First Year Analysis of Lake Walter E. Long

Project #524

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Lake Walter E. Long is a reservoir built on Decker Creek as a source of cooling water for Decker Creek Power Station. . Recent urban encroachment around Lake Long has raised some concern by the City of Austin as to the water quality present in Lake Long. Water samples were collected at five sites on Lake Long in October 2008, January 2009, April 2009, and July 2009 to investigate the quality of the lake water. Sediment samples were collected at three of these sites in May 2009. Phytoplankton samples were collected in January, April, and August 2009. Both water quality and sediment were compared to the TCEQ screening levels for general use, recreation use, and aquatic life use. Water quality parameters were compared with Lady Bird Lake (Town Lake) data, as well as between sites, seasons, and depths on Lake Long. Phytoplankton community structure was evaluated for site or seasonal groupings. Chlorophyll-a and nutrient values exceeded the TCEQ screening levels in several sampling events. Some nutrients and field parameters were significantly different between Lake Long and Lady Bird Lake. No significant site differences existed on Lake Long; however, most parameters showed significant seasonal differences and some nutrients showed significant differences with depth. Phytoplankton communities showed similarities between sites but differences between seasons. Continued monitoring of Lake Long is recommended at three of the five sites for water quality, one site for sediment, and three sites for phytoplankton.

Introduction

Lake Walter E. Long is a reservoir located in northeast Austin (Figure 1) and was built in 1968 as a source of cooling water for Decker Creek Power Station. In order to track changes due to urban development on the Decker Creek watershed and Lake Walter E. Long, an on-going water quality assessment to monitor and trend the surface water has been implemented which includes water quality samples, sediment samples, and descriptions of phytoplankton communities. This assessment also provides the first complete set of background data available for the lake.

The capacity of Lake Walter E. Long is approximately 33,940 acre feet. To maintain the lake level for power plant operation, water is pumped from the Colorado River, at an average rate of 16,156 acre feet/year. This can vary greatly by year; in 2008, 2,490,900,000 gallons were pumped into the lake, while in 2009, only 1,581,900,000 gallons were added according to Austin Energy (Morris Christian, personal communication, January 21, 2010). Under full power plant operation (typically during peak demand and the summer) the water in the lake is circulated every three days. Austin Energy also releases 500 gallons per month downstream to Decker Creek

During the initial year of monitoring (Oct 2008 – July 2009) 1,825,800,000 gallons of water were pumped into Lake Long from the Colorado River. Samples were collected in October, January, March, and July. The percent of water pumped into the lake during these months was 12.5%, 2.5%, 0%, and 21.3% respectively. November also had a large percentage of the pumping at 22%. The pumping of water may contribute to differences in water quality and phytoplankton communities on the lake at different times of year.

The assessment compares the water and sediment quality in Lake Long to the current screening levels proposed by TCEQ to investigate if the lake is acceptable for general use, recreation use, or aquatic life use. This report also investigates the usefulness of sampling every site on the lake quarterly at different depths.

Table 1: Site number and site name for water sampling sites on Lake Long during 2008 – 2009.

FSDB #	Site Name
4342	Lake Walter E. Long @ Intake
4343	Lake Walter E. Long @ Discharge Canal
4344	Lake Walter E. Long @ Dam
4345	Lake Walter E. Long @ NE Arm
4346	Lake Walter E. Long @ SW Arm

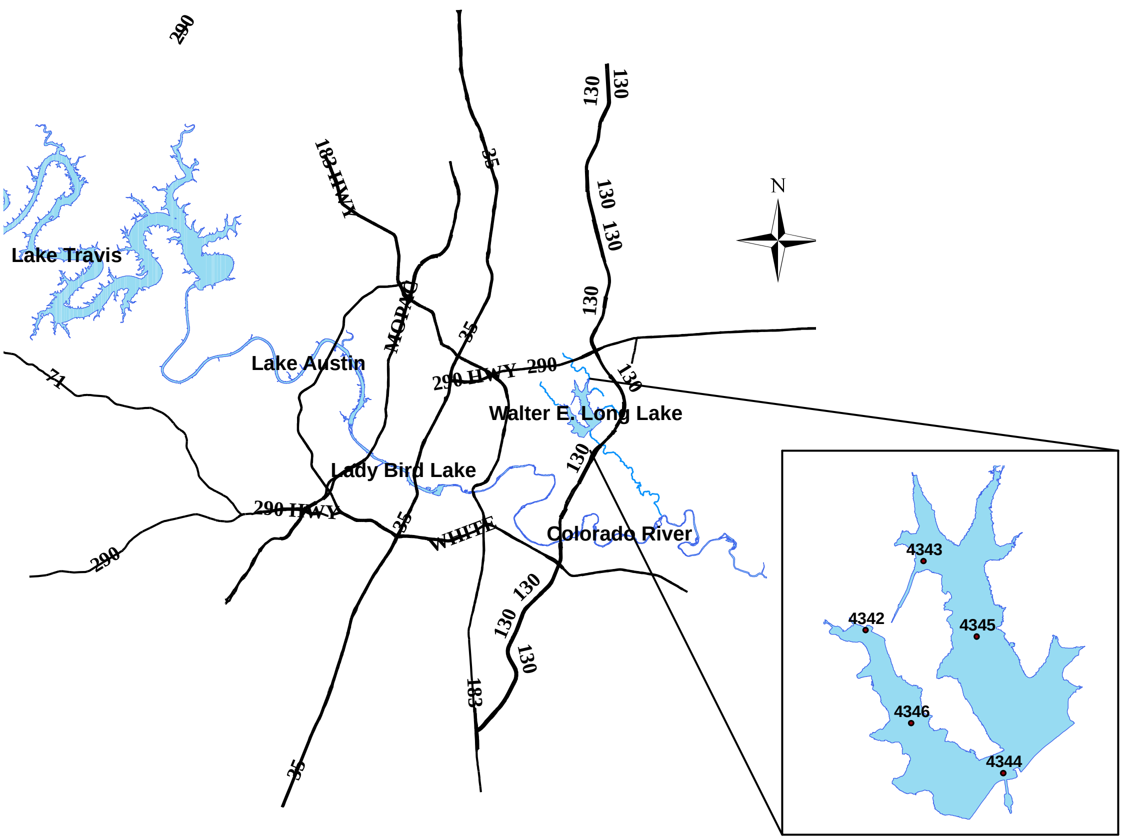

Figure 1: Map of Lake Travis, Lake Austin, Lady Bird Lake, and Lake Walter E. Long with the major roads in Austin, Texas. Sample site numbers on Lake Long are mapped in the blown up section.

Methods

Water and sediment samples were collected from Lake Long beginning in October 2008. Water samples were collected from five sites on the lake in October 2008, January 2009, April 2009, and July 2009 (Table 1, Figure 1). All sampling was conducted according to Water Resource Evaluation Standard Operating Procedures (COA, 2008); with field parameters collected 0.2 m from the surface and at 1 m intervals to the bottom of the lake. Nutrients were collected at the surface and the bottom of the lake while other parameters were collected only at the surface (Table 2). Phytoplankton samples were collected at Lake Long @ Intake, Lake Long @ Discharge, and Lake Long @ Dam in January, April, and August, with two additional sites (Lake Long @ Northeast Arm and Lake Long @ Southwest Arm) added in August. Sediment samples were collected at Lake Long @ Intake, Lake Long @ Discharge, and Lake Long @ Dam in May 2009. Sediment samples were analyzed for ammonia, total solids, TOC, TPH, arsenic, cadmium, chromium, copper, iron, lead, zinc, mercury, nickel, silver, PAHs, PCBs, organochloride pesticides, chlorophenoxy acid herbicides, organophosphate pesticides, and texture.

Table 2: Parameter list for the water quality samples on Lake Long with the appropriate analysis and depth.

Parameter	**Analysis**	**Depth**
Conductivity	Field	Depth Profile
pH	Field	Depth Profile
Water Temperature	Field	Depth Profile
Dissolved Oxygen	Field	Depth Profile
Secchi Disk Depth	Field	n/a
Phytoplankton	BW	Surface only
Chlorophyll-a	Lab	Surface only
COD	Lab	Surface only
TSS	Lab	Surface only
E coli bacteria	Lab	Surface only
Nutrients (NO3+NO2, TKN, NH3, TP, OP, SO4, Chloride, Sulfate)	Lab	Surface and bottom
Total metals (As, Cu, Fe, Pb, Zn) once only w/ sediment sample	Lab	Surface only

Water samples were analyzed at LCRA for the October, January, and April sampling events, while the July sample was analyzed by the Austin Energy Laboratory Services (AELS). *E. coli* was analyzed by City of Austin Environmental Resource Management while phytoplankton enumeration and identification to was done by Winsborough Consulting. Most phytoplankton was identified to species; however, some phytoplankton were only identifiable to genus and others were unidentified. The unidentified algae were separated and labeled as unidentified algae 1, unidentified algae 2, etc. Sediment samples were analyzed by DHL Analytical Laboratory.

Data Analysis Methods

Parameters in the water and sediment samples were compared to the current TCEQ screening levels. Values that exceeded the TCEQ screening level were highlighted in blue, while values that did not meet qa/qc standards were flagged in orange.

Lake Long water quality data was compared to Lady Bird Lake water quality data from the same period of record. Parameters included in the analysis were ammonia, chemical oxygen demand, chloride, chlorophyll-a, conductivity, dissolved oxygen, nitrate, orthophosphorus, pH, pheophytin, phosphorus, secchi disk depth, sulfate, total kjeldahl nitrogen, total suspended solids, and water temperature. Each parameter was compared between the Lake Long sites and the Basin site on Lady Bird Lake using the Wilcoxon rank-sum test. The Basin site was chosen for comparison because Lady Bird Lake is a run-of-the-river reservoir, and under certain flow regimes, its other sampling sites are more similar to a large river.

The at-depth data was compared to the surface data in order to determine the need for future at-depth sampling. Ammonia, nitrate, phosphorus, orthophosphorus, total kjeldahl nitrogen, chloride, and sulfate (all parameters analyzed from at-depth samples) were compared using the Wilcoxon sign-ranked test to adjust for site differences.

In order to determine if future sampling should include every sample site, surface water data for all parameters was combined at each site to test for site differences within the lake using the Kruskal-Wallis test. The need for quarterly sampling was investigated by recombining the surface water data by visit date to test for differences in season using the Kruskal-Wallis test. When the Kruskal-Wallis test was significant, the minimum p-value multiple comparison test was used to analyze site or season differences respectively.

As depth increases, water bodies can separate vertically due to differences in temperature and light. If the water body stratifies, water quality differences may develop in each zone, and sampling at varying depths could yield valuable information. In order to see if the water in Lake Long was stratifying, linear regression was used to detect any relationship between depth and conductivity, dissolved oxygen, pH, or water temperature. The depth profile was input as the independent variable and the field parameters were input as the dependent variables. All tests used alpha values of 0.05 unless noted otherwise.

Phytoplankton counts were transformed to organisms/mL in order to compensate for volume differences. The number of organisms/mL was log transformed and used in a non-metric Multidimensional Scaling (nMDS) ordination to investigate site and seasonal differences. NMDS is a distance based procedure that ordinates data by dissimilarity (Minchin 1987, Clarke 1993). The Bray-Curtis dissimilarity was used as the distance measure in the ordination as this has been demonstrated as a robust measure for ecological communities (Faith and Norris 1989). Two dimensions were used for the ordination because the stress value was 0.009 and did not decrease when a third dimension was added. The minimum stress value is obtained when there are adequate dimensions in the ordination to fully display distances between units. Two hundred iterations were used in the ordination. The data was also used in a complete-linkage agglomerative cluster analysis using the Bray-Curtis dissimilarity as the distance measure. The samples were grouped by the ordination analysis and used in a SIMPER analysis to investigate which phytoplankton species was most responsible for the separation. For the nMDS, cluster, and SIMPER analysis the sites were labeled differently (Table 3). The January samples were given the same label as the original sample site number. The April samples were labeled in the 4350's instead of in the 4340's to distinguish the separate sampling event. The August samples were labeled in the 4360's instead of the 4340's like the originals.

Table 3: Labels for nMDS, cluster, and SIMPER with the actual sample site number, month of the sample, and site name.

LABEL	ORIGINAL SAMPLE SITE #	MONTH	SITE NAME
4342	4342	January	Lake Long @ Intake
4343	4343	January	Lake Long @ Discharge
4344	4344	January	Lake Long @ Dam
4352	4342	April	Lake Long @ Intake
4353	4343	April	Lake Long @ Discharge
4354	4344	April	Lake Long @ Dam
4362	4342	August	Lake Long @ Intake
4363	4343	August	Lake Long @ Discharge
4364	4344	August	Lake Long @ Dam
4365	4345	August	Lake Long @ NE Arm
4366	4346	August	Lake Long @ SW Arm

Results

Table 4 shows the surface and at-depth values for samples collected at Lake Long and the current TCEQ screening value for applicable parameters (SWQM 2008). Data points for total suspended solids in October did not pass the standards portion of the qa/qc procedure and were not used in any analysis. Phosphorus was above the screening level at the intake site in April at the surface and in October at depth. No values were above the screening level at the discharge site. Chlorophyll-a was over the screening level at the dam in April, while at depth ammonia was over the level in October and July and at depth phosphorus was over the level in July. Chlorophyll-a was also over the screening level in October and April on the NE arm site and over the level in April on the SW arm site of Lake Long. Phosphorus was over the screening level at the surface and at depth in October at the NE arm site, while ammonia at depth was over in July. At depth ammonia was over the screening level in July on the SW arm site, and at depth phosphorus was over the level in July and October. The levels of chlorophyll-a, total phosphorus, and nitrate may be compared to trophic boundaries to determine trophic status of the lake (Dodds 1998, Olen 1990). Lake Long may be considered oligotrophic, mesotrophic, or eutrophic depending on the parameter chosen to determine the trophic status. Chlorophyll-a levels were all greater than 10 µg/L which indicates that the lake is eutrophic. Total phosphorus fluctuated between a mesotrophic (0.025 – 0.075 mg/L) and a eutrophic (> 0.075 mg/L) state. Nitrate levels were always less than 0.7 mg/L which indicates that the lake is oligotrophic.

The sediment samples taken at the intake, the discharge, and the dam sites did not have any values above the current TCEQ screening level (Table 5). Lead, oil and grease, and organic carbon failed the standards portion of the qa/qc procedure and would not be used in further analysis of the data.

Mean values for parameters collected on Lady Bird Lake (Town Lake) during 2008 and 2009 are listed in Table 6. All of the Lake Long sites have significantly higher values for chemical oxygen demand, conductivity, pH, pheophytin, phosphorus, sulfate and total kjeldahl nitrogen when compared to the Basin on Lady Bird Lake (Table 7). Dissolved oxygen was significantly higher than the Basin at the Intake, Discharge, NE Arm, and SW Arm of Lake Long. Water temperature was significantly colder at the Dam, the NE Arm, and the SW Arm than at the Basin.

Table 4: Surface and at depth samples collected on Lake Long in October, January, April, and July with the current TCEQ screening values for appropriate parameters. Rejected values are shaded orange while values above the screening level are shaded in blue.

