of phosphorous in the water column (Wetzel 1983). This release of phosphorous from the sediments to the water column is called internal loading. There were anoxic conditions found at site #1, #2, and #3, but the extent and duration of the anoxia varied. Site X results did not include any anoxic conditions due to the shallow depths and lack of a thermocline at the site which would have provided for oxygenation of the site from the surface winds throughout the open water season.

Site #1 oxygen profile recorded values of less than 0.5 mg/L on three separate dates: May 9th, July 5th, and September 1st. These three dates do not correspond with the expected seasonal change in anoxia. Anoxic conditions typically persist and expand over the mid-summer months when the lake is stratified. Also of interest is that the only anoxic conditions recorded were those taken at a depth of 30 m, where measurements were obtained approximately 20 to 30 cm from the bottom. It is felt that these anoxic readings were caused by the probe becoming too close to the substrate and receiving DO readings from the substrate instead of the water column.

Anoxic conditions were found at site #2 (outlet of Lower Black Sturgeon) on August 4th, with the lack of oxygen only recorded at the deepest reading of 16 m. There was also a significant reduction in oxygen levels (although not anoxic conditions) below the thermocline at site #2 on September 1st. This is the result of the establishment of the thermocline by June 6th, after which time mixing throughout the water column ceased and the hypolimnetic oxygen supply was limited until fall turnover in October. The decomposition of organic matter on the bottom of the lake, along with biological activity in the hypolimnion, would have reduced the oxygen concentrations steadily throughout the summer, resulting in the one anoxic reading and a general reduction in oxygen concentrations in the hypolimnion. This anoxia and reduction in oxygen concentrations is likely a natural process in this section of Lower Black Sturgeon Lake, as similar results were found during the 2009 sampling season.

Site #3 (the inlet of Lower Black Sturgeon) exhibited anoxia on July 5th, August 4th, and September 1st. On July 5th and August 4th the anoxia was located from 7 m below the water surface to the bottom of the lake; on September 1st anoxic conditions were recorded from 8 m below the surface to the bottom. This prolonged period of anoxia is likely due to a combination of the small basin area with limited hypolimnetic oxygen supplies, and decomposing organic matter which consumes oxygen in the hypolimnion. A similar profile and anoxic conditions were recorded during the 2009 field season.

4.1.3 Dissolved Oxygen, Temperature, and Fish

Freshwater fish species that are most sensitive to the summer increases in temperature and subsequent decreases in dissolved oxygen concentrations are cool water species. The cool water species that are found in Black Sturgeon Lakes include lake whitefish (*Coregonus clupeaformis*) and cisco (*Coregonus* *artedii*). While the upper lethal temperature for these species is high [26^{o}C (Edsall and Colby 1970)], the preferred temperature range for lake whitefish is 10 to 14^{o}C (Mosindy pers. comm. 2009) and the optimum temperature for lake whitefish is 12^{o}C (Christie and Regier 1988). Temperatures above 14^{o}C for extended periods of time will stress lake whitefish and cisco which will affect their life processes. This is due to the fact that fish are cold-blooded and their internal temperature (and thus metabolism) is directly related to water temperature. Temperatures above 14^{o}C will cause lake whitefish and cisco to metabolize food at a faster than ideal rate, resulting in reduced body size and reproductive capacity.

The Ontario provincial water quality objectives for dissolved oxygen for cold water biota, which includes lake whitefish and cisco, is 6 mg/L for the temperature range of 10 to 15^{o}C (MOE 1994).

