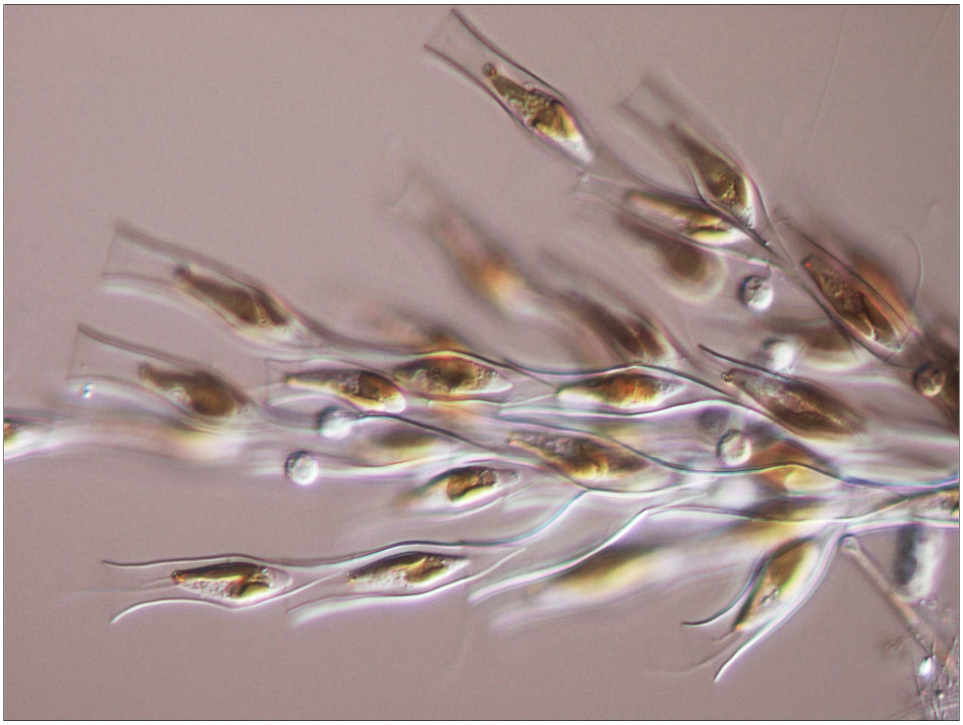
3-11-2011

Lake Samish Water Monitoring Project 2011 Final Report

Robin A. Matthews
Western Washington University, robin.matthews@wwu.edu

Joan Vandersypen
Western Washington University, joan.vandersypen@wwu.edu



Lake Samish Water Monitoring Project
2011 Final Report

Dr. Robin A. Matthews
Ms. Joan Vandersypen

Institute for Watershed Studies
Huxley College of the Environment
Western Washington University

March 11, 2011

Funding for this project was provided by the Samish Water District. We thank students Clay Bailes, Jeff Edwards, Rachael Gravon, Kara Hitchko, Kris Kannarr, Jessie Rosanbalm, Jordan Sly, Dan Whealdon-Haught; Huxley College GIS Specialist Stefan Freelan; and volunteers Mark Herrenkohl, Gordon Nolan, John Ploeger, and Kathy Ploeger for their assistance.

Contents

List of Figures

List of Tables

Background Information

Lake Samish is a valuable aquatic resource, providing public access for boating, fishing, swimming, picnicking, and other water and lakeshore activities. Residents around the lake enjoy outstanding views of both the lake and its surrounding watershed, and the lake serves as a water supply for many of the lakeshore residents. Lake Samish is located in the Washington State Department of Ecology's Water Resource Inventory Area #3 (WRIA 3), and discharges into Friday Creek, a salmon spawning tributary of the Samish River.

Lake Samish experiences periodic algal blooms, including blooms of potentially toxic cyanobacteria. The major goal of the monitoring project was to collect data that would help identify the causes of the blooms, and possibly provide insight into how to protect the lake from water quality degradation.

The Lake Samish monitoring project was initiated in June 2005 to collect water quality data from the lake and from major tributaries in the watershed. This report describes work done as a continuation of the monitoring project started in 2005. Additional information is available in previous summary reports (Matthews, et al., 2006; Matthews and Vandersypen, 2007; 2008; 2010).

Although the primary goal for this project was to collect baseline water quality data, a second goal was to begin looking as options for protecting water quality in the lake. A full assessment of lake management options is beyond the scope of this project, but several important observations can be made concerning the direction of future lake management efforts.

Lake Samish features that affect management choices: First, is it important to recognize the features of Lake Samish that will affect management options and factor heavily into the success of any lake management effort. Lake Samish is predominantly a shallow, mesotrophic lake. With the exception of the west arm, which is unusual in itself, the lake favors the growth of aquatic plants, whether they are algae, cyanobacteria, or shoreline vegetation. The mean depth in the east arm is only 9.4 m (Bortleson, et al., 1976), and all of the east arm sites have had high chlorophyll concentrations at some point during the monitoring project. While the lake is shallow enough to support algal growth throughout the water column, it is deep enough to stratify in both arms. Because of it's mesotrophic state, the hypolimnion in both arms becomes anoxic, releasing phosphorus. The water column in the west arm may not mix thoroughly during winter (Figure 3, page 10), which can result in extended periods of anoxia in the hypolimnion that persist past winter and into the next period of stratification. This has the potential to release of large amounts of phosphorus into the lake from the sediments (Figure 7, page 14). The release of phosphorus from sediments due to low oxygen concentrations in the hypolimnion is called *internal phosphorus loading,* and is one of the items that must be considered in the future management of Lake Samish.

A second important feature that affects lake management is land use in the Lake Samish watershed. The tributary data revealed that there is *external phosphorus loading* from the watershed. The lakeshore is developed, mostly with single-family homes, and the upper watershed is largely devoted to forestry and timber harvesting. A major interstate highway, with heavy truck and vehicle traffic, passes along the eastern side of the lake. Although these land use activities are not necessarily incompatible with recreational use of the lake, they are not particularly desirable in a lake that provides drinking water for lakeshore residents.

Recommendations for maintaining Lake Samish water quality: Our recommendations for Lake Samish focus on controlling external phosphorus loading, minimizing internal phosphorus loading, and educating watershed residents about drinking water issues and lake stewardship. These recommendations are not intended to serve as a substitute for developing a comprehensive lake management plan.

This list of recommendations was presented in an earlier Lake Samish annual report by Matthews and Vandersypen (2008); the original text has been updated to provide continuity.

- Develop an environmental education program to help residents of the Lake Samish watershed understand the water quality issues in the lake, and what can be done at the individual level. While it may be difficult to measure the direct success of public education programs in terms of water quality improvement, an educated public is more likely to understand and support watershed and lake management actions.

- Develop strategies for controlling external phosphorus loading. Phosphorus is very difficult to remove after it get into streams or lakes, so where possible, source control remains the best approach. This means either reducing the amount of phosphorus that enters surface runoff (e.g., using phosphorus-free fertilizers) or decreasing the amount of surface runoff that enters the lake (e.g., adding retention/detention basins that facilitate infiltration into the groundwater). Because of the scale of this task, the Samish Water District should work with an experienced storm water consultant to develop a comprehensive storm water management plan for the watershed.

  Lake Samish is already mesotrophic, and in some cases eutrophic, so reducing external phosphorus loading from the watershed will probably not eliminate cyanobacteria blooms. If external loading is reduced, however, the lake should stabilize around its current levels of productivity, and possibly even show some improvement over a long period of time.

- Optionally, after external phosphorus loading has been addressed, develop strategies for reducing internal phosphorus loading. There are many lake management techniques that, given sufficient funding for installation *and maintenance*, can be used to reduce internal loading. The addition of chemicals such as alum will bind with phosphorus, often resulting in years of reduced algal densities. The effect is temporary, and reapplication of the chemical is required on a periodic basis. Hypolimnetic aerators are available that can maintain sufficient oxygen in the hypolimnion to prevent internal phosphorus loading. Aerators are also available that circulate the entire water column, but in most stratified lakes, this is not a desirable approach, and may even increase algal growth. All of these techniques require a significant initial investment, long-term funding for maintenance, and are unlikely to be effective if external loading is not controlled.

- Consider developing a public drinking water supply and distribution system. The algal densities in the lake were very high and probably contribute to the formation of harmful disinfection by-products, particularly in systems that disinfect the water by chlorinatation. Although the coliform levels were low in the lake, the results may not reflect conditions at private drinking water intakes. Finally, the lake is subject to potentially hazardous cyanobacteria blooms and exposed to potentially hazardous chemicals from boating activities and the nearby highway. These represent an ongoing risk to individuals drawing domestic drinking water from the lake.

- Conduct an evaluation of on-site sewage disposal in the upper watershed, and its potential influence on water quality in Lake Samish. This evaluation should be included in the assessment of external phosphorus loading into the lake. On-site sewage disposal may be a minor factor in phosphorus loading into the lake because the Lake Samish shoreline is served by a public sewer line, so only portions of the upper watershed are likely to have on-site sewage disposal.

- Although monitoring priority pollutants is beyond the scope of this project, Lake Samish was placed on Washington State's 2004 and 2008 Water Quality Assessment 303(d) list due to the high levels of PCBs in sports fish collected from the lake. The levels of PCBs were high enough to generate a "Category 5" listing, which results in placement on the 303(d) list. The lake was listed at Category 2 ("waters of concern") based on mercury levels in fish.

  High levels of mercury and PCBs have been found in fish tissue from many other lakes in Washington, and throughout North America, so the presence of these pollutants in Lake Samish reflects widespread contamination of freshwater lakes rather than a unique local source. Nevertheless, due to the popularity of sports fishing in Lake Samish, we recommend additional monitoring of priority pollutants in water, sediments, and fish tissue in Lake Samish.

Methods

Water samples were collected at representative sites in Lake Samish (Figure 1, page 8) and analyzed following the protocols in Table 1 (page 27). The original scope of work specified monthly sampling at four lake sites (Sites A–D) from June 2005 through July 2006; the contract was amended to include quarterly sampling from June 2007 through October 2010. This effort has supplemented by IWS, at no additional cost, to provide additional sampling at two lake sites (Sites A and B) when resources were available. Water samples were also collected from Barnes Creek, Finney Creek, Friday Creek (outlet), and two unnamed tributaries[1] approximately twice each year (Tables 2–4, pages 28–30).

Lake sampling methods: Temperature and dissolved oxygen field measurements were collected at 1 meter depth intervals from the surface to the bottom at each site using a Hydrolab field meter. Beginning in March 2006, conductivity and pH profiles were also collected at 1 meter depth intervals using the Hydrolab field meter. Secchi depth was measured at each site by lowering a black and white disk into the water and recording the depth at which it was no longer visible from the lake surface. The field measurement protocols are summarized in Table 1 (page 27).

Surface and bottom water samples were collected at each lake site and transported to the laboratory to measure pH, conductivity, phosphorus (total phosphorus and soluble orthophosphate), nitrogen (total nitrogen, nitrate/nitrite[2], ammonium), turbidity, and alkalinity following the protocols listed in Table 1. Separate surface and bottom water samples were collected to measure fecal coliform counts; the coliform samples were delivered on ice to the Samish Water District or to a certified laboratory contracted by the District.

From June 2005 through May 2007, chlorophyll fluorescence was measured in the field (*in vivo*) at 1 meter depth intervals from the surface to the bottom using a field fluorometer. Water samples were collected from approximately 10-20% of the depths where fluorescence was measured, and the water samples were used to measure chlorophyll biomass (Table 1). A linear regression between the

[1]The unnamed tributaries are listed as Mia Creek and Mud Creek in the results and discussion.

[2]Nitrate and nitrite were analyzed together because nitrite concentrations are usually very low in surface water and require low level analytical techniques to measure accurately.

paired *in vivo* fluorescence and chlorophyll biomass data was used to estimate chlorophyll biomass at all depths along the fluorescence profiles.[3] Due to equipment failure, the field fluorometer was not used after May 2007. Beginning in June 2007, chlorophyll biomass was measured using water samples collected at approximately 5 meter depth intervals. For more information about *in vivo* fluorometric chlorophyll measurements, refer to the previous Lake Samish annual reports (Matthews, et al., 2006; Matthews and Vandersypen, 2007; Matthews and Vandersypen, 2008).

Creek sampling methods: Temperature and dissolved oxygen were measured using a field meter. Water samples were collected at each stream site and transported to the laboratory to measure pH, conductivity, phosphorus (total phosphorus and soluble orthophosphate), nitrogen (total nitrogen, nitrate/nitrite, ammonium), turbidity, and alkalinity. Separate water samples were collected to measure fecal coliform counts; the coliform samples were delivered on ice to the Samish Water District or to a certified commercial laboratory contracted by the District. All water samples collected in the field were stored on ice and in the dark until they reached the laboratory, and were analyzed as described in Table 1.

[3] Chlorophyll biomass is more commonly used to describe lake trophic status than fluorescence, but fluorescence is easier to measure in the field.

1 Annotated Figures and Tables

The Lake Samish monitoring project started in June 2005 and has resulted in the accumulation of more than five years of lake and creek data. The lake data are summarized in a series of annotated figures (Figures 1 –15, pages 8 –22) designed to show seasonal and annual patterns in the lake. Each figure includes a descriptive caption that provides background information as well as a brief interpretation of the Lake Samish results. The creek data are summarized in Tables 5–9 (pages 31–35).

The field hydrolab profiles for all sampling dates are plotted in Appendix A, beginning on page 37. Chlorophyll *in vivo* fluorescence profiles and biomass measurements are included in Appendix B, beginning on page 80. Raw data reports for the current sampling program are included in Appendix C of the printed report; online copies of this report will not contain the raw data, but electronic data files are available from the Institute for Watershed Studies.

As discussed in the methods section, some lake sites were sampled more frequently than others. Sites A and B, in particular, have been sampled more frequently to provide additional water quality data from the deepest sites in the lake's east and west arms. As a result, the plots on the following pages have fewer sample points for Sites C and D than for Sites A and B.

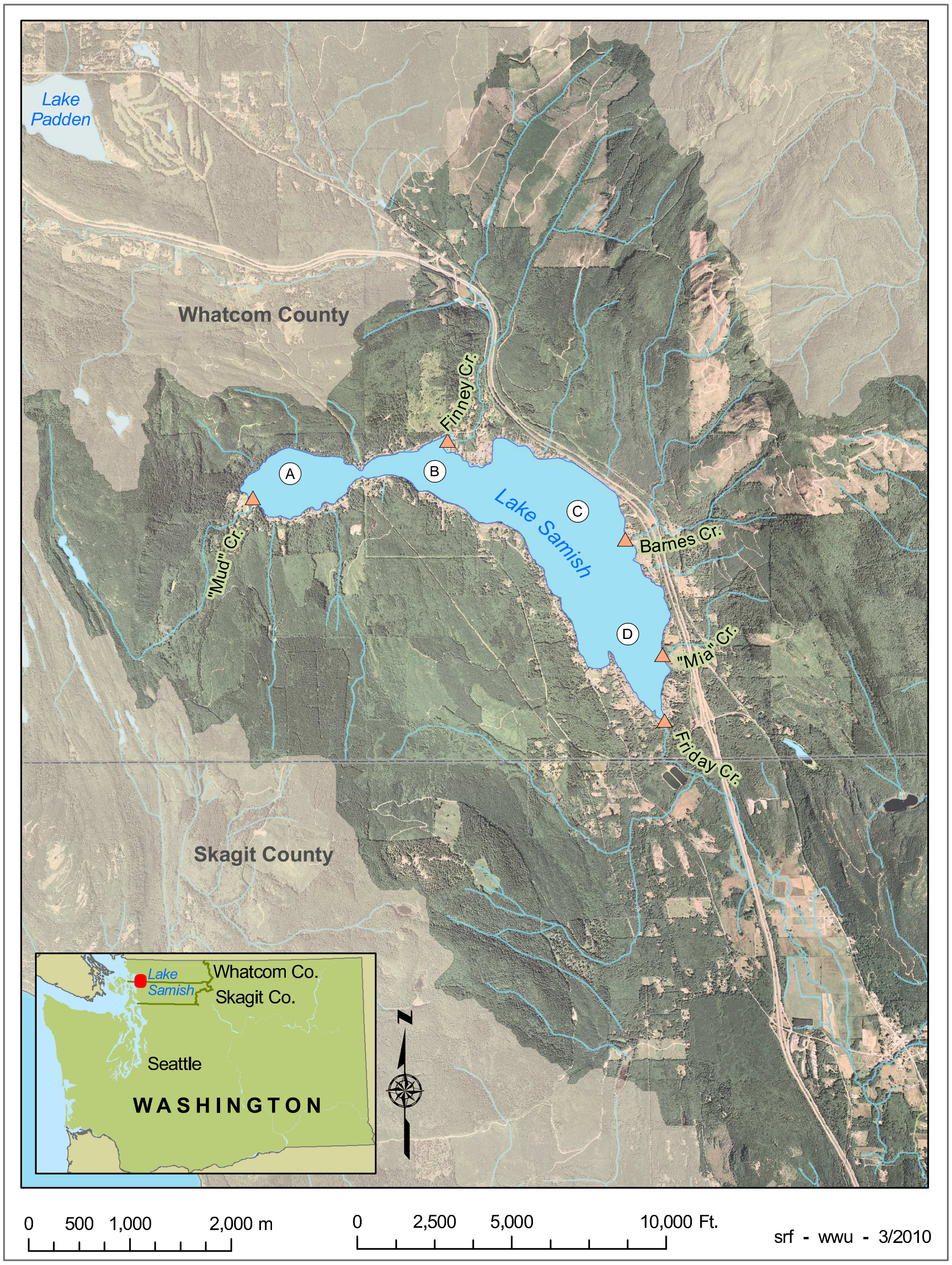


Figure 1: Lake Samish tributary and lake sampling sites, 2005–2010 (map provided by S. Freelan, Institute for Spatial Information and Analysis, Huxley College of the Environment, Western Washington University).

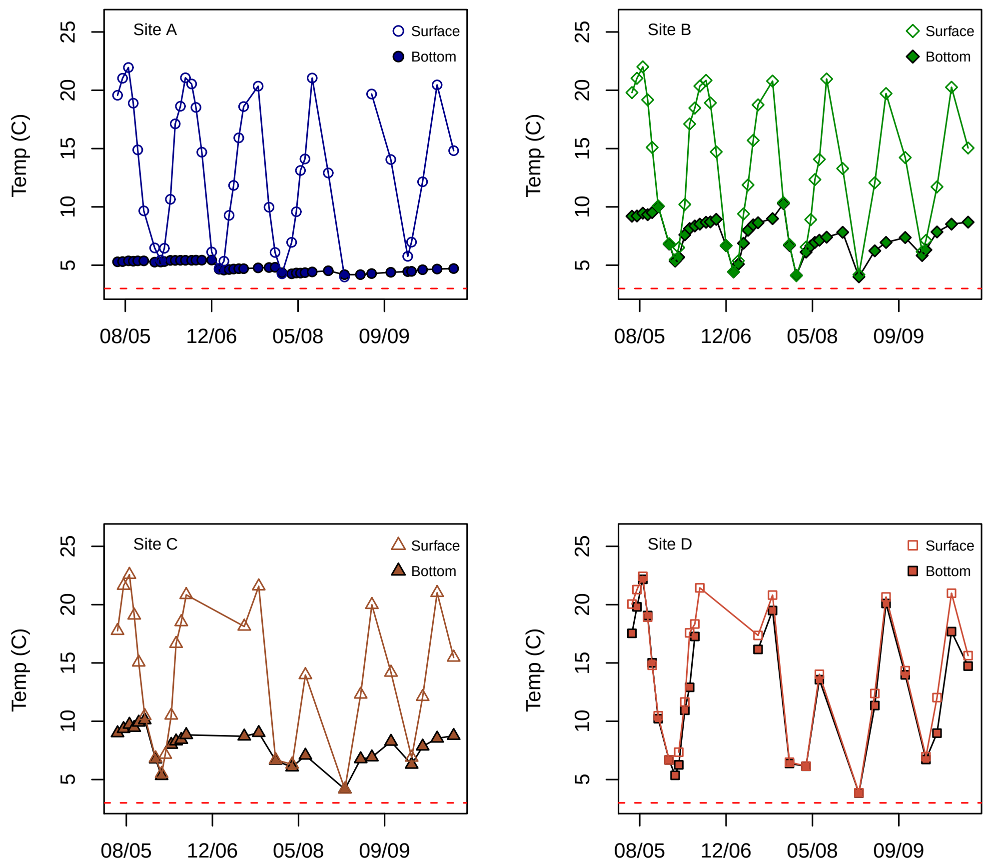


Figure 2: Surface and bottom water temperatures, June 2005 through October 2010. Temperature profiles show that much of the lake is stratified from spring through early fall (see Appendix A). Only Site D, which is very shallow, remains thermally unstratified throughout the year. During stratification the warmer upper portion of the water column (*epilimnion*) does not mix with the colder water near the bottom (*hypolimnion*). In the fall, after the surface water cools, the water column will start to mix again (*destratify*), and will continue to mix throughout the winter and early spring unless there is ice cover.

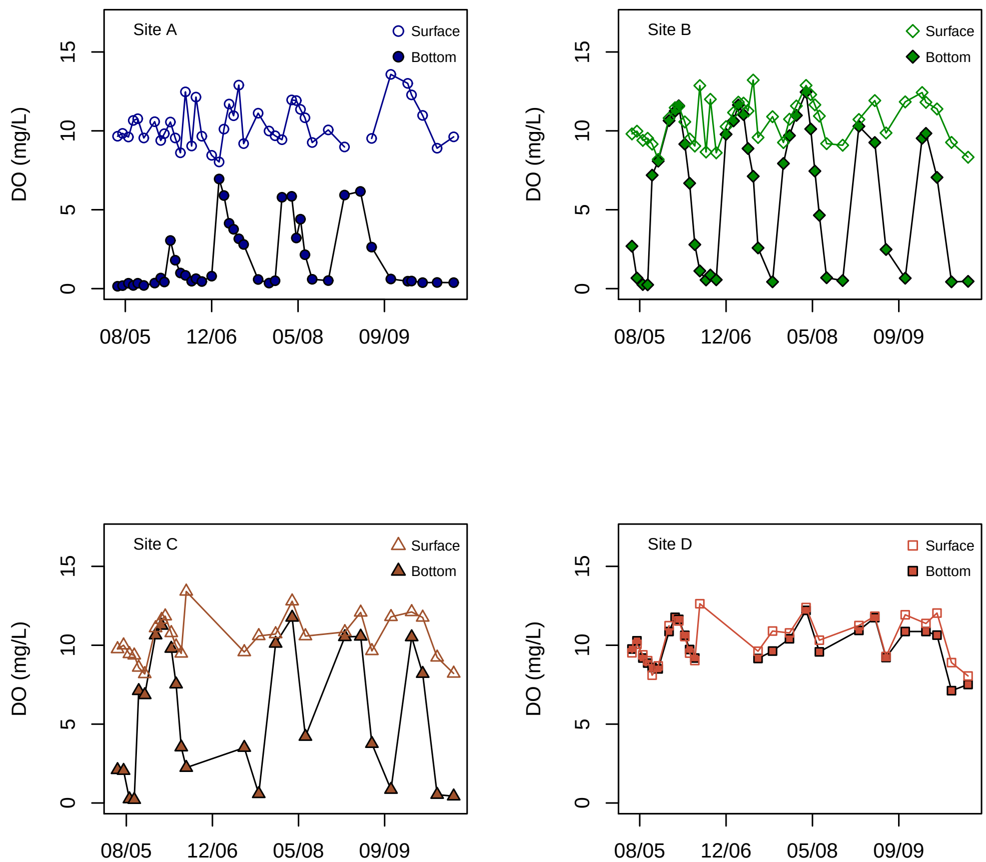


Figure 3: Dissolved oxygen concentrations, June 2005 through October 2010. The primary source of dissolved oxygen is the atmosphere. Algal photosynthesis is a source of oxygen during the day, but algae consume oxygen at night for respiration, so the net oxygen gain is minimal. All of the stratified sites in Lake Samish experience oxygen depletion in the hypolimnion, which is usually caused by bacteria decomposing organic matter (e.g., dead algae, leaf fragments, and other organic debris). When the lake destratifies, oxygen mixes throughout the water column, so the winter oxygen concentrations are similar for the surface and bottom samples at Sites B–D. Site A exhibits intermittent meromixis (Matthews and Vandersypen, 2008), where the water column does not always mix completely during the winter.

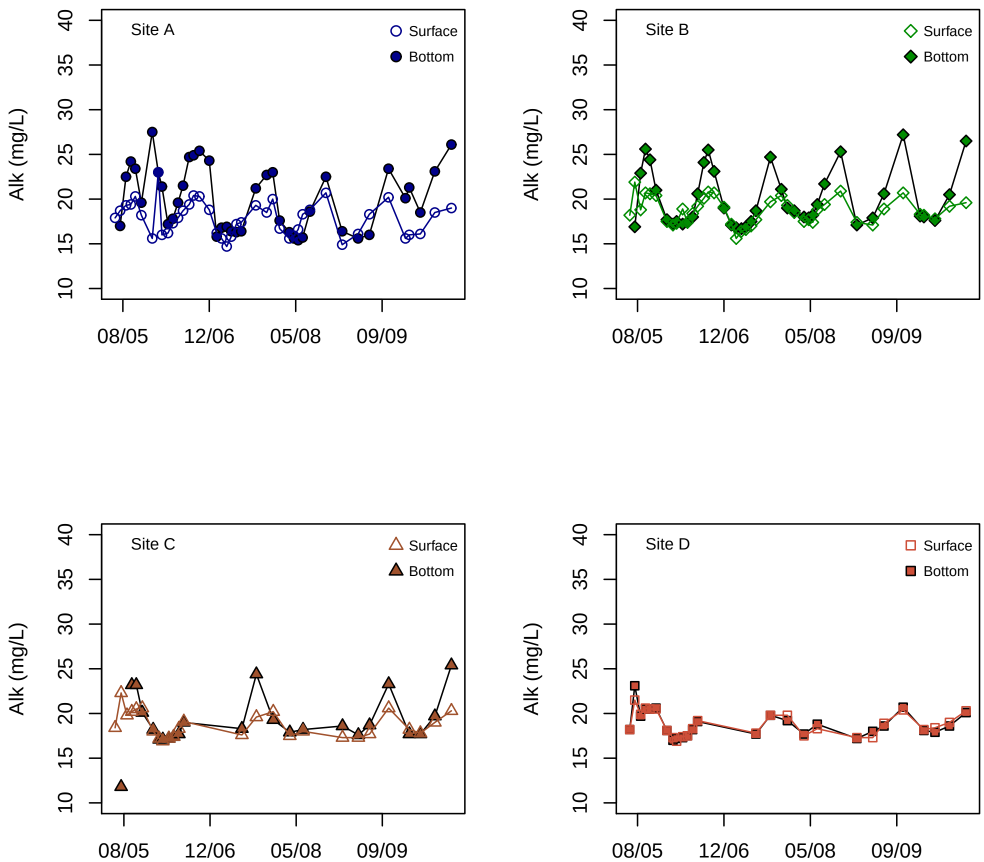


Figure 4: Alkalinity concentrations, June 2005 through October 2010. Alkalinity, pH, and specific conductance (conductivity) are related in surface waters. Alkalinity measures the *buffering capacity* or how resistant water is to pH changes. The alkalinity levels in Lake Samish are low, indicating that the water is poorly buffered against pH changes. This is typical for lakes in our region. The alkalinity levels fluctuate seasonally, especially in surface samples. During photosynthesis, algae remove dissolved CO_2 from the water, which can temporarily raise pH and lower alkalinity.

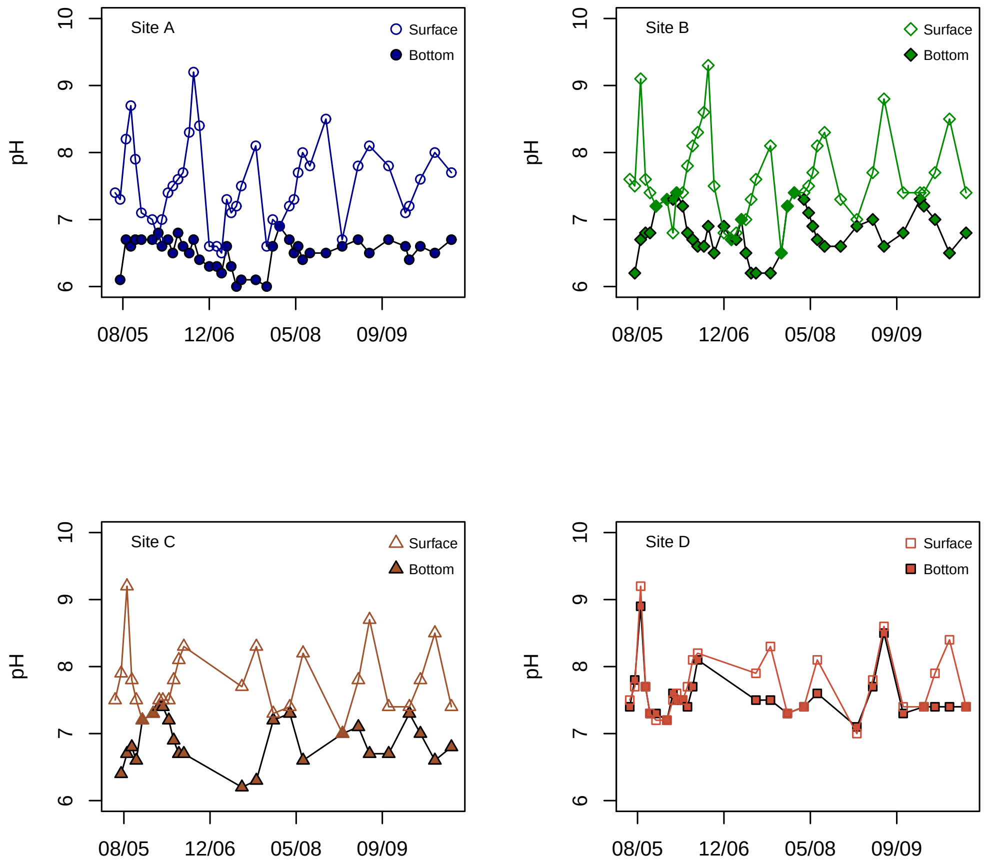


Figure 5: Surface and bottom pH levels (laboratory analysis), June 2005 through October 2010. Alkalinity, pH, and specific conductance (conductivity) are related in surface waters. The pH in water is determined by the concentration of H^+ ions. During photosynthesis, algae remove dissolved CO_2 from the water, which can temporarily raise pH by reducing the concentration of dissolved carbonic acid, which is formed when CO_2 reacts with water: $H_20 + CO_2 \leftrightarrow H_2CO_3$ (carbonic acid). This relationship is illustrated very clearly in the summer surface samples at Sites A and B.

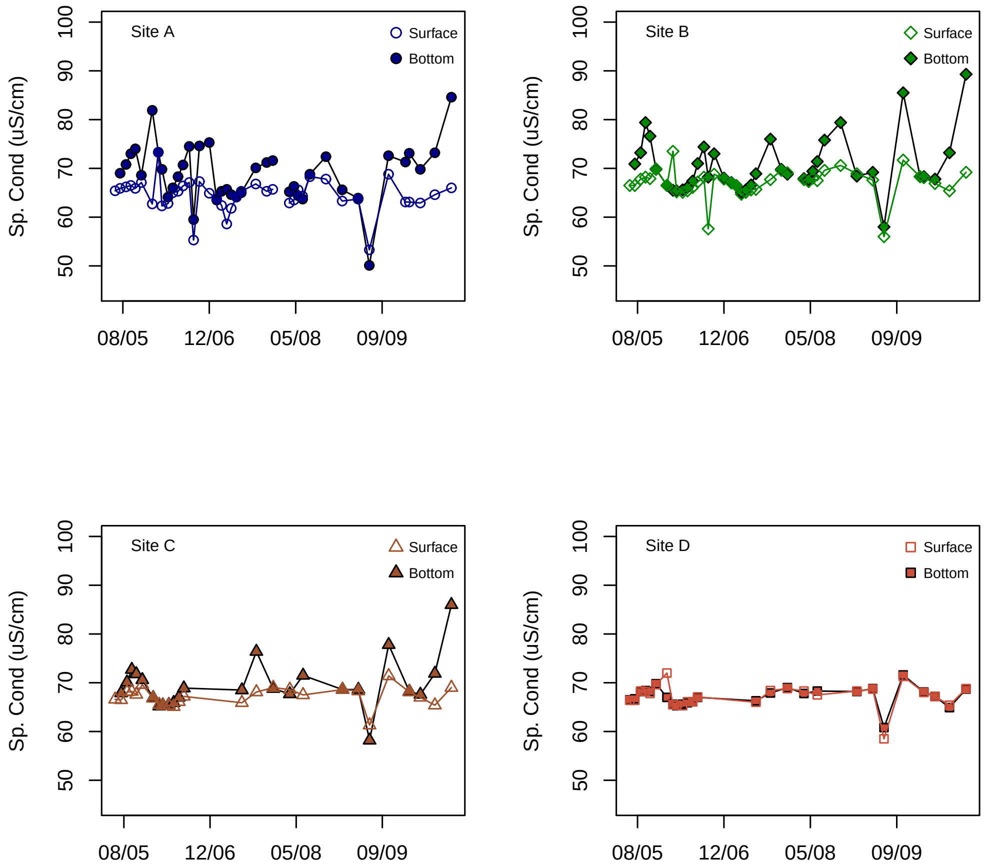


Figure 6: Conductivity levels (laboratory analysis), June 2005 through October 2010. Alkalinity, pH, and specific conductance (conductivity) are related in surface waters. Conductivity is determined by the types and amount of dissolved ions in the water. The soil type and land use in the watershed influence the amount of dissolved ions entering the lake from runoff and groundwater. Biological activity and chemical interactions determine whether dissolved ions remain in the water column. In Lake Samish, the conductivity levels are fairly low, which is typical for low-alkalinity lakes. The conductivity levels are slightly elevated near the bottom of the lake at Sites A and B, which is typical for stratified lakes with low oxygen concentrations near the sediments.