PARAMETER	TCEQ VALUE	29-Oct-08	21-Jan-09	08-Apr-09	29-Jul-09	29-Oct-08	21-Jan-09	08-Apr-09	29-Jul-09
LAKE LONG @ INTAKE		**SURFACE**				**AT DEPTH**			
AMMONIA AS N (mg/L)	0.11	< 0.005	0.034	< 0.005	< 0.005	< 0.005	0.03	< 0.005	< 0.005
COD (mg/L)		19	18	24	20				
CHLORIDE (mg/L)		83.2	78.9	88.5	82.8	83.4	79.6	84.2	77.4
CHLOROPHYLL-A (µg/L)	26.7	25.7	15.1	18	12.8				
CONDUCTIVITY (uS/cm)		707.3	728.2	743	726.7				
DISSOLVED OXYGEN (mg/L)		7.85	10.22	10.75	6.57				
E COLI BACTERIA (Col/100mL)	394	.	29.2	9.7	< 1				
NITRATE/NITRITE AS N (mg/L)	0.37	< 0.004	0.24	< 0.004	< 0.004	< 0.004	0.27	< 0.004	< 0.004
ORTHOPHOSPHORUS (mg/L)		< 0.002	0.019	< 0.002	< 0.002	< 0.002	0.028	< 0.002	< 0.002
PH (stand. unit)		8.34	8.49	8.68	8.58				
PHEOPHYTIN (µg/L)		2.7	3.42	3.23	2.97				
PHOSPHORUS AS P (mg/L)	0.2	0.045	0.073	0.233	0.03	0.275	0.076	0.081	0.034
SECCHI DISK DEPTH (m)		1.15	1.2	0.8	1.4				
SULFATE (mg/L)		61.7	65.5	67.3	64.4	63.6	65.6	67.3	64.3
COLIFORM BACTERIA		.	866.4	.	.				
TKN (mg/L)		0.97	1.05	1.11	0.97	0.877	0.894	1.21	0.938
TSS (mg/L)		7	5.9	18.8	.				
TEMPERATURE (Deg. Cel.)		21.88	11.64	18.44	29.7				
LAKE LONG @ DISCHARGE		**SURFACE**				**AT DEPTH**			
AMMONIA AS N (mg/L)	0.11	0.005	0.04	< 0.005	< 0.005	0.057	0.064	< 0.005	0.02
COD (mg/L)		23	16	23	21				
CHLORIDE (mg/L)		82.9	78.4	87.9	82.2	83.9	80.7	88.3	78.8
CHLOROPHYLL-A (µg/L)	26.7	21.4	16.2	24	11.5				
CONDUCTIVITY (uS/cm)		709.6	732.3	743.3	730				
DISSOLVED OXYGEN (mg/L)		8.12	9.76	11.01	5.97				
E COLI BACTERIA (Col/100mL)	394	5.2	142.1	2	< 1				
NITRATE/NITRITE AS N (mg/L)	0.37	< 0.004	0.24	< 0.004	< 0.004	< 0.004	0.25	< 0.004	< 0.004
ORTHOPHOSPHORUS (mg/L)		< 0.002	0.021	< 0.002	< 0.002	< 0.002	0.019	< 0.002	< 0.002
PH (stand. unit)		8.36	8.4	8.69	8.48				
PHEOPHYTIN (µg/L)		2.7	3.12	3.96	2.05				
PHOSPHORUS AS P (mg/L)	0.2	0.056	0.071	0.061	0.037	0.055	0.083	0.067	0.053
SECCHI DISK DEPTH (m)		1.15	0.8	0.8	0.9				
SULFATE (mg/L)		62.1	65.7	67.4	64.7	62.1	66	67.3	65.1
COLIFORM BACTERIA		2419.6	1413.6	.	.				
TKN (mg/L)		0.875	0.741	1.26	0.77	0.783	0.939	1.09	0.956
TSS (mg/L)		2	16.2	16.2	.				
TEMPERATURE (Deg. Cel.)		24.35	12.02	19.65	34.57				
LAKE LONG @ DAM		**SURFACE**				**AT DEPTH**			
AMMONIA AS N (mg/L)	0.11	0.09	0.042	< 0.005	< 0.005	0.118	0.034	0.022	0.746
COD (mg/L)		20	16	21	19				
CHLORIDE (mg/L)		82	79.4	88.6	84	82.6	79.3	87.9	78.8
CHLOROPHYLL-A (µg/L)	26.7	16.5	19	36.6	12				
CONDUCTIVITY (uS/cm)		712.6	730.9	745	734.6				
DISSOLVED OXYGEN (mg/L)		4.94	9.59	9.25	5.65				
E COLI BACTERIA (Col/100mL)	394	1	24.6	1	< 1				
NITRATE/NITRITE AS N (mg/L)	0.37	0.02	0.27	< 0.004	< 0.004	0.01	0.27	< 0.004	< 0.004
ORTHOPHOSPHORUS (mg/L)		< 0.002	0.022	< 0.002	< 0.002	< 0.002	0.022	< 0.002	0.176
PH (stand. unit)		7.96	8.52	8.62	8.55				
PHEOPHYTIN (µg/L)		2.64	3.74	4.09	2.77				
PHOSPHORUS AS P (mg/L)	0.2	0.038	0.075	0.058	0.03	0.152	0.085	0.063	0.218
SECCHI DISK DEPTH (m)		1.45	1.4	1.05	1.7				
SULFATE (mg/L)		61.3	65.7	67.1	65.4	61	65.7	67.3	43.5
COLIFORM BACTERIA		2419.6	1119.9	.	.				
TKN (mg/L)		0.832	0.82	0.98	0.72	1.09	1.12	1.04	1.44
TSS (mg/L)		2	5.1	11	.				
TEMPERATURE (Deg. Cel.)		22.08	12.22	17.22	30.14				

Table 4 (cont.): Surface and at depth samples collected on Lake Long in October, January, April, and July with the current TCEQ screening values for appropriate parameters. Rejected values are shaded orange while values above the screening level are shaded in blue.

PARAMETER	TCEQ VALUE	29-Oct-08	21-Jan-09	08-Apr-09	29-Jul-09	29-Oct-08	21-Jan-09	08-Apr-09	29-Jul-09
LAKE LONG @ EAST ARM		**SURFACE**				**AT DEPTH**			
AMMONIA AS N (mg/L)	0.11	< 0.005	0.041	< 0.005	< 0.005	0.088	0.041	< 0.005	0.882
COD (mg/L)		23	15	24	21				
CHLORIDE (mg/L)		83.3	79.4	88.3	81	82.3	79.3	88.9	80.4
CHLOROPHYLL-A (µg/L)	26.7	33.6	17.7	34.2	17.3				
CONDUCTIVITY (uS/cm)		708.1	732	743.1	732.5				
DISSOLVED OXYGEN (mg/L)		9.02	9.67	10.81	6.91				
E COLI BACTERIA (Col/100mL)	394	< 1	36.8	2	< 1				
NITRATE/NITRITE AS N (mg/L)	0.37	< 0.004	0.29	< 0.004	< 0.004	0.01	0.26	< 0.004	< 0.004
ORTHOPHOSPHORUS (mg/L)		< 0.002	0.021	< 0.002	< 0.002	< 0.002	0.021	< 0.002	0.15
PH (stand. unit)		8.45	8.46	8.7	8.61				
PHEOPHYTIN (µg/L)		2.81	3.28	4.32	1.68				
PHOSPHORUS AS P (mg/L)	0.2	0.305	0.079	0.063	0.041	0.377	0.088	0.068	0.191
SECCHI DISK DEPTH (m)		.	1.3	0.6	1.3				
SULFATE (mg/L)		61.8	65.7	67.1	65.3	61.7	65.7	67.2	39.1
COLIFORM BACTERIA		2419.6	980.4	.	.				
TKN (mg/L)		0.958	0.812	1.11	0.854	1.09	0.827	1.34	1.82
TSS (mg/L)		6	5.8	14.96	.				
TEMPERATURE (Deg. Cel.)		22.67	12.23	17.96	32.73				
LAKE LONG @ WEST ARM		**SURFACE**				**AT DEPTH**			
AMMONIA AS N (mg/L)	0.11	< 0.005	0.035	< 0.005	< 0.005	0.016	0.055	< 0.005	1.17
COD (mg/L)		20	19	25	21				
CHLORIDE (mg/L)		83	79.9	88.2	82	83.3	79.4	86	79.2
CHLOROPHYLL-A (µg/L)	26.7	25.8	17.7	38.3	12.2				
CONDUCTIVITY (uS/cm)		708	728.7	742.5	726.9				
DISSOLVED OXYGEN (mg/L)		7.26	9.92	10.58	6.33				
E COLI BACTERIA (Col/100mL)	394	4.1	30.1	4	< 1				
NITRATE/NITRITE AS N (mg/L)	0.37	0.01	0.29	< 0.004	< 0.004	0.02	0.27	< 0.004	< 0.004
ORTHOPHOSPHORUS (mg/L)		< 0.002	0.021	< 0.002	< 0.002	< 0.002	0.021	< 0.002	0.267
PH (stand. unit)		8.33	8.53	8.74	8.54				
PHEOPHYTIN (µg/L)		2.87	3.34	5.16	3.1				
PHOSPHORUS AS P (mg/L)	0.2	0.035	0.078	0.063	0.028	3.56	0.072	0.075	0.297
SECCHI DISK DEPTH (m)		1.45	1.3	0.9	1.7				
SULFATE (mg/L)		63.4	65.4	67.4	64.4	63.8	65.6	66.4	37.6
COLIFORM BACTERIA		2419.6	721.5	.	.				
TKN (mg/L)		0.801	0.919	1.44	0.917	1.03	0.84	1.51	2.22
TSS (mg/L)		3	5.3	13.2	.				
TEMPERATURE (Deg. Cel.)		22.05	11.95	17.57	29.68				

Table 5: Sediment samples collected at the intake, discharge, and dam on Long Lake during May 2009 with TCEQ screening levels for appropriate parameters. Rejected values are shaded orange.

PARAMETER	TCEQ_VALUE	LAKE LONG @ INTAKE	LAKE LONG @ DISCHARGE	LAKE LONG @ DAM
2_4_5-TP (SILVEX)	.	< 0.6	< 0.97	< 1.52
2_4_5-TRICHLOROPHENOXYACETIC ACID	.	< 0.36	< 0.59	< 0.92
2_4-DICHLOROPHENOXYACETIC ACID	.	< 0.52	< 0.84	< 1.31
4_4'-DDD	0.03	< 0.00366	< 0.00602	< 0.00927
4_4'-DDE	0.03	< 0.00366	< 0.00602	< 0.00927
4_4'-DDT	0.06	< 0.00366	< 0.00602	< 0.00927

Table 5 (cont.): Sediment samples collected at the intake, discharge, and dam on Long Lake during May 2009 with TCEQ screening levels for appropriate parameters. Rejected values are shaded orange.

PARAMETER	TCEQ_VALUE	LAKE LONG @ INTAKE	LAKE LONG @ DISCHARGE	LAKE LONG @ DAM
ACENAPHTHENE	.	< 0.0377	< 0.0592	< 0.096
ACENAPHTHYLENE	.	< 0.0188	< 0.0296	< 0.048
ALDRIN	0.08	< 0.00366	< 0.00602	< 0.00927
ALPHA-BHC (BENZENE HEXACHLORIDE)	0.1	< 0.00366	< 0.00602	< 0.00927
ALPHA-CHLORDANE	.	< 0.00366	< 0.00602	< 0.00927
AMMONIA AS N	.	44	51.7	162
ANTHRACENE	.	< 0.0188	< 0.0296	< 0.048
AROCLOR 1016	.	< 0.0879	< 0.15	< 0.226
AROCLOR 1221	.	< 0.0879	< 0.15	< 0.226
AROCLOR 1232	.	< 0.0879	< 0.15	< 0.226
AROCLOR 1242	.	< 0.0879	< 0.15	< 0.226
AROCLOR 1248	.	< 0.0879	< 0.15	< 0.226
AROCLOR 1254	.	< 0.0879	< 0.15	< 0.226
AROCLOR 1260	.	< 0.0879	< 0.15	< 0.226
ARSENIC	33	4.16	5.34	6.44
AZINPHOS METHYL (GUTHION)	.	< 16.8	< 27.2	< 42.4
BENZO(A)ANTHRACENE	.	< 0.0377	< 0.0592	< 0.096
BENZO(A)PYRENE	.	< 0.0565	< 0.0888	< 0.144
BENZO(B)FLUORANTHENE	.	0.0479	< 0.0592	< 0.096
BENZO(E)PYRENE	.	< 0.0565	< 0.0888	< 0.144
BENZO(GHI)PERYLENE	.	< 0.0377	< 0.0592	< 0.096
BENZO(K)FLUORANTHENE	.	< 0.0565	< 0.0888	< 0.144
BETA-BHC (BENZENE HEXACHLORIDE)	0.21	< 0.00366	< 0.00602	< 0.00927
CADMIUM	4.98	0.187	0.301	0.322
CHLORPYRIFOS (DURSBAN)	.	< 14.9	< 24.1	< 37.5
CHROMIUM	111	19.5	25.7	32.6
CHRYSENE	.	< 0.0377	< 0.0592	< 0.096
COPPER	149	13.9	64.2	56.6
DELTA-BHC (BENZENE HEXACHLORIDE)	0.12	< 0.00366	< 0.00602	< 0.00927
DEMETON	.	< 27.2	< 44	< 68.6
DEMETON-O	.	< 16.6	< 26.9	< 42
DEMETON-S	.	< 12.4	< 20	< 31.2
DIAZINON	.	< 16.7	< 27	< 42.1
DIBENZ(AH)ANTHRACENE	0.14	< 0.0377	< 0.0592	< 0.096
DICAMBA (BANVEL)	.	< 0.59	< 0.96	< 1.5
DIELDRIN	.	< 0.00366	< 0.00602	< 0.00927
DINOSEB	.	< 0.51	< 0.82	< 1.29
ENDOSULFAN I	.	< 0.00366	< 0.00602	< 0.00927
ENDOSULFAN II	.	< 0.00366	< 0.00602	< 0.00927
ENDOSULFAN SULFATE	.	< 0.00548	< 0.00903	< 0.0139
ENDRIN	0.21	< 0.00366	< 0.00602	< 0.00927
ENDRIN ALDEHYDE	.	< 0.00366	< 0.00602	< 0.00927
ENDRIN KETONE	.	< 0.00366	< 0.00602	< 0.00927
FLUORANTHENE	.	0.0681	< 0.0296	< 0.048

Table 5 (cont.): Sediment samples collected at the intake, discharge, and dam on Long Lake during May 2009 with TCEQ screening levels for appropriate parameters. Rejected values are shaded orange.

PARAMETER	**TCEQ_VALUE**	**LAKE LONG @ INTAKE**	**LAKE LONG @ DISCHARGE**	**LAKE LONG @ DAM**
FLUORENE (9H-FLUORENE)	.	< 0.0188	< 0.0296	< 0.048
GAMMA-BHC (LINDANE)	.	< 0.00366	< 0.00602	< 0.00927
GAMMA-CHLORDANE	.	< 0.00366	< 0.00602	< 0.00927
HEPTACHLOR	.	< 0.00366	< 0.00602	< 0.00927
HEPTACHLOR EPOXIDE	.	< 0.00366	< 0.00602	< 0.00927
INDENO(1_2_3-CD)PYRENE	.	< 0.0188	< 0.0296	< 0.048
IRON	40000	12700	16900	20600
LEAD	.	9.49	13.9	16.5
MALATHION	.	< 11.6	< 18.9	< 29.4
MERCURY	1.06	0.0176	0.026	< 0.0355
METHOXYCHLOR	.	< 0.00366	< 0.00602	< 0.00927
METHYL PARATHION	.	< 17.5	< 28.4	< 44.2
NAPHTHALENE	.	< 0.0188	< 0.0296	< 0.048
NICKEL	48.6	9.76	15.3	17.5
OIL AND GREASE	.	15.5	43.4	45.7
ORGANIC CARBON	.	15200	31700	53300
PAH	0.02	0.0002083	< 0.0007992	< 0.001296
PAH	0.02	0.00030165	0.0002812	0.000456
PENTACHLOROPHENOL	.	< 0.42	< 0.68	< 1.07
PERCENT MOISTURE	.	47.75862	67.77081	79.47977
PETROLEUM HYDROCARBONS >C12-C28	.	< 12.4	< 20.9	< 32.2
PETROLEUM HYDROCARBONS >C28-C35	.	< 12.4	< 20.9	< 32.2
PETROLEUM HYDROCARBONS C6-C12	.	< 12.4	< 20.9	< 32.2
PETROLEUM HYDROCARBONS C6-C35	.	< 12.4	< 20.9	< 32.2
PHENANTHRENE	.	0.041	< 0.0296	< 0.048
PYRENE	.	0.0513	< 0.0592	< 0.096
SILVER	2.2	< 0.0934	< 0.147	< 0.239
TEXTURE CLAY (<0.002MM)	.	39.9	28.3	49.9
TEXTURE GRAVEL	.	4.14	< 0	0.21
TEXTURE SAND (0.05-2.0MM)	.	28.3	31.5	25
TEXTURE SILT (0.002-0.05MM)	.	27.7	40.2	24.8
TOTAL CHLORDANE	17.6	< 0.00366	< 0.00602	< 0.00927
TOXAPHENE	32	< 0.0548	< 0.0903	< 0.139
ZINC	459	31.8	51.4	56.8

Table 6: Frequency, mean, and standard deviation for water samples collected at Lady Bird Lake (Town Lake) during 2008 and 2009.

	Lady Bird Lake (Town Lake) @ Basin		
PARAMETER	**N**	**MEAN**	**STD**
AMMONIA	8	0.015	0.003
COD	3	11	2
CHLORIDE	.	.	.
CHLOROPHYLL-A	5	60.5	107.5
CONDUCTIVITY	24	432.7	44.8
DISSOLVED OXYGEN	24	6.58	1.32
E COLI	4	73	97
NITRATE/NITRITE	8	0.113	0.024
ORTHOPHOSPHORUS	6	0.016	0.000
PH	24	7.74	0.17
PHEOPHYTIN	4	0.93	0.43
PHOSPHORUS	8	0.033	0.011
SECCHI DISK DEPTH	3	1.6	0.5
SULFATE	8	21.8	2.6
COLIFORM BACTERIA	.	.	.
TKN	8	0.324	0.016
TSS	3	3.3	1.4
WATER TEMPERATURE	32	23.22	3.69

Table 7: Frequency, mean, and standard deviation for water samples collected at Lake Long during 2008 and 2009. Blue cells indicate a significant difference between the collected values at a Lake Long site and the Basin for a given parameter.