Due to these requirements, lake whitefish and cisco found in Lower Black Sturgeon Lake are likely to be found in the deeper, center section of the lake such as site #1 during the summer months. Therefore, any time the water column at site #1 does not have a layer of water with temperatures equal to or less than 14^{o}C and dissolved oxygen concentrations equal to or greater than 6 mg/L, cool water fish species such as lake whitefish and cisco may become stressed. These conditions were found at site #1 on August 4th and September 1st. On August 4th, the temperature was below 14^{o}C for the depths of 10 to 30 m, and DO concentrations declined from 5.38 to 3.54 mg/L over these depths (Figure 9). Similarly, on September 1st the temperature was below 14^{o}C at depths between 11 and 30 m, and DO concentrations were below 6 mg/L (4.94 to 0.32 mg/L) along this portion of the water column (Figure 10).

During the entire sampling season, there were no water temperatures observed at or over the 26^{o}C lethal temperature (highest temperature reading was 23.1^{o}C at site #3 on August 4th).

The lack of ideal conditions for lake whitefish and cisco for a period of approximately one month is not uncommon for moderately productive lakes such as Lower Black Sturgeon, which cannot support lake trout (*Salvelinus naymaycush*), a cool water species with higher oxygen requirements and lower temperature tolerances than lake whitefish and cisco. These findings are consistent with information collected by the Ontario Ministry of Natural Resources in 1988, indicating that similar midsummer DO and temperature profiles were found in Black Sturgeon Lakes over two decades ago.

4.2 Total Phosphorous

There are two aspects of the total phosphorous readings that are of the most interest for water quality analysis. One is the amount of phosphorous in the water column during turnover events, as this is when the phosphorous is mixed throughout the water column and it is also when past phosphorous concentrations have been measured to enable analysis of trends over time. The second important relationship is the ratio of total phosphorous concentrations between the surface and bottom water samples. The surface to bottom ratio gives an indication of the amount of phosphorous entering the water column from the sediments via internal loading.

4.2.1 Turnover Phosphorous Concentrations and Lake Productivity

The Ontario provincial water quality objective for total phosphorous concentrations is less than 20.0 µg/L (0.02 mg/L) "to avoid nuisance concentrations of algae in lakes" (MOE 1994). The spring turnover phosphorous concentrations collected on April 18th during the 2010 sample season (average of euphotic zone and bottom samples) were above Ontario's provincial water quality objective for sites #2, #3, and X (20.6, 22.1, and 20.5 µg/L, respectively). The samples analyzed from October 5th exceeded the provincial water quality objective for site #3 (28.2 µg/L). The average phosphorous levels for site #2 and site X on October 5th were below the water quality objective (15.8 and 19.8 µg/L respectively). The average phosphorous levels for November 1st were well below the provincial water quality objective for site #2, #3, and X (11.6, 11.5, and 11.8 µg/L, respectively). The average spring phosphorous concentrations for both 2009 (12.4 µg/L) and 2010 (19.7 µg/L) were within the range of historical data collected by the Ministry of the Environment Lake Partner Program (12 to 22.9 µg/L).

The summer of 2010 was a long, warm year for the area with exceptionally large rain events. For these reasons, it is felt that the total phosphorous concentrations for this season provide an upper level for the range of phosphorous on Black Sturgeon Lakes and do not indicate that development activities over 2009 and 2010 have resulted in an exceedance of acceptable development on the watershed. This is demonstrated by the phosphorous levels shown for November 1st, which followed the only relatively dry period of the open water season and following turnover. The phosphorus concentrations would be uniform throughout the water column following turnover; a condition that is necessary for comparison with the Provincial Water Quality Objectives. These phosphorous levels were well below the provincial water quality objectives at all three sites. In addition, historical data collected by the Lake Partner Program indicate that large fluctuations of phosphorous levels between years on Black Sturgeon Lakes in not uncommon. This demonstrates that exceedance of the provincial water quality objectives for phosphorous on April 18th and October 5th may be a result of increased overland flows into the lake from increased precipitation and not due to an overall increase in nutrient inputs and phosphorous levels in the lake.