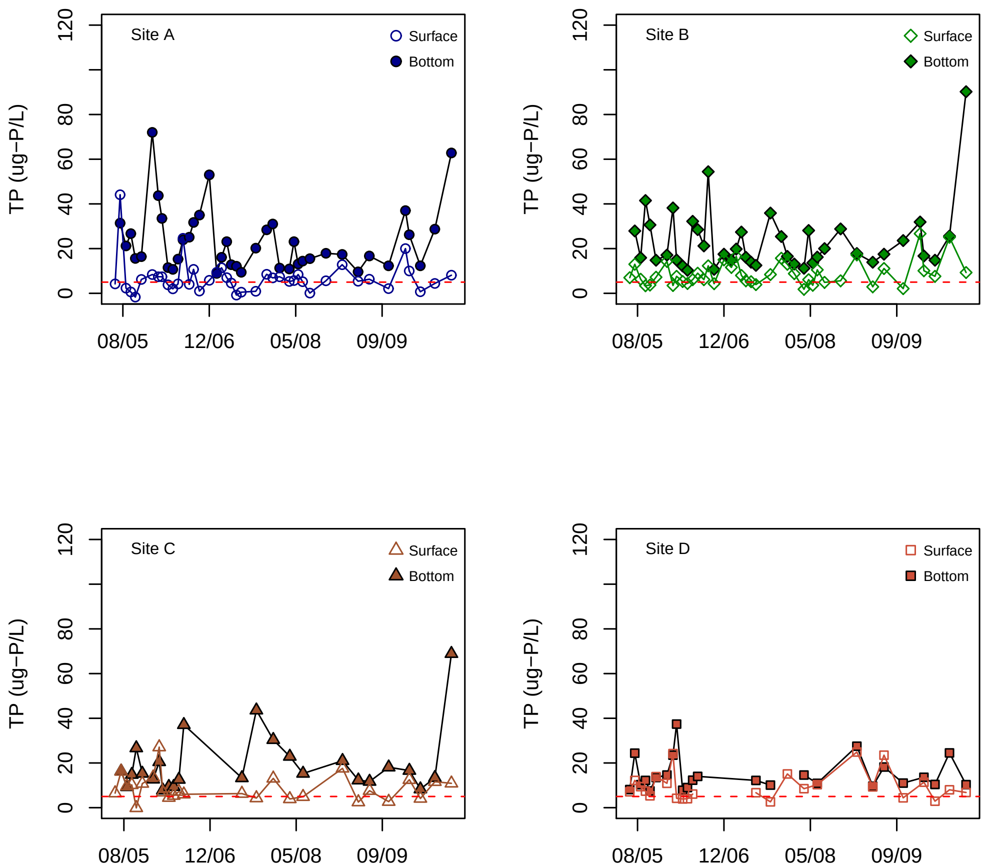


Figure 7: Total phosphorus concentrations, June 2005 through October 2010 (horizontal red line = detection limit of 5 μg-P/L). Total phosphorus includes organic phosphorus (phosphorus associated with algae and other biota) and dissolved phosphorus (primarily soluble orthophosphate). Phosphorus is an important nutrient for algae and is usually the nutrient that limits the amount of algae in a lake. Phosphorus is released from anaerobic sediments, so the bottom samples at Sites A and B often contained high concentrations of total and soluble phosphorus (see Figure 8). Although median total phosphorus concentrations were fairly low at each site (10–15 μg-P/L), the bottom concentrations often exceeded 30 μg-P/L.

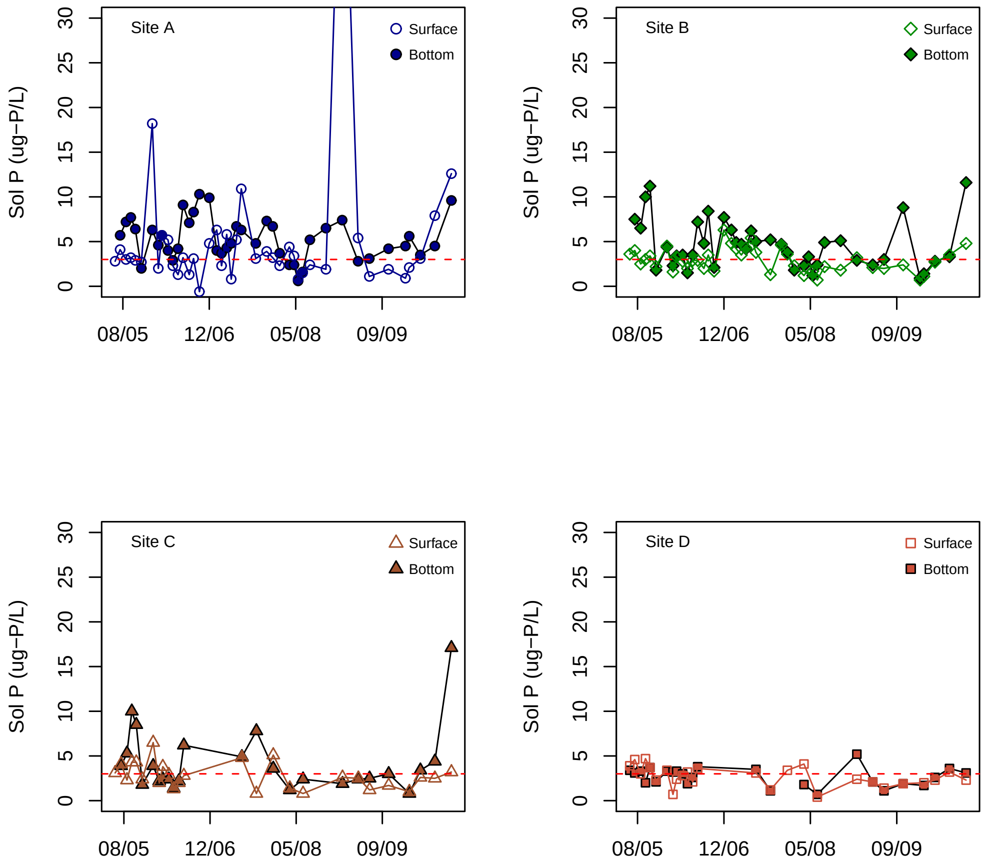


Figure 8: Soluble orthophosphate concentrations, June 2005 through October 2010 (horizontal red line = detection limit of 3 μg-P/L). Soluble orthophosphate is the soluble inorganic portion of total phosphorus. Soluble phosphate concentrations are often low in the water column, even when algal concentration are high, because this form of phosphorus is easily and rapidly taken up by algae and other microbiota. Soluble phosphate is released from anaerobic sediments, which accounts for the high concentrations occasionally measured in the bottom samples. The atypical surface sample outlier (59.7 μg-P/L at Site A on Jan 25, 2009) probably resulted from sample contamination because the total phosphorus concentrations in the sample was only 12.8 μg-P/L.

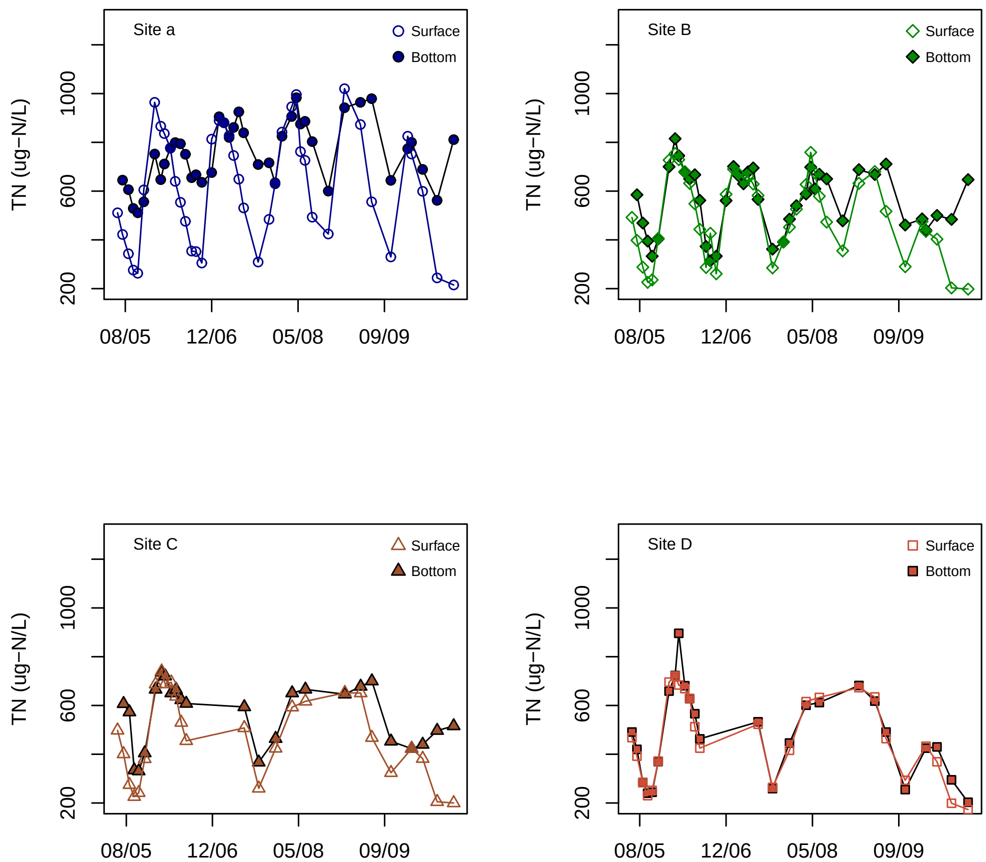


Figure 9: Total nitrogen concentrations, June 2005 through October 2010. Total nitrogen represents the combined concentrations of organic nitrogen (nitrogen associated with algae and other biota) and dissolved inorganic nitrogen (DIN = nitrate + nitrite + ammonium). In Lake Samish, about two thirds of the total nitrogen was inorganic ($\text{average } \frac{\text{DIN}}{\text{TN}} = 68\%$). Algae use inorganic nitrogen for growth, so it is common to see depletion of total nitrogen and DIN during the summer in samples collected at $\leq$10 meters. (Photosynthesis is usually limited by insufficient light in deeper samples.) Nitrogen rarely limits total algal growth because cyanobacteria can convert dissolved nitrogen gas (N_2) into inorganic nitrogen. Low concentrations of inorganic nitrogen, however, will limit the growth of certain types of algae and favor the growth of cyanobacteria.

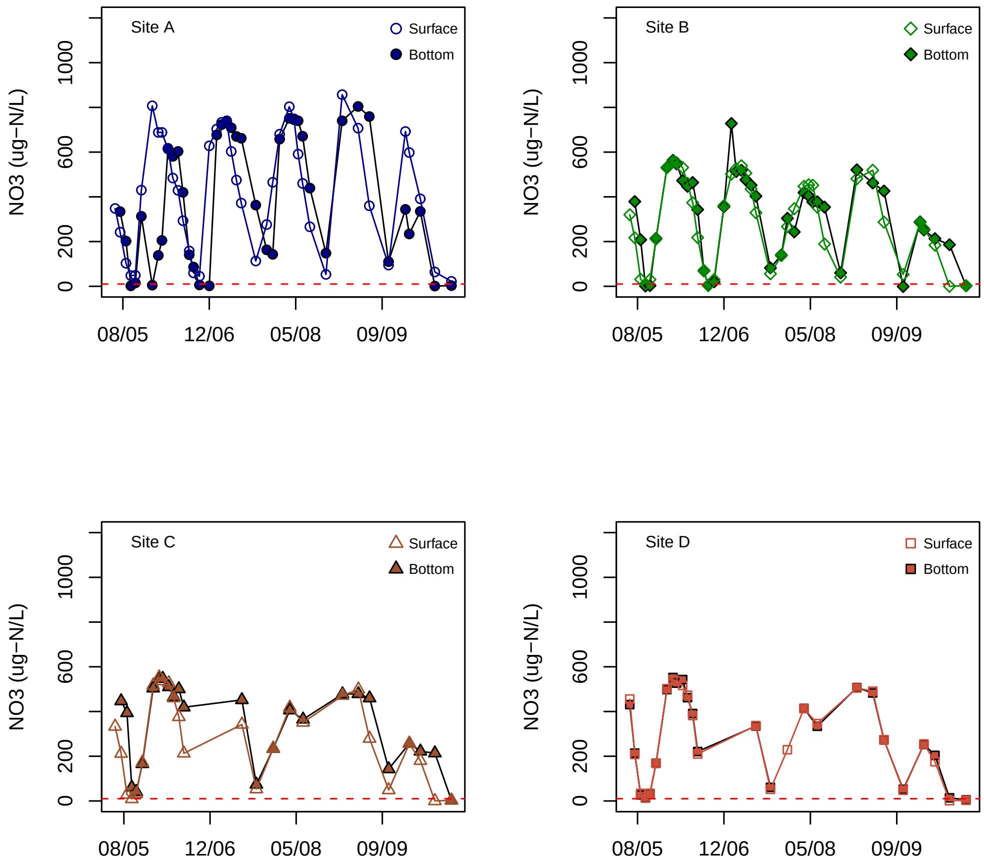


Figure 10: Nitrate/nitrite data, June 2005 through October 2010 (horizontal red line = detection limit of 10 μg-P/L). Nitrate and nitrite are often measured simultaneously because nitrite concentrations are usually negligible and below analytical detection levels. Nitrate/nitrite is usually the major component of dissolved inorganic nitrogen (DIN), the primary nitrogen source for algal growth. In Lake Samish, most DIN was in the form of nitrate/nitrite (average $\frac{NO_{2+3}}{DIN} = 84\%$). The Lake Samish nitrate/nitrite concentrations were depleted in both the surface and bottom samples during the summer, but for different reasons. The depletion in samples $\leq$10 meters was due to algal uptake; the depletion in deeper samples (bottom samples at Sites A and B) was due to nitrate reduction by anaerobic bacteria that use nitrate (and nitrite) as an alternative to oxygen.

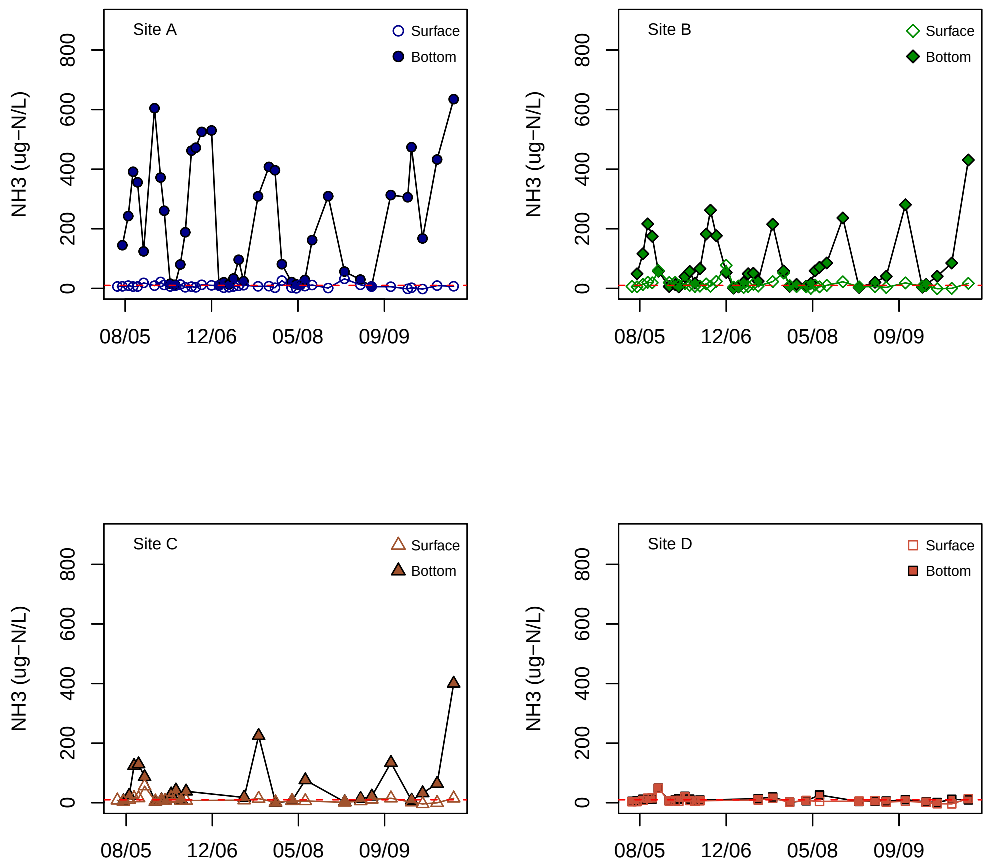


Figure 11: Lake Samish ammonium data, June 2005 through October 2010 (horizontal red line = detection limit of 10 μg-P/L). Ammonium is easily taken up by algae as a nitrogen source. Most of the ammonium in surface waters comes from decomposition of organic matter or is excreted by animals. In aerobic water, ammonium is rapidly converted into nitrite and nitrate by bacteria or lost through volitization. When oxygen concentrations are low, however, these bacteria are inactive, so ammonium can build up, especially in the hypolimnion. In Lake Samish, ammonium concentrations were low except in bottom samples during periods of stratification at sites that developed anoxia in the hypolimnion. The highest ammonium concentrations were from bottom samples at Site A, which may be due to incomplete water column mixing at that site.

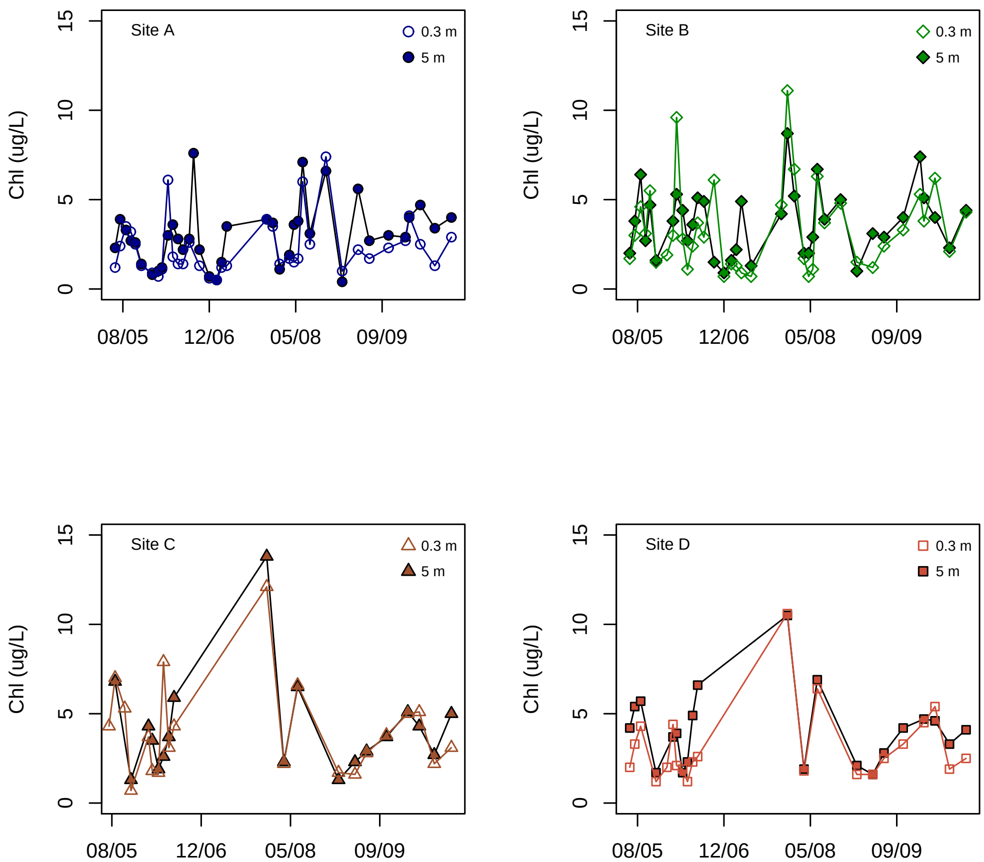


Figure 12: Lake Samish near-surface chlorophyll levels, June 2005 through October 2010. Chlorophyll is the primary photosynthetic pigment in algal cells and is generally the best indicator of the amount of algae present in lakes. In Lake Samish, as in most lakes, chlorophyll levels were usually low during the winter, with peaks in the spring and summer coinciding with spring/summer algal blooms. This figure shows chlorophyll biomass that was either measured in the laboratory (preferred method), or estimated from *in vivo* fluorescence measured in the field. For more information about these methods, see Matthews, et al. (2008).

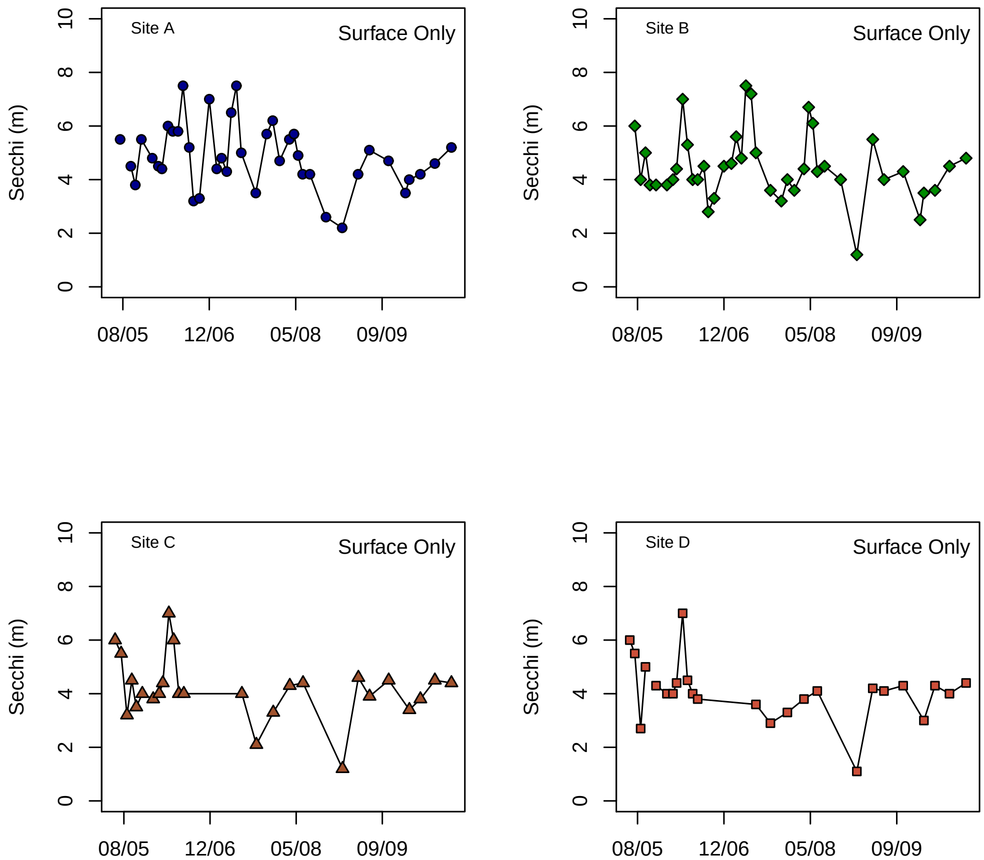


Figure 13: Secchi depths, June 2005 through October 2010. Secchi depth is an indicator of lake transparency and is defined as the depth at which a black and white disk is no longer visible from the lake surface. Secchi depth determines the approximate depth of the *photic* zone, where light conditions favor photosynthesis. Lake Samish Secchi depths were usually 4–6 meters (average = 4.3 m), consistent with peak chlorophyll concentrations, but for any particular sampling date, the relationship between Secchi depth and chlorophyll was weak. This indicates that inorganic and non-algal sediments contribute to the cloudiness of the water column.

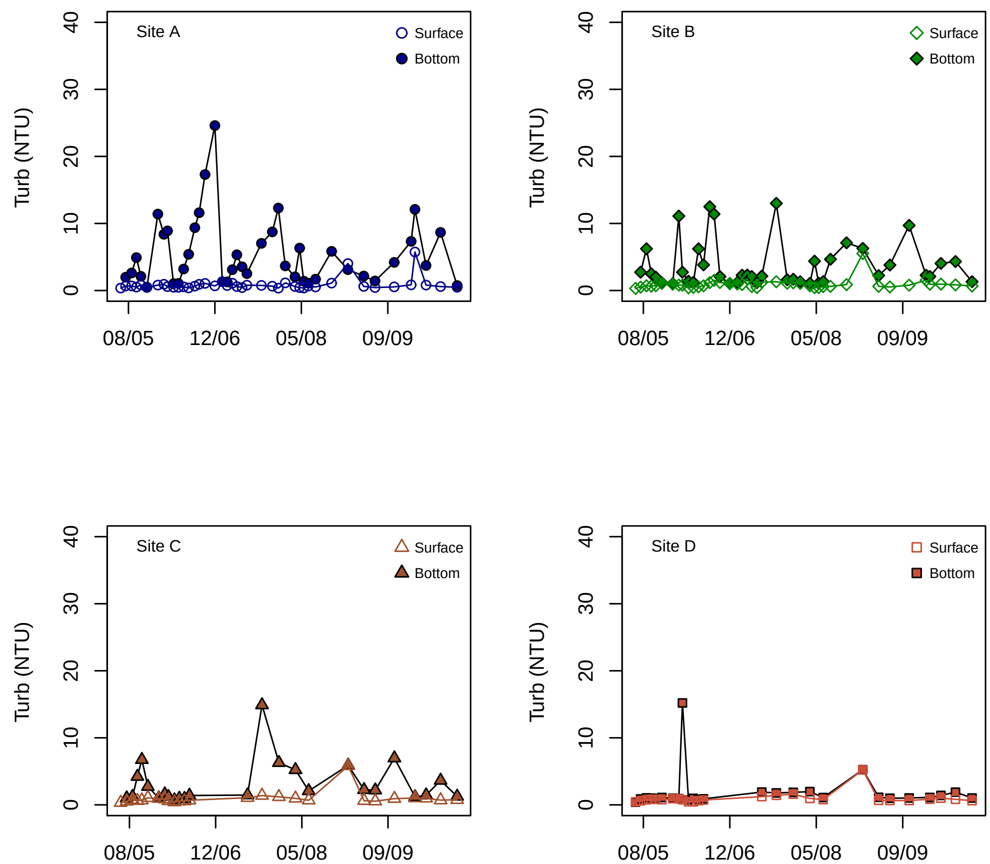


Figure 14: Turbidity data, June 2005 through October 2010. Turbidity is a measure of the suspended particles in water, which include algae, inorganic particles, and non-living organic matter. When most of the suspended particles in the water column are algae, chlorophyll concentrations are closely related to Secchi depth and turbidity. If non-algal particles are abundant, the relationship between Secchi depth and turbidity is still good, but neither are closely related to chlorophyll. Turbidity levels in the lake did not show typical near-surface summer peaks. Instead, the turbidity peaks were related to suspended particles in the hypolimnion.

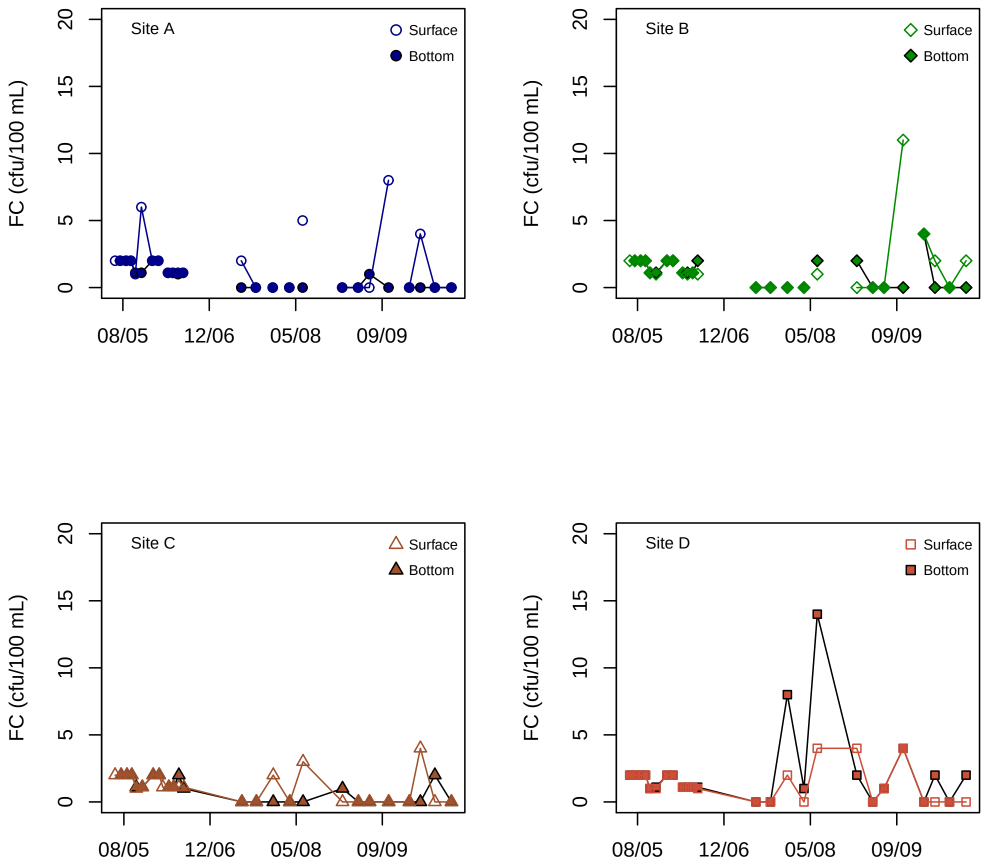
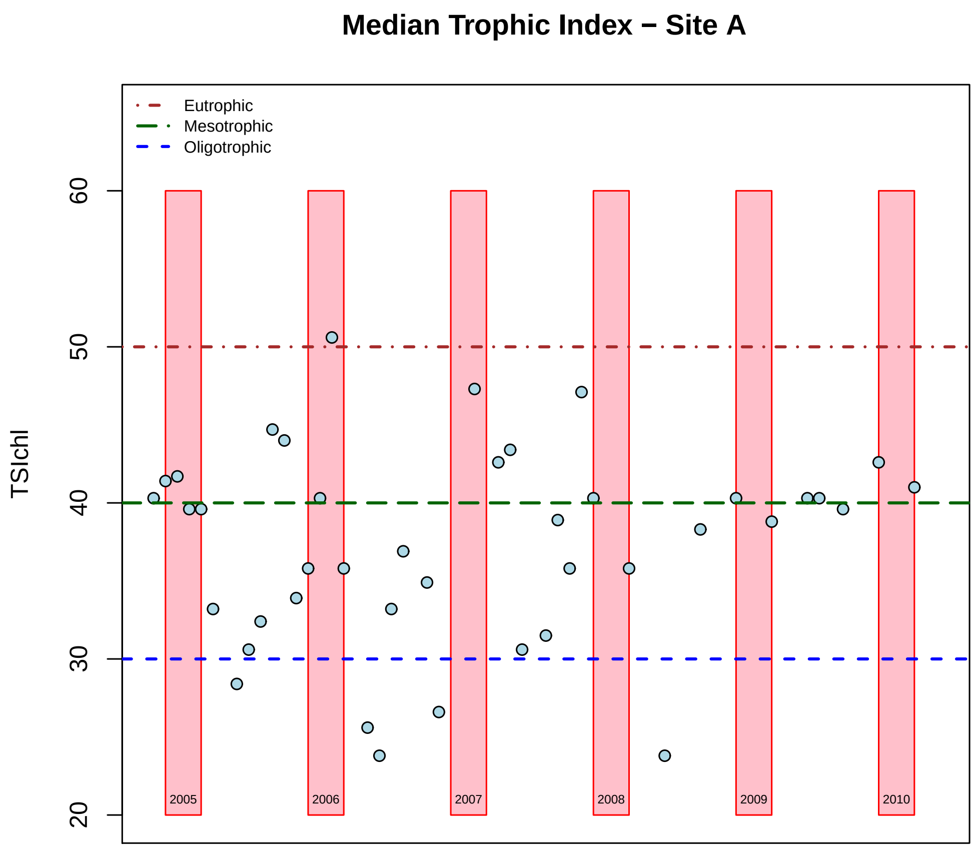
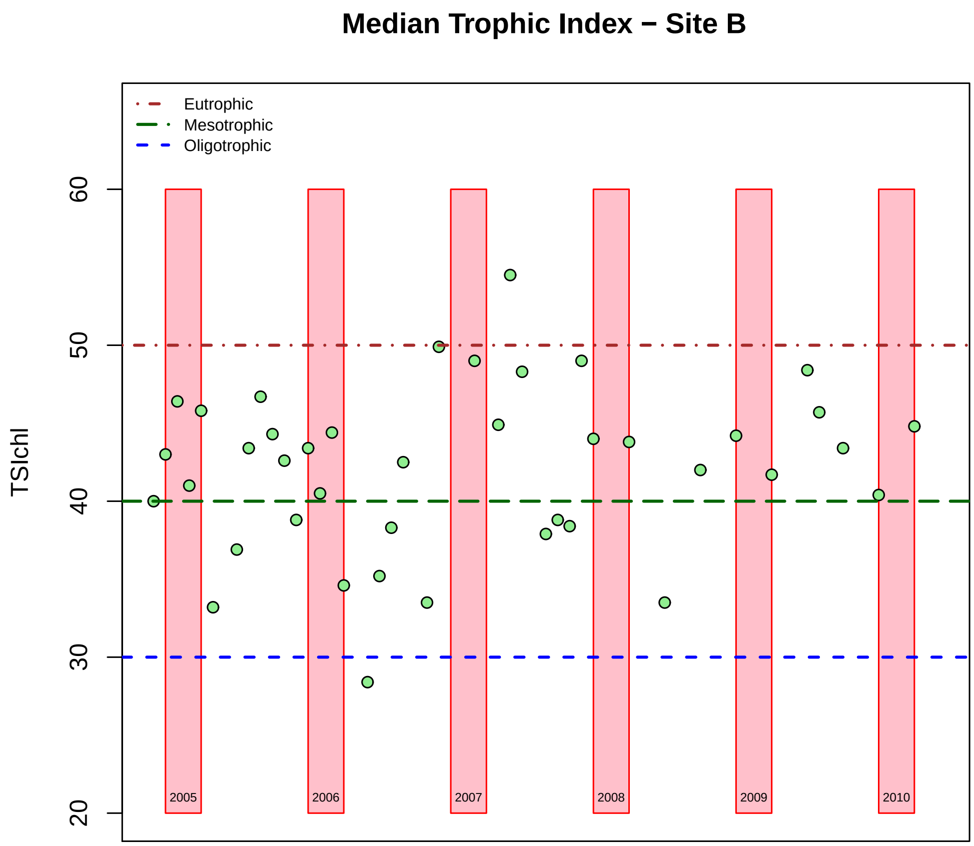


Figure 15: Fecal coliform data, June 2005 through October 2010. Fecal coliforms are normally found in the intestinal tract and feces of warm blooded animals, so their presence in water samples can be used to detect sewage or fecal contamination. Most types of fecal coliforms are not pathogenic, but if fecal coliforms are present, other potentially harmful pathogens may also be present. The fecal coliform counts in Lake Samish were low, with only two samples exceeding 10 cfu/100 mL (cfu=colony-forming unit). If there are concerns about swimming beaches or drinking water safety, however, additional samples should be collected following the protocols described by the Washington Administrative Code Section 173-201A, which deals with coliform standards in recreational waters.