	Lake Long @ Intake			Lake Long @ Discharge			Lake Long @ Dam			Lake Long @ East Arm			Lake Long @ West Arm		
PARAMETER	**N**	**MEAN**	**STD**	**N**	**MEAN**	**STD**	**N**	**MEAN**	**STD**	**N**	**MEAN**	**STD**	**N**	**MEAN**	**STD**
AMMONIA	8	0.030	0.001	8	0.025	0.009	8	0.137	0.090	8	0.152	0.113	8	0.167	0.155
COD	4	20	3	4	21	3	4	19	2	4	21	4	4	21	3
CHLORIDE	8	82.3	3.5	8	82.9	3.7	8	82.8	3.8	8	82.9	3.8	8	82.6	3.2
CHLOROPHYLL-A	4	17.9	5.6	4	18.3	5.6	4	21.0	10.8	4	25.7	9.5	4	23.5	11.3
CONDUCTIVITY	25	726.6	12.8	22	728.7	12.0	63	733.6	16.6	48	732.2	15.6	43	729.5	16.8
DISSOLVED OXYGEN	25	8.58	1.80	22	8.13	2.32	63	6.38	3.08	48	7.59	3.04	43	7.74	2.83
E COLI	3	13	14	3	3	2	3	1	0	3	1	1	3	3	2
NITRATE/NITRITE	8	0.244	0.005	8	0.241	0.002	8	0.076	0.046	8	0.076	0.050	8	0.079	0.047
ORTHOPHOSPHORUS	8	0.020	0.001	8	0.019	0.000	8	0.041	0.022	8	0.037	0.018	8	0.052	0.035
PH	25	8.48	0.11	22	8.41	0.15	63	8.20	0.44	48	8.32	0.39	43	8.37	0.38
PHEOPHYTIN	4	3.08	0.31	4	2.96	0.80	4	3.31	0.72	4	3.02	1.10	4	3.62	1.05
PHOSPHORUS	8	0.106	0.033	8	0.060	0.005	8	0.090	0.023	8	0.151	0.045	8	0.526	0.434
SECCHI DISK DEPTH	4	1.1	0.2	4	0.9	0.2	4	1.4	0.3	3	1.1	0.4	4	1.3	0.3
SULFATE	8	65.0	1.9	8	65.1	2.1	8	62.1	7.9	8	61.7	9.4	8	61.8	9.8
COLIFORM BACTERIA	1	866.4	.	1	2419.6	.	1	2419.6	.	1	2419.6	.	1	2419.6	.
TKN	8	1.002	0.040	8	0.927	0.063	8	1.005	0.080	8	1.101	0.121	8	1.210	0.173
TSS	2	12.4	6.5	2	16.2	0.0	2	8.0	3.0	2	10.4	4.6	2	9.3	4.0
TEMPERATURE	25	20.65	6.80	22	22.58	8.04	63	19.29	5.73	48	20.32	6.60	43	20.12	6.18

Another monitoring objective was to evaluate any site or seasonal differences on Lake Long in order to determine future monitoring needs. Graphs for each parameter for a given site at the surface, a given month at the surface, and a given site with combined surface and depth data are depicted in Figure 2 through Figure 18.

There was no significant difference between sites for ammonia at the surface (Figure 2a); however, there was a significant difference between months at the surface (Figure 2b). Ammonia was significantly higher in January than in April or July. Ammonia at-depth was significantly higher than ammonia at the surface when site was considered (Figure 2c).

No significant difference between sites was detected for chloride at the surface (Figure 3a), but there was a significant difference between months for chloride at the surface (Figure 3b). Chloride was significantly highest in April and significantly lowest in January. October and July had similar values for chloride. There was no significant difference between at-depth chloride and surface chloride when site was considered (Figure 3c).

Chlorophyll-a was not significantly different between sites (Figure 4a). But there was a significant difference between months for chlorophyll-a (Figure 4b). Chlorophyll-a was significantly higher in April than in January and July. The increase in chlorophyll-a from phytoplankton might be attributable to a combination of the temperature increasing, nutrients in the water, and the lack of pumping from the Colorado River in March and April. Three of the five values for chlorophyll-a in April were above the TCEQ screening level. The values for chlorophyll-a in October were significantly higher than the chlorophyll-a values measured in July.

The chemical oxygen demand (COD) was not significantly different between sites (Figure 5a), but it was significantly different between months (Figure 5b). COD was significantly lowest in January, and the COD in April was significantly higher than in January and July.

Conductivity was not significantly different between sites at the surface (Figure 6a). However, there was a significant difference in conductivity between months at the surface (Figure 6b). Conductivity was significantly highest in April and significantly lowest in October. The values for conductivity during January and July were similar at the surface.

There was no significant difference between sites for dissolved oxygen at the surface (Figure 7a), but there was a significant difference between months for dissolved oxygen at the surface (Figure 7b). The dissolved oxygen in October and July was significantly lower than the dissolved oxygen in January and April. The higher levels of dissolved oxygen in January may be due to the lower water temperatures, while the increased levels in April may be attributable to higher levels of phytoplankton in the lake.

There was no significant difference between sites (Figure 8a) or between months (Figure 8b) for *E. coli*. Some values for *E. coli* were rejected, thus there were less data values to compare for this analysis.

Nitrate/nitrite showed no significant difference between sites at the surface (Figure 9a), while there was a significant difference between months for nitrate/nitrite at the surface (Figure 9b). Nitrate/nitrite was significantly higher in January than any other month. It may be that the large population of phytoplankton in April assimilated much of the nitrate/nitrite in the lake. The values from October, April, and July were close to the detection limit. There was no significant difference between nitrate/nitrite at-depth and at the surface when site was considered (Figure 9c).

There was no significant different between sites for orthophosphorus at the surface (Figure 10a), but there was a significant difference between months for orthophosphorus at the surface (Figure 10b). Orthophosphorus was significantly higher in January than the other months. Similar to nitrate, it is possible that the increased phytoplankton in April assimilated much of the orthophosphorus. No significant difference existed between the at-depth orthophosphorus and surface orthophosphorus when site was considered (Figure 10c).

There was no significant difference between sites for pH at the surface (Figure 11a). But there was a significant difference between months for pH at the surface (Figure 11b). The pH in April was significantly higher than pH in January or October, while pH in October was also significantly lower than in January and July.

Pheophytin is a degradation product of chlorophyll-a and adds to the understanding of algal biomass present. No significant difference between sites existed for pheophytin (Figure 12a). Pheophytin in January was significantly higher than the pheophytin in July, while pheophytin in April was significantly higher than in October or July (Figure 12b).

There was no significant difference between sites for total phosphorus at the surface (Figure 13a), and there was no significant difference between months for phosphorus at the surface (Figure 13b). Phosphorus at-depth was significantly higher than the phosphorus at the surface when site was taken into account (Figure 13c).

No significant difference existed between sites for secchi disk depth (Figure 14a). However, there was a significant difference between months for secchi disk depth (Figure 14b). The secchi disk depth was significantly lower in April than in October or July. This means that visibility decreased in April, which may be caused by the increased levels of phytoplankton in the lake in April.

There was no significant difference between sites for sulfate at the surface (Figure 15a), but there was a significant difference between months for sulfate at the surface (Figure 15b). The sulfate in April was significantly higher than the sulfate in other months, while the sulfate in October was significantly less than in any other month. There was no significant difference between at-depth sulfate and surface sulfate when site was taken into account (Figure 15c).

There was not a significant difference between sites for total kjeldahl nitrogen (TKN) at the surface (Figure 16a). But there was a significant difference between months for TKN at the surface (Figure 16b). TKN was significantly higher in April than in the other months. Again this may be attributable to the increased phytoplankton or lack of pumping during this time. TKN was significantly higher at-depth than at the surface when site was taken into account (Figure 16c).

Total suspended solids (TSS) were not collected in July and the value for the October sample was rejected, so there were only values of TSS for January and April. There was no significant difference between sites for TSS (Figure 17a), but TSS in April was significantly higher than in January (Figure 17b).

There was no significant difference between sites for water temperature at the surface (Figure 18a). However, there was a significant difference between months for water temperature at the surface (Figure 18b). Water temperature in each month was significantly different from any other month. The values in January were the lowest water temperature values, followed by April, October, and July in increasing order.

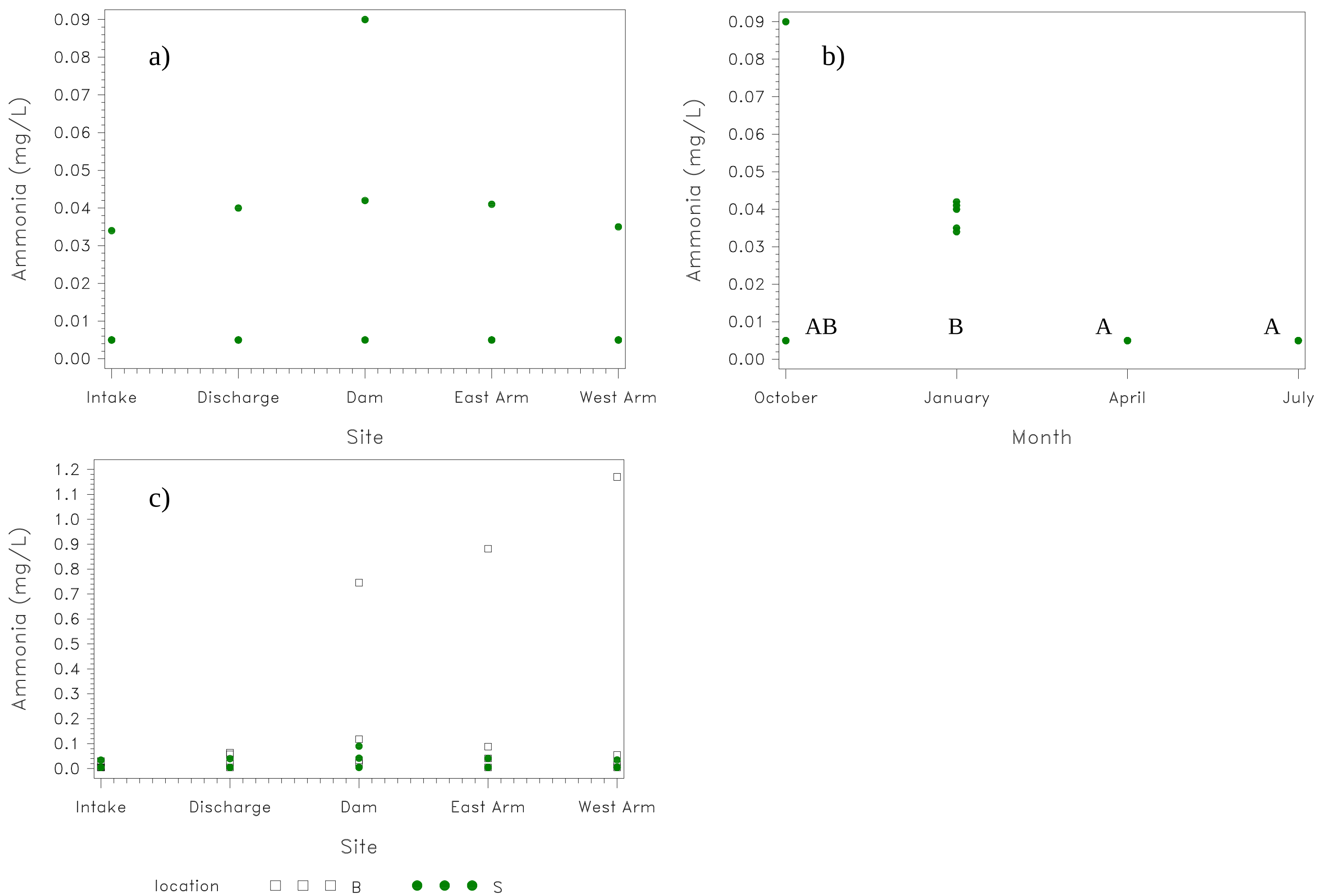

Figure 2: Ammonia (mg/L) collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month c) for both the surface and at depth for each site. Letters in the plot indicate significant differences between categories. Categories that share similar letters are not significantly different.

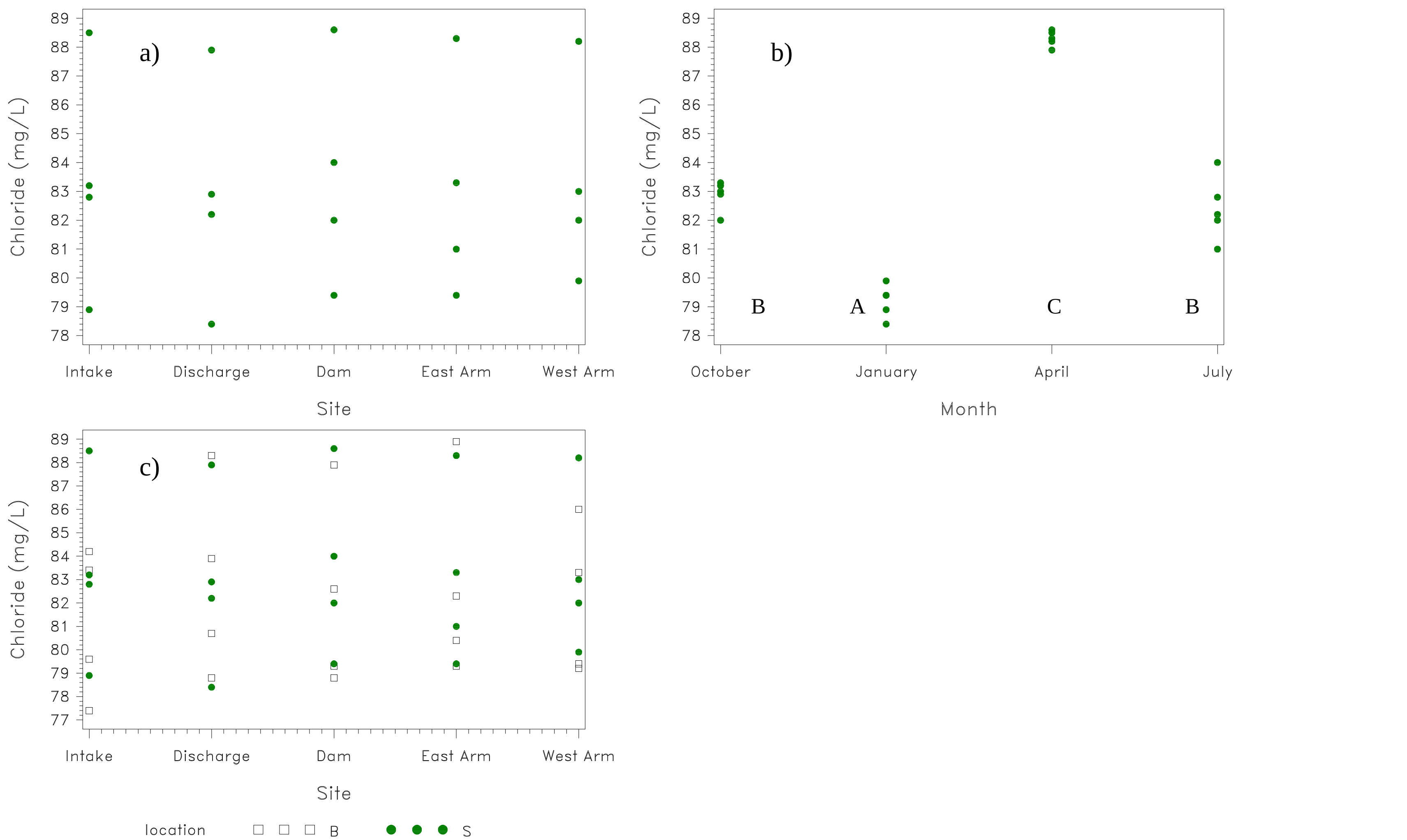

Figure 3: Chloride (mg/L) collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month c) for both the surface and at depth for each site. Letters in the plot indicate significant differences between categories. Categories that share similar letters are not significantly different.

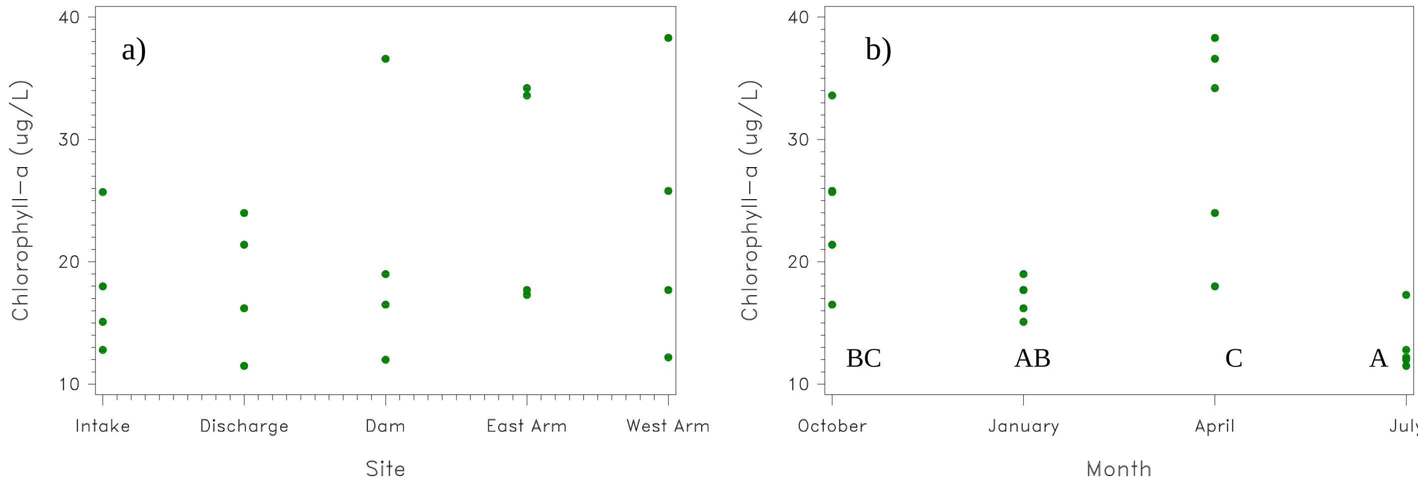

Figure 4: Chlorophyll-a (µg/L) collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month. Letters in the plot indicate significant differences between categories. Categories that share similar letters are not significantly different.