Overland flow can play a large role in transporting nutrients into a water body. The increases in phosphorous levels due to large rain events during the 2010 field season highlights the importance of intact riparian vegetation in an effective watershed plan. Removal of trees and vegetation along the shoreline will dramatically increase the amount of nutrients that enter the watershed during rain events and spring melting. Ensuring that riparian vegetation remains intact during development activities on and near Black Sturgeon Lakes will help to reduce the impacts of the development on water quality in the watershed.

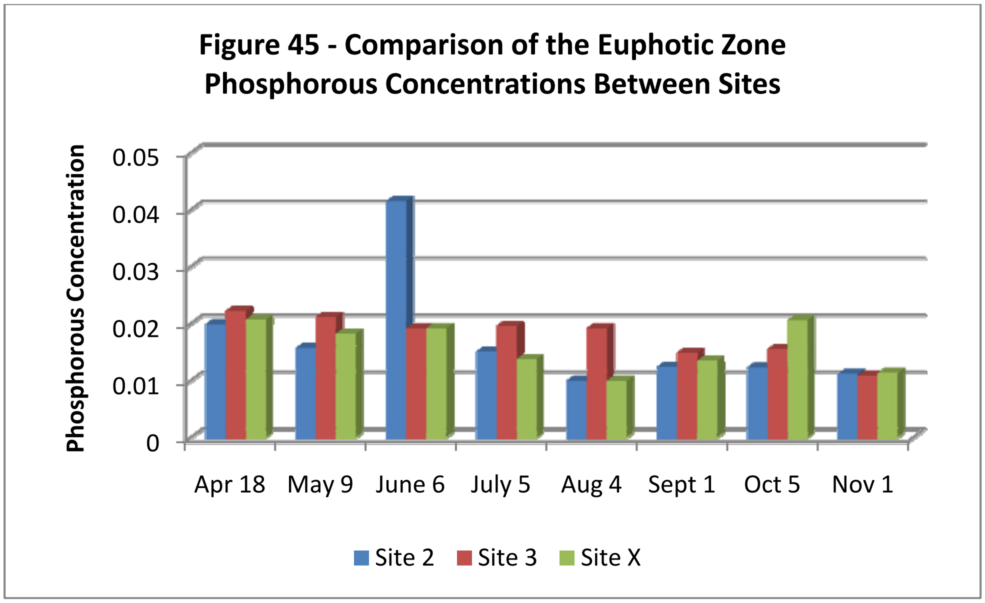
4.2.2 Euphotic Zone and Bottom Phosphorous Comparisons: Internal Loading

For site #2, phosphorous concentrations were greater in samples taken from the lake bottom compared to euphotic zone samples for every sampling session with the exception of June 6th. For site #3, lake-bottom phosphorous concentrations were greater than euphotic zone concentrations for five out of the eight sampling sessions, with April 18th, July 5th and August 4th being the exceptions. For site X, the euphotic zone phosphorus concentration was greater than the lake-bottom concentration on April 18th, September 1st, and October 5th. The August 4th phosphorous concentrations for site X were below the detectable limits of the lab of 0.01 mg/L for both the euphotic zone and bottom samples. For the remaining samples the bottom samples had greater concentrations of phosphorous than the euphotic zone, which is what would be typically expected as small amounts of phosphorous will release from the sediments even with well-oxygenated water at the sediment-water interface (Wetzel 1983). However, the degree of difference between the concentrations at the bottom and euphotic zone did not increase as the season progressed and thermal stratification took place as would be expected.

For all three sites, the phosphorous concentrations for both the euphotic zone and the bottom sample collected on August 4th were the lowest concentrations of the summer. While it is difficult to determine the exact cause of this uncharacteristic midsummer drop in phosphorous concentration, it is felt that this may further demonstrate the large impact that overland flow and rainfall events may have on nutrient levels. Heavy rain events were documented prior to the sample dates on May 9th and July 5th, and the continually wet summer with large rain events may have resulted in a flushing of Black Sturgeon Lakes with a subsequent midsummer drop in phosphorous concentrations. Flushing would also explain why the lowest recorded turnover phosphorous levels over the past two sampling seasons for all sites were measured in the samples taken on November 1st, 2010.