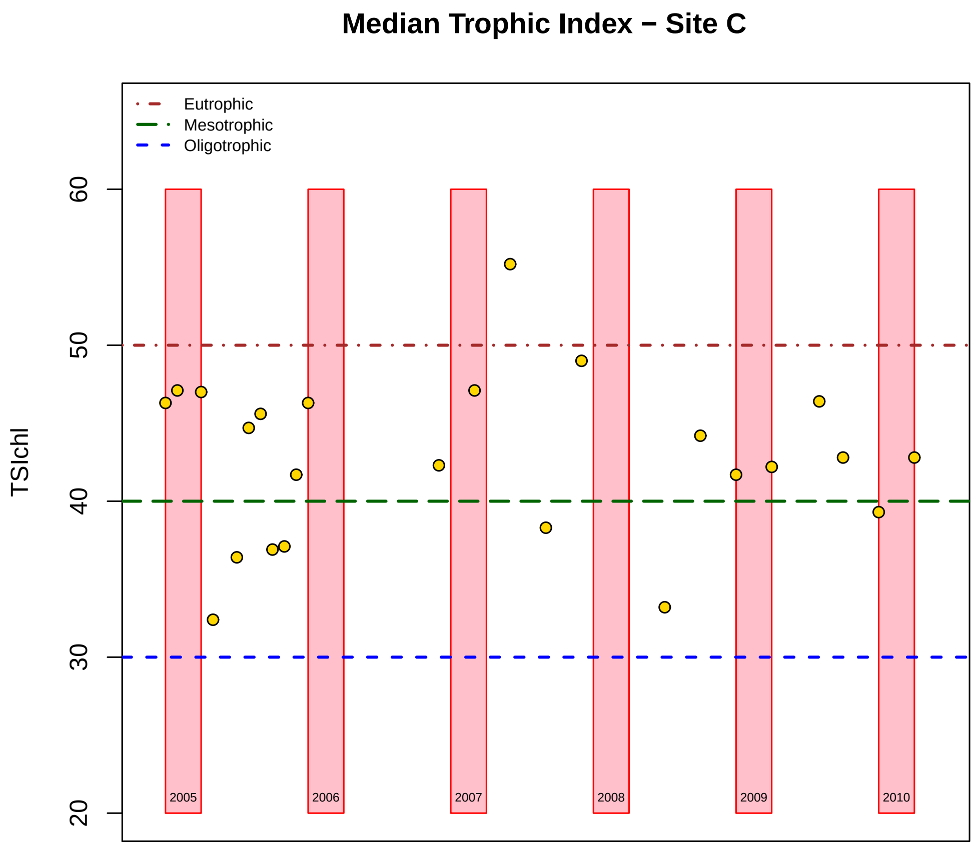
$$TSI_{chl} = 9.81 (\ln Chl (\mu g/L) + 30.6)$$

Figure 16: Median TSI_{chl} values at Site A, June 2005 through October 2010. Carlson's Trophic State Index (TSI_{chl}; Carlson and Simpson, 1966) is a simple way to classify lakes based on biological productivity using chlorophyll measurements. The shaded rectangles show summer months (July-October), which are often described as having higher TSIs compared to the rest of the year. This is not always true for Lake Samish. Most of the Site A values fell between the oligotrophic and mesotrophic ranges, indicating that this site had lower algal concentrations and would be less likely to experience algal blooms than other portions of the lake.



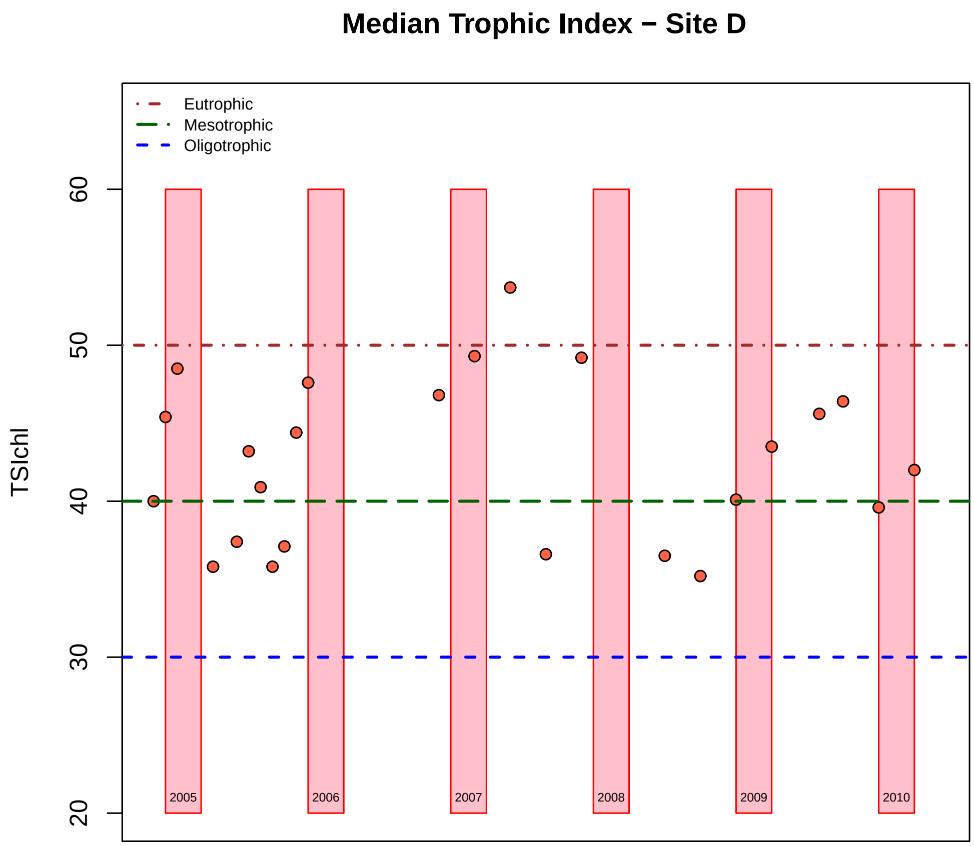
$$\text{TSI}_{chl} = 9.81 (\ln \text{Chl} (\mu\text{g/L}) + 30.6)$$

Figure 17: Median Lake Samish TSI_{chl} values at Site B, June 2005 through October 2010; the shaded rectangles show summer months (July-October). The TSI values at Site B were higher than Site A, and most were near the level that indicates a mesotrophic or moderately productive lake. Sites B–D, located in the shallower arm of Lake Samish, are more likely to experience algal blooms than Site A.



$$\text{TSI}_{chl} = 9.81\ (\ln \text{Chl}\ (\mu\text{g/L}) + 30.6)$$

Figure 18: Median Lake Samish TSI_{chl} values at Site C, June 2005 through October 2010; the shaded rectangles show summer months (July-October). The TSI values at Site C were higher than Site A, and some of the values were in the eutrophic range, indicating high levels of algal productivity. Sites B–D, located in the shallower arm of Lake Samish, are more likely to experience algal blooms than Site A.



$$TSI_{chl} = 9.81 (\ln Chl (\mu g/L) + 30.6)$$

Figure 19: Median Lake Samish TSI_{chl} values at Site D, June 2005 through October 2010; the shaded rectangles show summer months (July-October). The TSI values at Site D were higher than Site A, and some of the values were in the eutrophic range, indicating high levels of algal productivity. Sites B–D, located in the shallower arm of Lake Samish, are more likely to experience algal blooms than Site A.

Analyte	Abbr.	Method Reference (APHA 2005)	Detection Limit/ Sensitivity
Alkalinity	Alk	SM2320, titration	$\pm$0.5 mg $CaCO_3$/L
Chlorophyll - field	Chl	Turner fluorometer (field meter)	NA
Chlorophyll - lab	Chl	SM10200 H, acetone extraction	$\pm$0.1 μg/L
Conductivity - field/lab	Sp. Cond	SM2510, lab or field meter	$\pm$0.1 units
Dissolved oxygen - field	DO	SM4500-O G.,membrane electrode (field meter)	$\pm$0.1 mg/L
Dissolved oxygen - lab	DO	SM4500-O C., Winkler, azide	$\pm$0.1 mg/L
Fecal coliforms	FC	SM9221 E , MPN*	$<$2
Nitrogen - ammonium	NH_3	SM4500-NH3 H., flow inject, phenate	10 μg NH_3-N/L
Nitrogen - nitrate/nitrite	NO_3	SM4500-NO3 I., flow inject, Cd reduction	10 μg NO_3-N/L
Nitrogen - total	TN	SM4500-NO3 I., flow inject, persulfate digest	10 μg N/L
pH - field/lab	pH	SM4500-H, electometric lab or field meter	$\pm$0.1 units
Phosphorus - soluble	Sol P	SM4500-P G., flow inject	3 μg PO_4-P/L
Phosphorus - total	TP	SM4500-P G., flow inject, persulfate digest	5 μg P/L
Temperature - field	Temp	SM2550 thermistor (field meter)	$\pm$0.1 C
Turbidity	Turb	SM2130, nephelometric	$\pm$0.2 NTU

*Fecal coliform analyses were provided by Edge Analytical, 805 Orchard Dr., Bellingham, WA and Exact Scientific Services, 3929 Spur Ridge Ln., Bellingham, WA.

Table 1: Summary of analytical methods used by the Institute for Watershed Studies in the Lake Samish monitoring project.

Date	Measured Parameters[†]	Chlorophyll Measurements
June 21, 2005	all field/lab analyses except pH/cond	chl profiles (A, B, D)
July 20, 2005	all field/lab analyses except pH/cond	chl profiles
August 23, 2005	all field/lab analyses except pH/cond	chl profiles
September 20, 2005	all field/lab analyses except pH/cond	chl profiles (A, B)
October 16, 2005	all field/lab analyses except pH/cond	chl profiles (A, B)
November 20, 2005	all field/lab analyses except pH/cond	chl profiles
January 22, 2006	all field/lab analyses except pH/cond	chl biomass(misc. depths)
February 26, 2006	all field/lab analyses	chl profiles
March 19, 2006	all field/lab analyses	chl profiles
April 23, 2006	all field/lab analyses	chl profiles
May 21, 2006	all field/lab analyses	chl profiles
June 20, 2006	all field/lab analyses	chl profiles
July 19, 2006	all field/lab analyses	chl profiles
June 21, 2007	all field/lab analyses	chl biomass(misc. depths)
September 13, 2007	all field/lab analyses (no coliforms)	chl biomass (misc. depths)
December 20, 2007	all field/lab analyses	chl biomass (5 m intervals)
March 25, 2008	all field/lab analyses	chl biomass (5 m intervals)
June 10, 2008	all field/lab analyses	chl biomass (5 m intervals)
January 25, 2009	all field/lab analyses	chl biomass (5 m intervals)
April 27, 2009	all field/lab analyses	chl biomass (5 m intervals)
July 1, 2009	all field/lab analyses	chl biomass (5 m intervals)
October 20, 2009	all field/lab analyses	chl biomass (5 m intervals)
February 17, 2010	all field/lab analyses	chl biomass (5 m intervals)
April 22, 2010	all field/lab analyses	chl biomass (5 m intervals)
July 15, 2010	all field/lab analyses	chl biomass (5 m intervals)
October 19, 2010	all field/lab analyses	chl biomass (5 m intervals)

[†] Field/lab analyses include Secchi depth, dissolved oxygen, water temperature, pH, conductivity, alkalinity, total nitrogen, nitrate/nitrite, ammonium, total phosphorus, soluble orthophosphate, turbidity, chlorophyll, and fecal coliforms.

Table 2: Lake Samish contract sampling dates for Sites A–D. Table 3 lists supplemental (no-cost) lake sampling dates and Table 4 lists tributary sampling dates.

Date	Measured Parameters[†]	Chlorophyll Measurements
August 24, 2006	all field/lab analyses (no coliforms)	chl profiles
September 18, 2006	all field/lab analyses (no coliforms)	chl biomass (misc. depths)
October 22, 2006	all field/lab analyses (no coliforms)	chl profiles
December 18, 2006	all field/lab analyses (no coliforms)	chl profiles
January 30, 2007	all field/lab analyses (no coliforms)	chl profiles
February 27, 2007	all field/lab analyses (no coliforms)	chl profiles
March 29, 2007	all field/lab analyses (no coliforms)	chl profiles
April 24, 2007	all field/lab analyses (no coliforms)	no chl data
May 24, 2007	all field/lab analyses (no coliforms)	chl profiles
November 15, 2007	all field/lab analyses (no coliforms)	chl biomass (5 m intervals)
January 29, 2008	all field/lab analyses (no coliforms)	chl biomass (5 m intervals)
April 21, 2008	all field/lab analyses (no coliforms)	chl biomass (5 m intervals)
May 15, 2008	all field/lab analyses (no coliforms)	chl biomass (5 m intervals)
July 22, 2008	all field/lab analyses (no coliforms)	chl biomass (5 m intervals)
October 23, 2008	all field/lab analyses	chl biomass (5 m intervals)
January 26, 2010	all field/lab analyses (no coliforms)	chl biomass (5 m intervals)

[†] Field/lab analyses include Secchi depth, dissolved oxygen, water temperature, pH, conductivity, alkalinity, total nitrogen, nitrate/nitrite, ammonium, total phosphorus, soluble orthophosphate, turbidity, chlorophyll, and fecal coliforms.

Table 3: Lake Samish supplemental (no-cost) lake sampling dates for Sites A–B. Table 2 lists contract sampling dates when all four sites (A–D) were sampled and Table 4 lists tributary sampling dates.

Date	Measured Parameters[†]	Sampling Locations
July 15, 2005	all field/lab analyses	Barnes, Finney, Mia, Mud
August 9, 2005	all field/lab analyses	Friday
November 10, 2005	all field/lab analyses	Barnes, Finney, Friday, Mia, Mud
July 16, 2007	all field/lab analyses	Barnes, Finney, Friday, (Mia dry), Mud
March 17, 2008	all field/lab analyses	Barnes, Finney, Friday, Mia, Mud
February 18, 2009	all field/lab analyses	Barnes, Finney, Friday, Mia, Mud
July 13, 2009	all field/lab analyses	Barnes, Finney, Friday, Mia, Mud
February 18, 2010	all field/lab analyses	Barnes, Finney, Friday, Mia, Mud
July 16, 2010	all field/lab analyses	Barnes, Finney, Friday, Mia, Mud

[†] Field/lab analyses include dissolved oxygen, water temperature, pH, conductivity, alkalinity, total nitrogen, nitrate/nitrite, ammonium, total phosphorus, soluble orthophosphate, turbidity, and fecal coliforms.

Table 4: Lake Samish tributary sampling dates. Table 2 lists dates when all four lakes sites (A–D) were sampled and Table 3 lists supplemental dates when Sites A–B were sampled.

	2005 Jul 15	2005 Nov 10	2007 Jul 16	2008 Mar 17	2009 Feb 18	2009 Jul 13	2010 Feb 18	2010 Jul 16
Alkalinity (mg/L)	52.0	37.5	59.7	40.0	52.0	55.9	45.5	58.1
Conductivity (μS/cm)	128.7	103.4	139.7	102.6	127.1	103.8	112.8	137.5
Dissolved oxygen (mg/L)	10.2	14.7	10.0	12.5	12.2	10.5	12.9	10.3
Nitrogen - ammonium (μg-N/L)	17.1	$<$10	$<$10	10.0	$<$10	19.7	13.2	10.5
Nitrogen - nitrate/nitrite (μg-N/L)	916	1518	678	767	677	619	572	496
Nitrogen - total (μg-N/L)	1083	1670	757	882	776	772	656	629
pH	7.2	7.5	7.3	7.6	7.7	7.7	7.7	7.7
Phosphorus - soluble (μg-P/L)	26.9	9.0	24.3	11.6	12.7	16.3	11.9	19.0
Phosphorus - total (μg-P/L)	46.0	15.1	18.0	17.1	13.4	24.8	35.2	23.8
Temperature (C)	12.5	9.0	12.9	6.0	5.9	12.8	6.5	12.3
Turbidity (NTU)	4.6	2.7	1.2	2.7	0.6	1.1	1.6	1.8
Fecal coliforms (cfu/100 mL)	23	23	240	4	$<$2	130	$<$2	50

	Data Summary - All Sites			
	Minimum	Median	Mean	Maximum
Alkalinity (mg/L)	12.2	21.8	29.5	59.7
Conductivity (μS/cm)	60.0	86.0	111.3	399.0
Dissolved oxygen (mg/L)	4.0	10.5	10.6	14.7
Nitrogen - ammonium (μg-N/L)	$<$10	10.0	16.3	108.6
Nitrogen - nitrate/nitrite (μg-N/L)	$<$10	572	692	1944
Nitrogen - total (μg-N/L)	323	719	868	2308
pH	6.1	7.2	7.2	7.7
Phosphorus - soluble (μg-P/L)	$<$3	8.2	10.8	35.3
Phosphorus - total (μg-P/L)	5.4	17.1	18.7	49.8
Temperature (C)	4.3	10.7	10.7	21.9
Turbidity (NTU)	0.3	1.4	2.0	11.9
Fecal coliforms (cfu/100 mL)	$<$2	23	116	1600

Table 5: Water quality data from Barnes Creek compared to summary data from all sites. Barnes Creek is one of the major tributaries into Lake Samish. This site had slightly higher alkalinities, conductivities, and pH values compared to the all-site median, indicating that the water contains more dissolved compounds. The nitrogen and phosphous concentrations were variable, but most values were close to the all-site medians. All but two of the Barnes Creek coliform counts in Barnes Creek were $<$50 cfu/100 mL.

	2005 Jul 15	2005 Nov 10	2007 Jul 16	2008 Mar 17	2009 Feb 18	2009 Jul 13	2010 Feb 18	2010 Jul 16
Alkalinity (mg/L)	28.0	12.2	41.4	16.2	21.8	42.1	17.1	37.4
Conductivity (μS/cm)	149.8	75.2	399	92.9	140	260	86	246
Dissolved oxygen (mg/L)	9.7	14.6	8.8	12.7	12.9	9.5	13.5	9.5
Nitrogen - ammonium (μg-N/L)	11.7	$<$10	24.2	$<$10	$<$10	16.0	$<$10	$<$10
Nitrogen - nitrate/nitrite (μg-N/L)	622	1860	435	1089	782	455	633	326
Nitrogen - total (μg-N/L)	748	2062	586	1197	948	652	719	436
pH	7.1	7.2	7.2	7.3	7.3	7.6	7.6	7.6
Phosphorus - soluble (μg-P/L)	35.3	5.7	21.4	7.2	7.5	11.2	6.5	15.1
Phosphorus - total (μg-P/L)	33.1	15.1	9.3†	13.2	12.8	20.9	13.2	19.7
Temperature (C)	13.5	9.2	16.2	5.6	4.6	14.5	5.7	14.2
Turbidity (NTU)	0.8	3.0	0.3	3.9	1.5	0.8	2.3	0.8
Fecal coliforms (cfu/100 mL)	23	130	170	52	12	1600	6	130

†Unusual result - soluble phosphate higher than total phosphorus; results verified.

	Data Summary - All Sites			
	Minimum	Median	Mean	Maximum
Alkalinity (mg/L)	12.2	21.8	29.5	59.7
Conductivity (μS/cm)	60.0	86.0	111.3	399.0
Dissolved oxygen (mg/L)	4.0	10.5	10.6	14.7
Nitrogen - ammonium (μg-N/L)	$<$10	10.0	16.3	108.6
Nitrogen - nitrate/nitrite (μg-N/L)	$<$10	572	692	1944
Nitrogen - total (μg-N/L)	323	719	868	2308
pH	6.1	7.2	7.2	7.7
Phosphorus - soluble (μg-P/L)	$<$3	8.2	10.8	35.3
Phosphorus - total (μg-P/L)	5.4	17.1	18.7	49.8
Temperature (C)	4.3	10.7	10.7	21.9
Turbidity (NTU)	0.3	1.4	2.0	11.9
Fecal coliforms (cfu/100 mL)	$<$2	23	116	1600

Table 6: Water quality data from Finney Creek compared to summary data from all sites. Finney Creek is one of the major tributaries into Lake Samish. This site had highly variable results, with most parameters ranging from well below to well above the all-site medians. Soluble phosphate, for example, ranged from 5.7 μg-P/L to 35.3 μg-P/L (maximum value recorded for all sites). Similarly, the coliform count ranged from 6 cfu/100 mL to 16000 cfu/100 mL, and five of the samples had counts $>$50 cfu/100 mL. The variability suggests that there may be some sort of intermittent watershed disturbance upstream from the sample site.

	2005 Jul 15	2005 Nov 10	2007 Jul 16	2008 Mar 17	2009 Feb 18	2009 Jul 13	2010 Feb 18	2010 Jul 16
Alkalinity (mg/L)	31.8	18.0	NA	32.0	32.7	NA	NA	52.1
Conductivity (μS/cm)	82.7	73.9	NA	131.8	155.4	NA	NA	124.5
Dissolved oxygen (mg/L)	9.1	13.6	NA	10.9	11.4	NA	NA	9.8
Nitrogen - ammonium (μg-N/L)	14.5	9.6	NA	13.2	36.1	NA	NA	$<$10
Nitrogen - nitrate/nitrite (μg-N/L)	293	1666	NA	534	1944	NA	NA	405
Nitrogen - total (μg-N/L)	478	1891	NA	801	2236	NA	NA	552
pH	6.7	7.1	NA	7.0	7.3	NA	NA	7.1
Phosphorus - soluble (μg-P/L)	30.9	10.3	NA	5.7	9.4	NA	NA	15.5
Phosphorus - total (μg-P/L)	49.8	21.2	NA	20.5	12.8	NA	NA	19.4
Temperature (C)	13.4	9.2	NA	6.5	5.7	NA	NA	12.5
Turbidity (NTU)	2.5	1.9	NA	11.9	1.2	NA	NA	0.8
Fecal coliforms (cfu/100 mL)	23	23	NA	104	$<$2	NA	NA	130

	Data Summary - All Sites			
	Minimum	Median	Mean	Maximum
Alkalinity (mg/L)	12.2	21.8	29.5	59.7
Conductivity (μS/cm)	60.0	86.0	111.3	399.0
Dissolved oxygen (mg/L)	4.0	10.5	10.6	14.7
Nitrogen - ammonium (μg-N/L)	$<$10	10.0	16.3	108.6
Nitrogen - nitrate/nitrite (μg-N/L)	$<$10	572	692	1944
Nitrogen - total (μg-N/L)	323	719	868	2308
pH	6.1	7.2	7.2	7.7
Phosphorus - soluble (μg-P/L)	$<$3	8.2	10.8	35.3
Phosphorus - total (μg-P/L)	5.4	17.1	18.7	49.8
Temperature (C)	4.3	10.7	10.7	21.9
Turbidity (NTU)	0.3	1.4	2.0	11.9
Fecal coliforms (cfu/100 mL)	$<$2	23	116	1600

Table 7: Water quality data from Mia Creek compared to summary data from all sites. Mia Creek is a small unnamed tributary to Lake Samish. The flow at the site is often too low to sample, resulting in missing values on that date. When flowing, Mia Creek has fairly typical water quality. The coliforms were $>$50 cfu/100 mL on two sampling dates and $<$50 cfu/100 mL on three sampling dates, so it is difficult to tell whether there is consistent contamination at this site.

	2005 Jul 15	2005 Nov 10	2007 Jul 16	2008 Mar 17	2009 Feb 18	2009 Jul 13	2010 Feb 18	2010 Jul 16
Alkalinity (mg/L)	24.7	15.9	19.2	15.1	16.1	19.8	17.9	21.3
Conductivity (μS/cm)	94.2	74.8	83.8	67	71.2	72.8	68.4	81.1
Dissolved oxygen (mg/L)	8.3	14.6	9.1	12.5	12.7	8.6	13.3	9.0
Nitrogen - ammonium (μg-N/L)	$<$10	108.6	31.7	$<$10	$<$10	25.6	$<$10	$<$10
Nitrogen - nitrate/nitrite (μg-N/L)	474	1902	465	1211	920	625	738	462
Nitrogen - total (μg-N/L)	582	2308	551	1328	1057	781	840	594
pH	6.3	7.1	6.4	7.1	7.1	6.7	7.1	7.0
Phosphorus - soluble (μg-P/L)	15.5	8.7	8.2	7.2	8.1	4.6	5.9	7.9
Phosphorus - total (μg-P/L)	20.2	18.6	11.7	9.1	8.8	9.1	23.1	14.5
Temperature (C)	12.9	8.5	13.5	5.9	4.3	12.8	5.8	12.2
Turbidity (NTU)	0.8	0.9	1.1	1.4	0.6	0.4	1.4	1.4
Fecal coliforms (cfu/100 mL)	23	13	23	4	$<$2	130	10	130

	Data Summary - All Sites			
	Minimum	Median	Mean	Maximum
Alkalinity (mg/L)	12.2	21.8	29.5	59.7
Conductivity (μS/cm)	60.0	86.0	111.3	399.0
Dissolved oxygen (mg/L)	4.0	10.5	10.6	14.7
Nitrogen - ammonium (μg-N/L)	$<$10	10.0	16.3	108.6
Nitrogen - nitrate/nitrite (μg-N/L)	$<$10	572	692	1944
Nitrogen - total (μg-N/L)	323	719	868	2308
pH	6.1	7.2	7.2	7.7
Phosphorus - soluble (μg-P/L)	$<$3	8.2	10.8	35.3
Phosphorus - total (μg-P/L)	5.4	17.1	18.7	49.8
Temperature (C)	4.3	10.7	10.7	21.9
Turbidity (NTU)	0.3	1.4	2.0	11.9
Fecal coliforms (cfu/100 mL)	$<$2	23	116	1600

Table 8: Water quality data from Mud Creek compared to summary data from all sites. Mud Creek is an unnamed tributary to Lake Samish with sufficient flow to sample on all dates. The site often has very high total nitrogen and nitrate/nitrite concentrations. The low coliform counts (usually $<$50 cfu/100 mL), low ammonium concentrations, and average phosphorus concentrations suggest that the high nitrogen was not necessarily from upstream contamination. It could instead come from upstream Alders (*Alnus rubra*), which form a relationship with soil microbiota that can contribute large amounts of soluble nitrogen into adjacent streams.

	2005 Jul 15	2005 Nov 10	2007 Jul 16	2008 Mar 17	2009 Feb 18	2009 Jul 13	2010 Feb 18	2010 Jul 16
Alkalinity (mg/L)	21.3	19.7	19.7	17.6	17.9	20.1	23.4	19.4
Conductivity (μS/cm)	69.4	68.4	66.5	66.4	68.8	60	67.3	66.9
Dissolved oxygen (mg/L)	4.0	8.5	4.8	12.4	11.7	4.3	12.4	6.7
Nitrogen - ammonium (μg-N/L)	40.6	28	23.0	9.2	9.3	21.1	$<$10	24.3
Nitrogen - nitrate/nitrite (μg-N/L)	10	188	88	424	466	92	253	$<$10
Nitrogen - total (μg-N/L)	362	410	358	590	664	420	416	323
pH	6.1	7.2	6.4	7.3	7.3	6.8	7.4	6.9
Phosphorus - soluble (μg-P/L)	$<$3	$<$3	7.8	$<$3	3.5	$<$3	$<$3	$<$3
Phosphorus - total (μg-P/L)	25.9	9.6	13.8	5.4	10.4	14.9	24.1	17.9
Temperature (C)	20.5	10.7	21.9	6.4	5.7	19.5	7.7	20.2
Turbidity (NTU)	3.7	0.9	1.4	1.5	1.9	1.8	1.3	4.3
Fecal coliforms (cfu/100 mL)	130	8	80	8	500	300	4	50

	Data Summary - All Sites			
	Minimum	Median	Mean	Maximum
Alkalinity (mg/L)	12.2	21.8	29.5	59.7
Conductivity (μS/cm)	60.0	86.0	111.3	399.0
Dissolved oxygen (mg/L)	4.0	10.5	10.6	14.7
Nitrogen - ammonium (μg-N/L)	$<$10	10.0	16.3	108.6
Nitrogen - nitrate/nitrite (μg-N/L)	$<$10	572	692	1944
Nitrogen - total (μg-N/L)	323	719	868	2308
pH	6.1	7.2	7.2	7.7
Phosphorus - soluble (μg-P/L)	$<$3	8.2	10.8	35.3
Phosphorus - total (μg-P/L)	5.4	17.1	18.7	49.8
Temperature (C)	4.3	10.7	10.7	21.9
Turbidity (NTU)	0.3	1.4	2.0	11.9
Fecal coliforms (cfu/100 mL)	$<$2	23	116	1600

Table 9: Water quality data from Friday Creek (outlet) compared to summary data from all sites. Lake outlets have very different water quality compared to tributary creeks, with the outlet usually resembling lake water quality. This was very apparent in Friday Creek. The soluble phosphorus and nitrate/nitrite concentrations were very low, reflecting uptake of these essential algal nutrients in Lake Samish. The alkalinity, conductivity, and turbidity values were lower and more consistent than at other sites, reflecting the moderating effect of Lake Samish. The coliform concentrations were $\geq$50 cfu/100 mL on five sampling dates, which is somewhat unusual for lake outlets. (Fecal coliforms generally do not survive long outside their host, so they are not usually high unless there is a nearby source.) The coliform counts at Site D in Lake Samish were all $\leq$20 cfu/100 mL (Figure 15, page 22), so the coliforms may be coming from some source near the outlet.

2 References

APHA. 2005. Standard Methods for the Examination of Water and Wastewater, 21st Edition. American Public Health Association, American Water Works Association, and Water Environment Federation, Washington, DC.

Bortleson, G. C., N. P. Dion, J. B. McConnell, and L. M. Nelson. 1976. Reconnaissance Data on Lakes in Washington, Volume 1, Clallam, Island, Jefferson, San Juan, Skagit, and Whatcom Counties. Water-Supply Bull. 43(1), Washington State Department of Ecology, Tacoma, WA.

Carlson, R E. and J. Simpson. 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society. 96 pp.

Matthews, R. A., J. Vandersypen, and K. Hitchko. 2006. Lake Samish Monitoring Project 2006 Final Report. Final Report prepared by the Institute for Watershed Studies, Western Washington University, for the Samish Water District, November 3, 2006, Bellingham, WA.

Matthews, R. A. and J. Vandersypen. 2007. Lake Samish Monitoring Project 2007 Final Report. Final Report prepared by the Institute for Watershed Studies, Western Washington University, for the Samish Water District, November 13, 2007, Bellingham, WA.

Matthews, R. A. and J. Vandersypen. 2008. Lake Samish Monitoring Project 2008 Final Report. Final Report prepared by the Institute for Watershed Studies, Western Washington University, for the Samish Water District, September 30, 2008, Bellingham, WA.

Matthews, R. A. and J. Vandersypen. 2010. Lake Samish Monitoring Project 2010 Final Report. Final Report prepared by the Institute for Watershed Studies, Western Washington University, for the Samish Water District, March 20, 2010, Bellingham, WA.