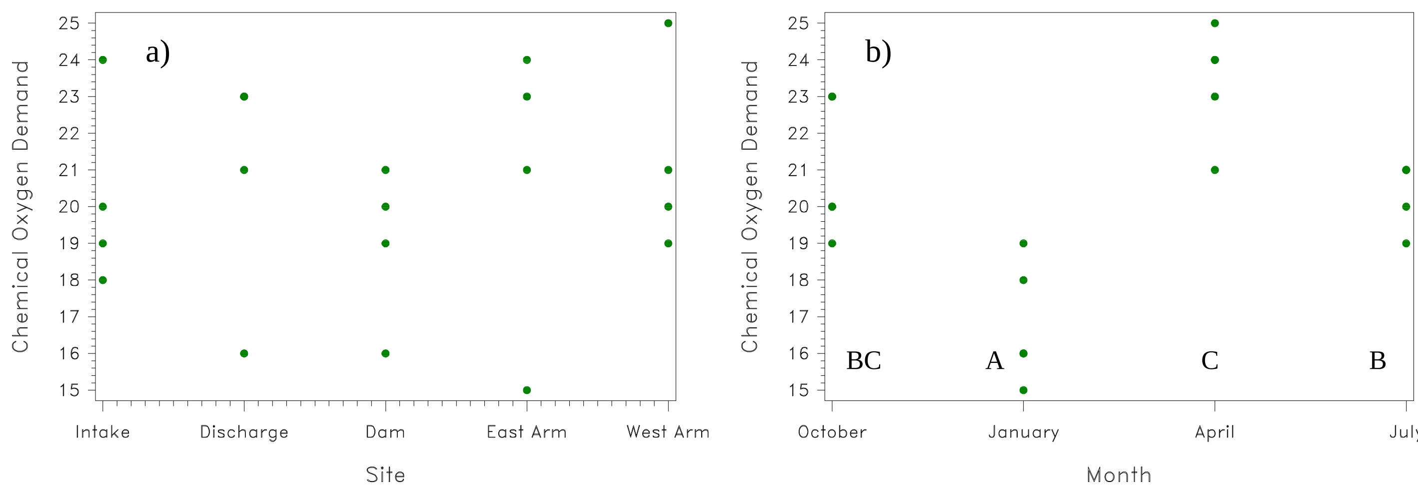

Figure 5: Chemical Oxygen Demand collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month. Letters in the plot indicate significant differences between categories. Categories that share similar letters are not significantly different.

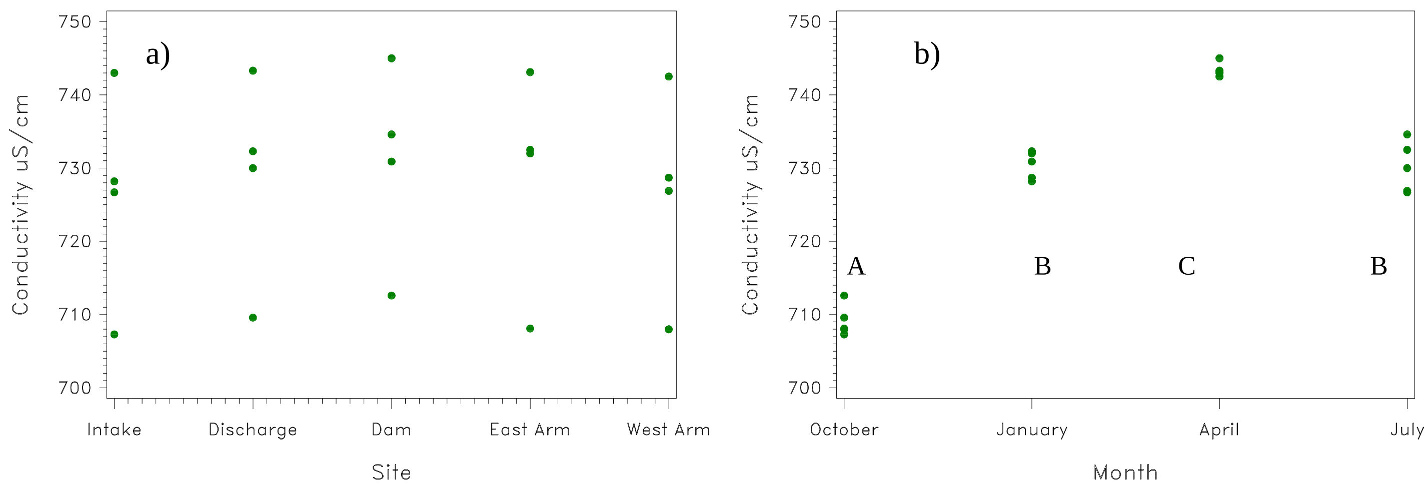

Figure 6: Conductivity (µS/cm) collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month. Letters in the plot indicate significant differences between categories. Categories that share similar letters are not significantly different.

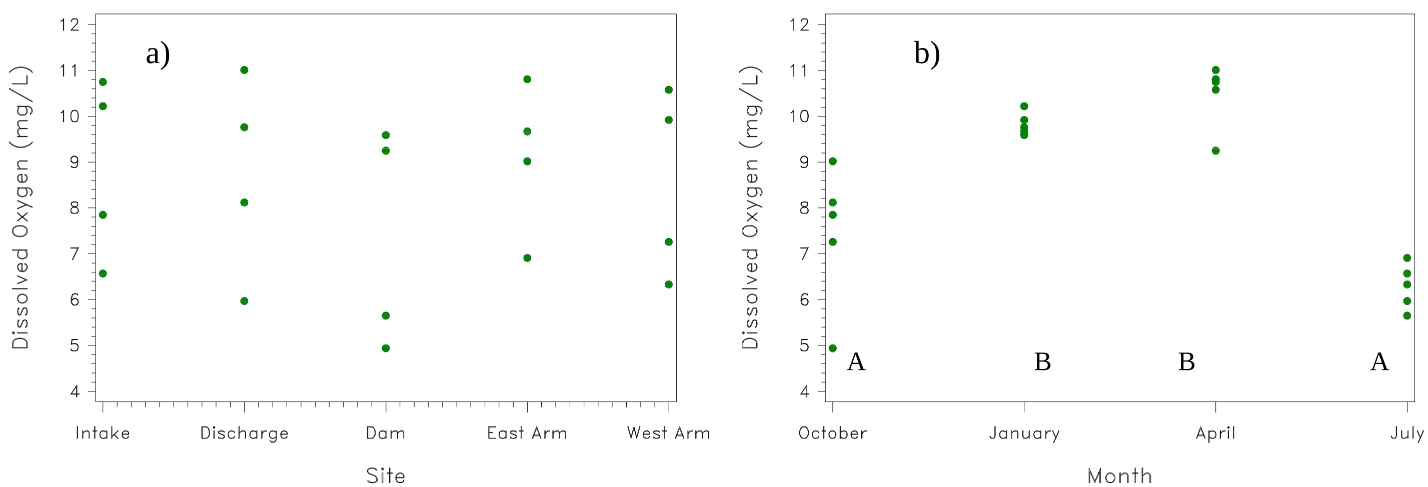

Figure 7: Dissolved Oxygen (mg/L) collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month. Letters in the plot indicate significant differences between categories. Categories that share similar letters are not significantly different.

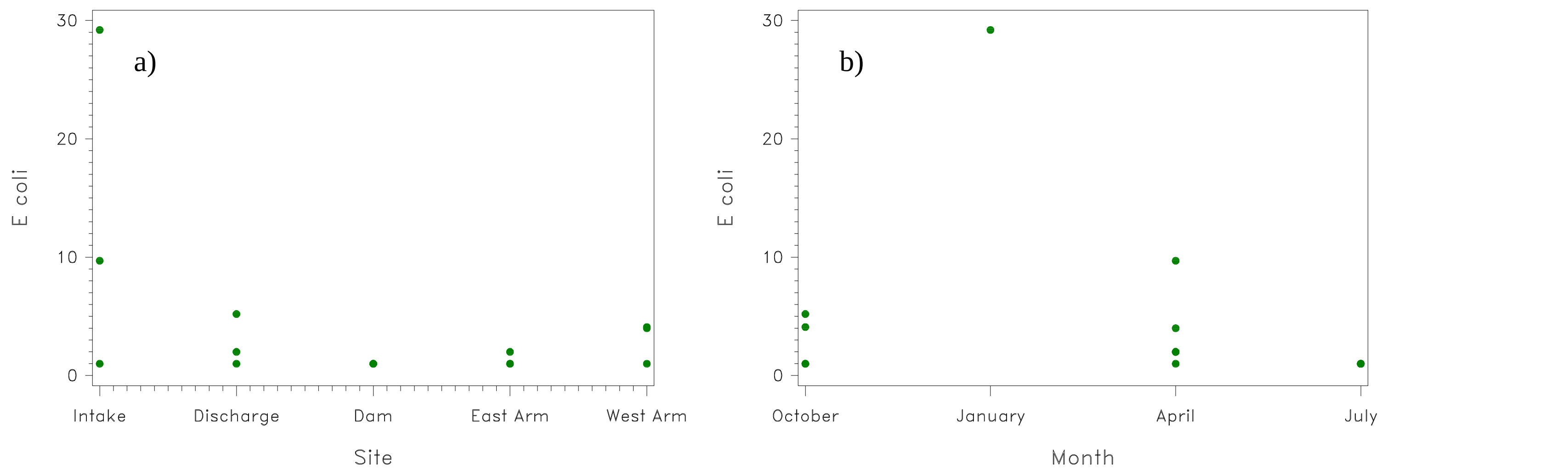

Figure 8: E. coli (mpn/100mL) collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month.

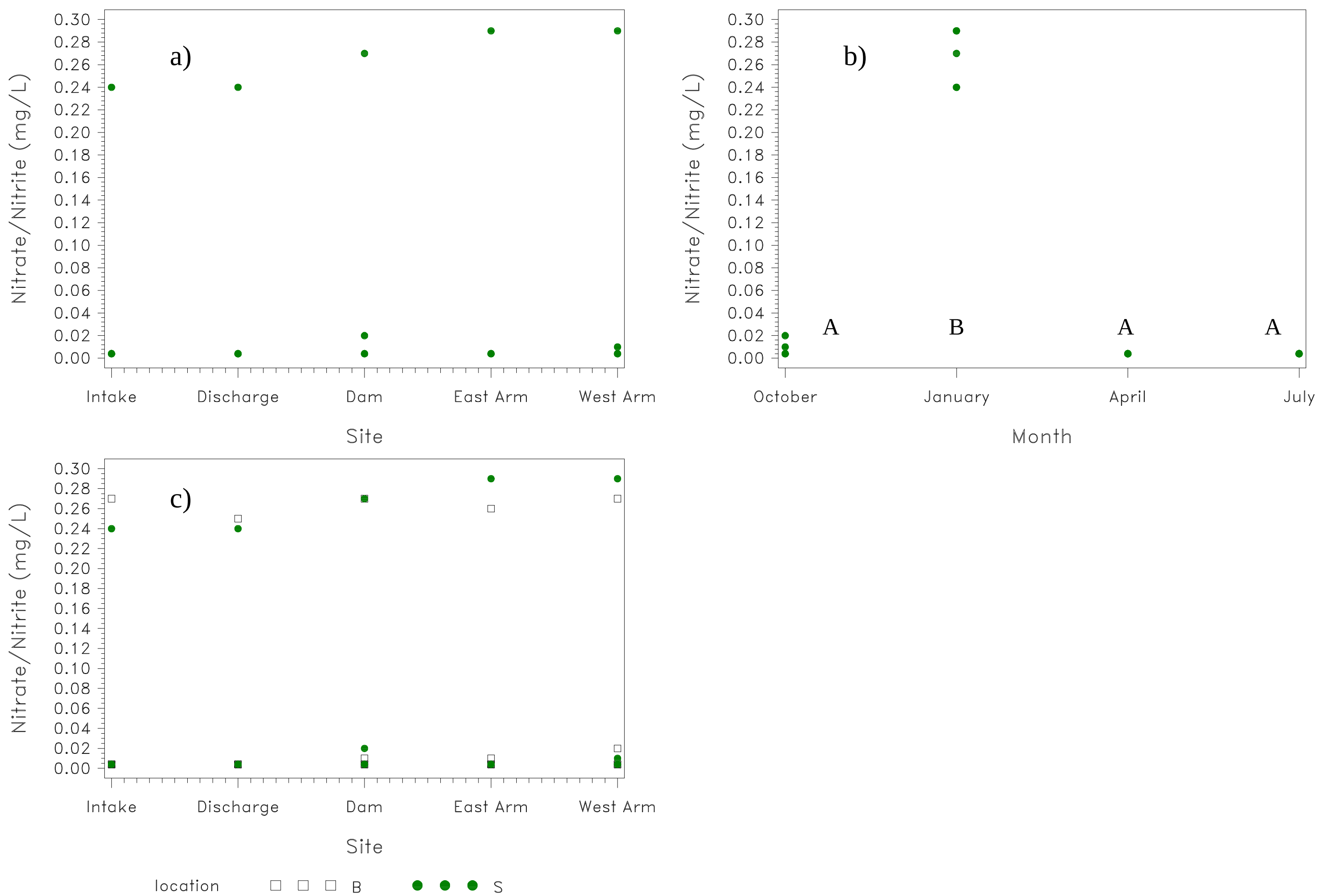

Figure 9: Nitrate/nitrite (mg/L) collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month c) for both the surface and at depth for each site. Letters in the plot indicate significant differences between categories. Categories that share similar letters are not significantly different.

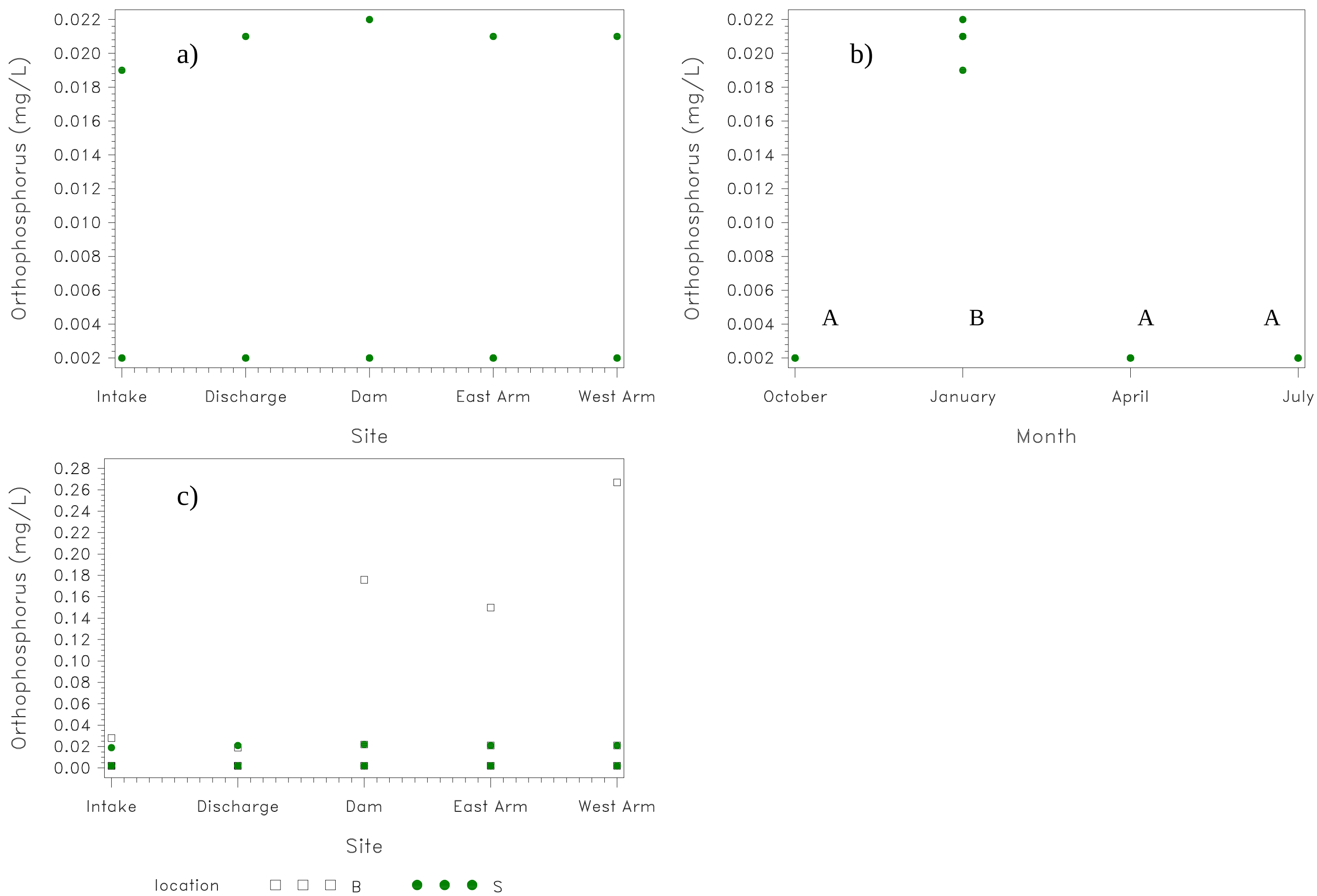

Figure 10: Orthophosphorus (mg/L) collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month c) for both the surface and at depth for each site. Letters in the plot indicate significant differences between categories. Categories that share similar letters are not significantly different.