4.2.3 Phosphorous Comparison between the Three Sites

The third sampling site on Upper Black Sturgeon Lake (site X) was added for the 2010 sampling season in an attempt to determine the potential source of the consistently higher phosphorous levels found at the inlet of Black Sturgeon Lake (site #3) when compared to the outlet (site #2). Due to the shallow nature of site X and the lack of a thermocline, euphotic zone concentrations will be used to compare concentrations at the three sites. With the exception of a spike in concentration at site #2 on June 6th, site #3 had higher concentrations than site #2 throughout the open water season until the final sampling date (Figure 45). November 1st results had all three sites with very similar concentrations, with site #2 having 0.0003 mg/L more phosphorous in the euphotic zone than site #3. This comparison between site #2 and site #3 is consistent with the results found during the 2009 sampling season, with Lower Black Sturgeon having greater concentrations of phosphorous entering the water body (site #3) than leaving it (site #2), thus acting as a diluter for nutrients.



It was due to this dilution factor of Lower Black Sturgeon Lakes that an additional site was added to determine the potential source of the nutrients entering Lower Black Sturgeon Lakes. The additional site at the outlet of Upper Black Sturgeon Lake was sampled to determine if the phosphorous entering lower Black Sturgeon Lakes was a natural occurrence from the wetland area along Black Sturgeon Creek between Upper and Lower Black Sturgeon Lakes or as a result of anthropogenic inputs from Upper Black Sturgeon Lake.

The euphotic zone phosphorous concentrations for the three sites indicate that the wetland area of Black Sturgeon Creek is the source of the higher phosphorous levels at site #3, with the phosphorous concentrations being greater at site #3 when compared to site X for sampling on April 18th, May 9th, July 5th, August 4th, and September 1st. The concentration at the two sites was equal on June 6th and site X had higher concentrations during the fall turnover (Figure 45). These results suggest that the higher phosphorus concentrations at the inlet of Lower Black Sturgeon Lake (site #3) when compared to the outlet of Lower Black Sturgeon Lake (site #2) are not due to anthropogenic inputs from Upper Black Sturgeon Lake.

4.3 Sulphur

There was evidence that purple sulphur bacteria were present at site #3, releasing sulphur into the water column and producing the sulphur smell in the bottom water samples in August and September. The presence of purple sulphur bacteria in anoxic waters is not uncommon. Purple sulphur bacteria use hydrogen sulphide as their reducing agent, which is oxidized to produce granules of elemental sulphur. These bacteria thrive in anoxic conditions. Sulphur is not listed in the Ontario provincial water quality objectives.

4.4 Chlorophyll a

Chlorophyll a is an indicator of water quality because it is an indicator of phytoplankton biomass and primary productivity of a water body. It has been demonstrated experimentally (Cole 1975; Ryther and Yentsch 1957) that a relatively constant relationship exists between chlorophyll a and photosynthesis at any given light intensity. Therefore, chlorophyll a concentrations will reflect any increases in primary production including algal growth that may be the result of shoreline development and other anthropogenic impacts on the watershed. While there are no provincial water quality objectives for chlorophyll a, changes in the concentration of chlorophyll a over time will provide an indication of the eutrophication (increase in productivity) of Black Sturgeon Lakes. The chlorophyll a sample results for 2010 provided seasonal averages of 4.8 µg/L (site #2), 4.3 µg/L (site #3), and 4.5 µg/L (site X). While these results demonstrate a marked increase over the seasonal averages of 3.9 µg/L (site #2) and 3.7 µg/L (site #3) for 2009, it is felt that these differences are likely the product of seasonal weather patterns (2009 was a cool, dry, summer and 2010 was a long, warm, wet summer) and gives a range that provides important baseline data to draw upon for future comparisons.