A Lake Samish Hydrolab Profiles

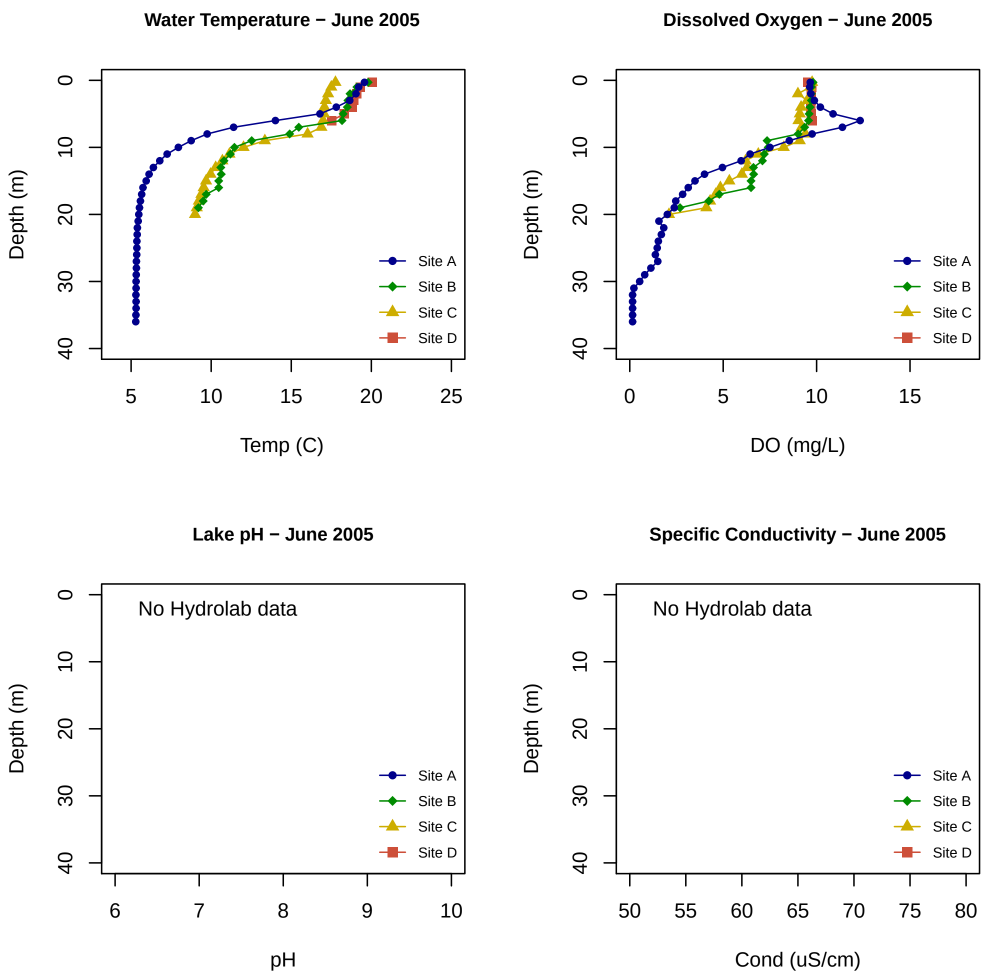


Figure 20: Lake Samish Hydrolab profiles for Sites A–D, June 21, 2005. Field pH and conductivity data were not collected on this date.

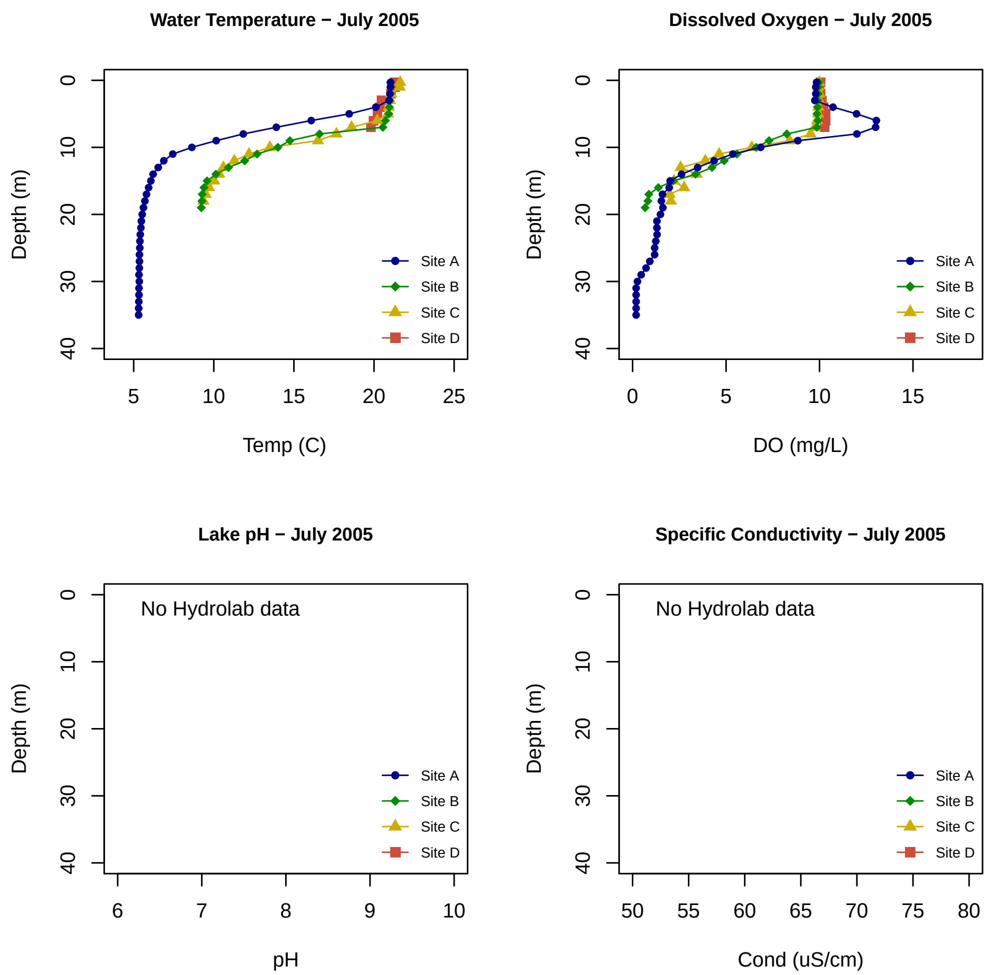


Figure 21: Lake Samish Hydrolab profiles for Sites A–D, July 20, 2005. Field pH and conductivity data were not collected on this date.

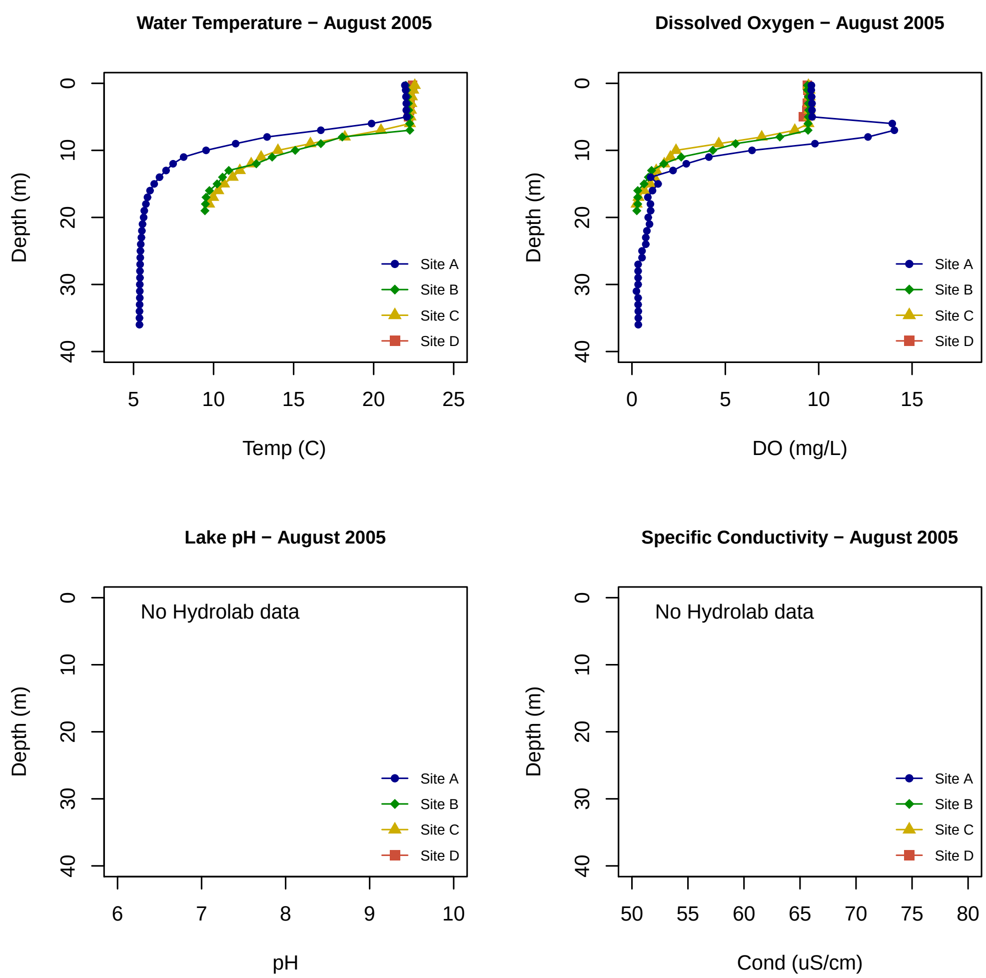


Figure 22: Lake Samish Hydrolab profiles for Sites A–D, August 23, 2005. Field pH and conductivity data were not collected on this date.

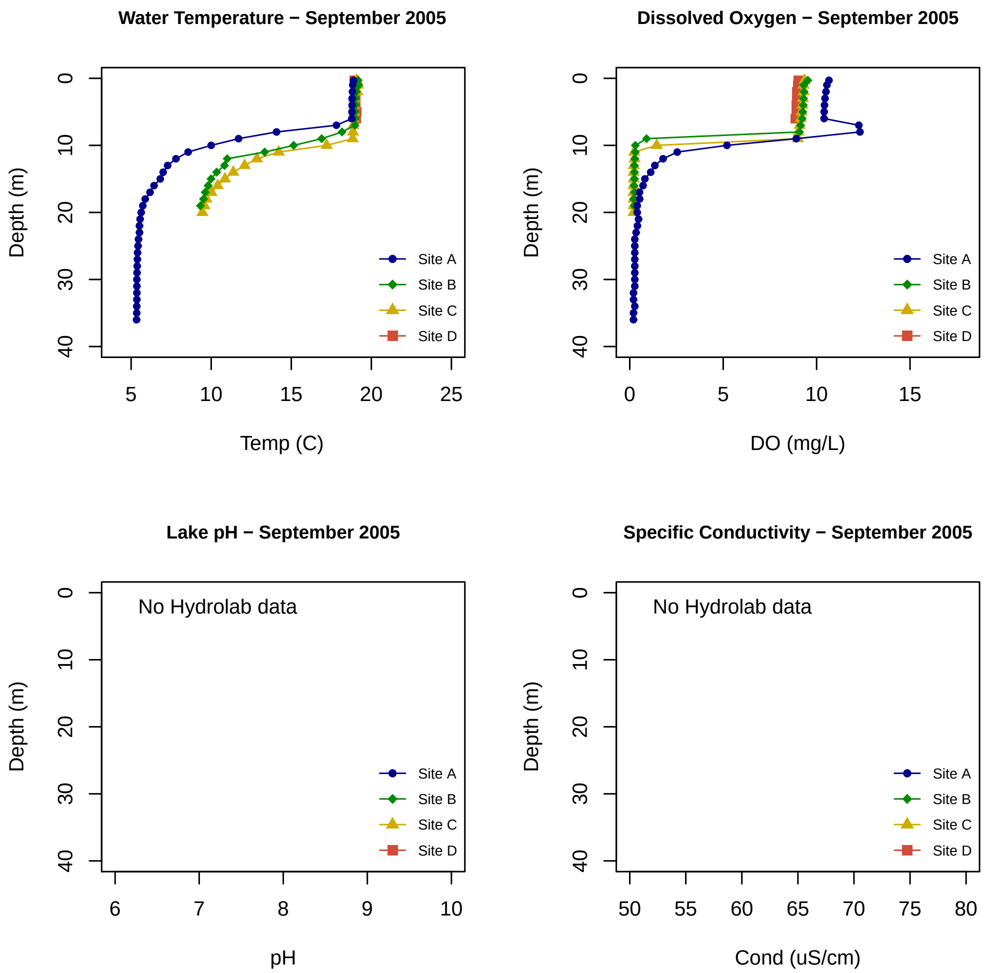


Figure 23: Lake Samish Hydrolab profiles for Sites A–D, September 20, 2005. Field pH and conductivity data were not collected on this date.

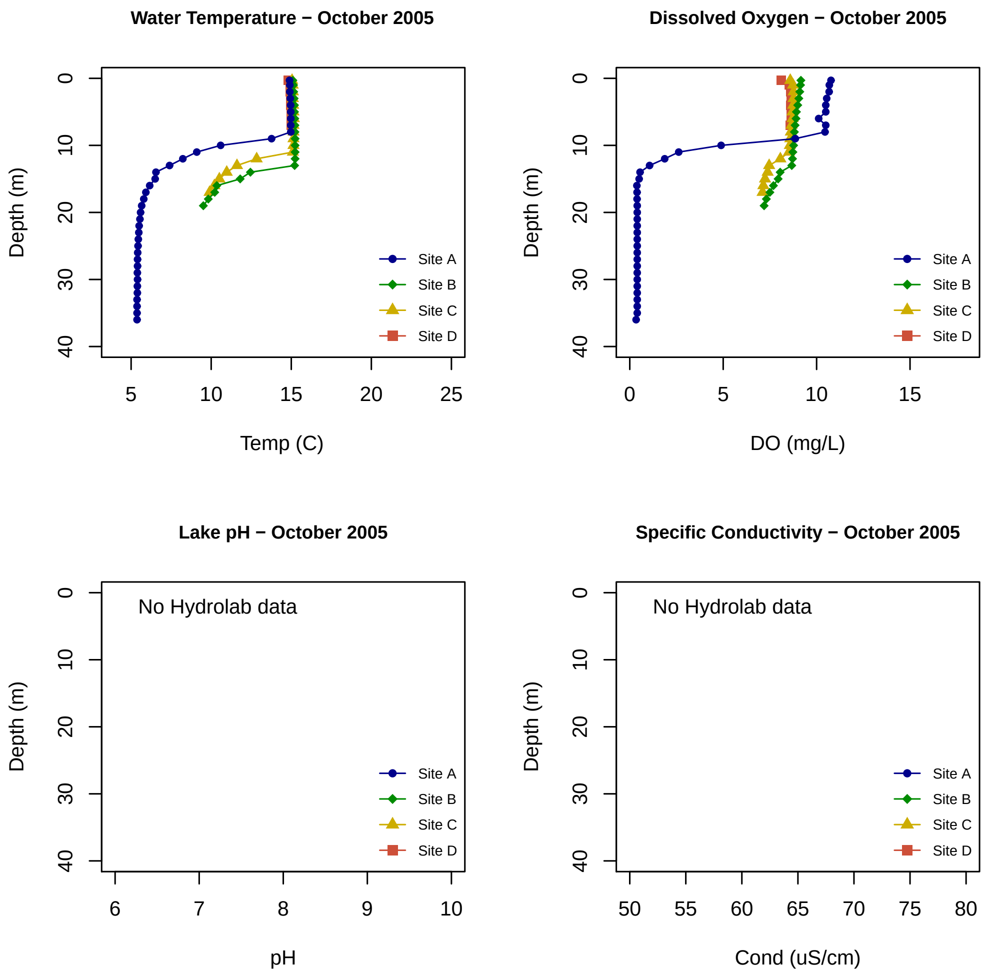


Figure 24: Lake Samish Hydrolab profiles for Sites A–D, October 16, 2005. Field pH and conductivity data were not collected on this date.

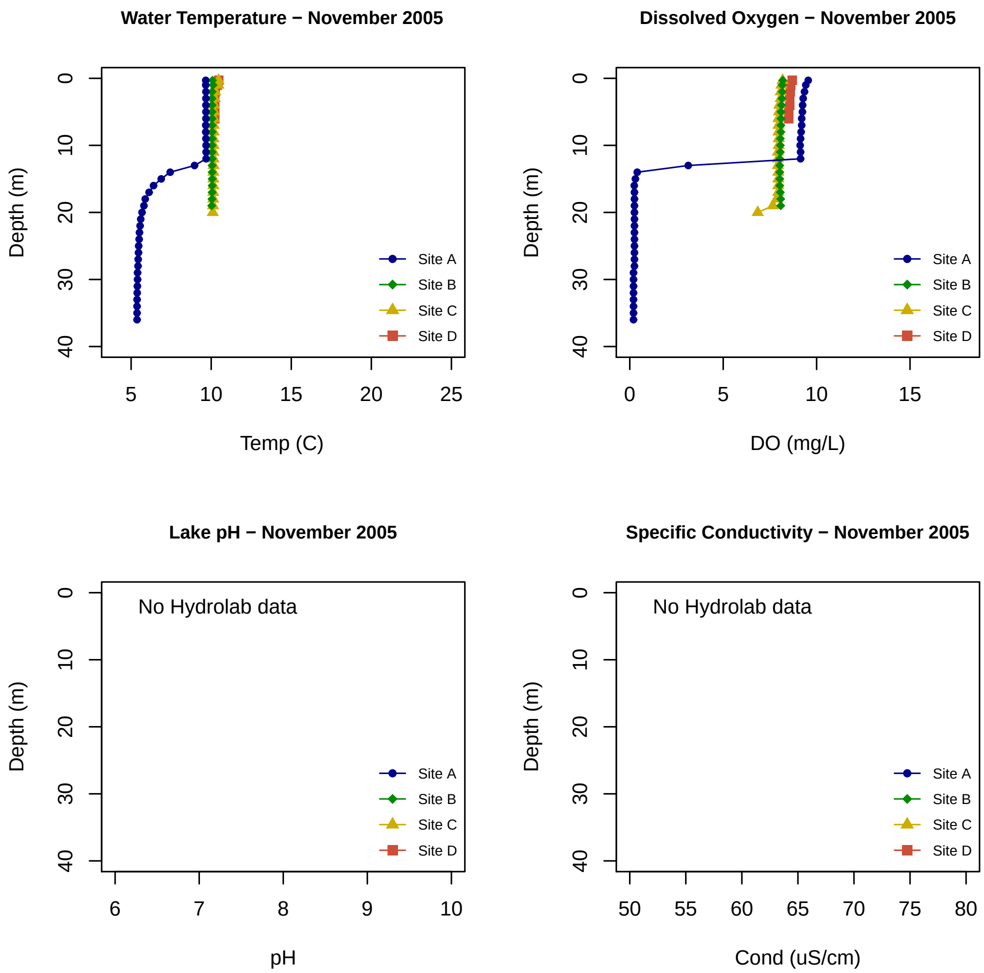


Figure 25: Lake Samish Hydrolab profiles for Sites A–D, November 20, 2005. Field pH and conductivity data were not collected on this date.

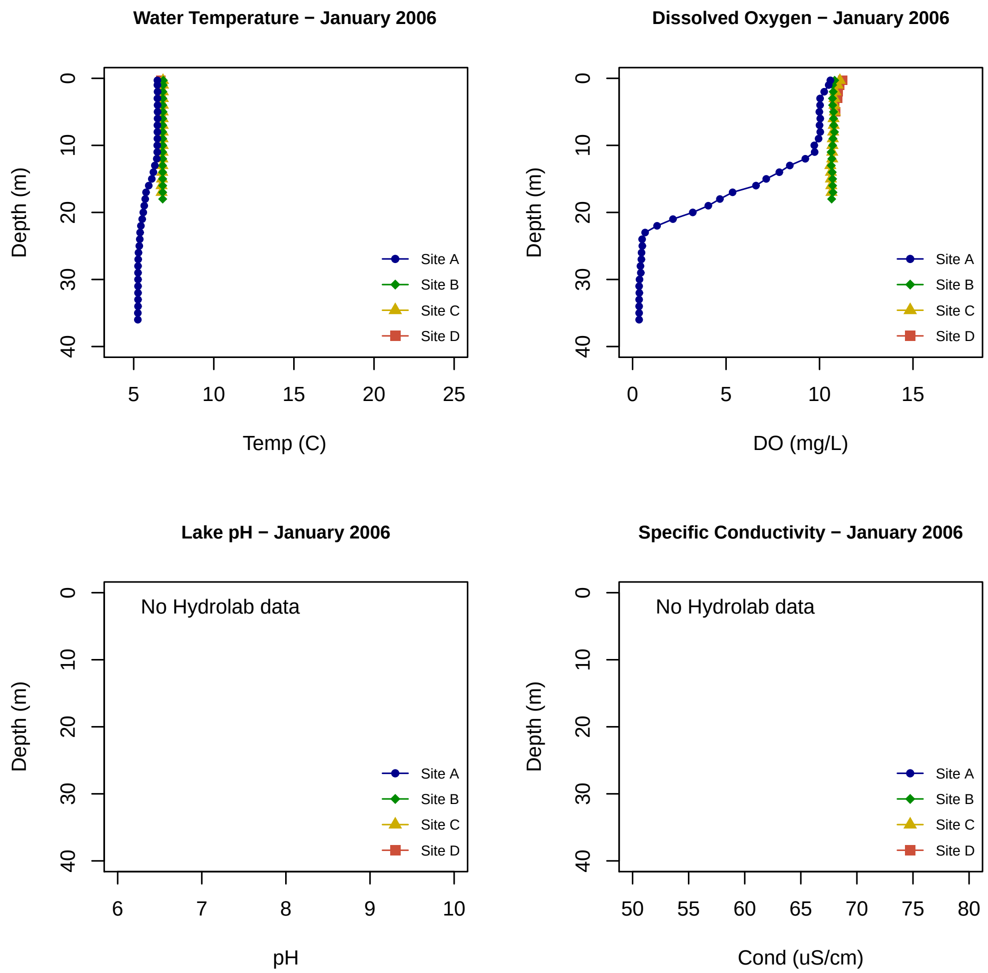


Figure 26: Lake Samish Hydrolab profiles for Sites A–D, January 22, 2006. Field pH and conductivity data were not collected on this date.

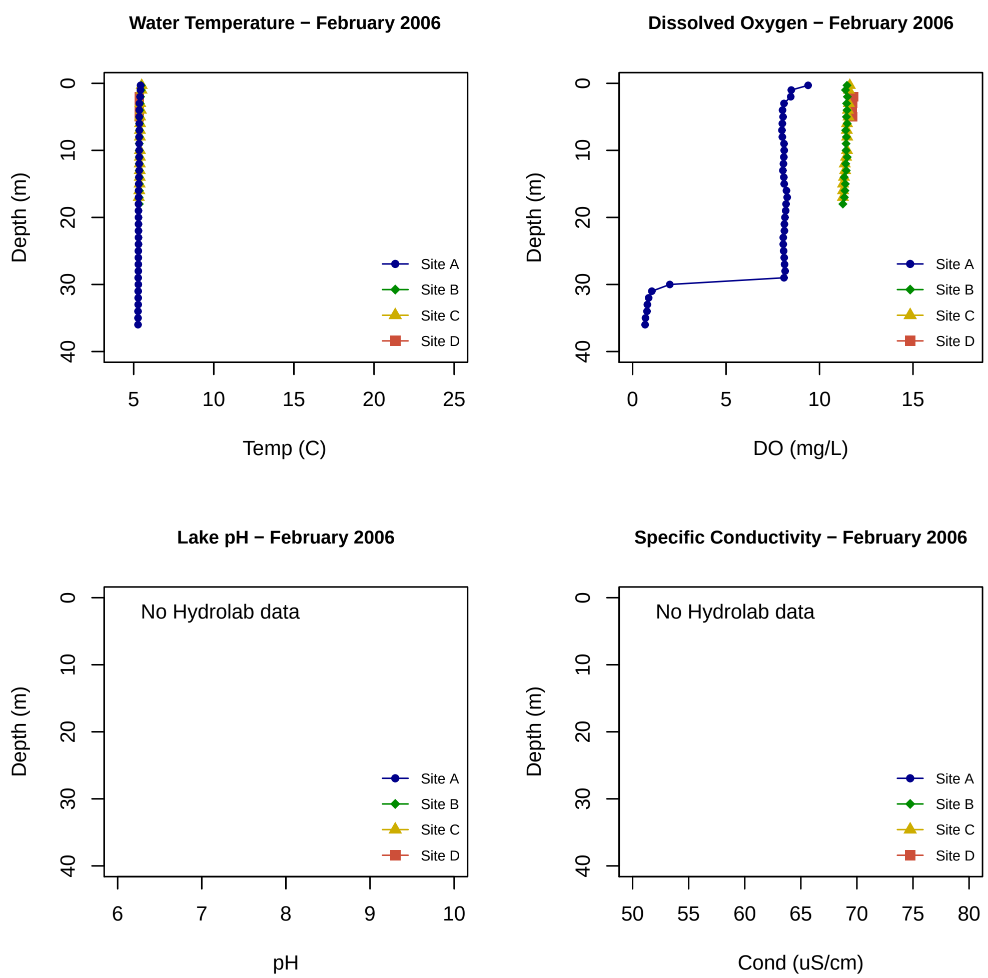


Figure 27: Lake Samish Hydrolab profiles for Sites A–D, February 26, 2006. Field pH and conductivity data were not collected on this date.

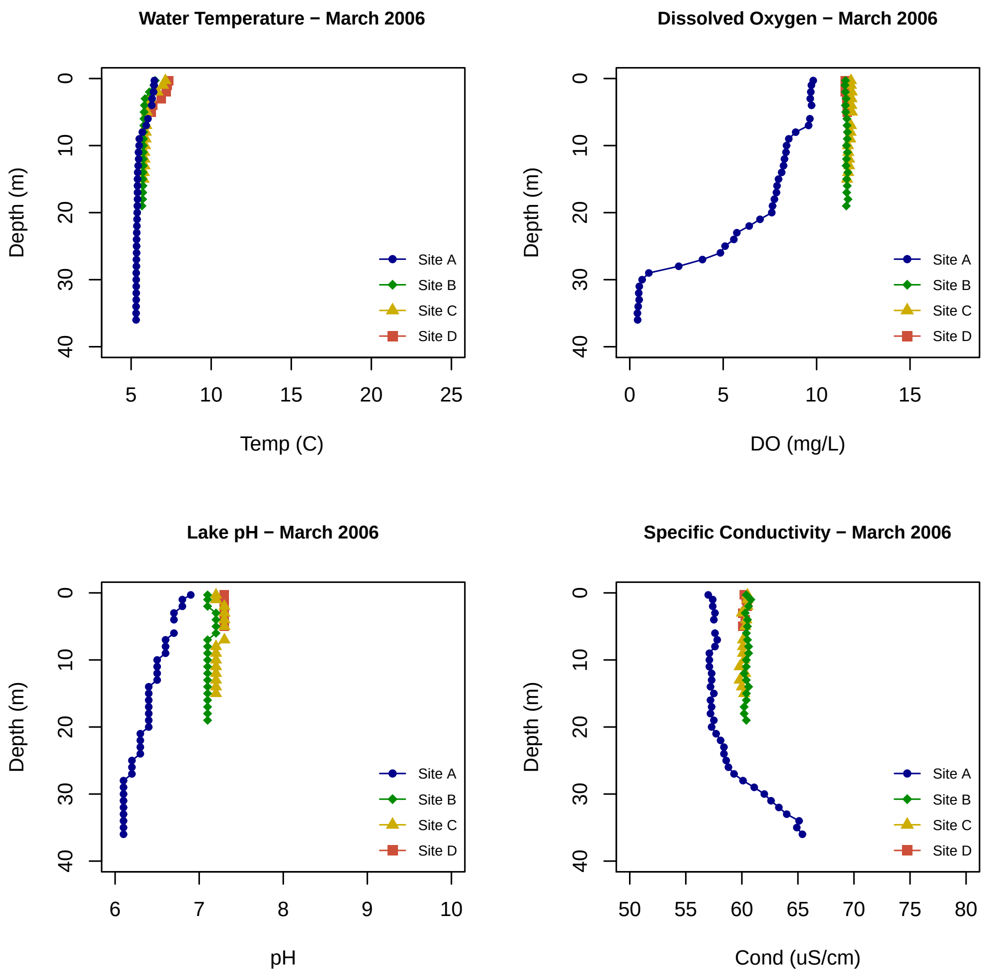


Figure 28: Lake Samish Hydrolab profiles for Sites A–D, March 19, 2006.

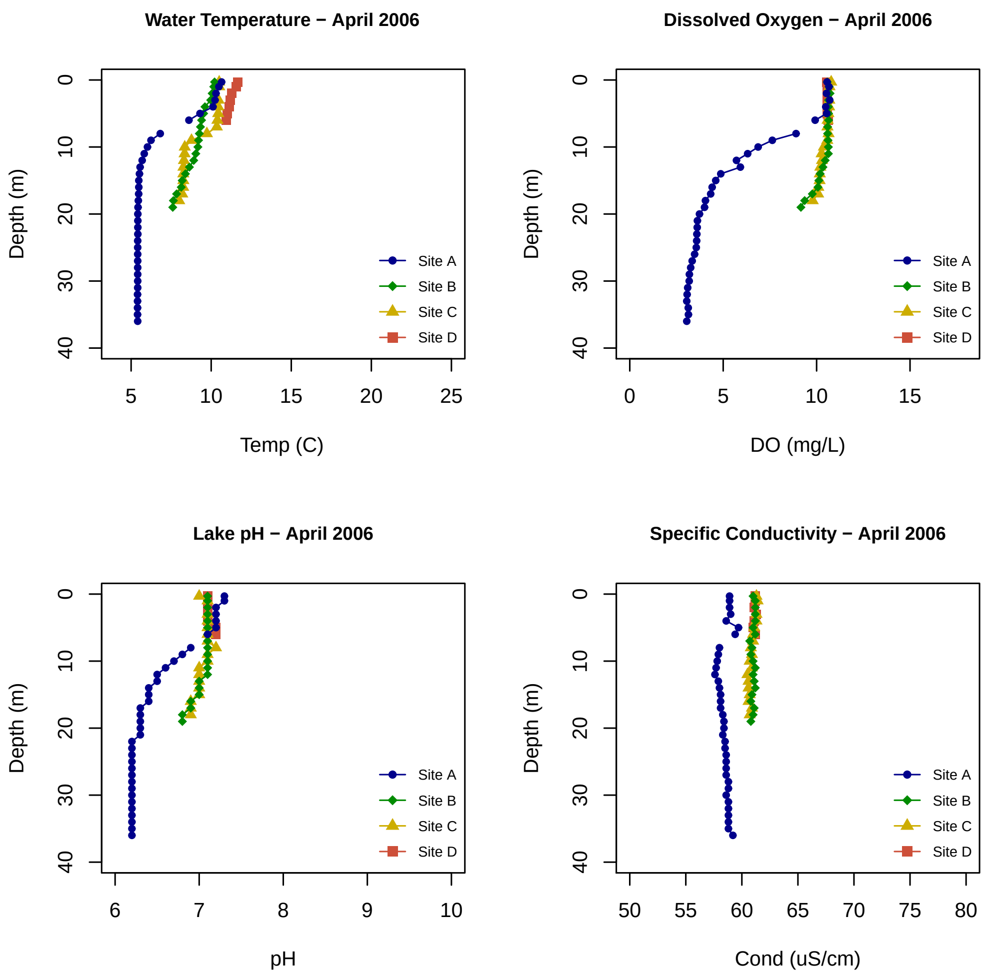


Figure 29: Lake Samish Hydrolab profiles for Sites A–D, April 23, 2006.

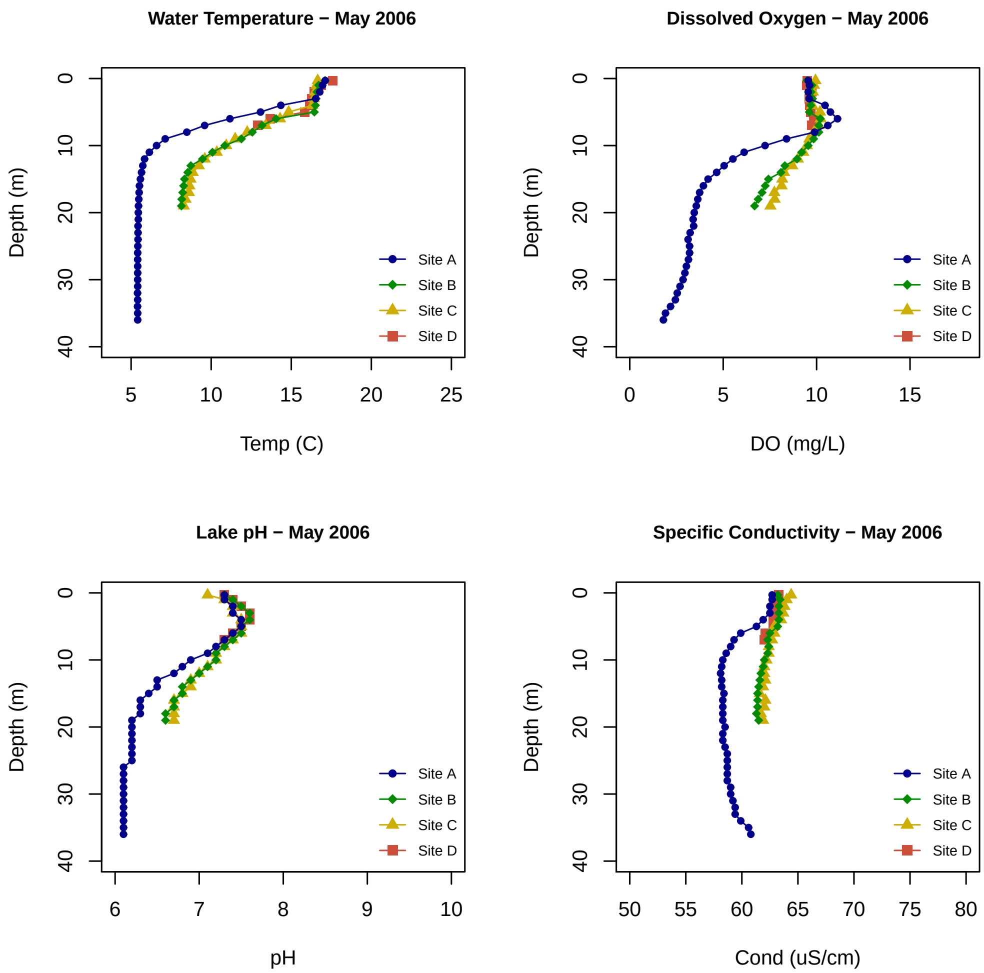


Figure 30: Lake Samish Hydrolab profiles for Sites A–D, May 21, 2006.