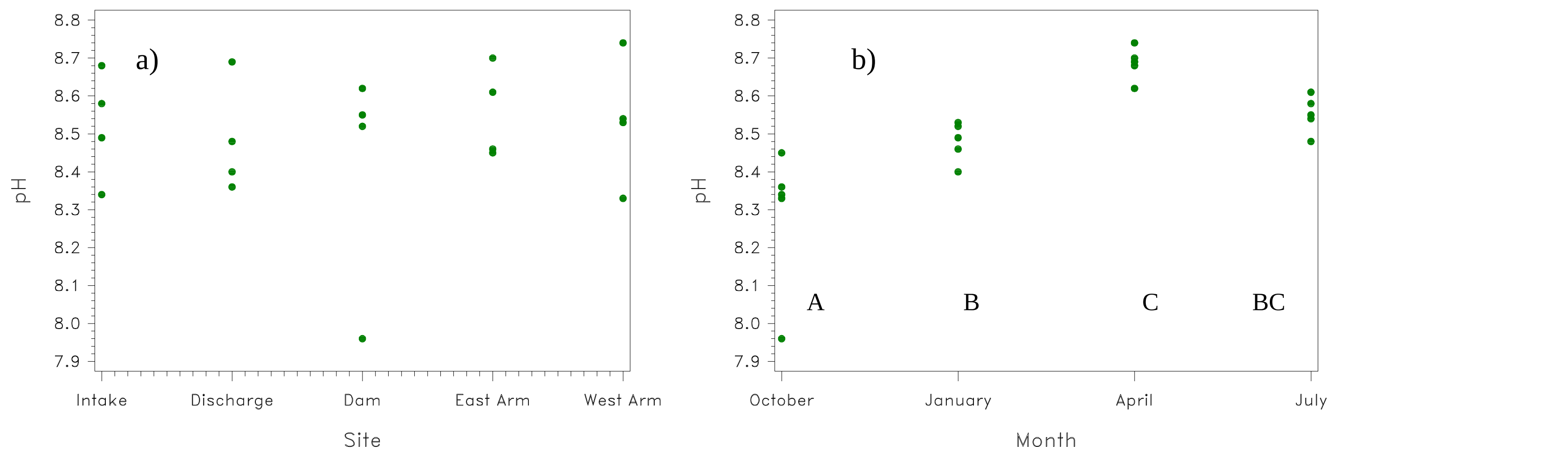

Figure 11: pH collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month. Letters in the plot indicate significant differences between categories. Categories that share similar letters are not significantly different.

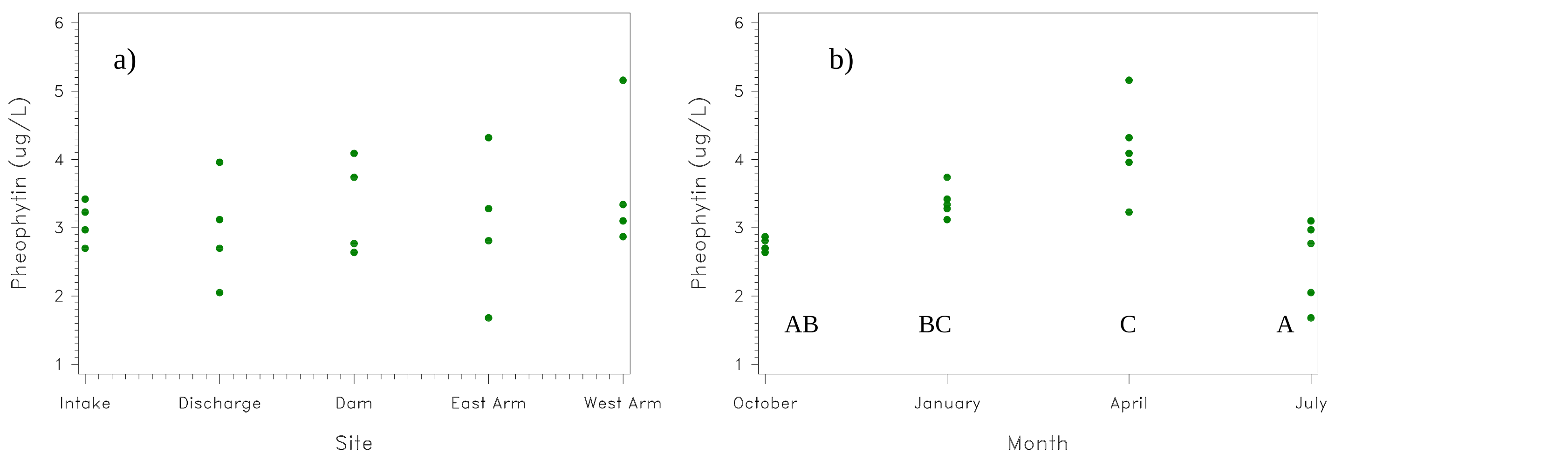

Figure 12: Pheophytin (µg/L) collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month. Letters in the plot indicate significant differences between categories. Categories that share similar letters are not significantly different.

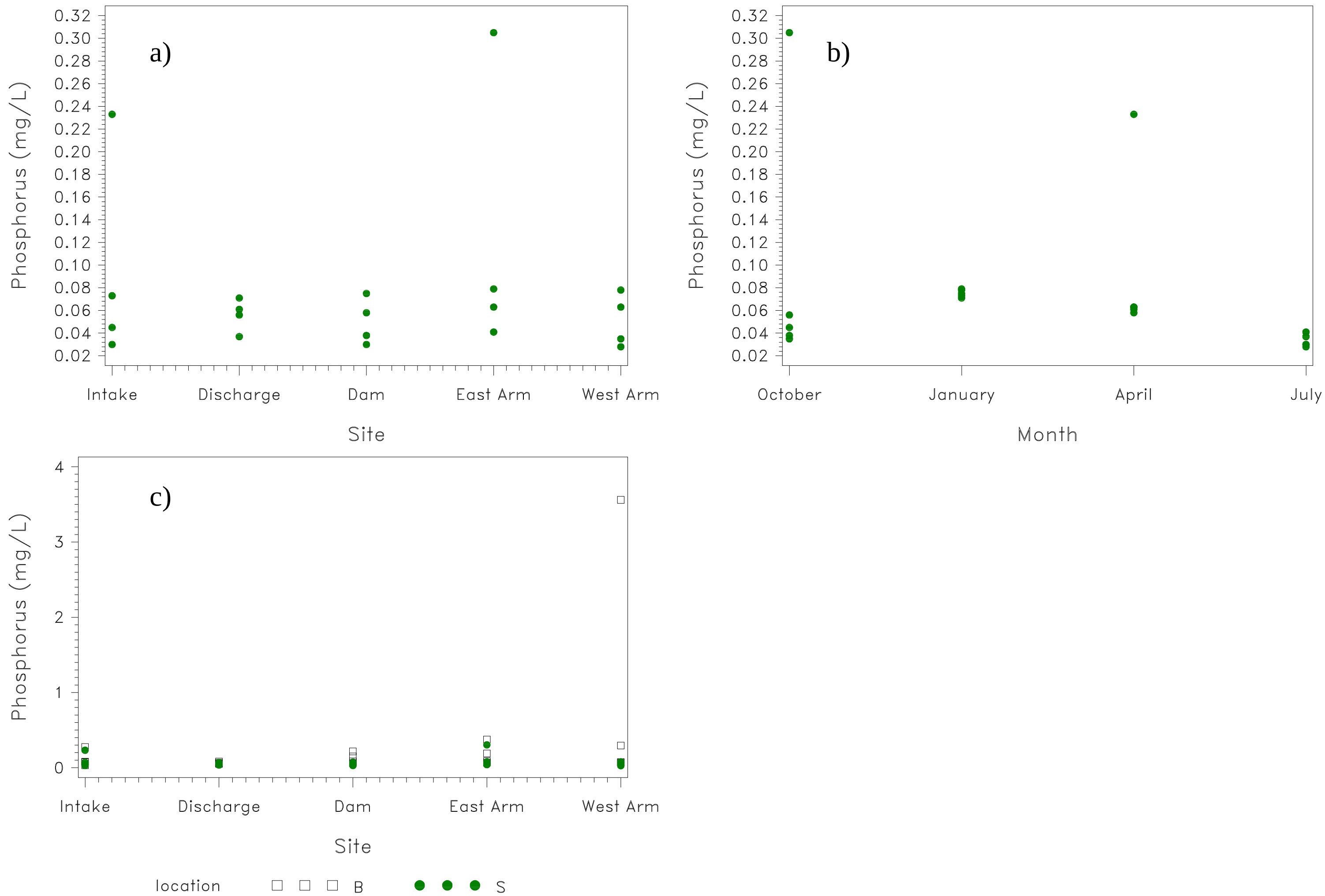

Figure 13: Phosphorus (mg/L) collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month c) for both the surface (S) and at depth (B) for each site.

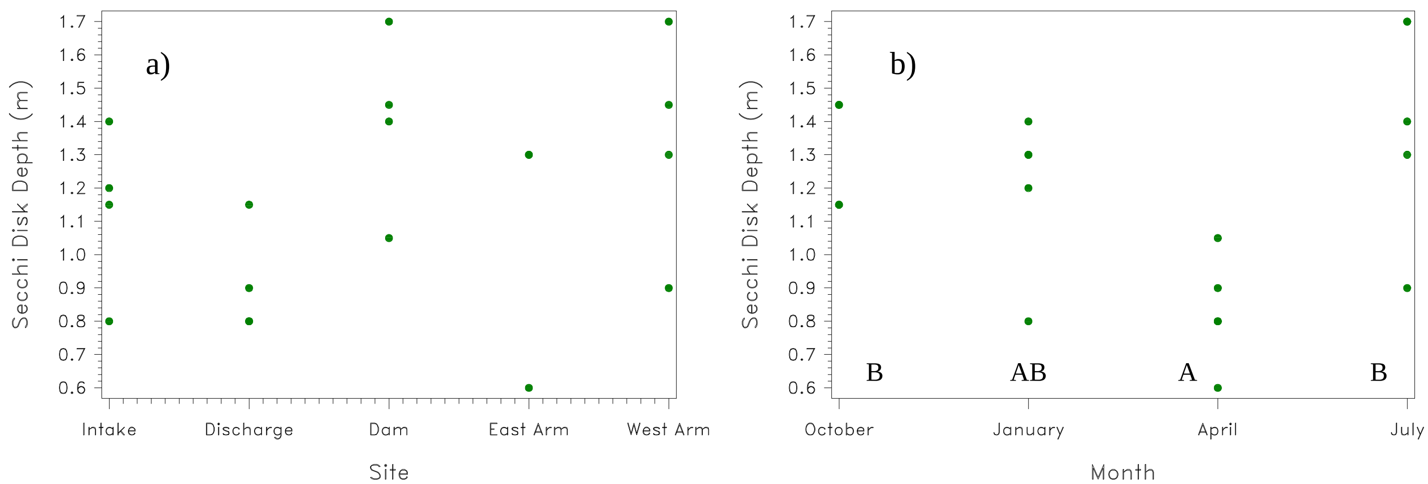

Figure 14: Secchi Disk Depth (m) collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month. Letters in the plot indicate significant differences between categories. Categories that share similar letters are not significantly different.

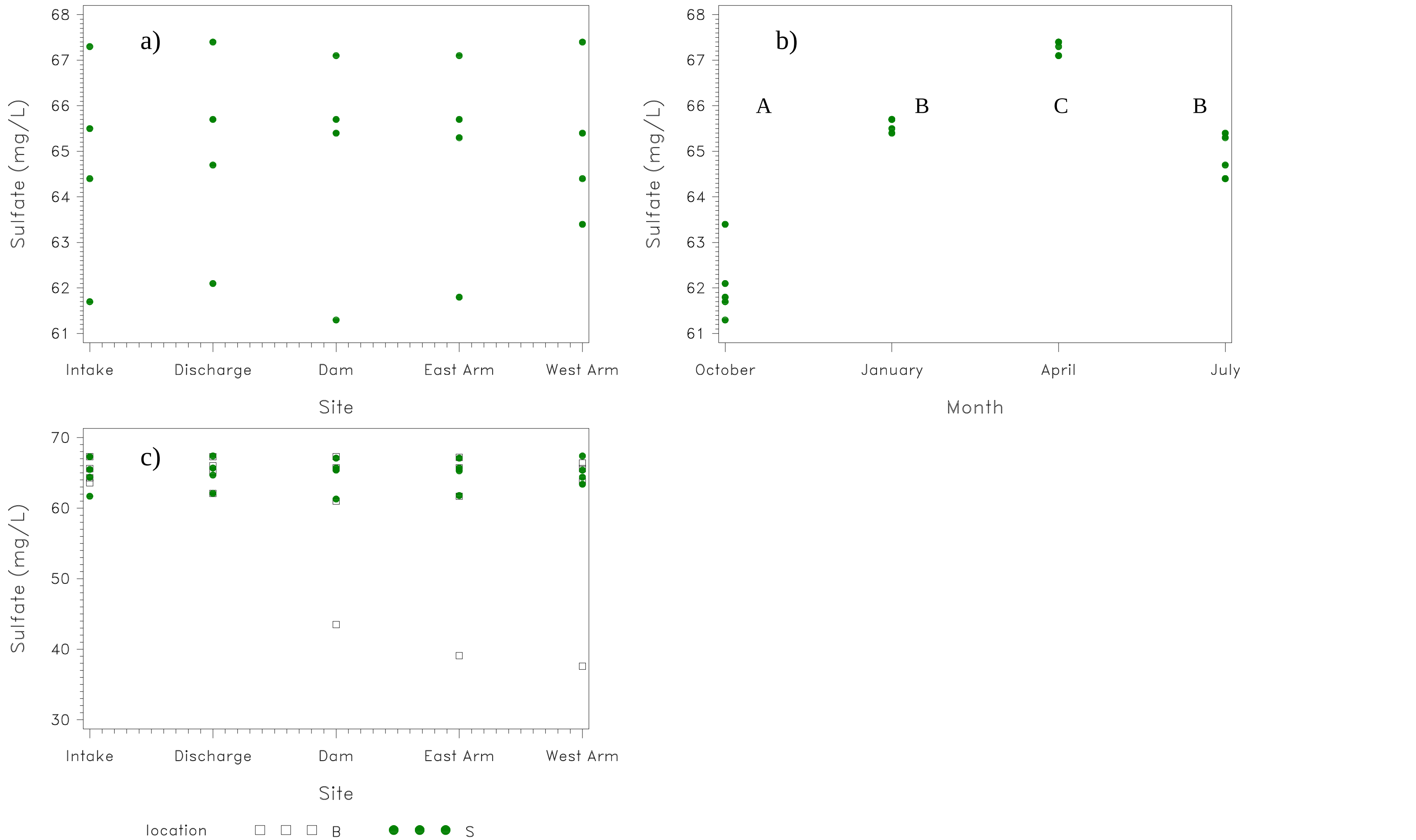

Figure 15: Sulfate (mg/L) collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month c) for both the surface (S) and at depth (B) for each site. Letters in the plot indicate significant differences between categories. Categories that share similar letters are not significantly different.

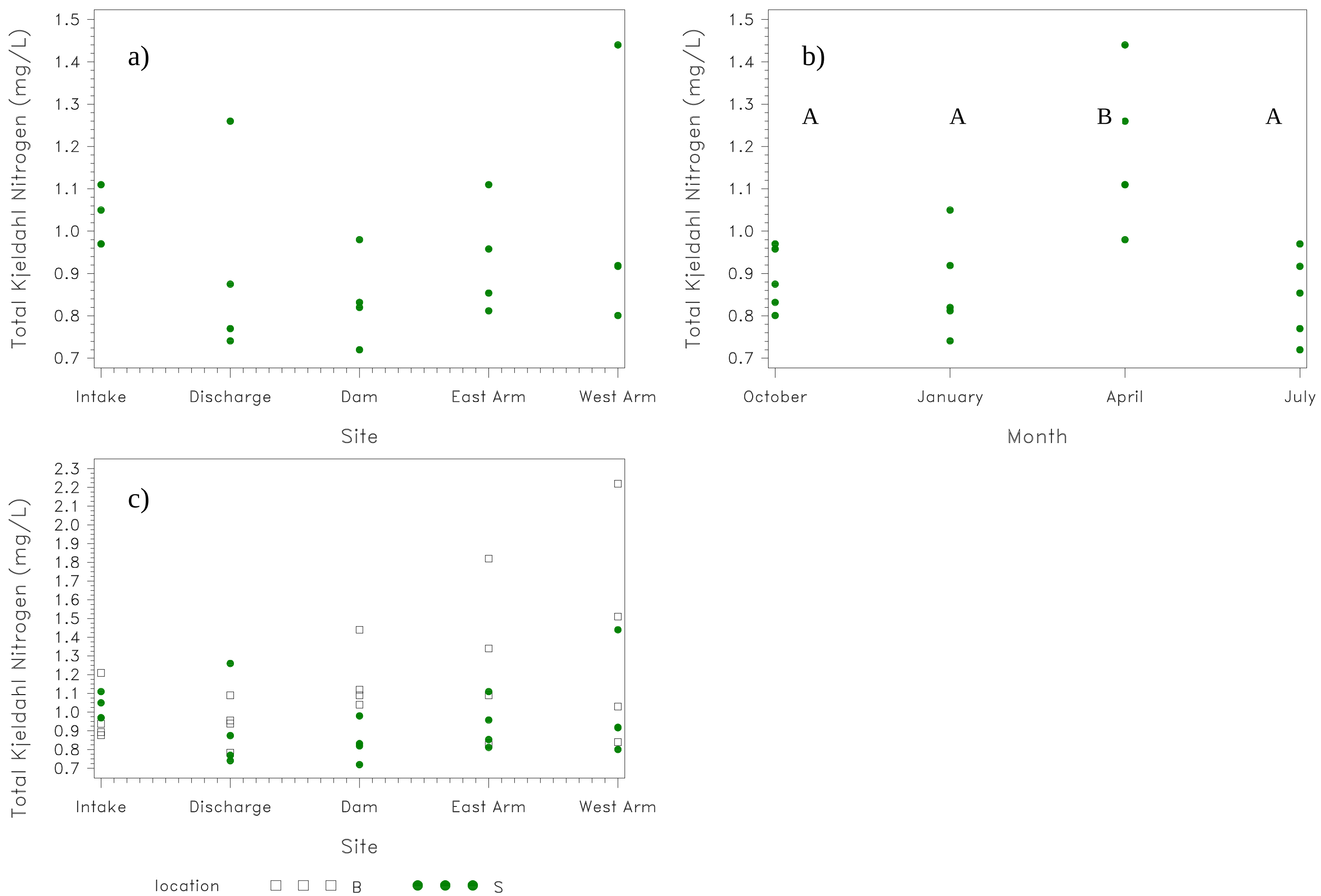

Figure 16: Total Kjeldahl Nitrogen (mg/L) collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month c) for both the surface (S) and at depth (B) for each site. Letters in the plot indicate significant differences between categories. Categories that share similar letters are not significantly different.