It should be noted that for both sample seasons, the chlorophyll a concentrations and phosphorous concentrations did not provide similar results as indicators of productivity. For example, site #3 had the lowest seasonal average of chlorophyll a for both the 2009 and 2010 sample seasons while having the highest phosphorous concentrations for the same sampling dates.

4.5 Algal Community

The Palmer Pollution Index for the algal samples ranged from values of 3 to 9. The fact that all three sites have scores less than 15 indicates the absence of organic pollution. The collection of algal samples on two dates during the open water season, while providing a snapshot of the algal community, is not a comprehensive algal analysis, as concentrations and species of algae present can vary daily. Comprehensive algal sampling is beyond the scope of this project. It is recommended that sample collection on two dates during midsummer for algal analysis should continue in the future as it provides information on potential organic pollution at a reasonable cost.

4.6 Secchi Depths

The mean Secchi depths for site #2 (2.88 m), site #3 (2.44 m), and site X (2.63 m) were within the mean range of 2.4 m to 3.9 m determined as part of the lake partner program from 1997 to 2006 (Ministry of the Environment 2009b). It is to be expected that the Secchi depths for this project would be slightly lower than those found during the lake partner program as scheduling of the sampling dates did not permit the Secchi depths to all be taken under ideal conditions.

The mean Secchi depth readings for the three sites during the 2010 season and the 2009 season (site #2 - 2.95 m, site #3 - 2.48 m) were consistent with the phosphorous concentrations for the sites. For both seasons the lowest Secchi depth reading was found at site #3, which is an indicator of higher productivity. This was consistent with the highest phosphorous concentrations, also an indicator of higher productivity, found at site #3.

4.7 Water Quality Characterization

All of the parameters analyzed in the water quality characterization were below the provincial water quality objectives where objectives exist. This indicates that Black Sturgeon Lakes do not have any additional nutrients (e.g. nitrogen), dissolved organic carbon (DOC), colour, pH, alkalinity, turbidity, cations/anions and trace metals that exceed acceptable limits. This information provides an excellent baseline to allow for comparison of future data to monitor potential impacts of development on a broad suite of parameters within the watershed.

5.0 SUMMARY AND RECOMMENDATIONS

5.1 Impact of Nutrient Inputs from Upper Black Sturgeon

Following the 2009 sampling season, it was recommended that an additional sample site be added at the outlet of Upper Black Sturgeon Lake to determine if the consistently higher concentrations of phosphorous found at the inlet of Lower Black Sturgeon (site #3) when compared to the outlet of Lower Black Sturgeon Lake (site #2) were due to anthropogenic inputs on Upper Black Sturgeon Lake. The addition of site X to the 2010 sampling protocol was implemented to address this information gap.

The 2010 sample results indicate that Upper Black Sturgeon Lake is not the cause of higher nutrients found at site #3, with site #3 typically having higher phosphorous concentrations than both site #2 and site X. Therefore, it is felt that the increase in nutrients is likely due to the presence of large wetland areas along Black Sturgeon Creek between Upper and Lower Black Sturgeon Lake.

The summer of 2010 was a long, warm, and wet year for the area, which provided excellent conditions for determining if runoff from developments on Upper Black Sturgeon were a major input source of nutrients into the system. Yet despite these ideal conditions, there are not any indications that Upper Black Sturgeon is contributing higher levels of nutrients due to developments in the area.

For these reasons, it is felt that the 2010 sample season has satisfied the outstanding information gap resulting from the 2009 sampling season results. Therefore, it is felt that a sampling site on Upper Black Sturgeon Lake is not required in future monitoring efforts to determine the impacts of development on the water quality in Lower Black Sturgeon Lake. However, if there were major changes to the land use on Upper Black Sturgeon Lake, impacts of this development should be monitored to ensure that potential increases in nutrients in Lower Black Sturgeon Lake are not originating upstream on Upper Black Sturgeon Lake.