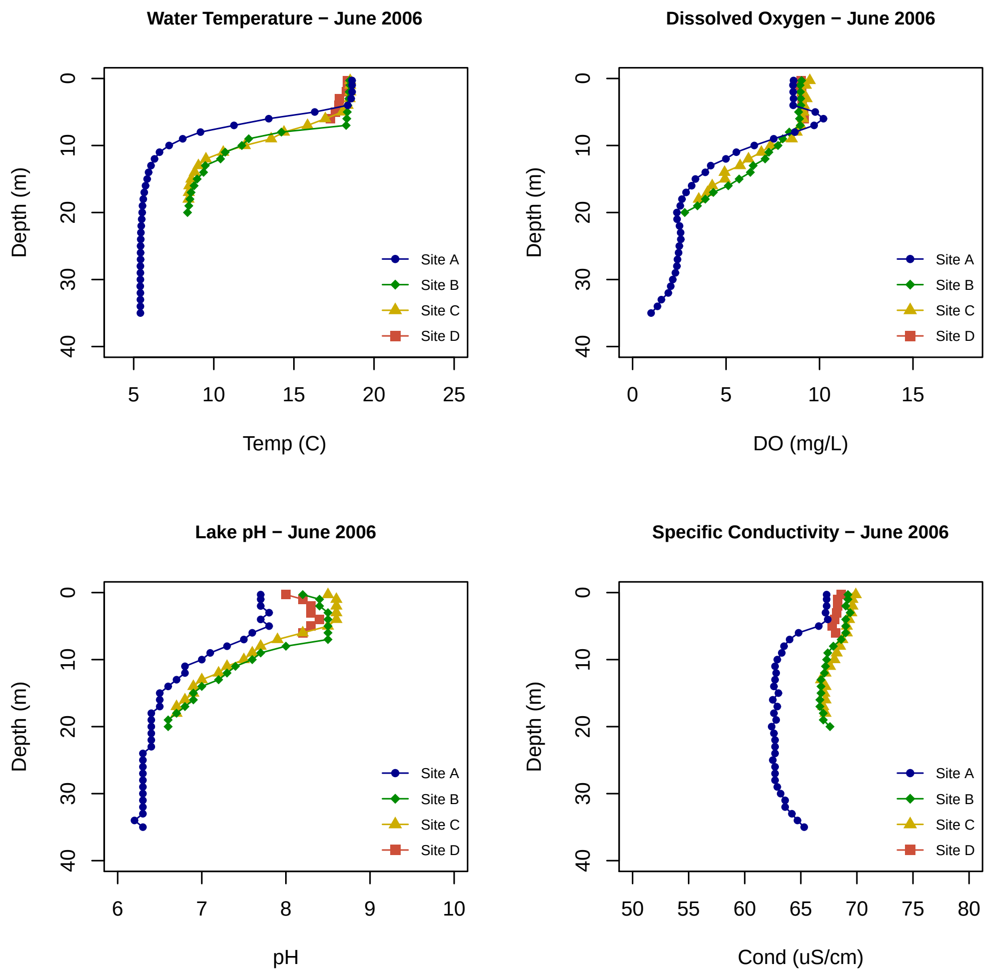


Figure 31: Lake Samish Hydrolab profiles for Sites A–D, June 20, 2006.

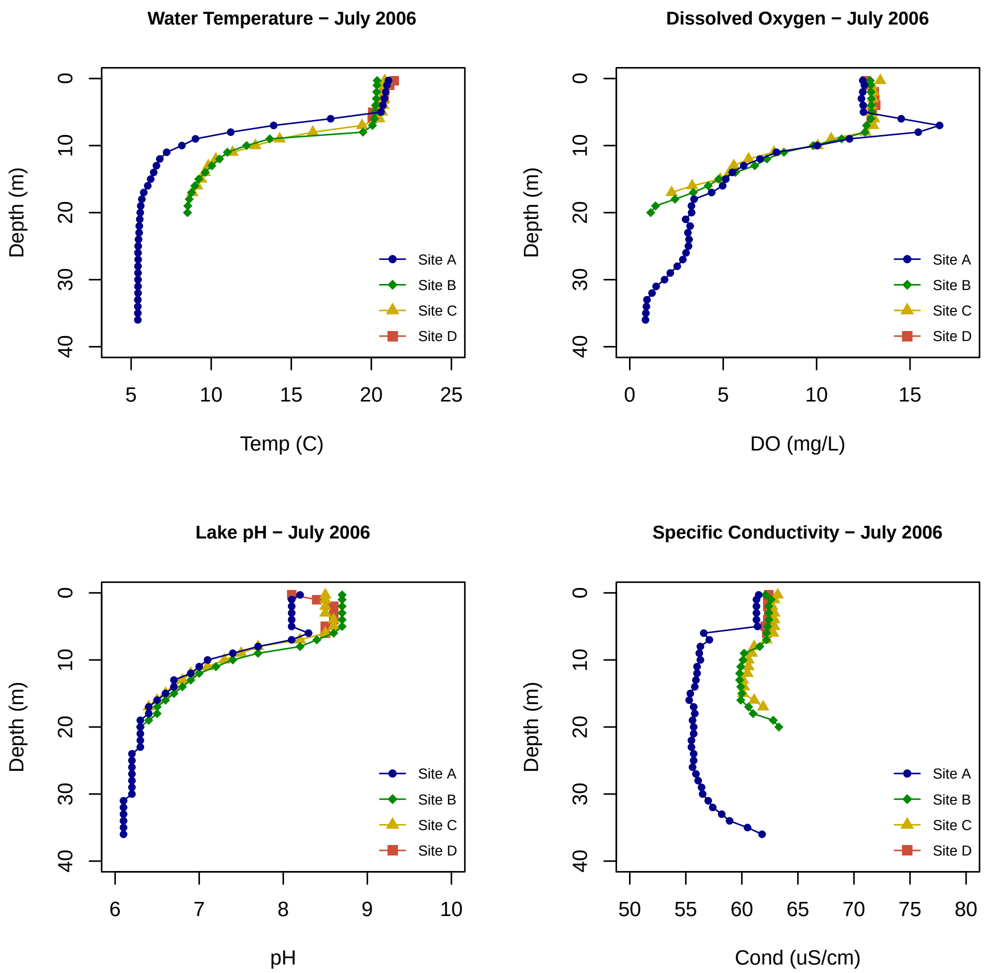


Figure 32: Lake Samish Hydrolab profiles for Sites A–D, July 19, 2006.

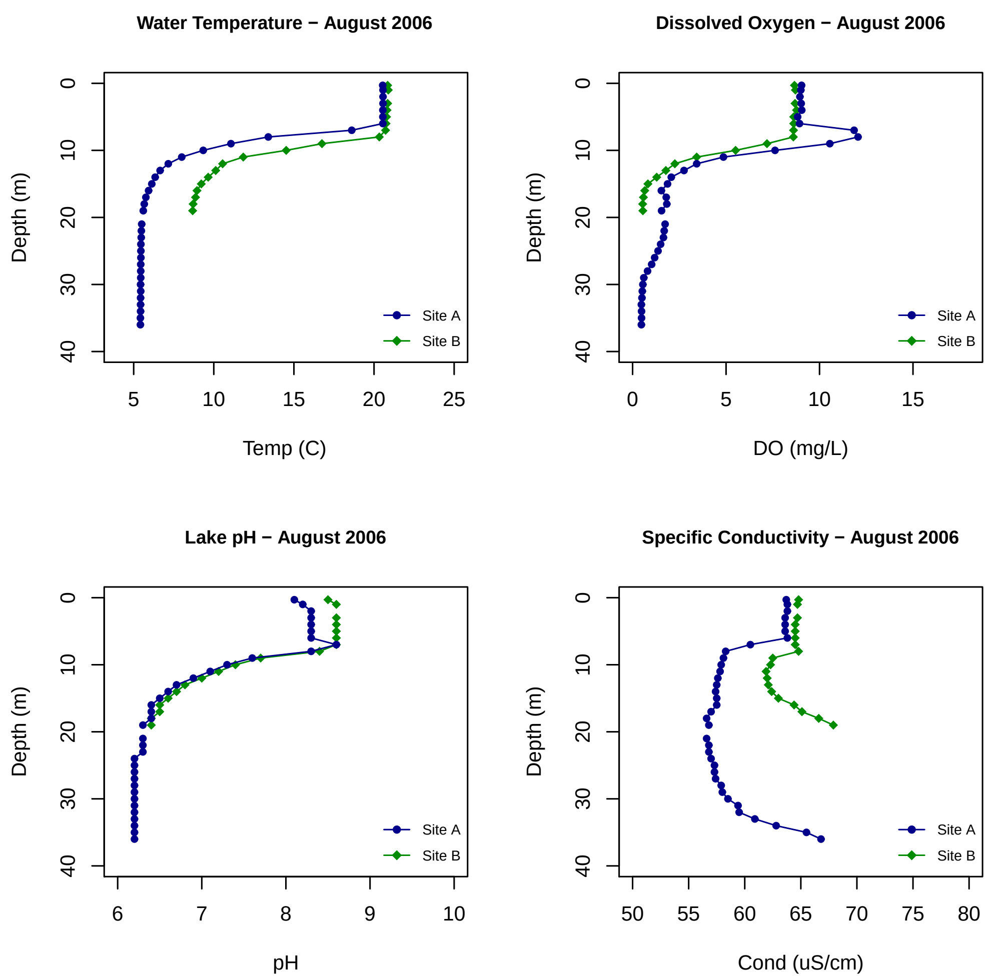


Figure 33: Lake Samish Hydrolab profiles for Sites A and B, August 24, 2006. Sites C and D were not sampled on this date.

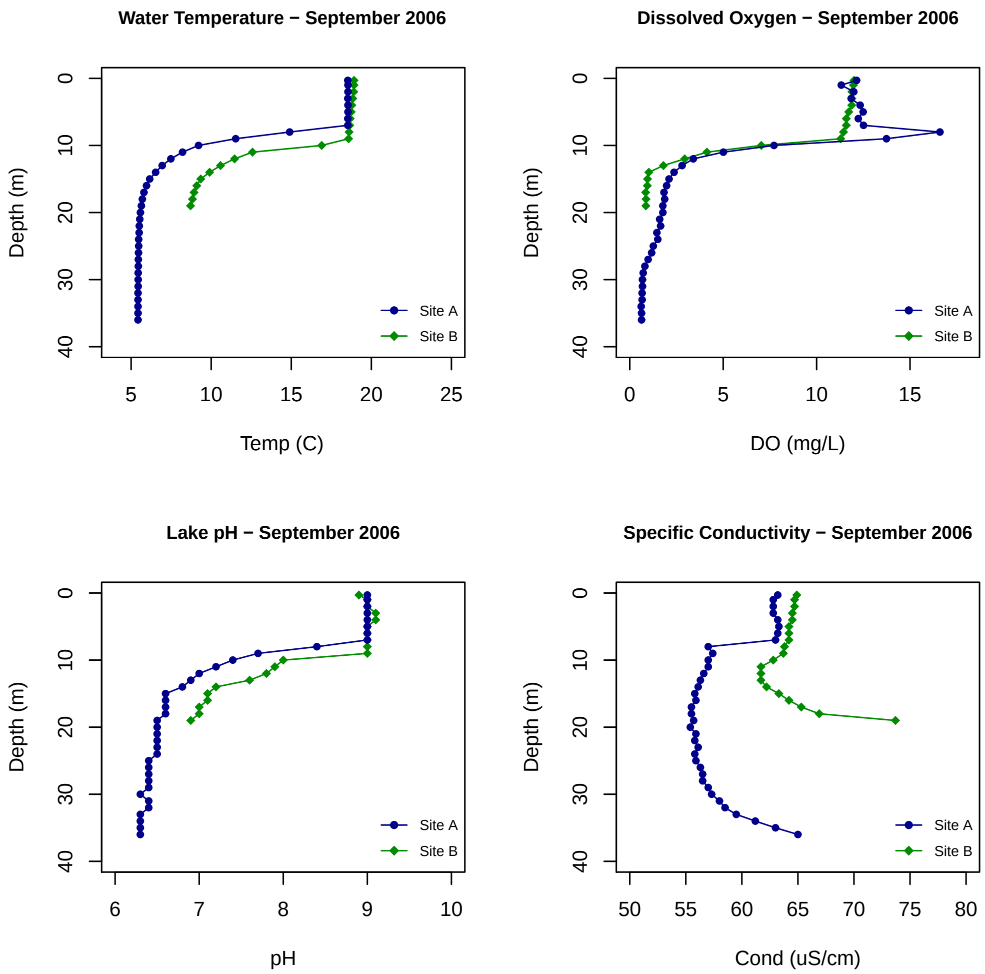


Figure 34: Lake Samish Hydrolab profiles for Sites A and B, September 18, 2006. Sites C and D were not sampled on this date.

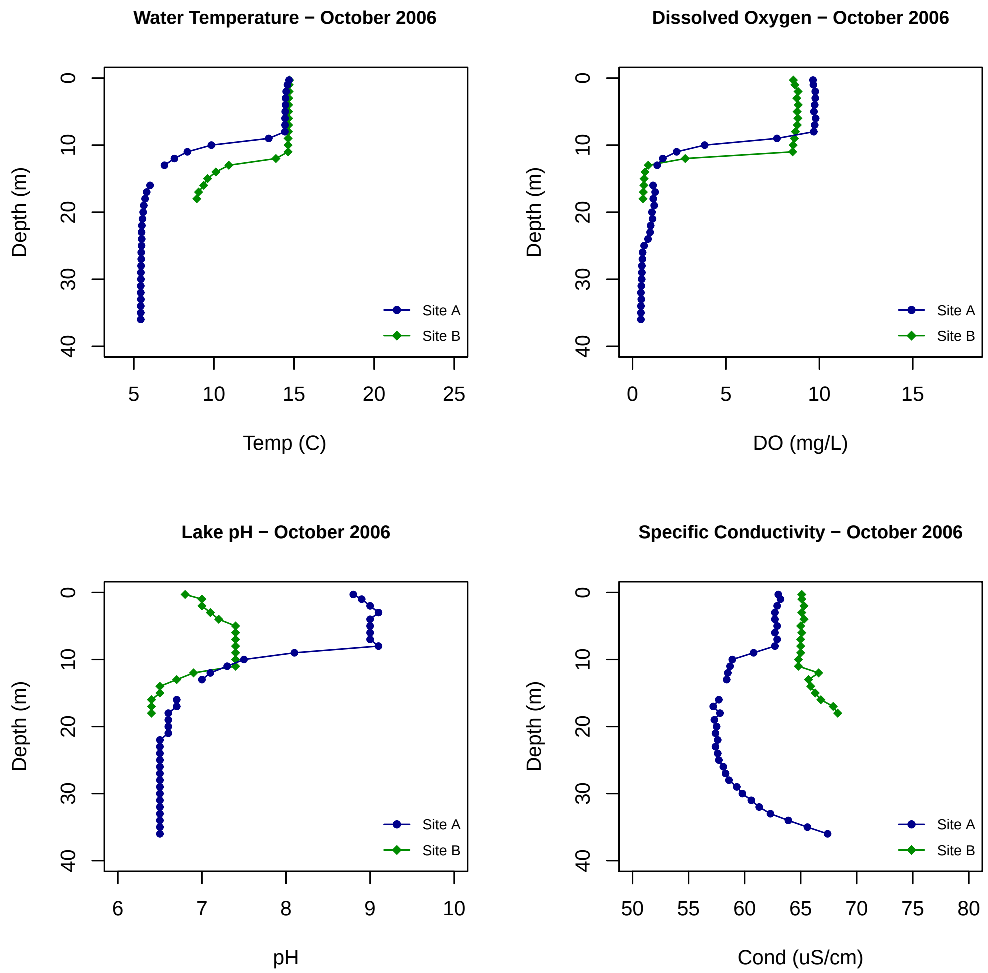


Figure 35: Lake Samish Hydrolab profiles for Sites A and B, October 22, 2006. Sites C and D were not sampled on this date.

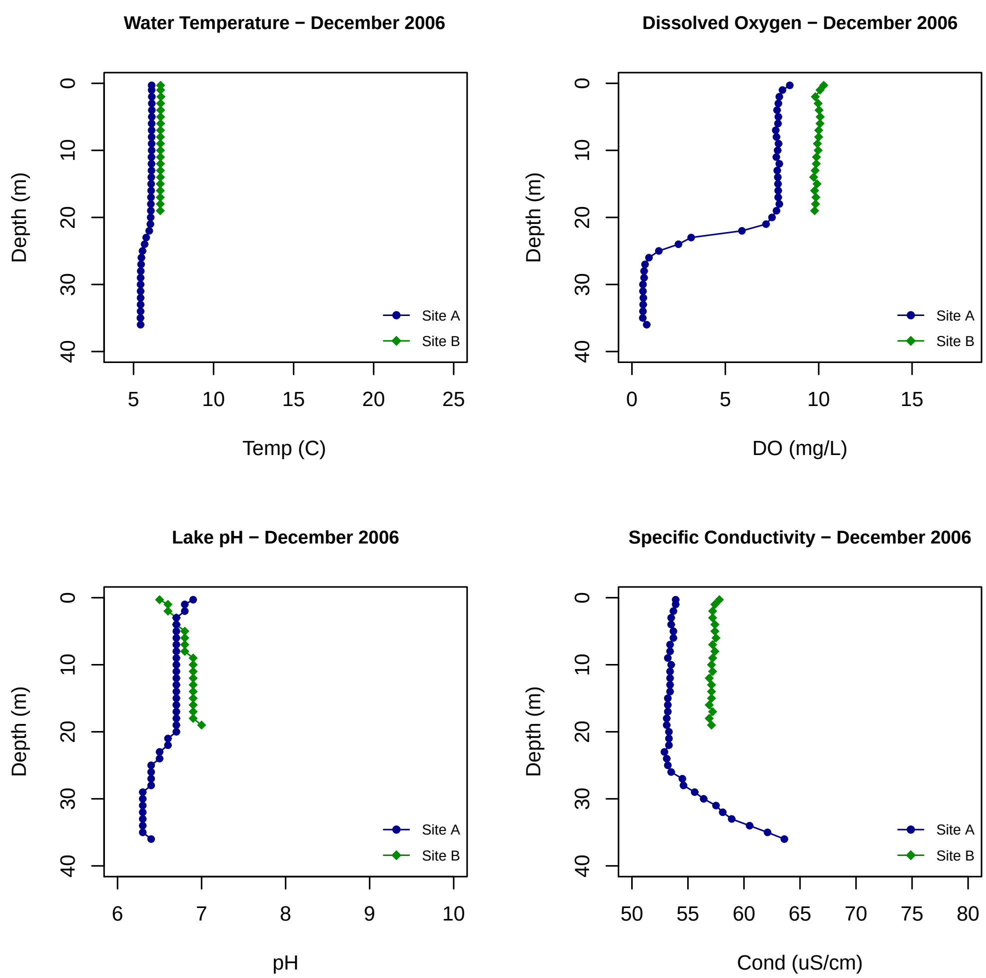


Figure 36: Lake Samish Hydrolab profiles for Sites A and B, December 18, 2006. Sites C and D were not sampled on this date.

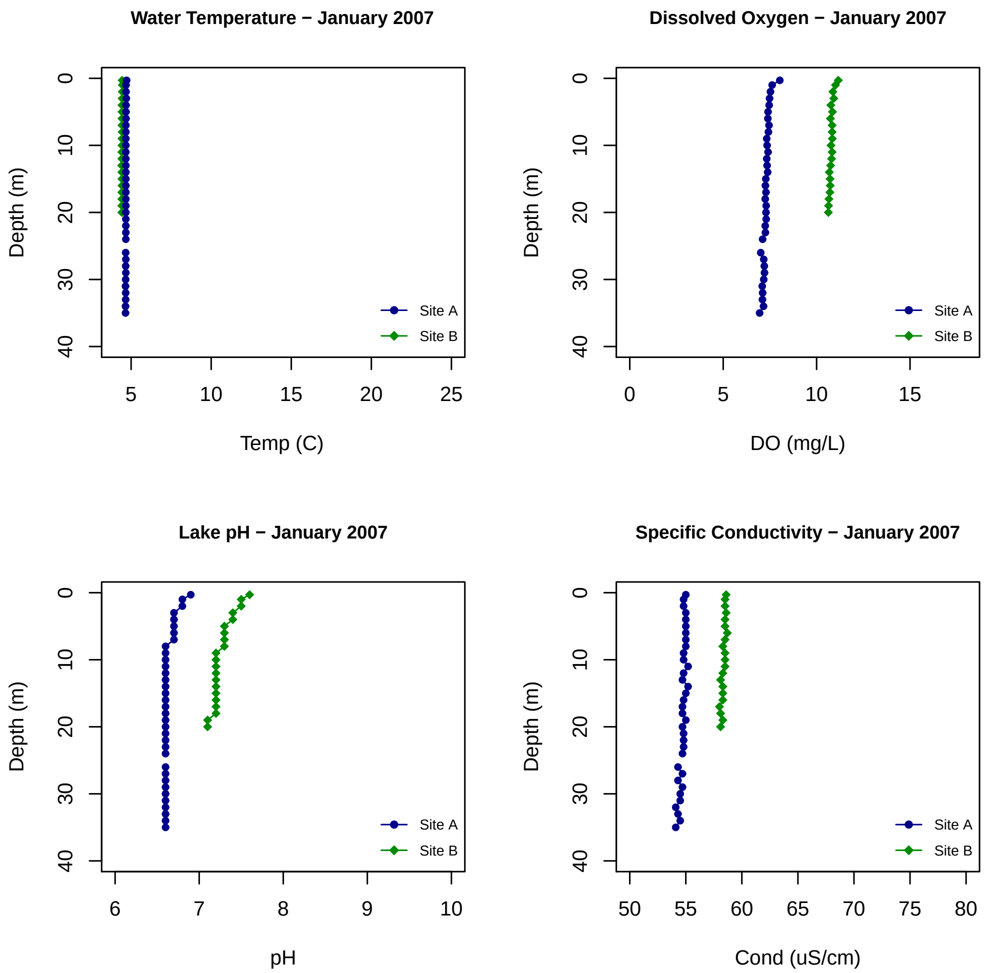


Figure 37: Lake Samish Hydrolab profiles for Sites A and B, January 30, 2007. Sites C and D were not sampled on this date.

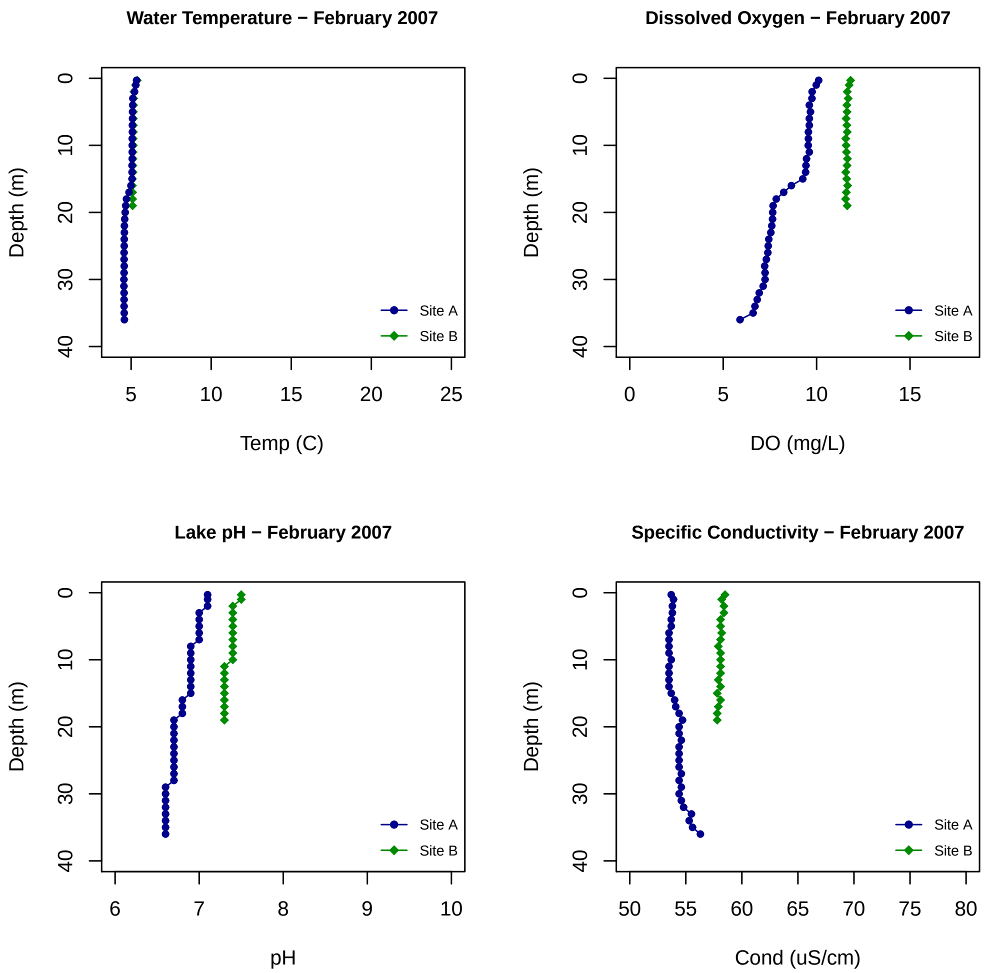


Figure 38: Lake Samish Hydrolab profiles for Sites A and B, February 27, 2007. Sites C and D were not sampled on this date.

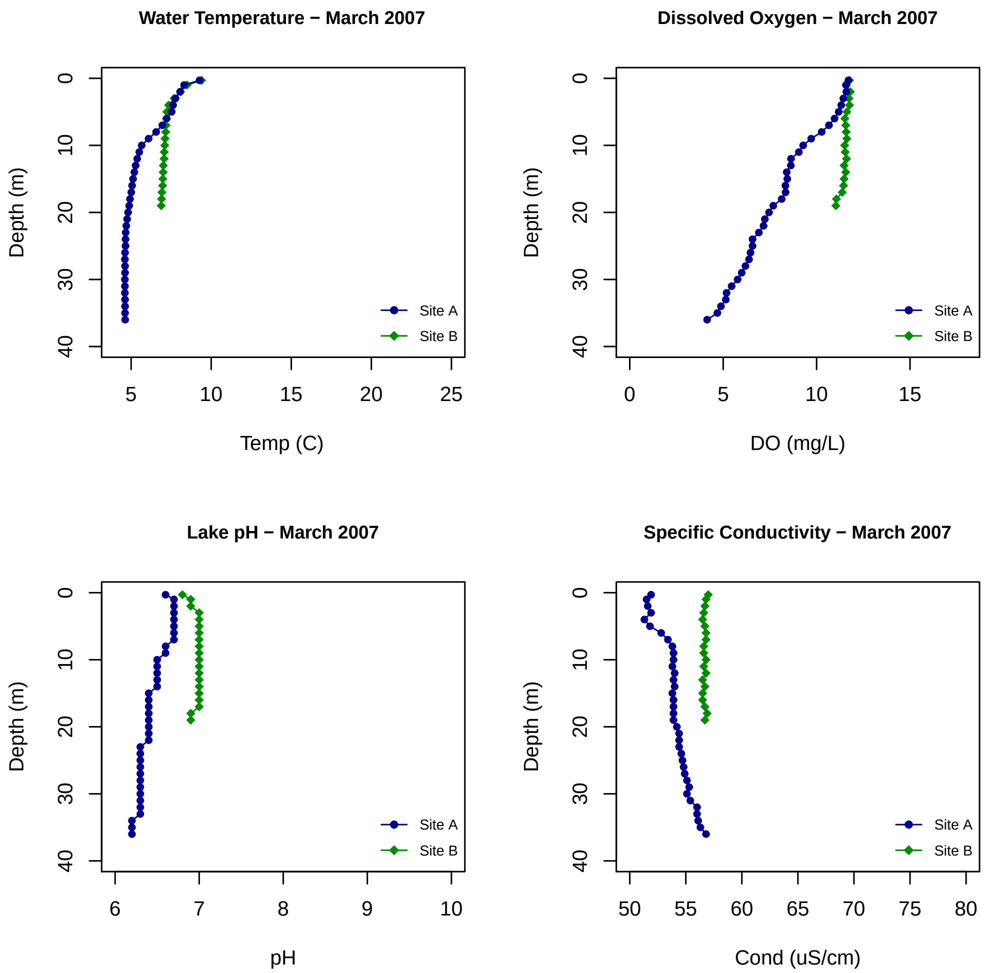


Figure 39: Lake Samish Hydrolab profiles for Sites A and B, March 29, 2007. Sites C and D were not sampled on this date.

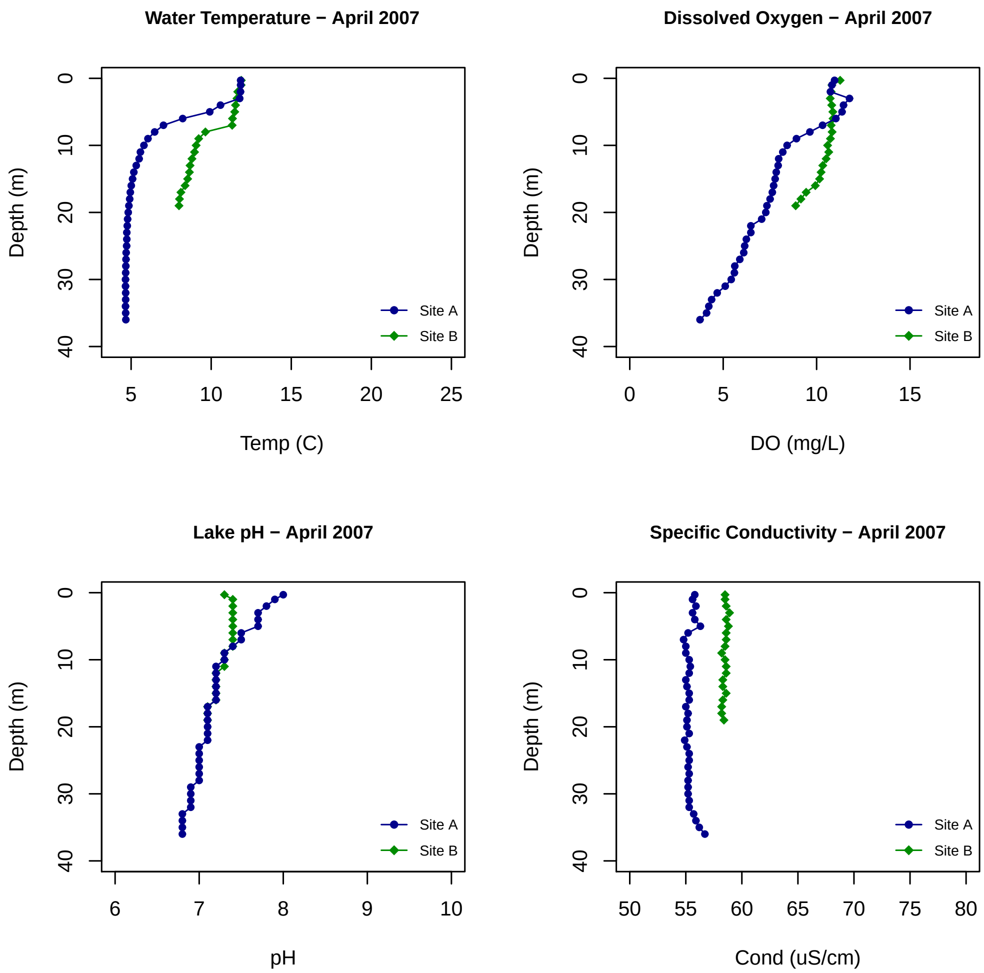


Figure 40: Lake Samish Hydrolab profiles for Sites A and B, April 24, 2007. Sites C and D were not sampled on this date.

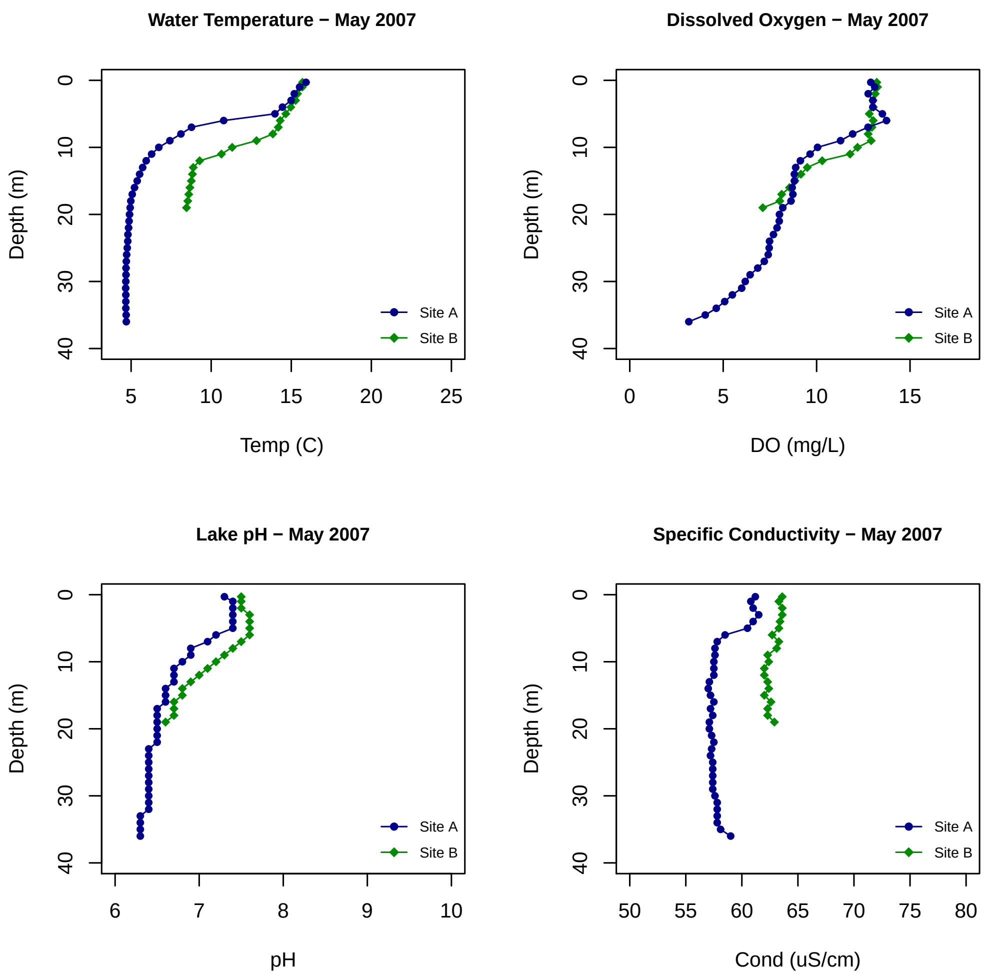


Figure 41: Lake Samish Hydrolab profiles for Sites A and B, May 24, 2007. Sites C and D were not sampled on this date.