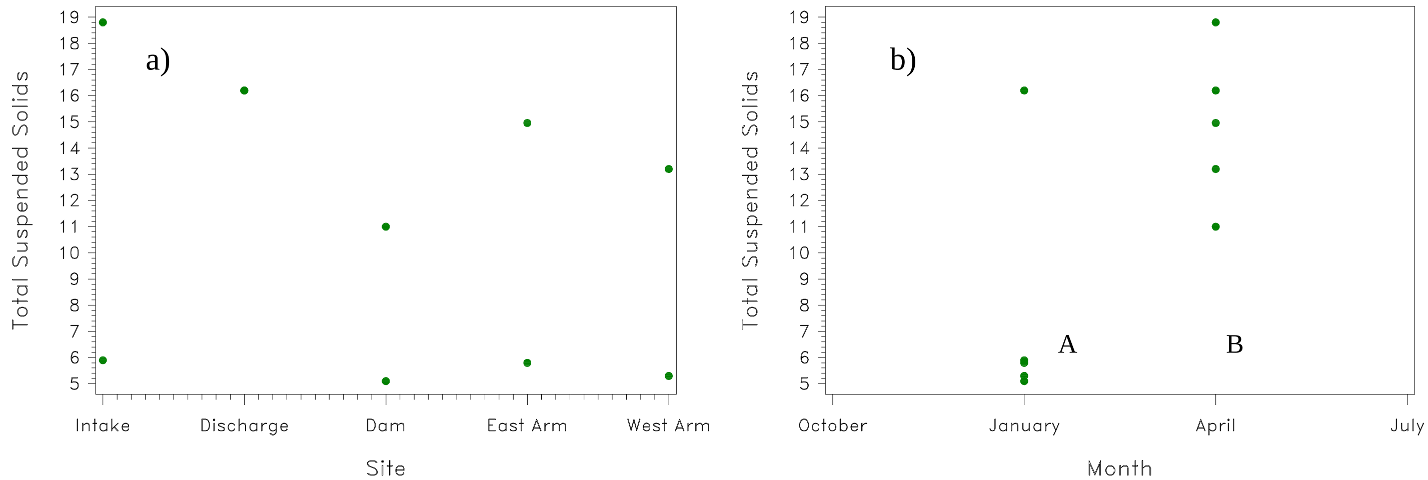

Figure 17: Total suspended solids (mg/L) collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month. Letters in the plot indicate significant differences between categories. Categories that share similar letters are not significantly different.

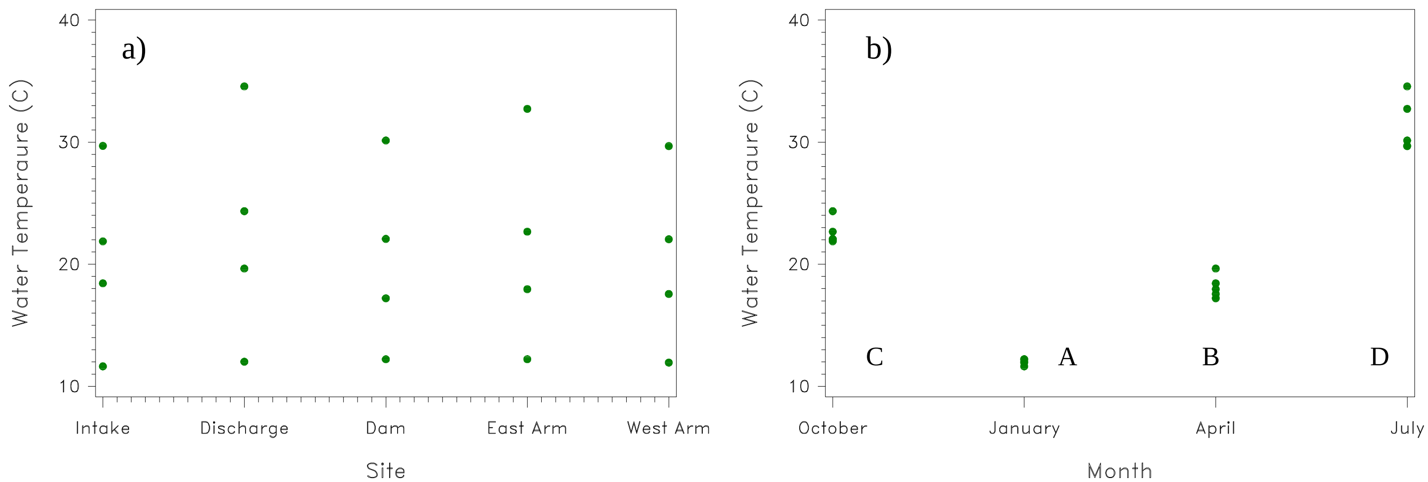

Figure 18: Water temperature (°C) collected on Lake Long during 2008 – 2009 a) at the surface for each site b) at the surface for each month. Letters in the plot indicate significant differences between categories. Categories that share similar letters are not significantly different.

The change in field parameters with depth for all sites is shown in Figures 19 – 24. A strong shift can indicate stratification of the water in the upper and lower portions of the lake. Nutrients can be trapped in the hypolimnion (bottom of the lake), unusable by the organisms at the top of the water body. In addition, organic material accumulating in the hypolimnion can create anoxic or low dissolved oxygen conditions as the decay processes use up oxygen (Fig 21b). A significant regression for a parameter indicated a significant shift in the value of that parameter as depth increased.

The depth at the intake site ranged from 5 m to 6 m. Conductivity significantly increased in July (R^2=0.7494) and in October (R^2=0.5778) as depth increased (Figure 19a). Dissolved oxygen significantly decreased in October (R^2=0.6223) from 7.85 mg/L to 6.55 mg/L (Figure 19b). The pH significantly decreased in January (R^2=0.9011), April (R^2=0.8657), and July (R^2=0.7370) with depth (Figure 19c). Water temperature significantly decreased in January (R^2=0.5977), April (R^2=0.6407), and July (R^2=0.8316) with depth (Figure 19d). The actual change in water temperature was less than one degree Celsius in every month.

Depth at the discharge site ranged from 4 m to 5 m. Conductivity significantly decreased in April (R^2=0.8795) with depth, but it significantly increased in July (R^2=0.6624) with depth (Figure 20a). Dissolved oxygen significantly decreased in July (R^2=0.6914) and in October (R^2=0.8900) with depth (Figure 20b). The pH significantly decreased in January (R^2=0.8122), April (R^2=0.9169), July (R^2=0.5880), and October (R^2=8684) with depth (Figure 20c). Water temperature decreased significantly in April (R^2=0.9572), July (R^2=0.8322), and October (R^2=0.8752) with depth (Figure 20d). The largest decrease in water temperature occurred in July where the overall decrease was around three degrees Celsius.

The depth at Lake Long at the Dam was deeper than the intake or the discharge with a depth range of 14 m to 15 m. Conductivity significantly increased in July (R^2=0.6880) and in October (R^2=0.2997) with depth (Figure 21a). The shift in conductivity was more dramatic in July as the conductivity jumped 30 µS/cm between 8 and 9 m of depth. Dissolved oxygen significantly decreased in January (R^2=0.3974), April (R^2=0.3223), July (R^2=0.8157), and October (R^2=0.6179) with depth (Figure 21b). The decrease in July was the most prominent as the dissolved oxygen dropped from between 5 and 6 mg/L close to the surface to less than 1 mg/L at depth. The pH significantly decreased in April (R^2=0.8722), July (R^2=0.8352), and October (R^2=0.7586) with depth (Figure 21c). In July the pH dropped from above 8.2 at 7 meters to around 7.2 at 9 meters. Water temperature decreased significantly in January (R^2=0.6498), April (R^2=0.7416), July (R^2=0.8189), and October (R^2=0.8687) with depth (Figure 21d). The decrease in water temperature for January, April, and October was less than half a degree overall, but the decrease in water temperature in July was over ten degrees Celsius.

Depth at the northeast arm on Lake Long remained constant at 11 m during all sampling events. Conductivity significantly increased in July (R^2=0.6933) and in October (R^2=0.4855) with depth (Figure 22a). A large increase in conductivity for July occurred between 8 and 9 m in depth similar to Lake Long at the Dam. Dissolved oxygen significantly decreased in January (R^2=0.3735), April (R^2=0.7790), July (R^2=0.8562), and October (R^2=6620) with depth (Figure 22b). The dissolved oxygen decreased by 6 mg/L in July from the surface to the bottom and decreased around 4 mg/L in October from the surface to the bottom. The pH significantly decreased in January (R^2=0.9468), April (R^2=0.8477), July (R^2=0.7755), and October (R^2=0.7677) with depth (Figure 22c). In July the largest decrease in pH happened between 6 and 9 meters while the largest decrease in October occurred between 2 and 4 meters. Water temperature significantly decreased in January (R^2=0.9206), April (R^2=0.8868), July (R^2=7840), and October (R^2=0.8192) with depth (Figure 22d). Temperature changes were less than one degree in January, April, and October, while the temperature change was over ten degrees Celsius in July.

Depth at the southwest arm ranged from 9 m to 11 m. Conductivity significantly increased in July (R^2=0.6103) and in October (R^2=0.7096) with depth (Figure 23a). There was a small jump in conductivity in July between 7 and 8 m followed by another large jump in conductivity between 8 and 9 m. Dissolved oxygen significantly increased in January (R^2=0.8118) with depth and significantly decreased in July (R^2=0.6765) and October (R^2=5906) with depth (Figure 23b). The pH significantly decreased in January (R^2=0.9664), April (R^2=0.8759), July (R^2=0.6699), and October (R^2=0.7536) with depth (Figure 23c). The largest decrease occurred in July between 7 and 9 meters where the pH decreased from above 8.4 to below 7.2 standard units. Water temperature significantly decreased in April (R^2=0.7994), July (R^2=0.5680), and October (R^2=0.8689) with depth (Figure 23d). Again the change for water temperature in April and October was minor while the temperature change in July was around ten degrees Celsius.

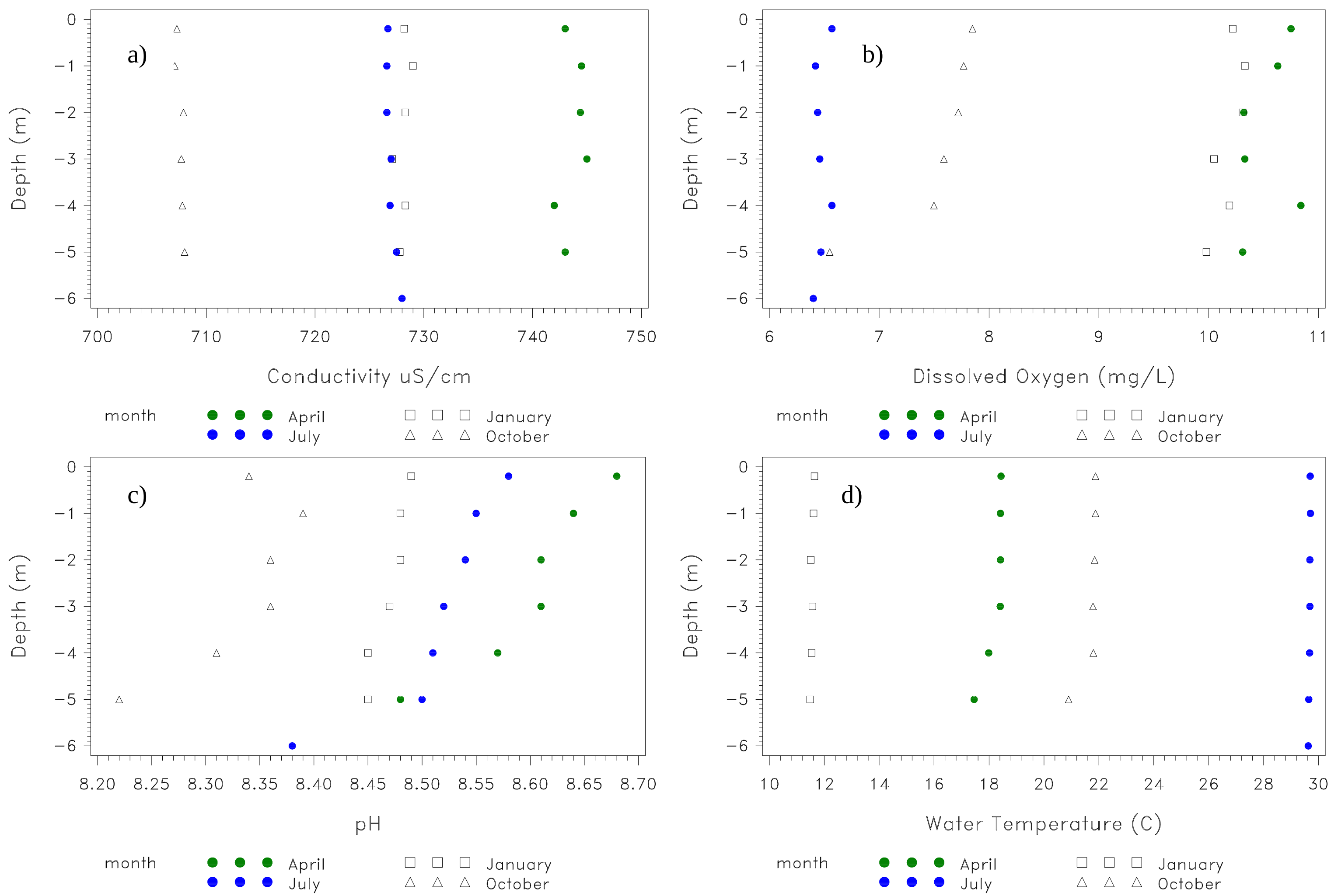

Figure 19: a) Conductivity, b) Dissolved Oxygen, c) pH, and d) water temperature collected at the intake on Lake Long in October 2008, April 2009, January 2009, and July 2009 as a function of depth in meters.