5.2 Potential Flushing of Nutrients Out of the System

When compared to the 2009 sampling season results, the phosphorous levels for almost every sampling date were higher during the 2010 season. In addition, euphotic zone concentrations exceeded the bottom concentrations of phosphorous for 25 percent of the sample dates in 2010, compared with 0 percent in 2009. This indicates that there was more phosphorous suspended in the water column during the 2010 season when compared to the 2009 season. This is to be expected given the warmer, wetter summer experienced in 2010.

However, during the final sampling date in 2010 (November 1st), the phosphorous concentrations were consistently the lowest of all of the spring and fall turnover concentrations found over the two sampling seasons. The turnover concentrations are important because they take place when the water column is completely mixed and the nutrient concentrations are the most accurate representation of the nutrient levels in the system. The fact that the lowest concentrations of phosphorous were found following fall turnover during a year where high rainfall events and warm conditions resulted in higher levels of phosphorous throughout the summer indicate that phosphorous was present in the water column in Upper and Lower Black Sturgeon Lakes during the open water season.

There are two potential exit points for phosphorous suspended in the water column, the sediments and the outlet flow out of the system. Sediments act as a sink or storage area for nutrients along the bottom of the lake. There are not any indications that the capacity of the sediments to absorb nutrients would have changed from the 2009 season, therefore, it is not likely that this is where the nutrients were deposited.

The other potential exit point for nutrients out of Black Sturgeon Lakes is the outlet located at the western end of the system where Lower Black Sturgeon Lake flows into the Winnipeg River. If, during years with high rainfall, large amounts of phosphorous are suspending in the water column and flowing out of the system into the Winnipeg River, effectively flushing the system of nutrients, it is important to monitor the amount of nutrients leaving the system via the outlet. Therefore, it is recommended that future monitoring efforts include a sampling protocol designed to measure the quantity of nutrients leaving the system through the outlet into the Winnipeg River. Ministry of the Environment has been recently been conducting seasonal analyses of the nutrients at the outlet of Black Sturgeon Lakes, and there is potential that the information collected by MOE could be used to determine the amount of phosphorous exiting the system. If the MOE data is not sufficient, or if MOE ceases to conduct the work, ease of access and the nature of the outlet should allow for an estimate of the total quantity of phosphorous leaving the system during the sampling dates while remaining within the budget estimates for the past two seasons of sampling.

5.3 Baseline Data

The discussion and summary portion of this report are an attempt to put into context the results found during the 2009 and 2010 sampling seasons. The primary purpose of these two consecutive years of water quality data is to provide baseline information to monitor the effects of future development activities on the water quality of Lower Black Sturgeon Lake. The varying weather conditions and subsequent varied water quality results indicate the importance of having more than one year of baseline data. It is felt that the 2009 and 2010 sampling seasons provided two extreme summers, with 2009 being cool and dry and 2010 being warm and wet, which provide for an excellent range of water quality data to be used for future comparisons. This information will prove extremely valuable as the City of Kenora monitors the short-term and long-term impacts of development on the watershed.

5.4 Future Sampling Design

Despite the fact there were no major changes to land use, the 2009 and 2010 sampling seasons produced very different results due to variations in weather during the two years. The increase in nutrient levels during the 2010 sampling season highlights the challenges faced when conducting a sampling protocol that only revisits the water body every 5 years. If future quinquennial sampling seasons were to fall on exceptionally dry or wet seasons, the information gained from them may provide a skewed picture of the impacts of development on the watershed. For this reason, it is recommended that the City of Kenora explore the potential of conducting a focussed annual water quality sampling program to monitor the impacts of development on water quality on Lower Black Sturgeon Lake. There is the possibility that, for similar costs, an annual sampling protocol may provide a more accurate picture of any potential changes to water quality on Black Sturgeon Lakes over time.

6.0 REFERENCES

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