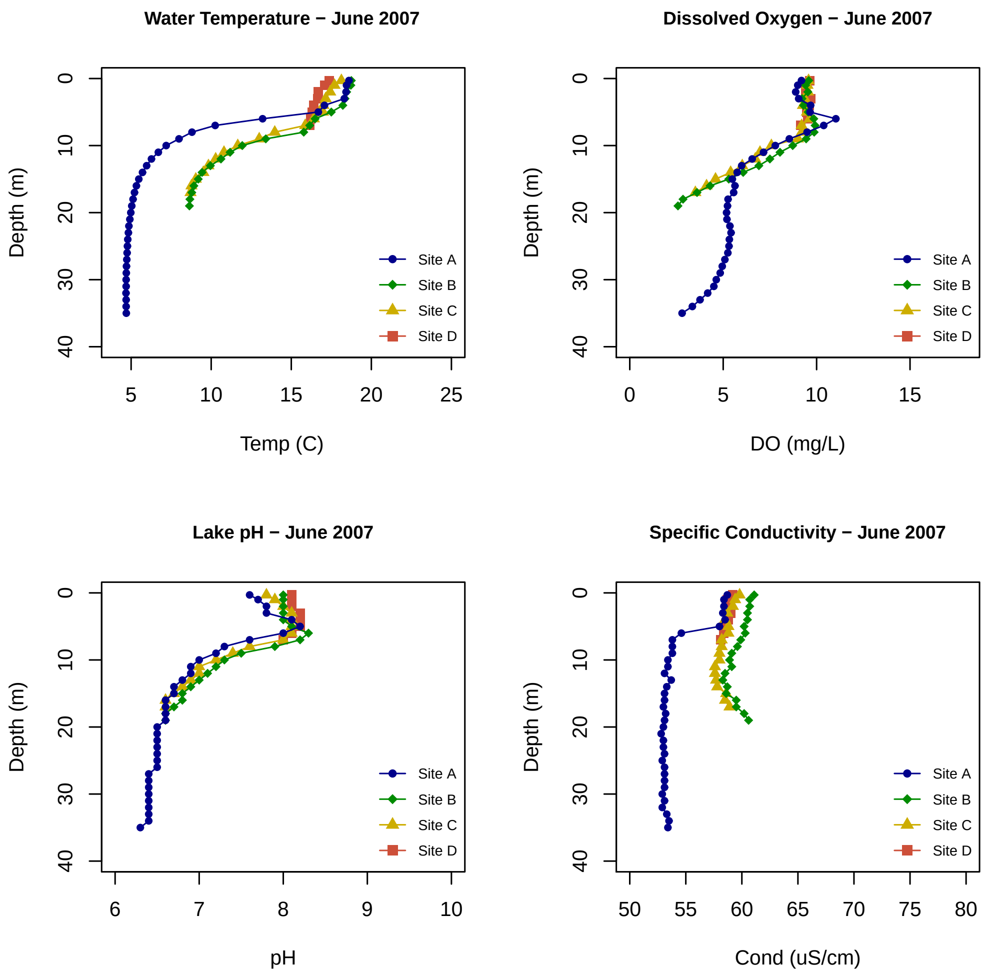


Figure 42: Lake Samish Hydrolab profiles for Sites A–D, June 21, 2007.

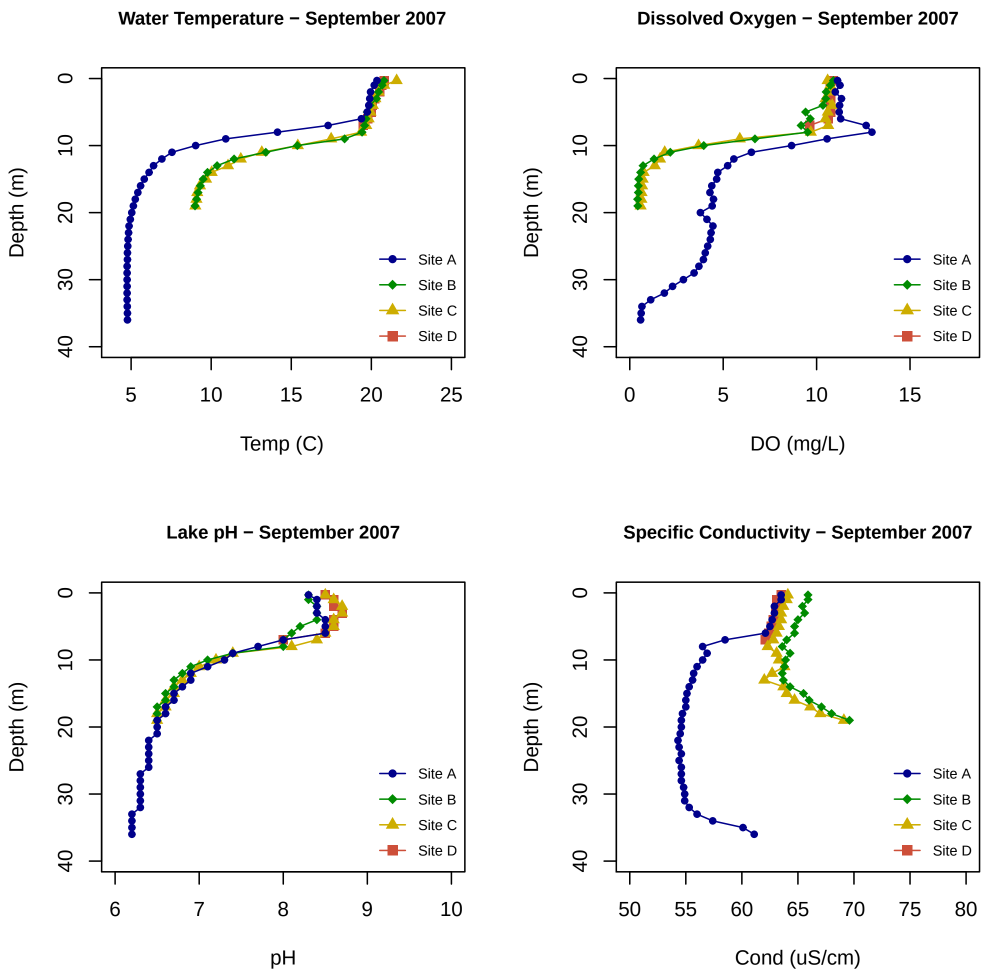


Figure 43: Lake Samish Hydrolab profiles for Sites A–D, September 13, 2007.

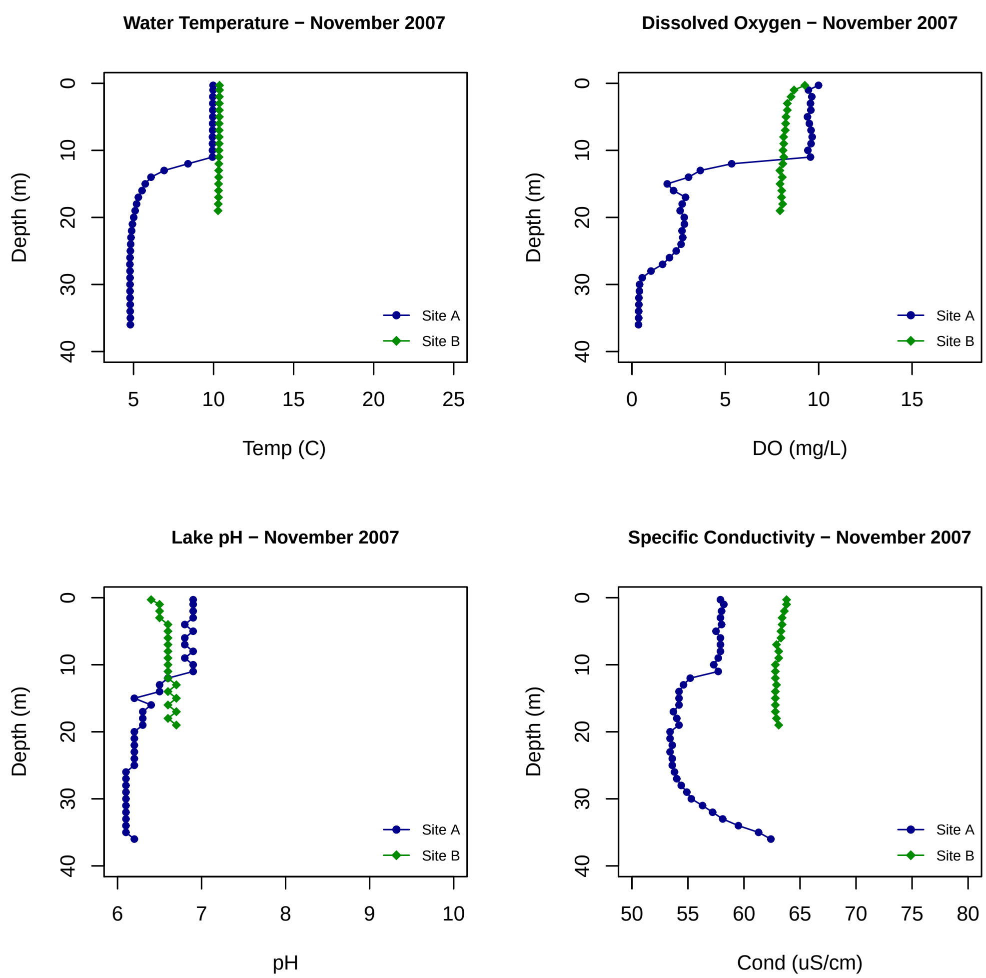


Figure 44: Lake Samish Hydrolab profiles for Sites A and B, November 15, 2007. Sites C and D were not sampled on this date.

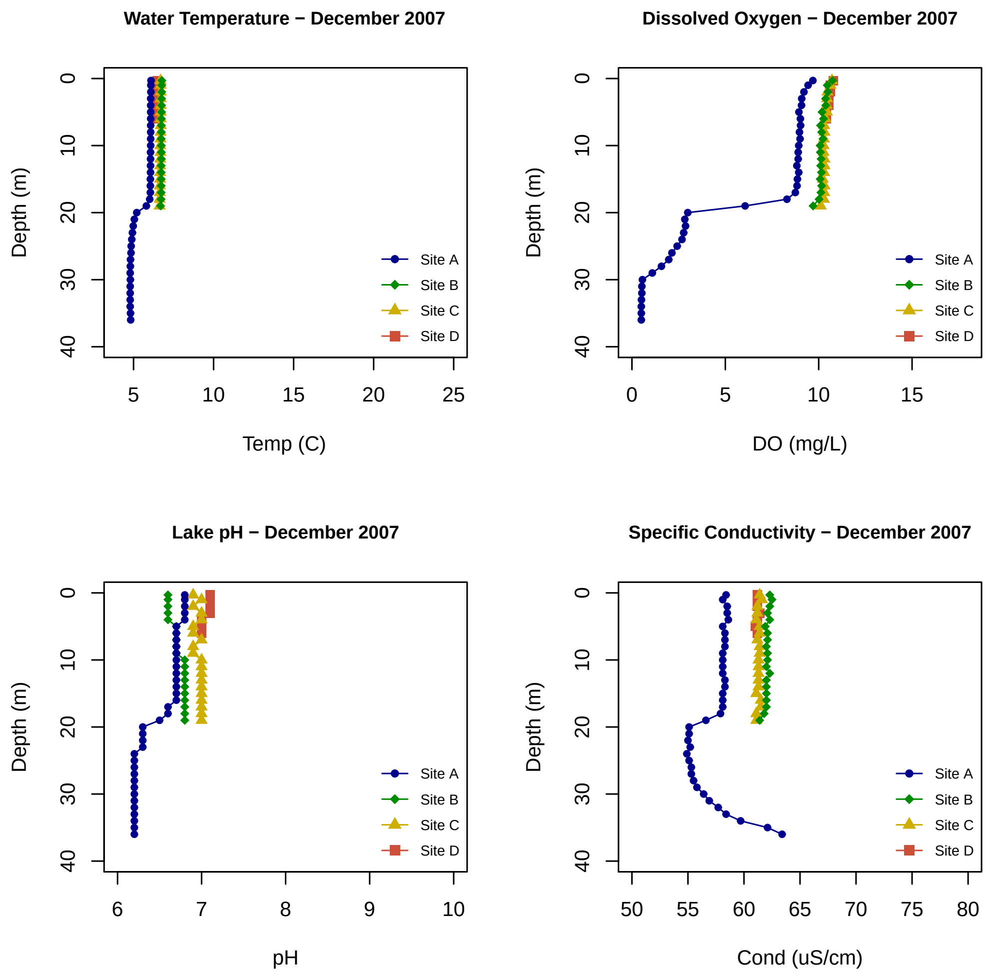


Figure 45: Lake Samish Hydrolab profiles for Sites A–D, December 20, 2007.

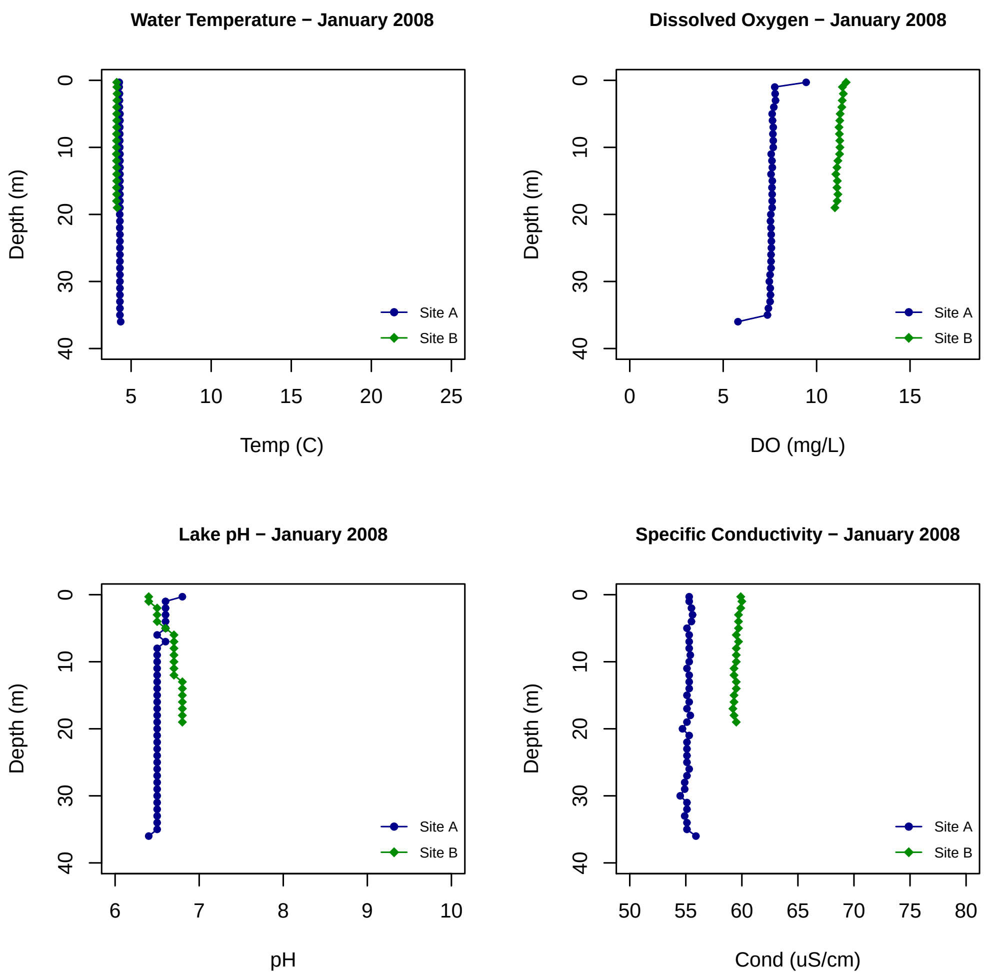


Figure 46: Lake Samish Hydrolab profiles for Sites A and B, January 29, 2008. Sites C and D were not sampled on this date.

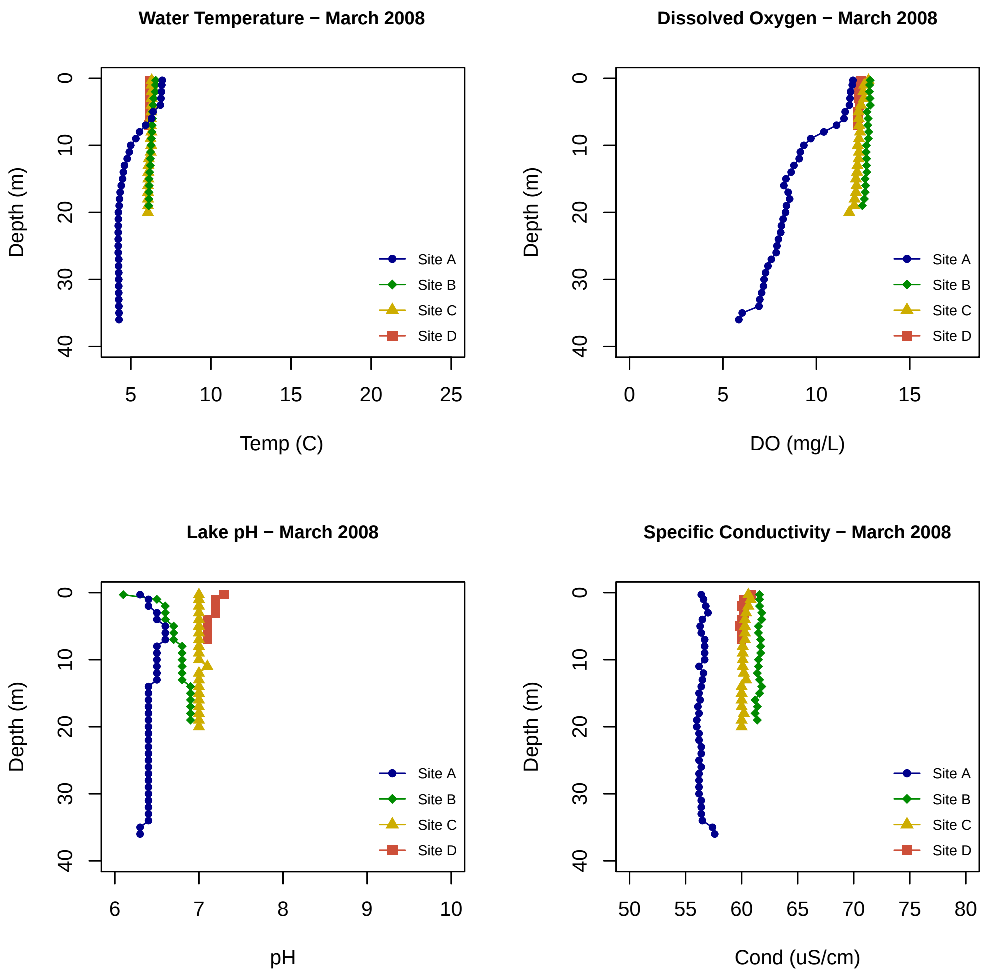


Figure 47: Lake Samish Hydrolab profiles for Sites A–D, March 25, 2008.

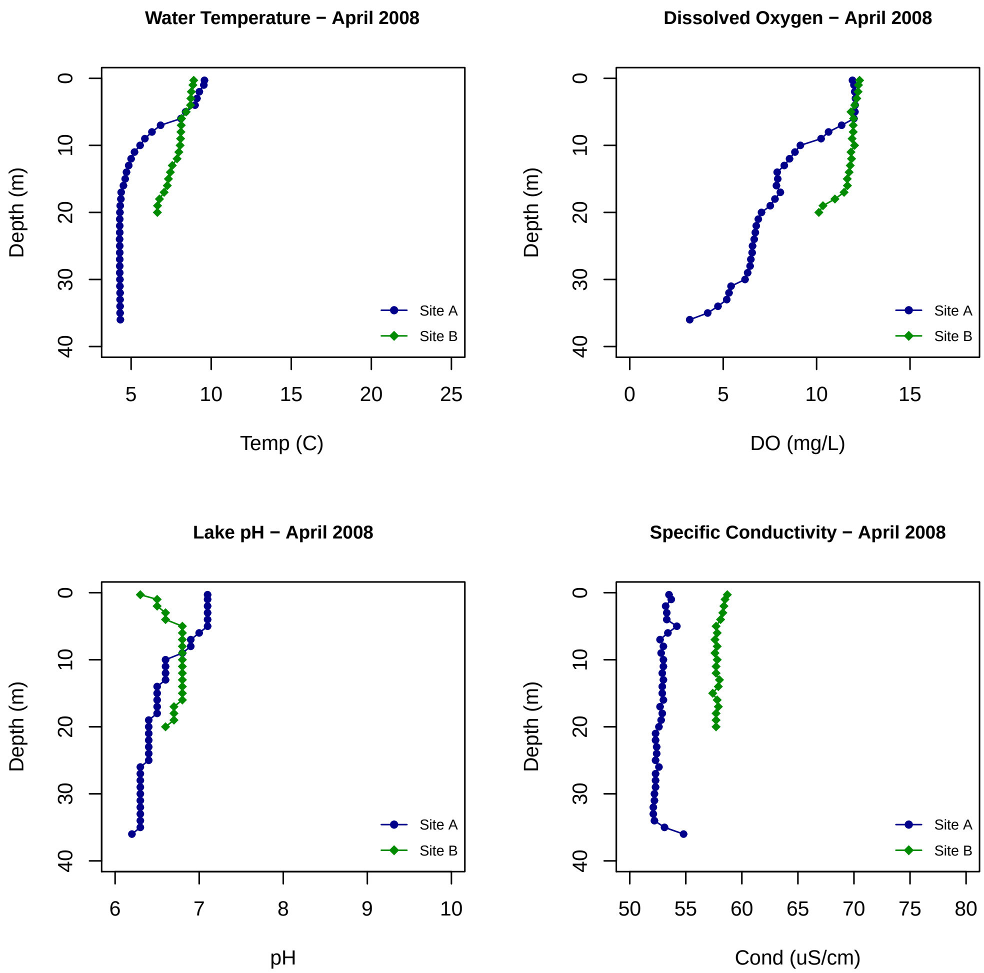


Figure 48: Lake Samish Hydrolab profiles for Sites A and B, April 21, 2008. Sites C and D were not sampled on this date.

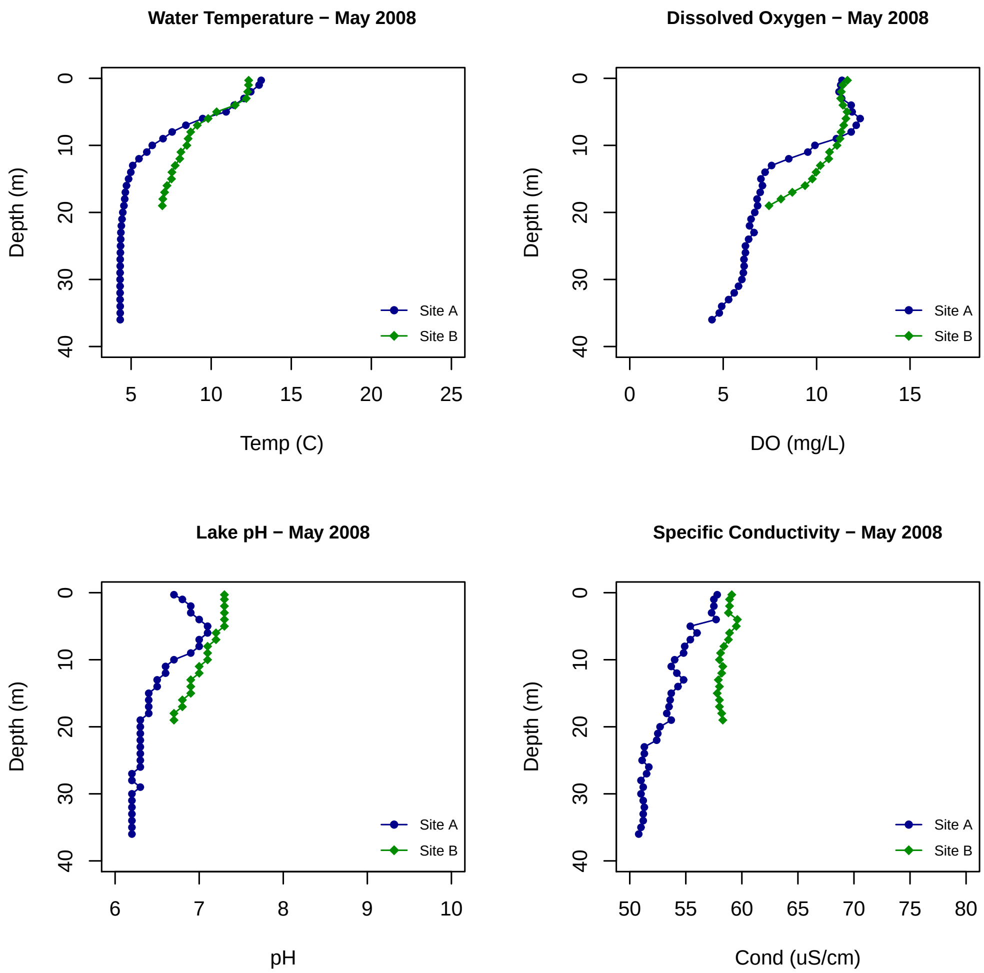


Figure 49: Lake Samish Hydrolab profiles for Sites A and B, May 15, 2008. Sites C and D were not sampled on this date.

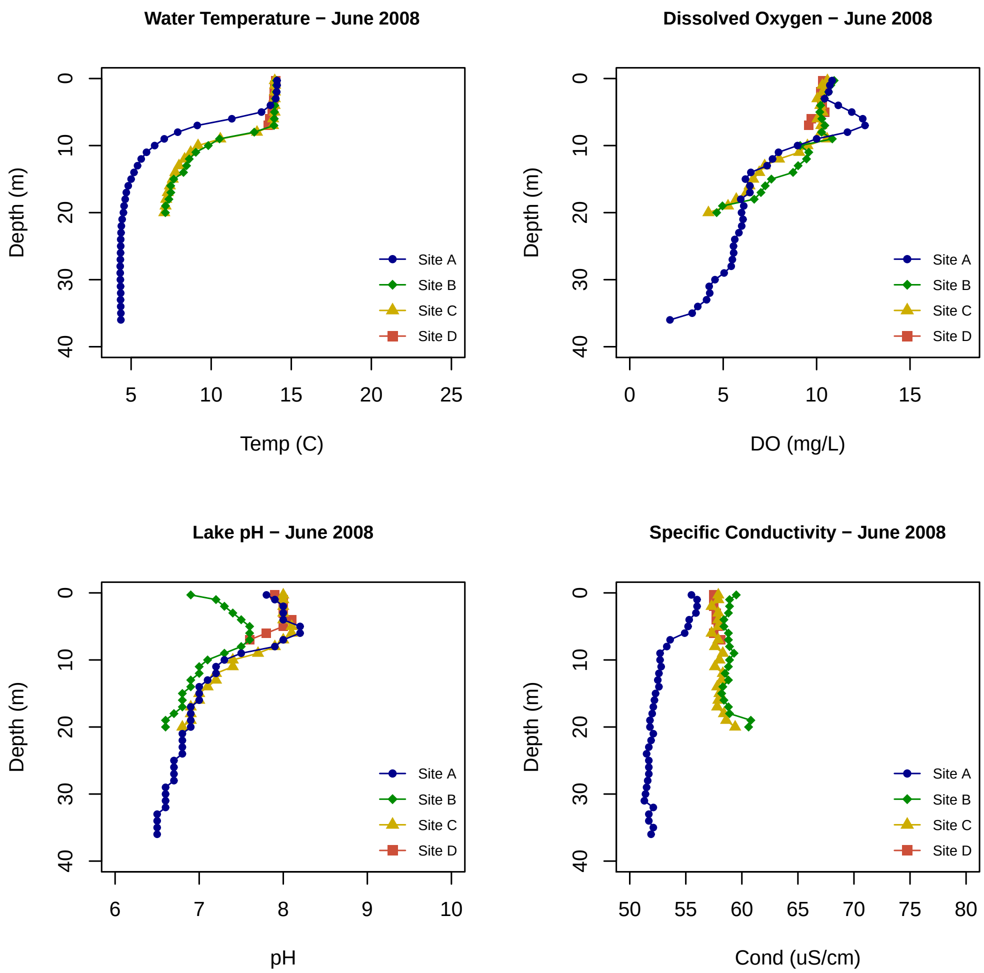


Figure 50: Lake Samish Hydrolab profiles for Sites A–D, June 10, 2008.

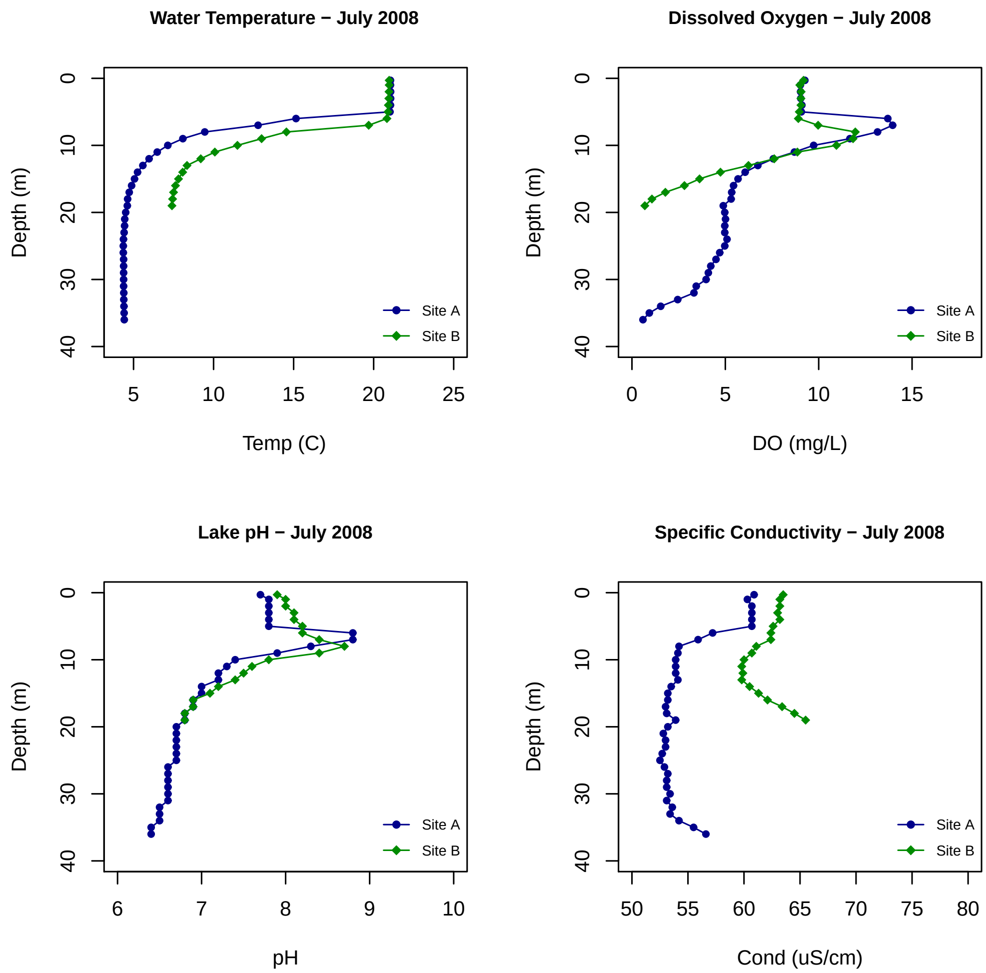


Figure 51: Lake Samish Hydrolab profiles for Sites A and B, July 22, 2008. Sites C and D were not sampled on this date.