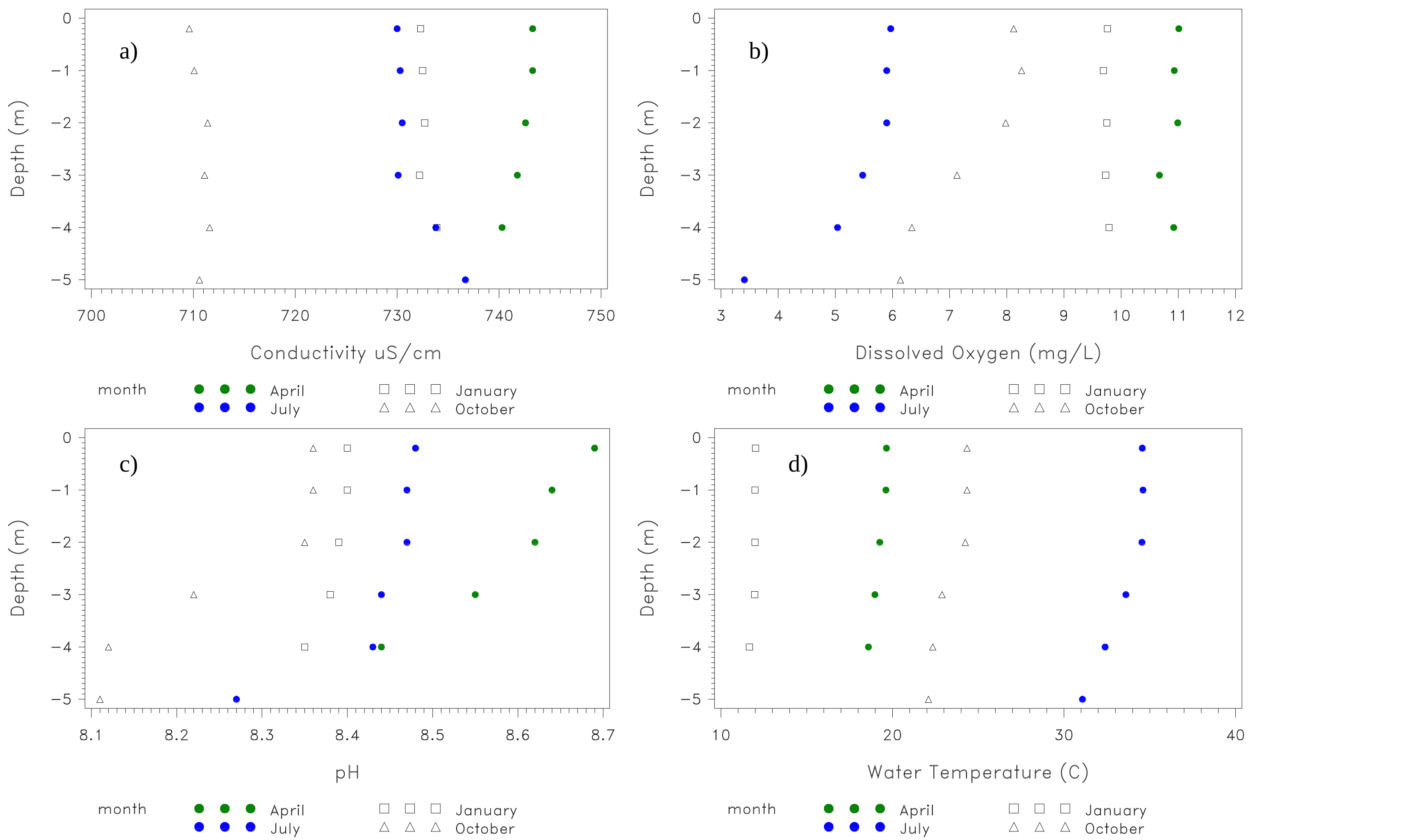

Figure 20: a) Conductivity, b) Dissolved Oxygen, c) pH, and d) water temperature collected at the discharge on Lake Long in October 2008, April 2009, January 2009, and July 2009 as a function of depth in meters.

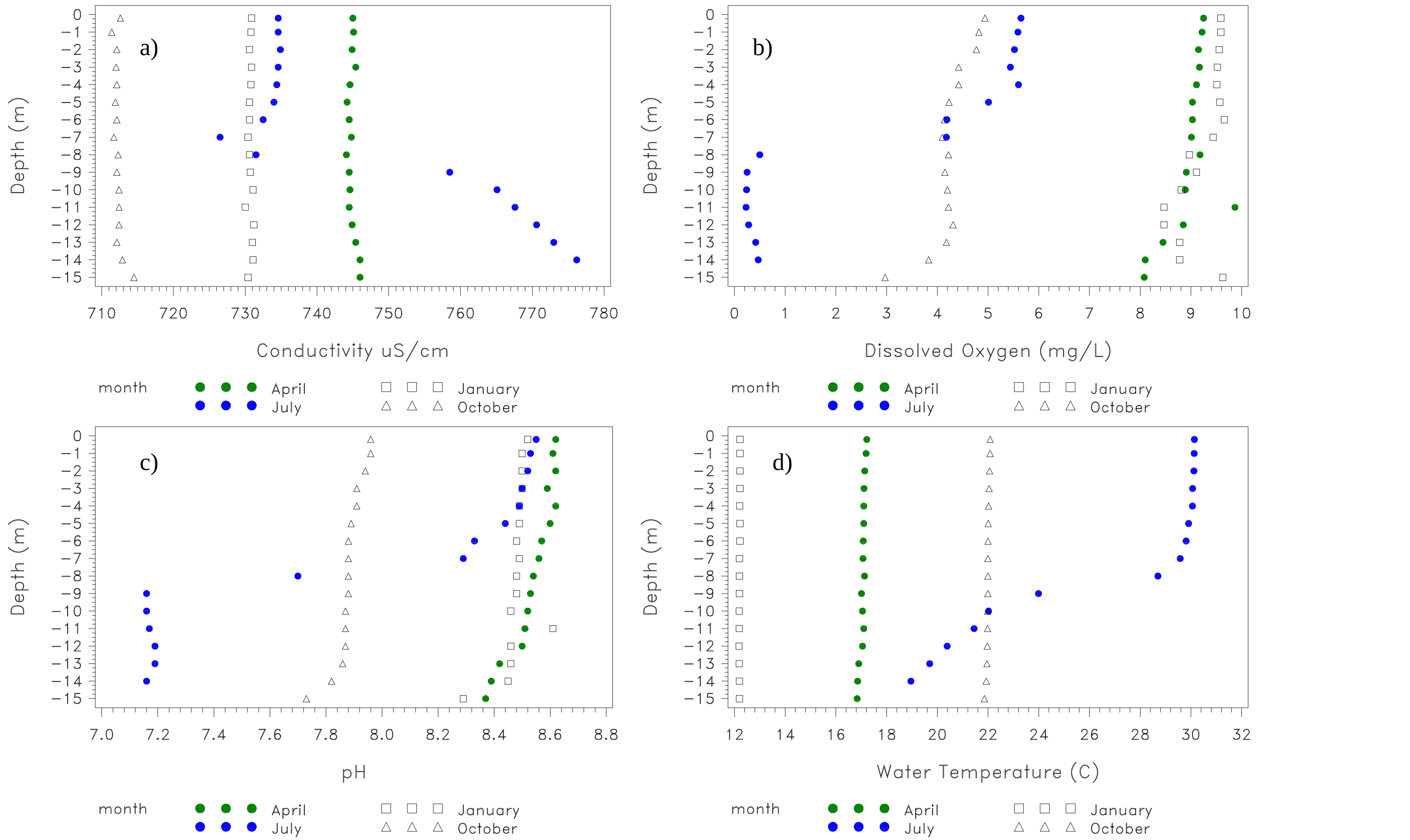

Figure 21: a) Conductivity, b) Dissolved Oxygen, c) pH, and d) water temperature collected at the dam on Lake Long in October 2008, April 2009, January 2009, and July 2009 as a function of depth in meters.

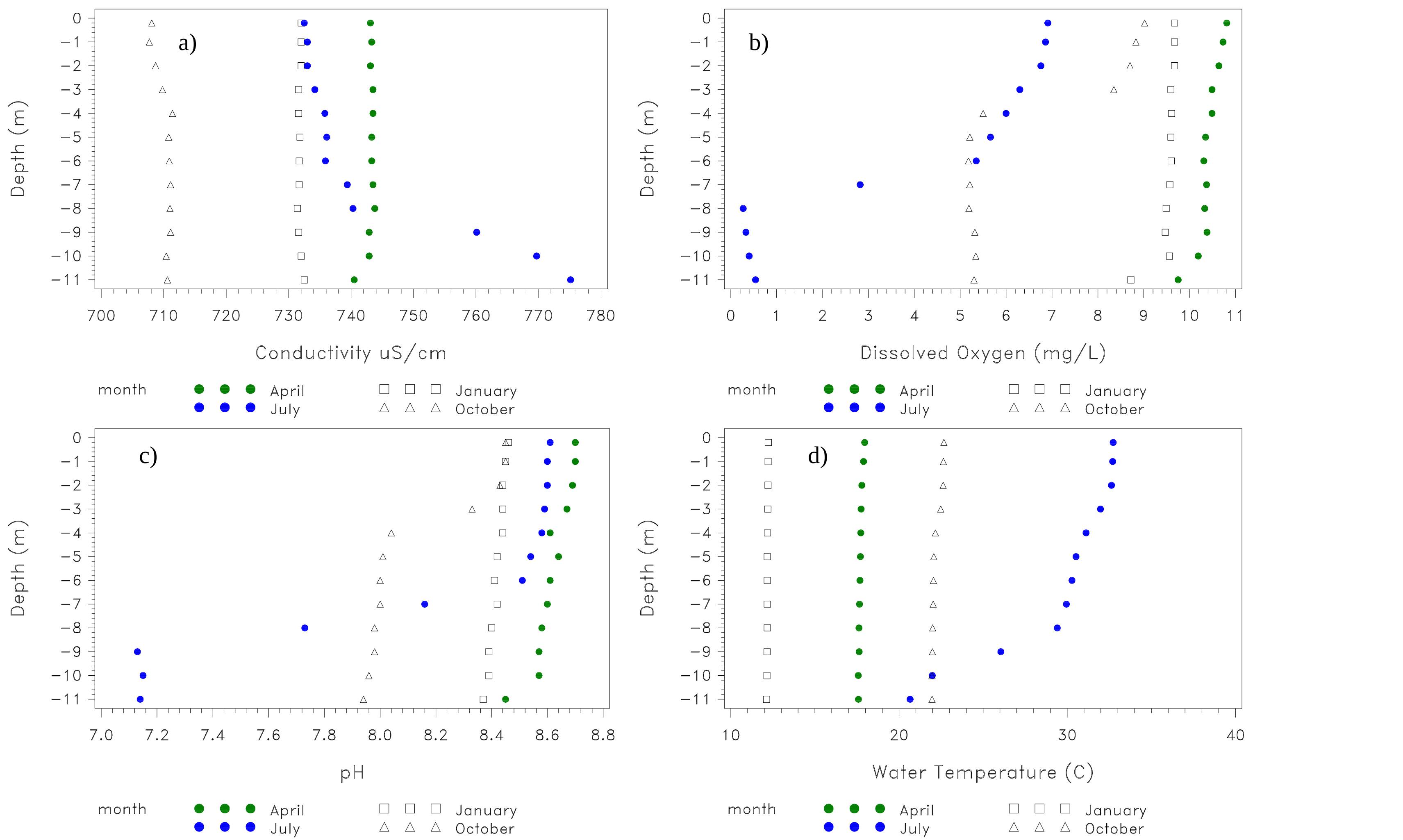

Figure 22: a) Conductivity, b) Dissolved Oxygen, c) pH, and d) water temperature collected at the northeast arm on Lake Long in October 2008, April 2009, January 2009, and July 2009 as a function of depth in meters.

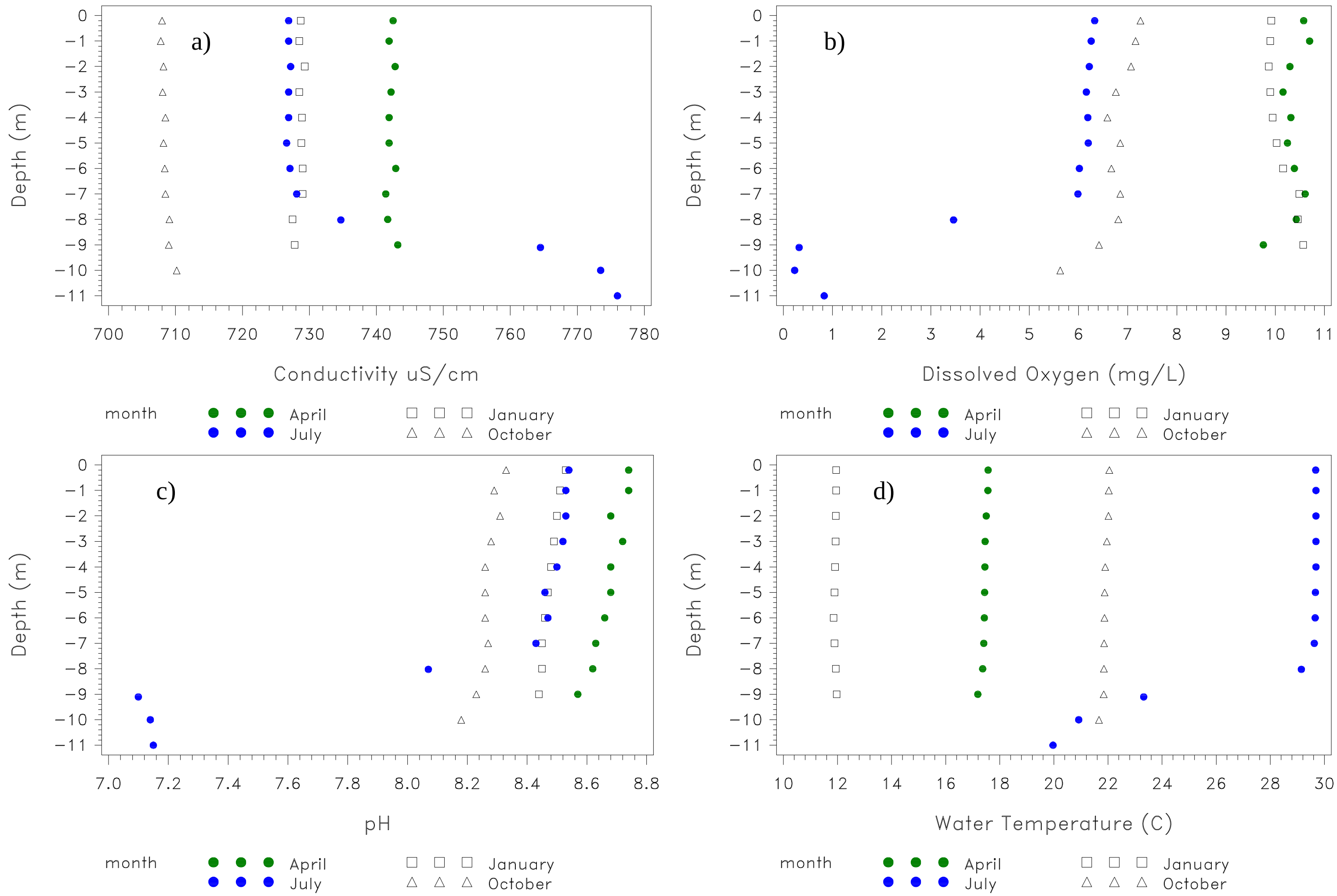

Figure 23: a) Conductivity, b) Dissolved Oxygen, c) pH, and d) water temperature collected at the southwest arm on Lake Long in October 2008, April 2009, January 2009, and July 2009 as a function of depth in meters.

The results of the non-metric Multidimensional Scaling (nMDS) ordination show there was no grouping by site on the lake, however, the phytoplankton communities were grouped by season (Figure 24). The samples labeled 4342, 4343, and 4344 (January samples) were colored yellow and clumped tightly together in the lower right portion of the graph. The samples labeled 4352, 4353, and 4354 (April samples) were colored red and were tightly clumped in the upper right portion of the graph. The samples labeled 4362 through 4366 (August samples) were clumped together in the left portion of the graph. The samples are clumped tightly enough in each seasonal grouping that there seems to be little difference between sites within a given season. The dendogram produced by the complete-linkage cluster analysis confirmed that the phytoplankton samples were grouped by season and not by site (Figure 25).

When the samples were grouped into seasons, a SIMPER analysis showed which species of phytoplankton were the most different between each group. The majority of the species that were dissimilar between the spring and winter groups were green algae (Table 8). There were a few blue-green algae genera like *Chroococcus*, *Nostoc*, and *Anabena* which were more abundant in the April sample, but it was mostly green algae that were more abundant in the April sample. The dissimilarity between the spring and summer samples showed that the green algae species were more abundant in the spring while the blue-green algae were more abundant in the summer (Table 9). Finally, for the dissimilarity between summer and winter groups it was mostly that blue-green algae were more abundant in the summer sample (Table 10).

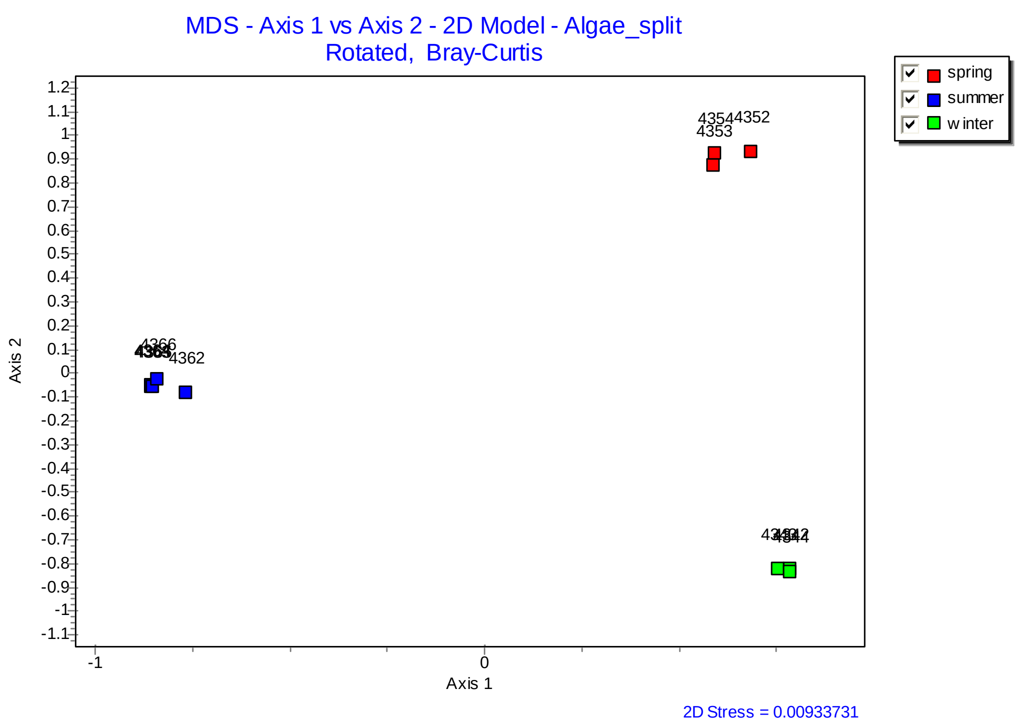

Figure 24: Non-metric Multidimensional Scaling ordination for phytoplankton species collected on Lake Long in January, April, and August 2009. The ordination used Bray-Curtis dissimilarity with two dimensions at 200 iterations. Yellow sites were collected in January, red sites were collected in April, and blue site were collected in August.