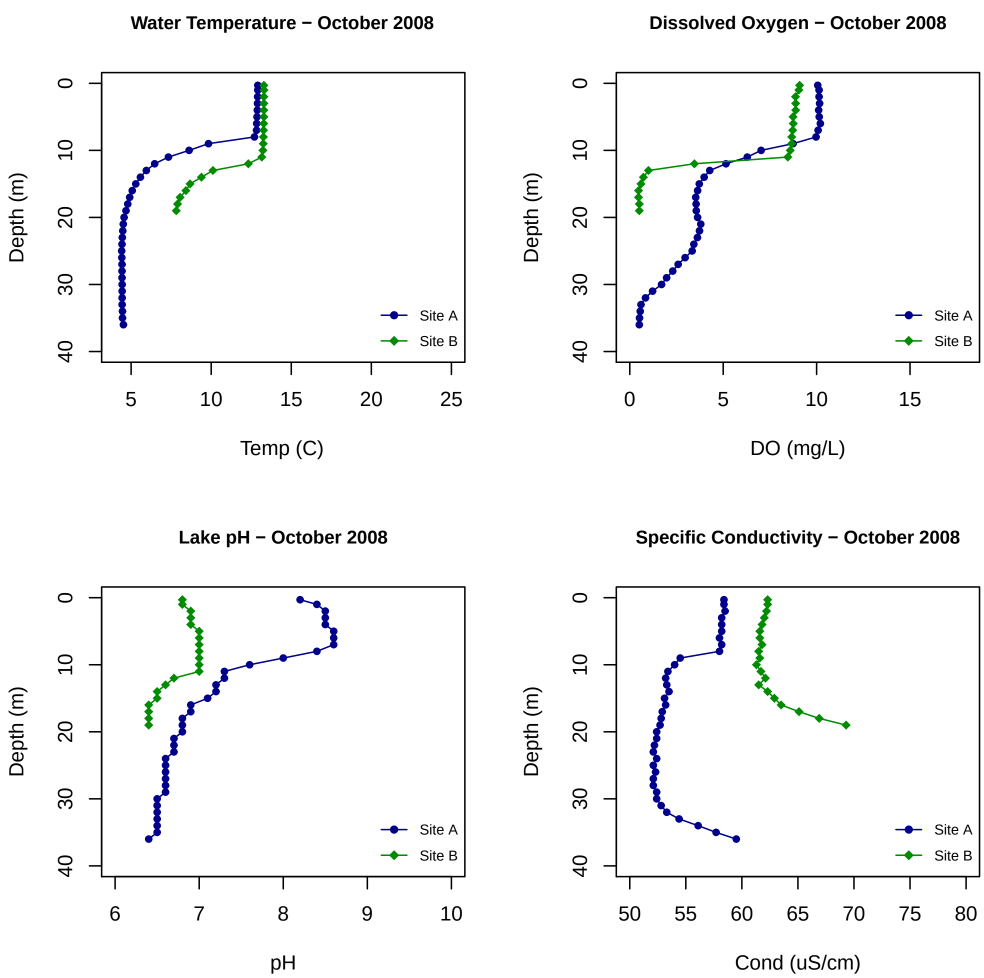


Figure 52: Lake Samish Hydrolab profiles for Sites A and B, October 23, 2008. Sites C and D were not sampled on this date.

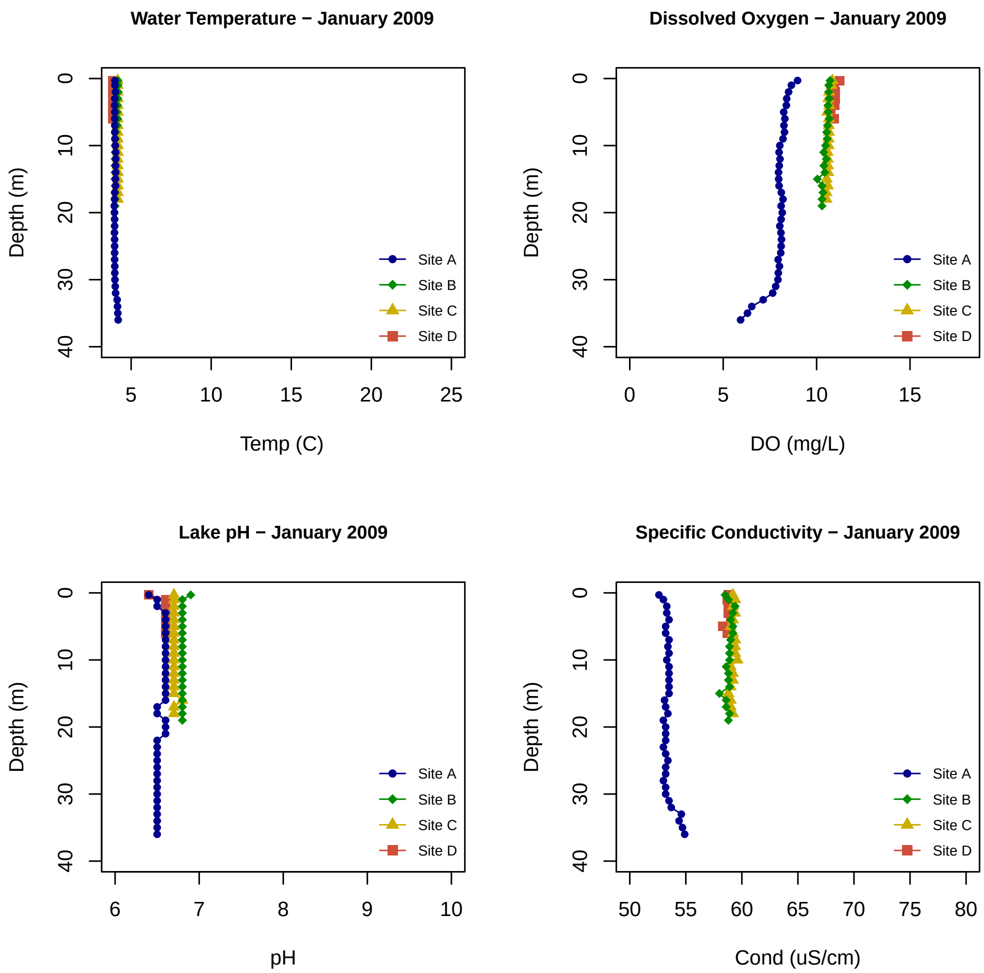


Figure 53: Lake Samish Hydrolab profiles for Sites A–D, January 25, 2009.

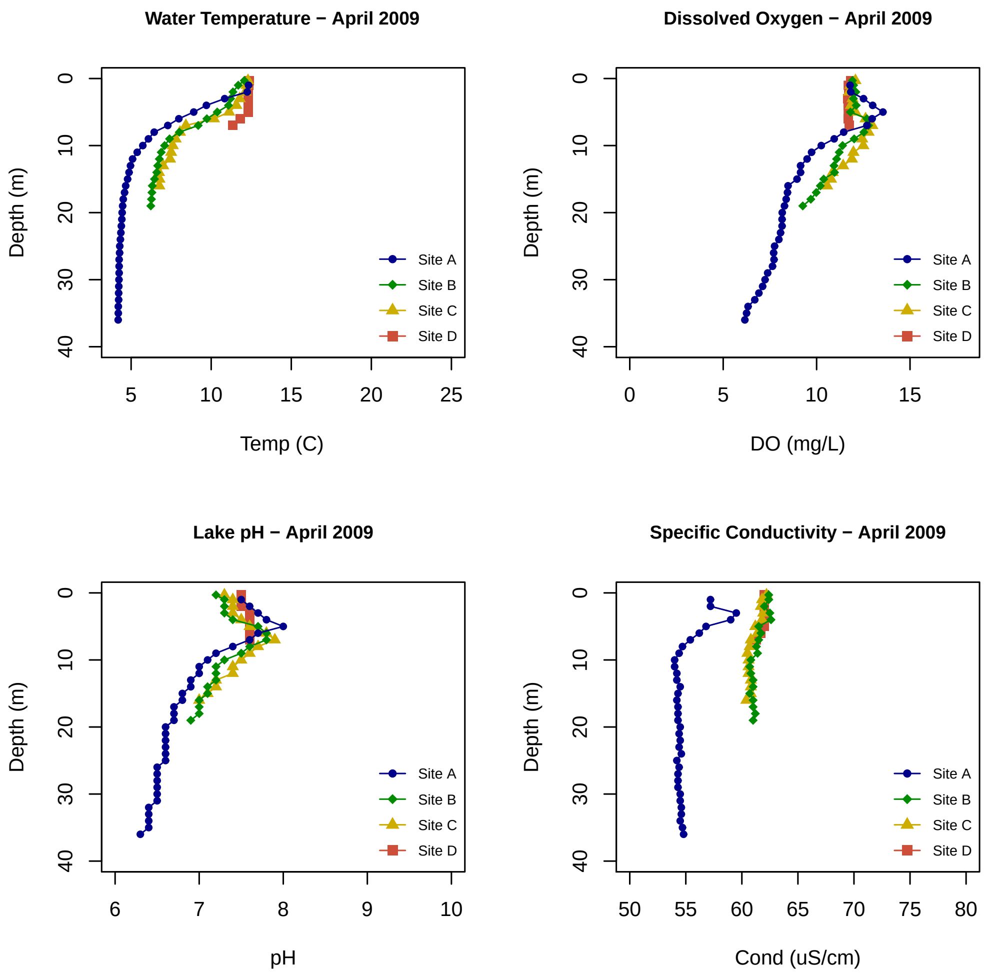


Figure 54: Lake Samish Hydrolab profiles for Sites A–D, April 27, 2009.

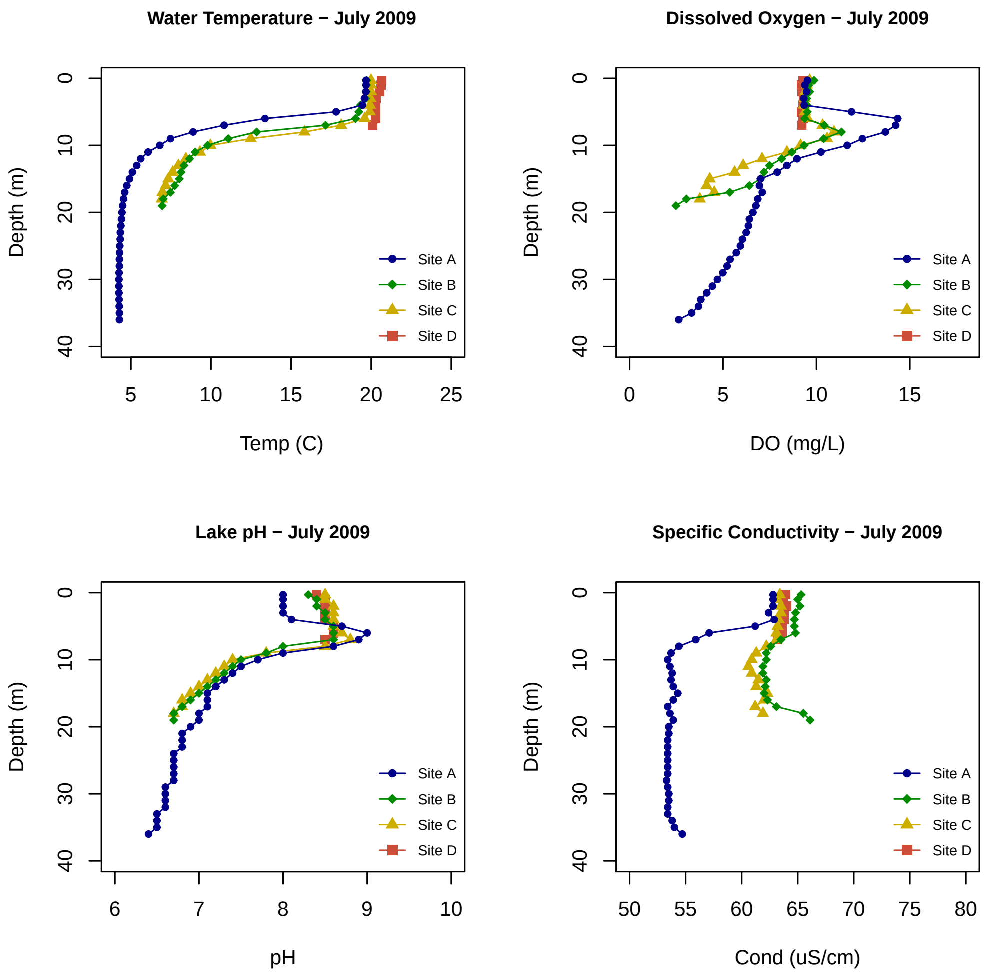


Figure 55: Lake Samish Hydrolab profiles for Sites A–D, July 1, 2009.

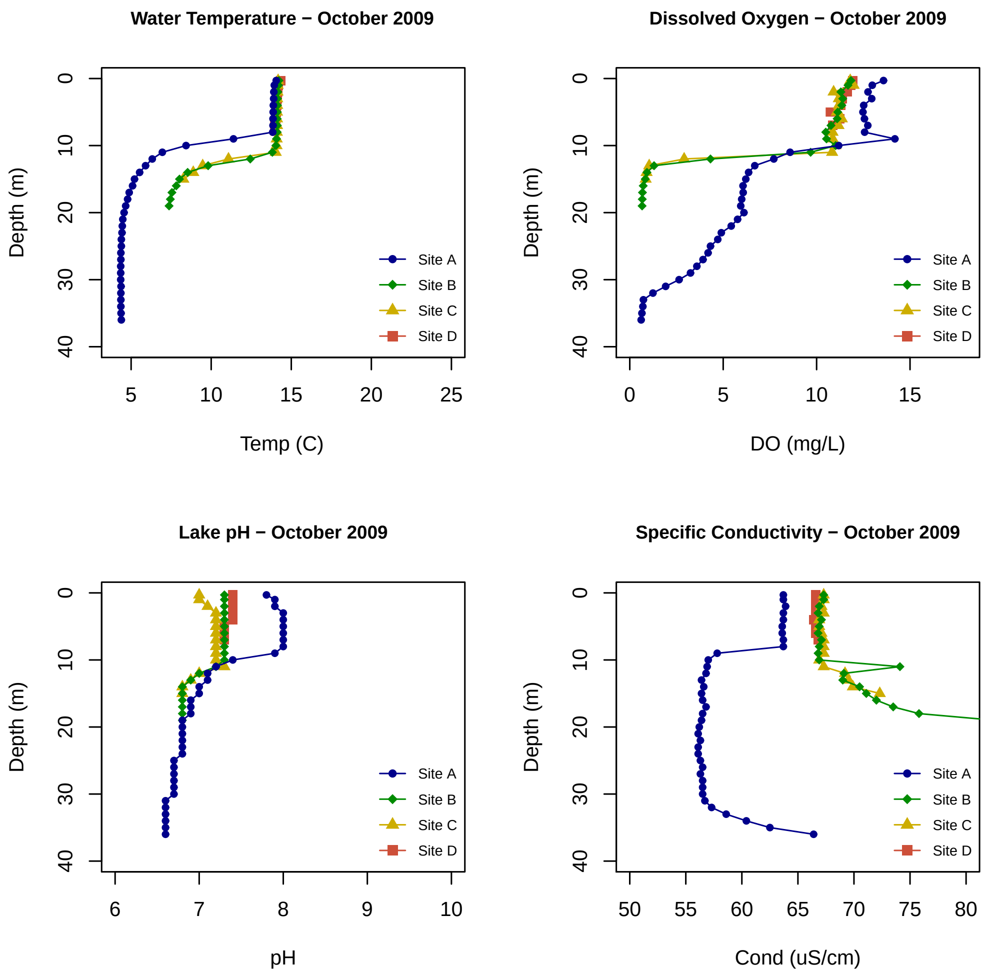


Figure 56: Lake Samish Hydrolab profiles for Sites A–D, October 20, 2009.

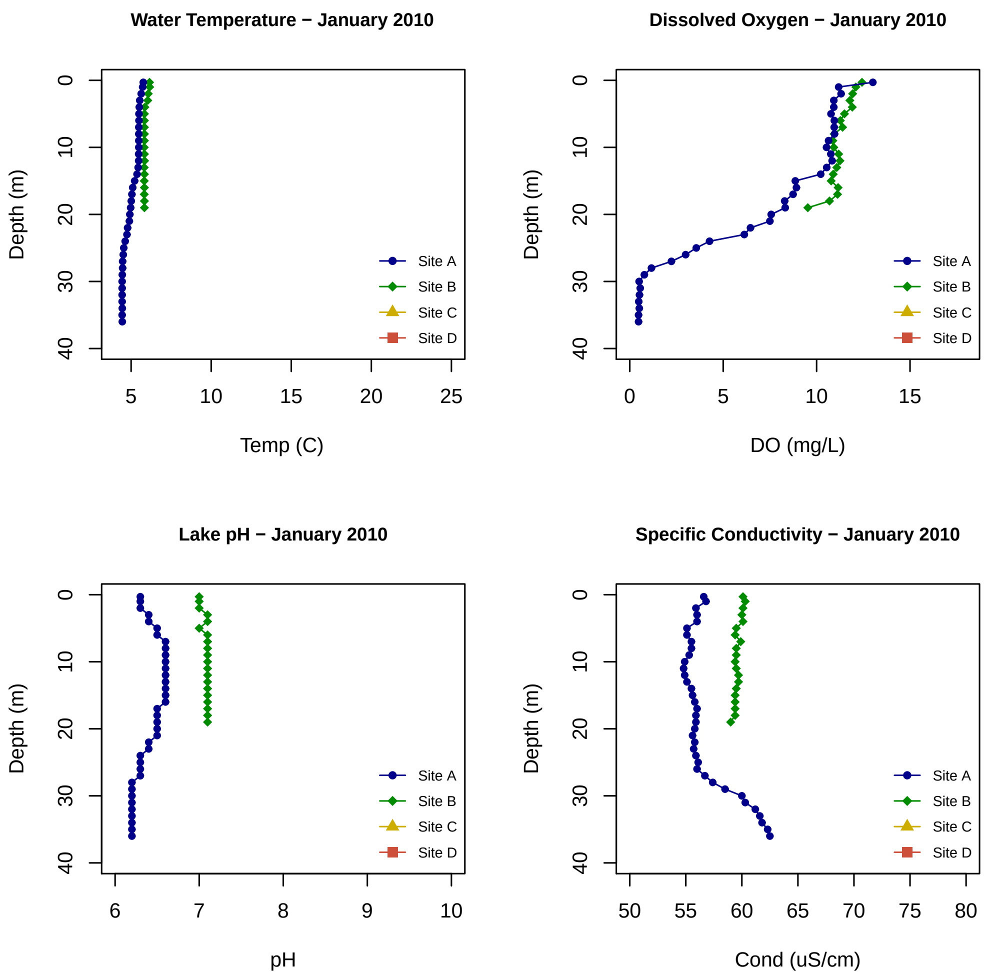


Figure 57: Lake Samish Hydrolab profiles for Sites A and B, January 26, 2010. Sites C and D were not sampled on this date.

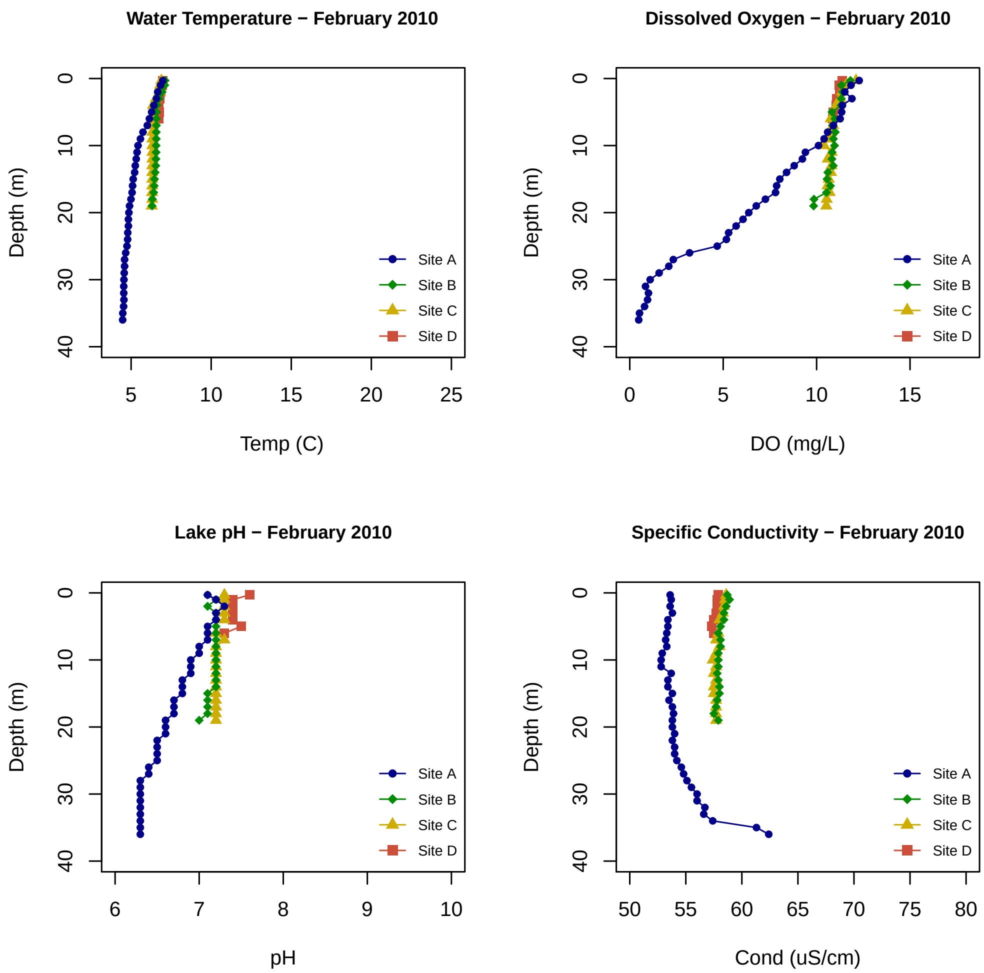


Figure 58: Lake Samish Hydrolab profiles for Sites A–D, February 17, 2010.

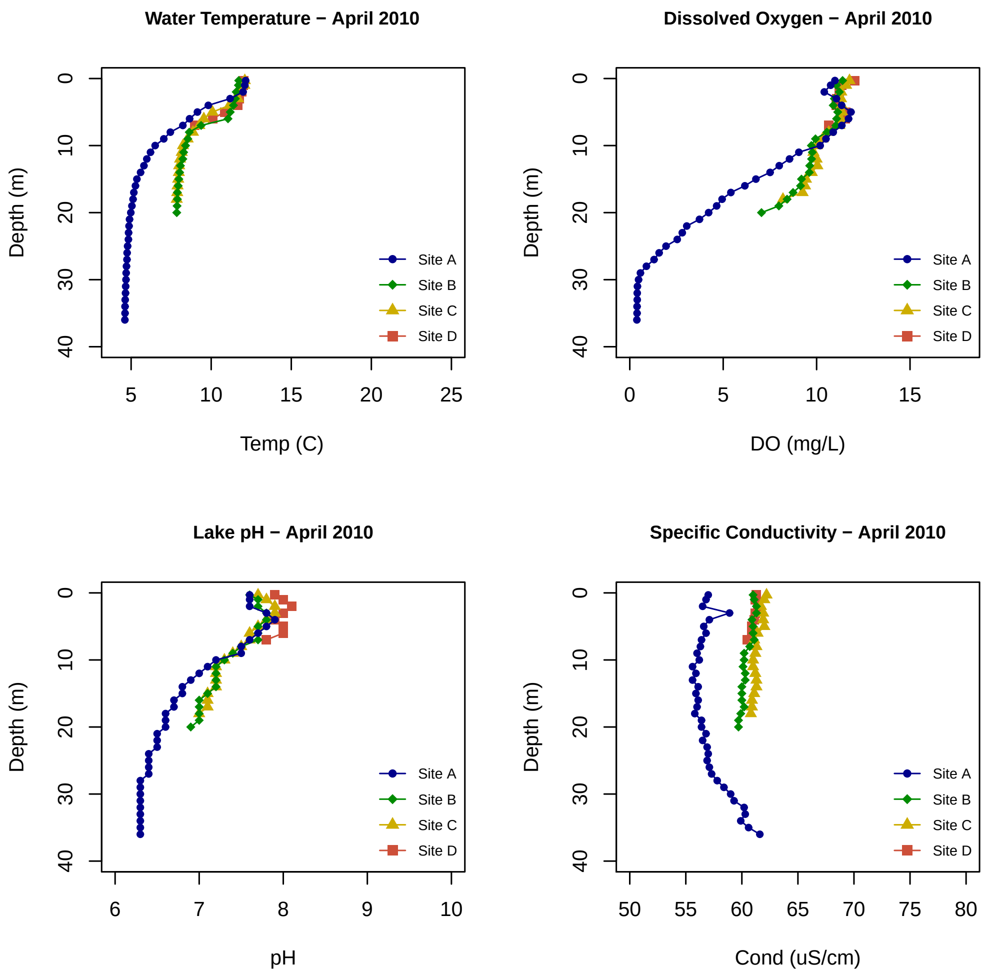


Figure 59: Lake Samish Hydrolab profiles for Sites A–D, April 22, 2010.

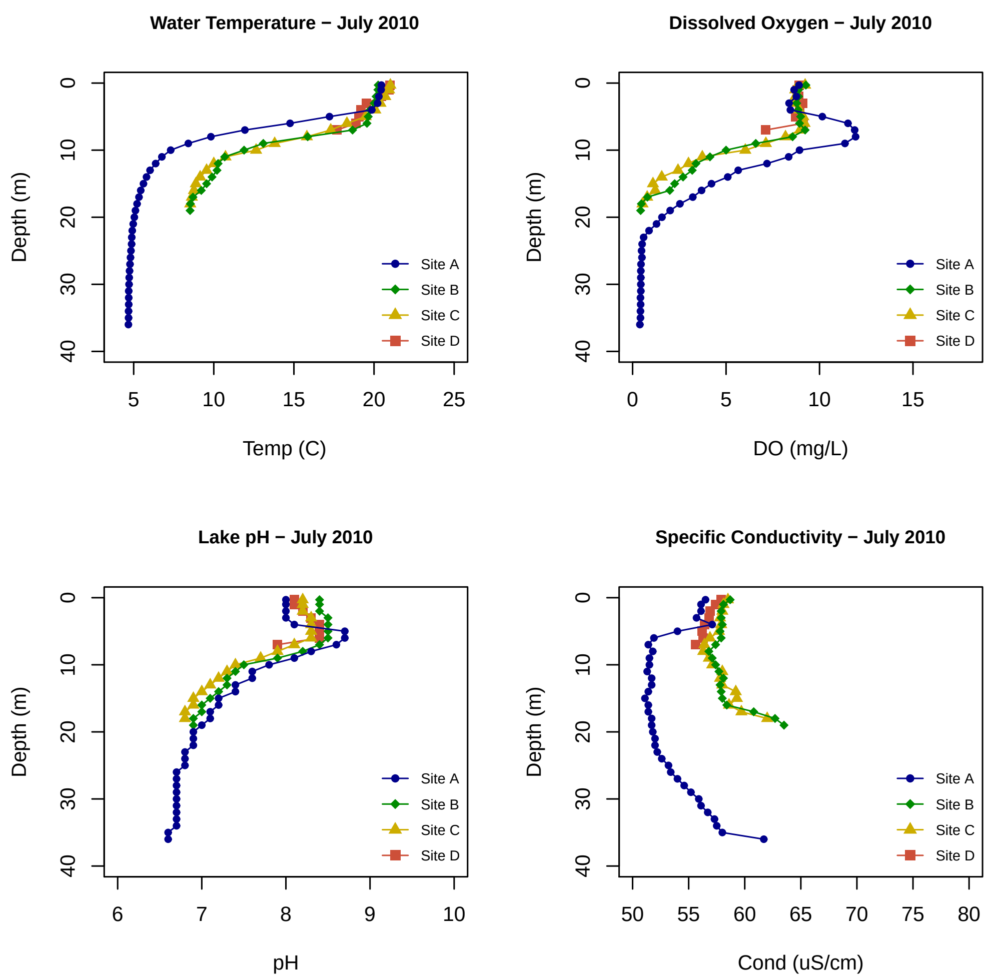


Figure 60: Lake Samish Hydrolab profiles for Sites A–D, July 15, 2010.

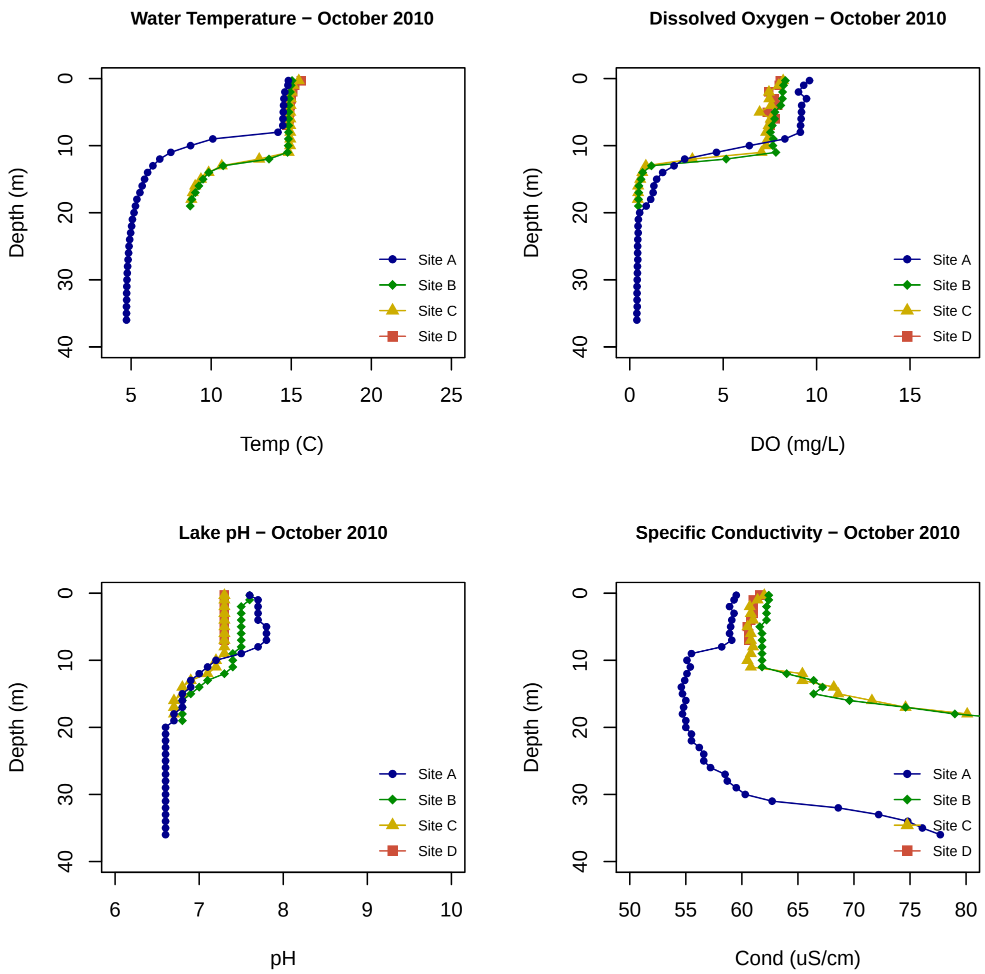


Figure 61: Lake Samish Hydrolab profiles for Sites A–D, October 19, 2010.

B Lake Samish Chlorophyll Profiles

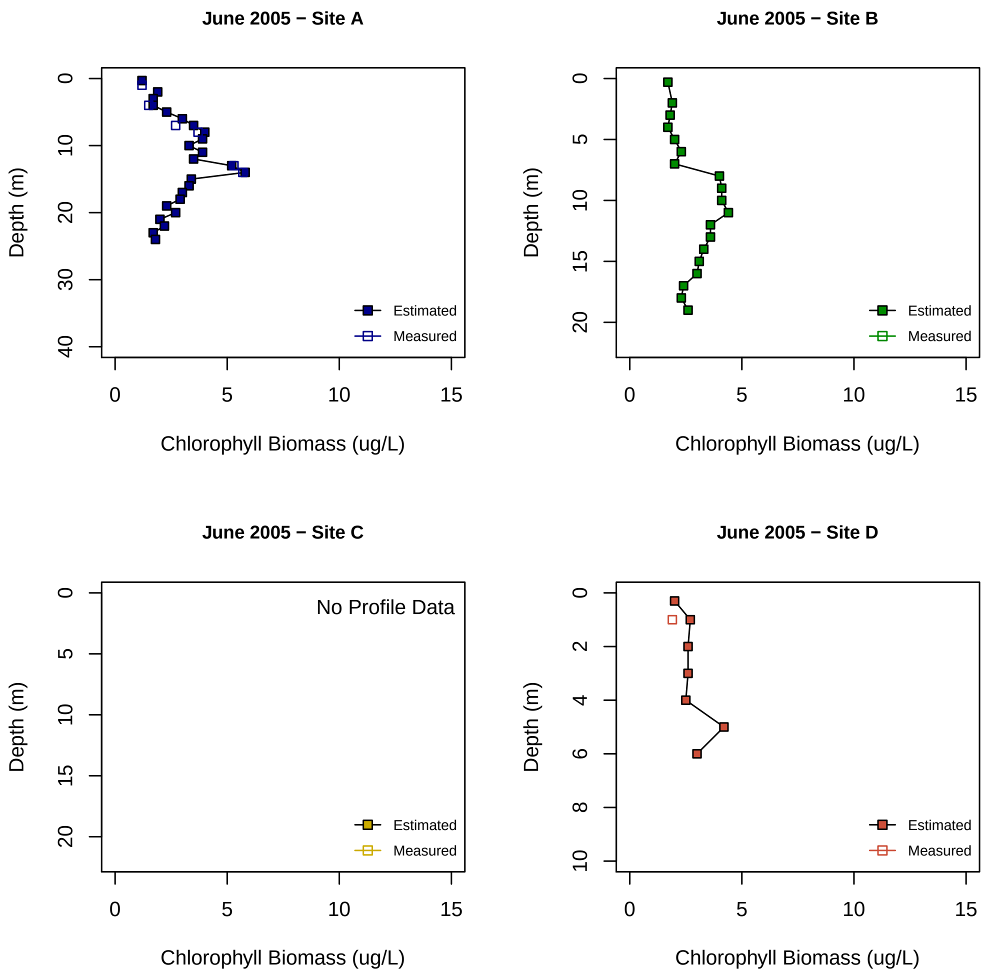


Figure 62: Lake Samish chlorophyll data for Sites A–D, June 15, 2005.