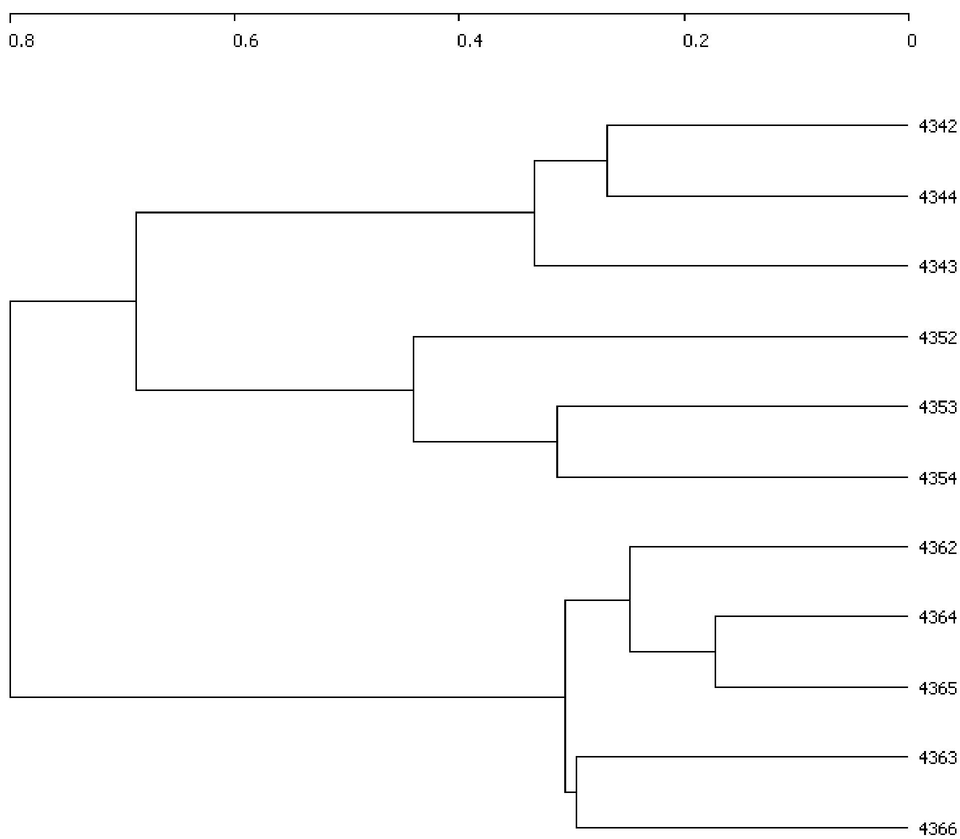

Figure 25: Dendogram produced by the complete-linkage cluster analysis of phytoplankton data collected on Lake Long in January, April, and August 2009. The intake site was labeled 4342, 4352, and 4362 for the January, April, and August sampling events respectively. Similar labeling conventions were used for the discharge, dam, east arm, and west arm on Lake Long.

Table 8: Dissimilarity of phytoplankton species present in the April sample (spring) and in the January sample (winter) produced by the SIMPER analysis. The average abundance represents the abundance of a given species within a group. The percent contribution of each phytoplankton species to the overall dissimilarity between the groups is also given.

	spring	winter			
Species	Average Abundance	Average Abundance	Average Dissimilarity	% Contribution	Cumulative %
UNIDENTIFIED ALGAE 1	0	2.74904	3.26577	5.11735	5.11735
CHROOCOCCUS SP.	0	2.71368	3.21885	5.04383	10.1612
ANKISTRODESMUS FALCATUS	2.36734	0	2.80918	4.40189	14.5631
PERIDINIUM	1.97853	0	2.35345	3.68778	18.2508
CHROOCOCCUS	1.99782	0	2.31227	3.62325	21.8741
CLOSTERIOPSIS LONGISSIMA	1.95319	0	2.30531	3.61234	25.4864
CHLAMYDOMONAS	1.93013	0	2.29355	3.59392	29.0804
CRUCIGENIA	0	1.879	2.22667	3.48912	32.5695
CHLAMYDOMONAS SP.	0	1.71409	2.04145	3.19888	35.7684

Table 8 (cont.): Dissimilarity of phytoplankton species present in the April sample (spring) and in the January sample (winter) produced by the SIMPER analysis. The average abundance represents the abundance of a given species within a group. The percent contribution of each phytoplankton species to the overall dissimilarity between the groups is also given.

	spring	winter			
Species	Average Abundance	Average Abundance	Average Dissimilarity	% Contribution	Cumulative %
NOSTOC	1.67279	0	2.01783	3.16187	38.9302
ANABAENA	1.80687	0.6835	1.85288	2.90339	41.8336
UNIDENTIFIED EUGLENOPHYTE	0	1.48711	1.76548	2.76644	44.6001
CRUCIGENIA TETRAPEDIA	1.45927	0	1.75756	2.75403	47.3541
OOCYSTIS	2.65219	1.24957	1.6318	2.55697	49.9111
COELOSPHAERIUM	1.84848	0.548473	1.60395	2.51334	52.4244
SPHAEROCYSTIS	0.765027	1.41323	1.45208	2.27536	54.6998
CERATIUM HIRUDINELLA	1.18817	0	1.42611	2.23466	56.9344
TETRASTRUM	1.19183	0	1.37996	2.16234	59.0968
GLOEOTHECE	0.487667	1.33167	1.36483	2.13865	61.2354
SCENEDESMUS	2.10262	1.01972	1.32756	2.08024	63.3156
QUADRIGULA CLOSTERIOIDES	1.09367	0	1.26548	1.98297	65.2986
PHACUS	1.87205	0.903543	1.13704	1.7817	67.0803
STAURASTRUM	0.622253	1.00144	1.13384	1.77668	68.857
COSMARIUM	0.508177	1.2384	1.09894	1.722	70.579
KIRCHNERIELLA OBESA	1.48985	2.14738	1.01254	1.58662	72.1656
SCHIZOTHRIX	1.774	0.93915	0.99913	1.5656	73.7312
CHLOROCOCCUM	0.802187	0	0.997529	1.56309	75.2943
CHLORELLA	2.48716	1.70307	0.994209	1.55789	76.8522
TETRAEDRON MINIMUM	0	0.807977	0.974813	1.5275	78.3797
CHARACIUM	0	0.807977	0.974813	1.5275	79.9072
PEDIATSTRUM SIMPLEX	0.487667	0.807977	0.906038	1.41973	81.3269
SPHAEROCYSTIS SCHROETERI	0.763907	0	0.890828	1.3959	82.7228
EUGLENA SP.	1.01153	0.82626	0.885632	1.38775	84.1106
DICTYOSPHAERIUM	2.18785	1.48762	0.851474	1.33423	85.4448
ALGAE GREEN	0.680333	0	0.846003	1.32566	86.7705
OSCILLATORIA SP.	0.643343	0	0.739358	1.15855	87.929
CHARACIUM LIMNETICUM	0.60634	0	0.707082	1.10797	89.037
UNIDENTIFIED ALGAE 2	0	0.5893	0.675085	1.05783	90.0948

Table 9: Dissimilarity of phytoplankton species present in the April sample (spring) and in the August sample (summer) produced by the SIMPER analysis. The average abundance represents the abundance of a given species within a group. The percent contribution of each phytoplankton species to the overall dissimilarity between the groups is also given.

	spring	summer			
Species	Average Abundance	Average Abundance	Average Dissimilarity	% Contribution	Cumulative %
MERISMOPEDIA GLAUCA	0	2.97739	3.0015	4.81311	4.81311
SPIRULINA	0	2.72559	2.74803	4.40665	9.21976
CHLORELLA	2.48716	0	2.5104	4.0256	13.2454
ANKISTRODESMUS FALCATUS	2.36734	0	2.386	3.82611	17.0715
COSMARIUM	0.508177	2.57317	2.08689	3.34647	20.4179
PERIDINIUM	1.97853	0	1.99817	3.2042	23.6221
CLOSTERIOPSIS LONGISSIMA	1.95319	0	1.95966	3.14245	26.7646
CHLAMYDOMONAS	1.93013	0	1.94764	3.12316	29.8878
TETRAEDRON MINIMUM	0	1.92958	1.9445	3.11814	33.0059
OOCYSTIS	2.65219	0.942222	1.72777	2.77059	35.7765
PHACUS	1.87205	0.296916	1.59582	2.559	38.3355
OSCILLATORIA SP.	0.643343	2.12109	1.56963	2.517	40.8525
UNIDENTIFIED ALGAE 3	0	1.50978	1.51342	2.42686	43.2794
SCHIZOTHRIX	1.774	3.27502	1.50588	2.41478	45.6941
DINOBRYON	0	1.45069	1.45661	2.33578	48.0299
CHROOCOCCUS	1.99782	3.26931	1.32707	2.12804	50.158
KIRCHNERIELLA OBESA	1.48985	0.631046	1.27098	2.03811	52.1961
CRUCIGENIA TETRAPEDIA	1.45927	0.67987	1.2472	1.99997	54.196
DICTYOSPHAERIUM	2.18785	0.986878	1.21401	1.94675	56.1428
MERISMOPEDIA CONVOLUTA	0	1.22448	1.21313	1.94533	58.0881
CERATIUM HIRUDINELLA	1.18817	0	1.20919	1.93902	60.0271
MICROCYSTIS	0.585493	1.49649	1.20533	1.93283	61.96
SPHAEROCYSTIS	0.765027	1.26717	1.19513	1.91647	63.8764
TETRASTRUM	1.19183	0	1.17659	1.88674	65.7632
CHARACIUM	0	1.13207	1.13125	1.81403	67.5772
ANABAENA	1.80687	2.48663	1.0945	1.7551	69.3323
QUADRIGULA CLOSTERIOIDES	1.09367	0	1.07909	1.73039	71.0627
UNIDENTIFIED DINOFLAGELLATE	0	1.02869	1.03609	1.66143	72.7241
EUGLENA SP.	1.01153	0	1.02777	1.64809	74.3722
NOSTOC	1.67279	2.00608	1.00006	1.60366	75.9759
TRACHELOMONAS	0	0.935532	0.941535	1.50981	77.4857
PANDORINA MORUM	0	0.94952	0.940023	1.50739	78.9931
CHLOROCOCCUM	0.802187	0	0.841264	1.34902	80.3421
SCENEDESMUS	2.10262	1.28392	0.820459	1.31566	81.6578
DISPORA	0	0.763422	0.779507	1.24999	82.9078

Table 9 (cont.): Dissimilarity of phytoplankton species present in the April sample (spring) and in the August sample (summer) produced by the SIMPER analysis. The average abundance represents the abundance of a given species within a group. The percent contribution of each phytoplankton species to the overall dissimilarity between the groups is also given.

	spring	summer			
Species	Average Abundance	Average Abundance	Average Dissimilarity	% Contribution	Cumulative %
SPHAEROCYSTIS SCHROETERI	0.763907	0	0.758741	1.21669	84.1245
ANKISTRODESMUS	0	0.725332	0.749004	1.20108	85.3255
PEDIATSTRUM SIMPLEX	0.487667	0.638616	0.742955	1.19138	86.5169
SCHROEDERIA SETIGERA	0.523863	0.593832	0.7306	1.17157	87.6885
ALGAE GREEN	0.680333	0	0.713475	1.1441	88.8326
STAURASTRUM	0.622253	0	0.652566	1.04643	89.879
COELASTRUM	2.06125	1.55753	0.638439	1.02378	90.9028

Table 10: Dissimilarity of phytoplankton species present in the August sample (summer) and in the January sample (winter) produced by the SIMPER analysis. The average abundance represents the abundance of a given species within a group. The percent contribution of each phytoplankton species to the overall dissimilarity between the groups is also given.

	summer	winter			
Species	Average Abundance	Average Abundance	Average Dissimilarity	% Contribution	Cumulative %
CHROOCOCCUS	3.26931	0	3.83427	5.45177	5.45177
UNIDENTIFIED ALGAE 1	0	2.74904	3.22975	4.59222	10.044
SPIRULINA	2.72559	0	3.19996	4.54987	14.5939
CHROOCOCCUS SP.	0	2.71368	3.1834	4.52633	19.1202
MERISMOPEDIA GLAUCA	2.97739	0.43042	3.00603	4.27412	23.3943
SCHIZOTHRIX	3.27502	0.93915	2.72622	3.87628	27.2706
OSCILLATORIA SP.	2.12109	0	2.49767	3.55131	30.8219
NOSTOC	2.00608	0	2.35387	3.34686	34.1688
CRUCIGENIA	0	1.879	2.20218	3.13117	37.2999
ANABAENA	2.48663	0.6835	2.13929	3.04176	40.3417
CHLAMYDOMONAS SP.	0	1.71409	2.01887	2.87054	43.2122
CHLORELLA	0	1.70307	1.99832	2.84131	46.0535
UNIDENTIFIED ALGAE 3	1.50978	0	1.7606	2.50332	48.5569
KIRCHNERIELLA OBESA	0.631046	2.14738	1.75113	2.48985	51.0467
MICROCYSTIS	1.49649	0	1.74838	2.48594	53.5327
UNIDENTIFIED EUGLENOPHYTE	0	1.48711	1.74602	2.48258	56.0152
DINOBRYON	1.45069	0	1.69501	2.41005	58.4253
COELOSPHAERIUM	1.96464	0.548473	1.67663	2.38392	60.8092
COSMARIUM	2.57317	1.2384	1.56443	2.22438	63.0336
GLOEOTHECE	0	1.33167	1.51148	2.14909	65.1827

Table 10 (cont.): Dissimilarity of phytoplankton species present in the August sample (summer) and in the January sample (winter) produced by the SIMPER analysis. The average abundance represents the abundance of a given species within a group. The percent contribution of each phytoplankton species to the overall dissimilarity between the groups is also given.

	summer	winter			
Species	Average Abundance	Average Abundance	Average Dissimilarity	% Contribution	Cumulative %
MERISMOPEDIA CONVOLUTA	1.22448	0	1.40847	2.00264	67.1853
TETRAEDRON MINIMUM	1.92958	0.807977	1.30022	1.84872	69.0341
STAURASTRUM	0	1.00144	1.18316	1.68228	70.7163
SPHAEROCYSTIS	1.26717	1.41323	1.1763	1.67252	72.3888
OOCYSTIS	0.942222	1.24957	1.13822	1.61839	74.0072
CHARACIUM	1.13207	0.807977	1.13599	1.61521	75.6224
UNIDENTIFIED DINOFLAGELLATE	1.02869	0.43042	1.10902	1.57686	77.1993
TRACHELOMONAS	0.935532	0	1.096	1.55835	78.7577
PANDORINA MORUM	0.94952	0	1.09126	1.5516	80.3093
PHACUS	0.296916	0.903543	0.994427	1.41393	81.7232
PEDIATSTRUM SIMPLEX	0.638616	0.807977	0.939729	1.33616	83.0593
EUGLENA SP.	0	0.82626	0.937673	1.33323	84.3926
SYNECHOCOCCUS	2.66626	1.87968	0.923969	1.31375	85.7063
SCENEDESMUS	1.28392	1.01972	0.911013	1.29533	87.0017
DISPORA	0.763422	0	0.90957	1.29327	88.2949
ANKISTRODESMUS	0.725332	0	0.87561	1.24499	89.5399
DICTYOSPHAERIUM	0.986878	1.48762	0.862215	1.22594	90.7659

Recommendations

Lake Long exceeded the current TCEQ screening levels for “general use” (which incorporates aquatic life, recreation, public water supply, and other uses of water) for nutrient and chlorophyll-a values during several of the sampling events. Also, differences existed between Lake Long data and Lady Bird Lake (Town Lake) data. For these reasons, it is recommended that monitoring continue for the next year with another review at the end of the year. Continued monitoring would allow a firmer determination of the trophic status of the lake. This could be used for future modeling of nutrient impacts of increased development in the watershed if necessary to evaluate Best Management Practices or changes in watershed regulations.

Although continued monitoring is recommended, the site number should be reduced, as sample sites are not significantly different. The exceedances for chlorophyll-a and the nutrients occur mostly on the northeast arm, southwest arm, and dam sites. Both the intake site and discharge site are recommended for removal from the water quality monitoring site list. Sediment data does not exceed the TCEQ standards, so sediment monitoring is recommended to be reduced to the dam site only. Phytoplankton community identification should continue at the southwest arm, northeast arm, and the dam in conjunction with ongoing water quality sampling.

The current depth regime should be maintained in order to continue tracking changes in nutrients with depth.

The quarterly sampling of Lake Long may be unnecessary. Although the January sampling event showed significantly higher nutrient values at the surface for nitrate and orthophosphorus, the values did not exceed the TCEQ screening level. The chlorophyll-a value was low in January and the phytoplankton community analysis showed that the winter samples had less abundant species. The January sampling event should be dropped for the current year, with the ability to add a winter sample based on future analysis.

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