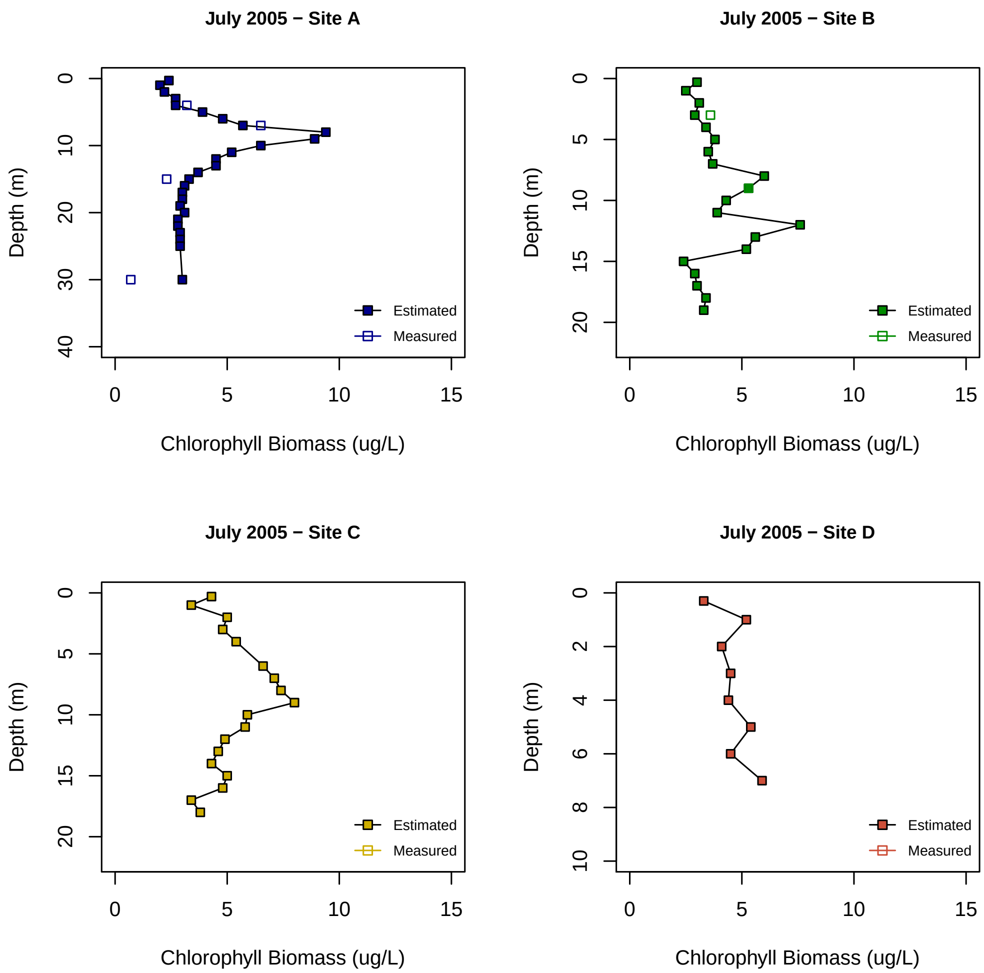


Figure 63: Lake Samish chlorophyll data for Sites A–D, July 20, 2005.

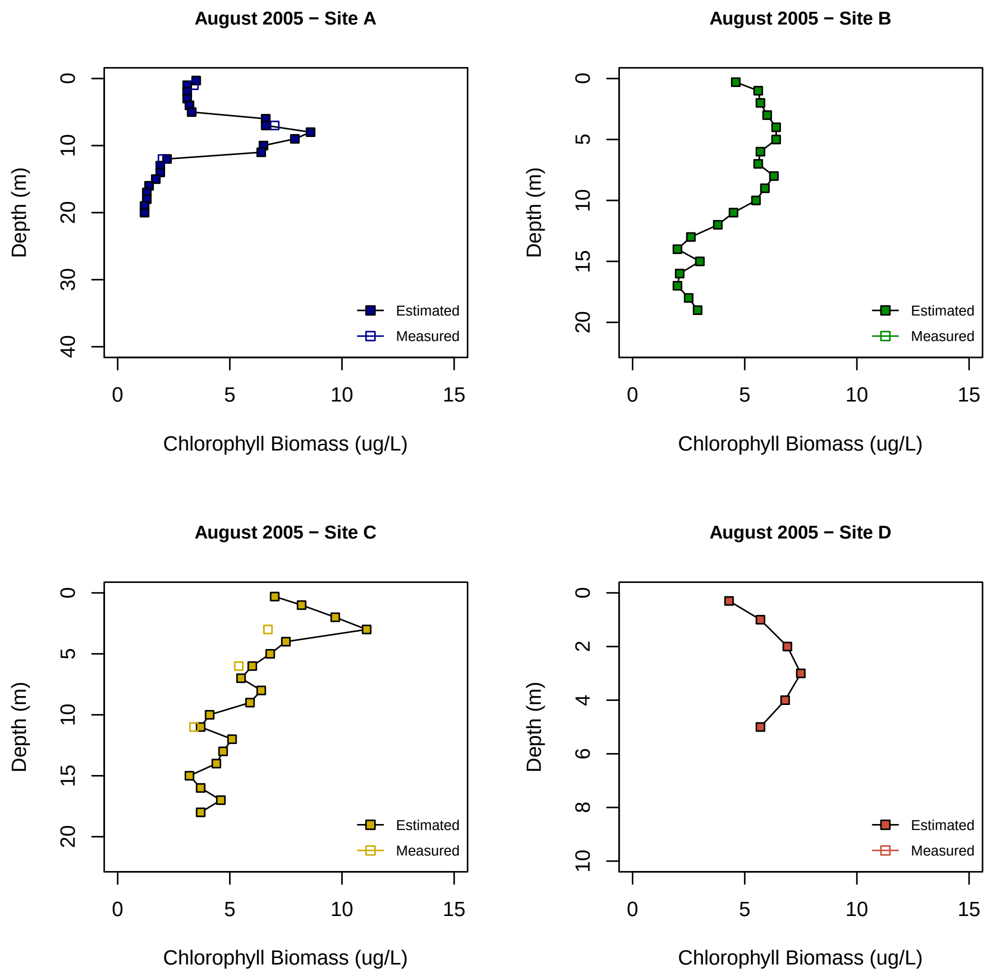


Figure 64: Lake Samish chlorophyll data for Sites A–D, August 23, 2005.

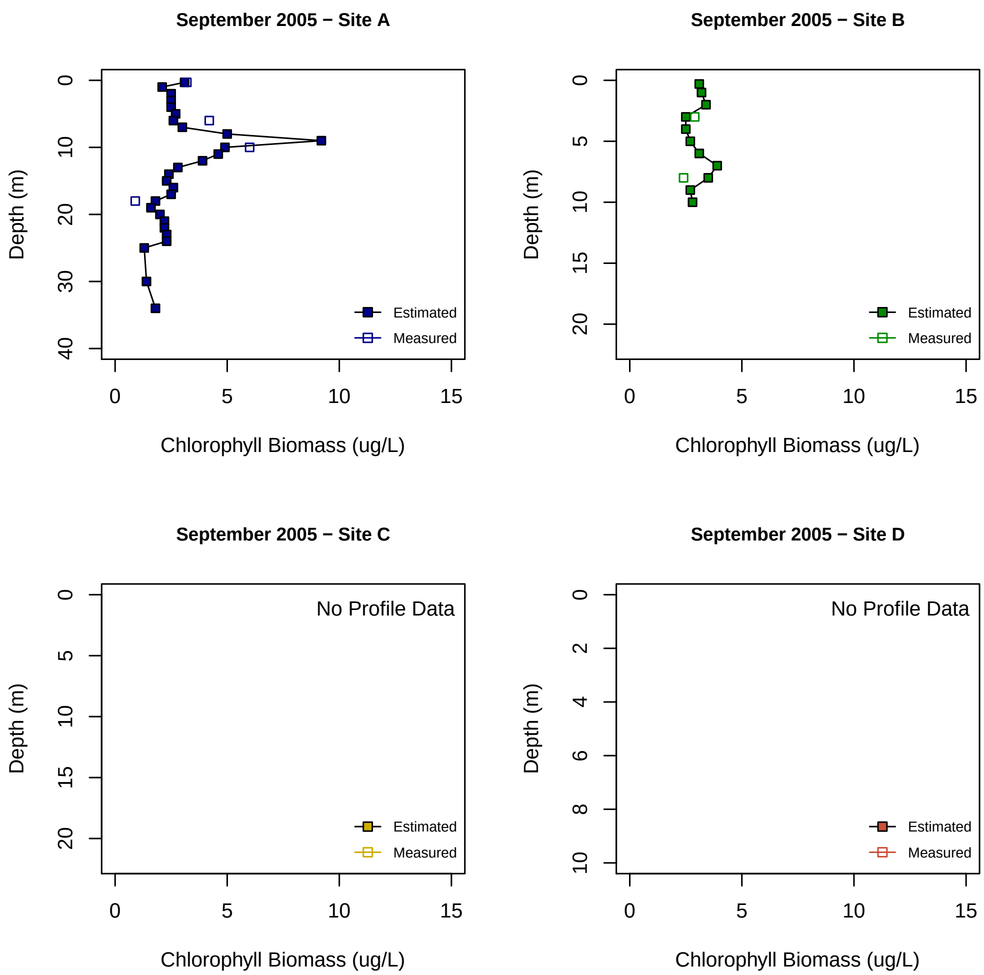


Figure 65: Lake Samish chlorophyll data for Sites A and B, September 20, 2005. Data from Sites C and D have been omitted due to equipment malfunction.

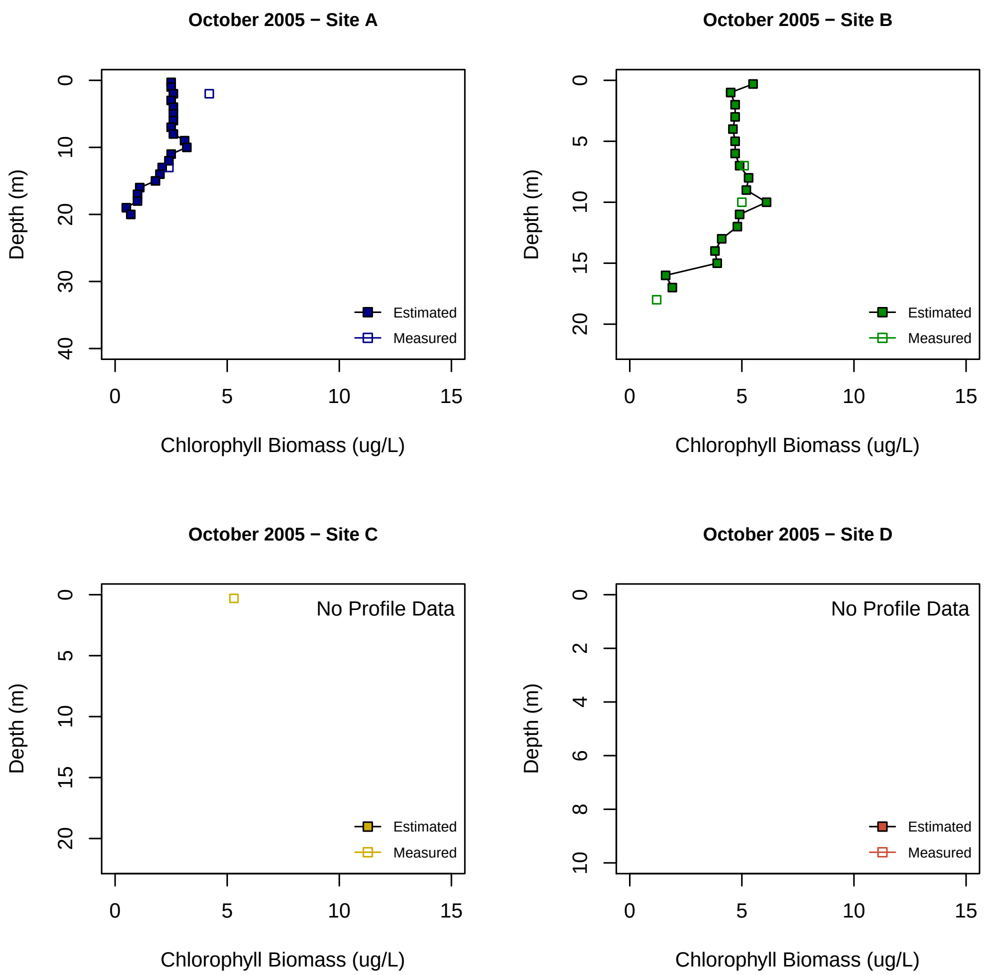


Figure 66: Lake Samish chlorophyll data for Sites A and B, October 16, 2005. Data from Sites C and D have been omitted due to equipment malfunction.

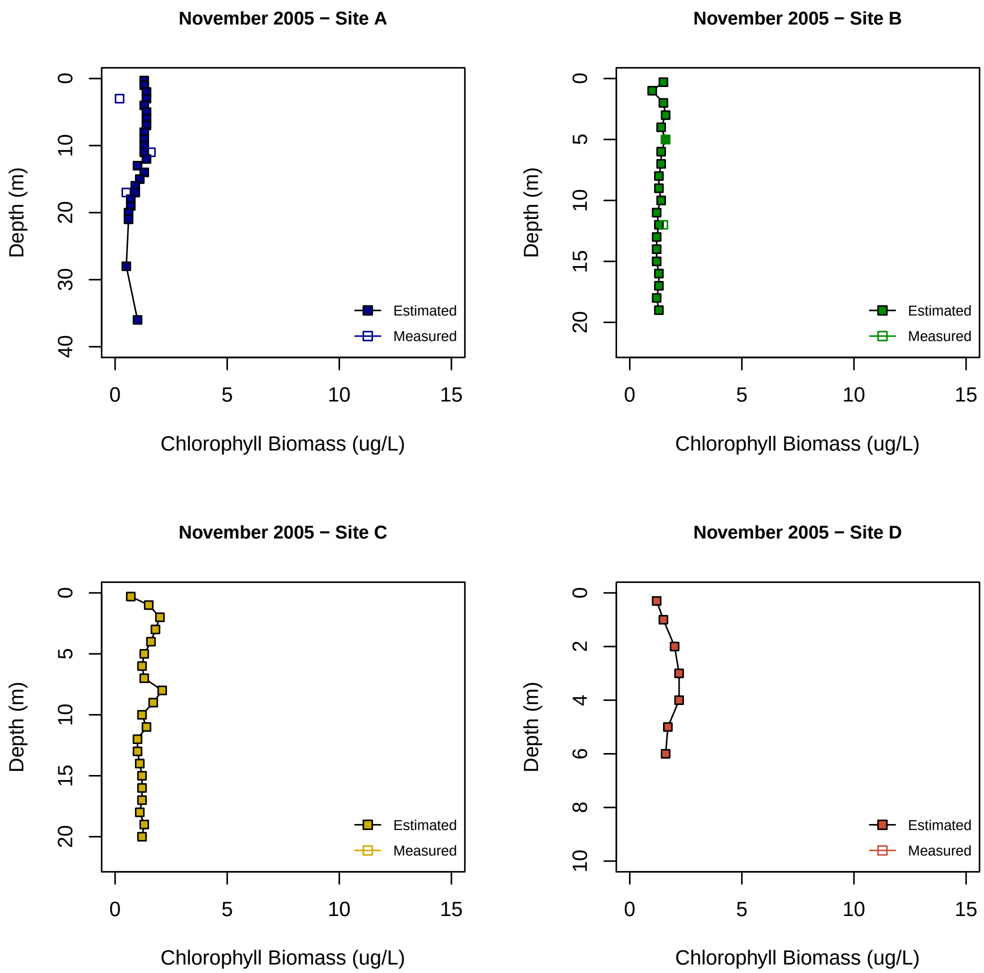


Figure 67: Lake Samish chlorophyll data for Sites A–D, November 20, 2005.

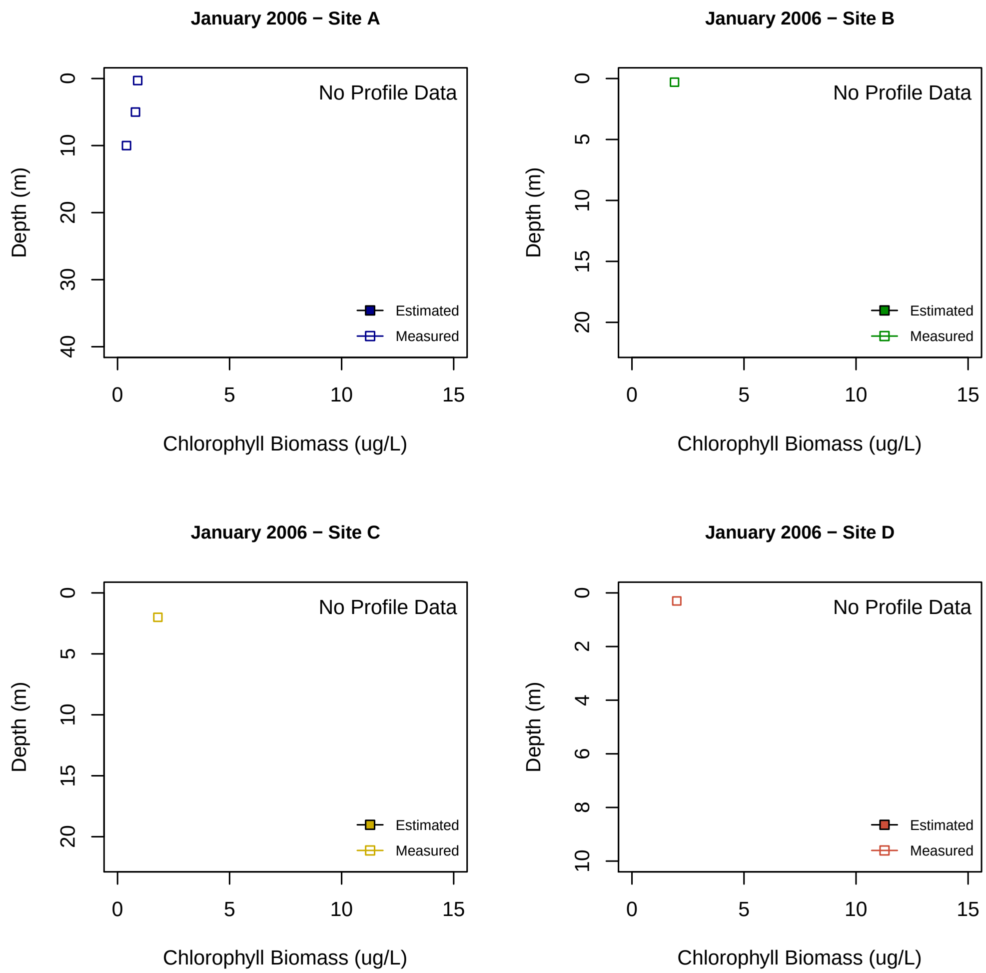


Figure 68: Lake Samish chlorophyll data for Sites A–D, January 22, 2006.

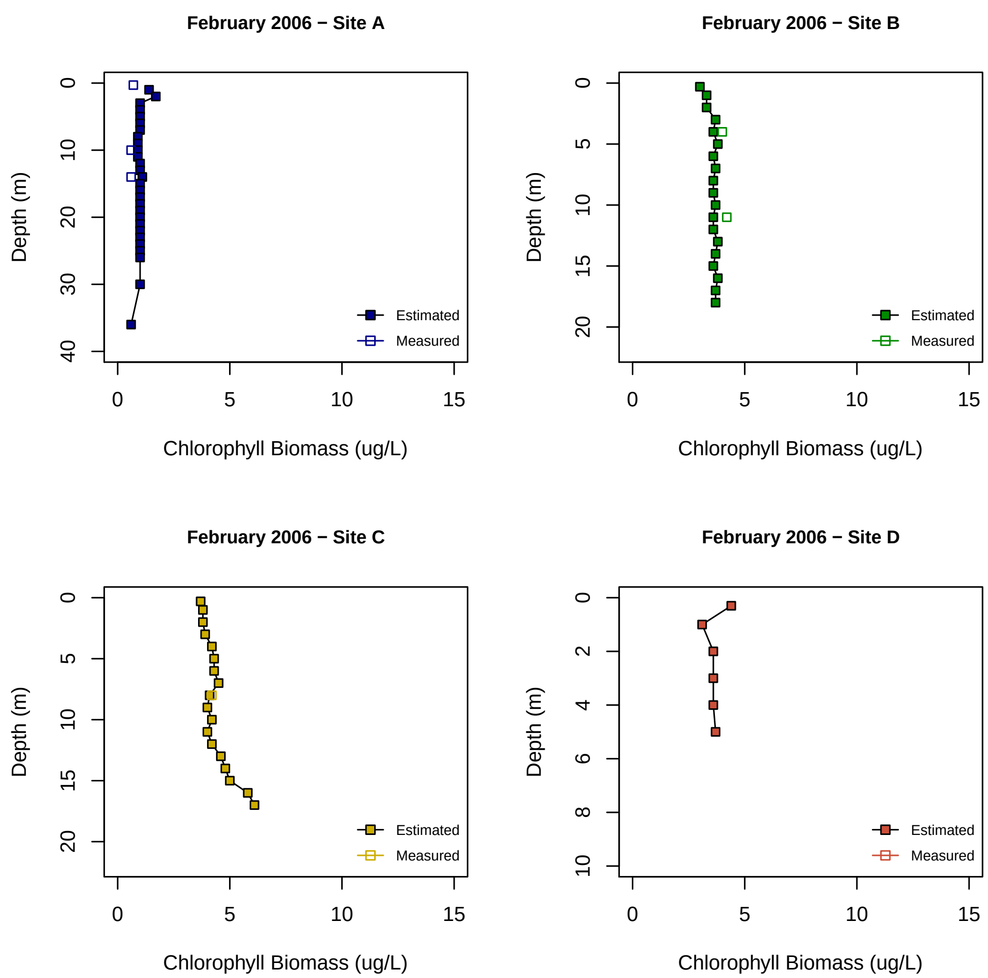


Figure 69: Lake Samish chlorophyll data for Sites A–D, February 26, 2006.

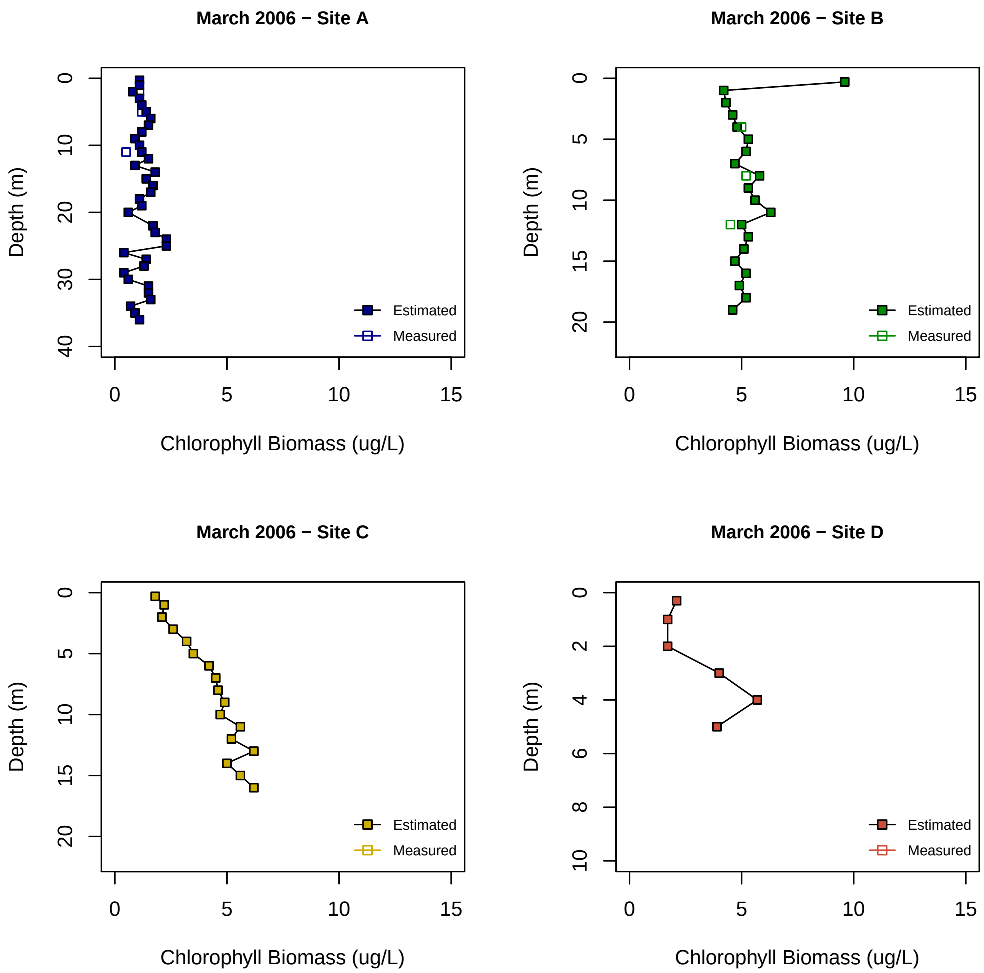


Figure 70: Lake Samish chlorophyll data for Sites A–D, March 19, 2006.

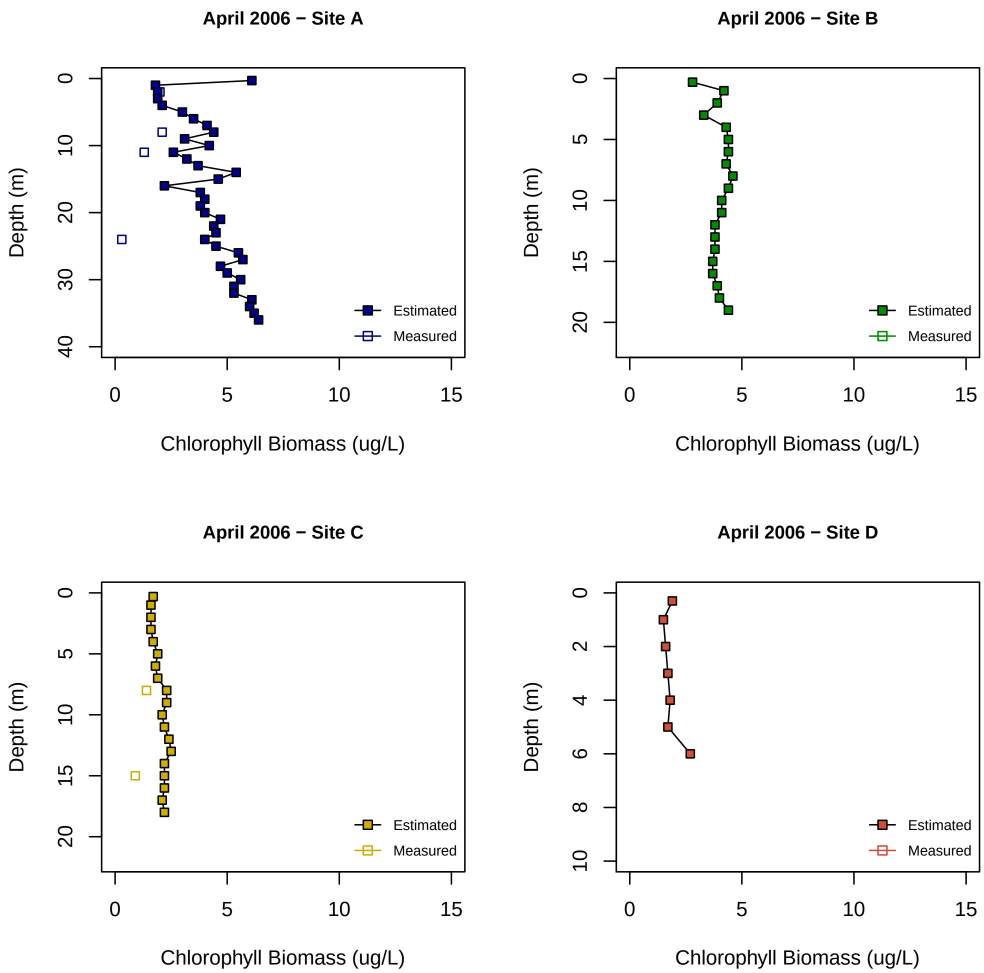


Figure 71: Lake Samish chlorophyll data for Sites A–D, April 23, 2006.

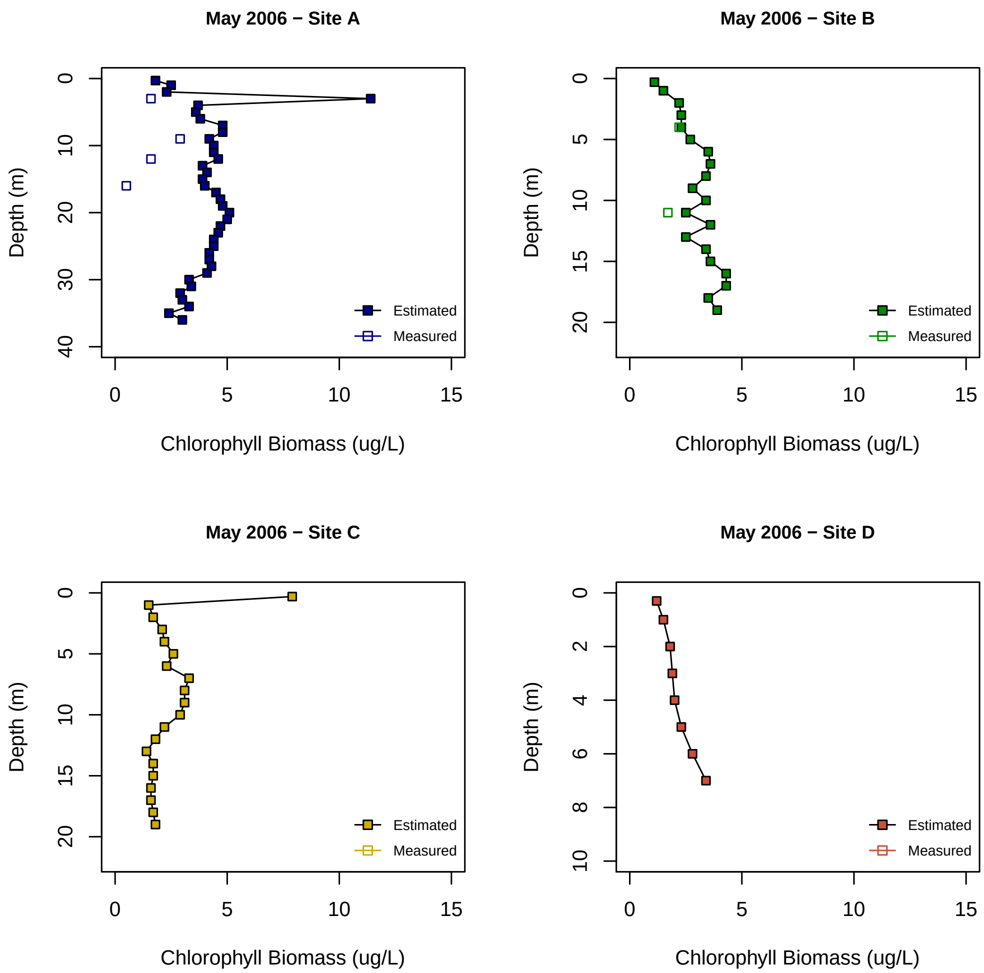


Figure 72: Lake Samish chlorophyll data for Sites A–D, May 21, 2006.

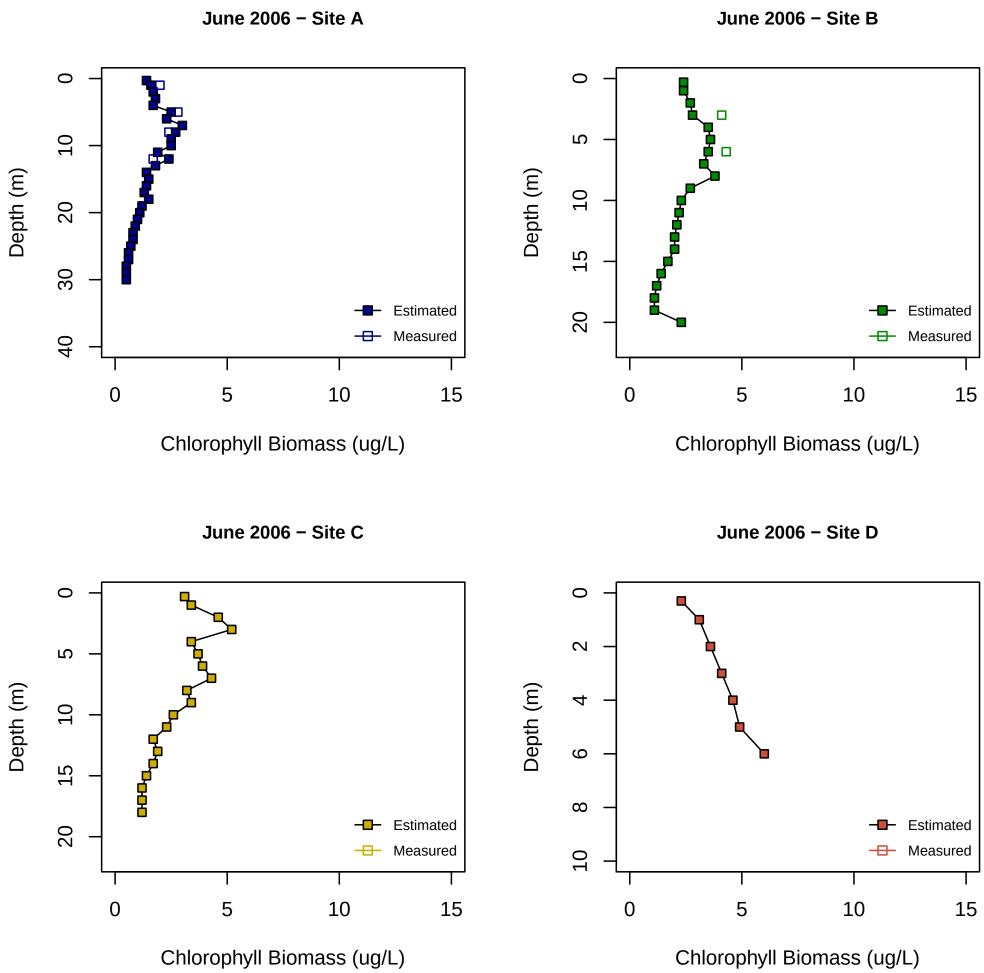


Figure 73: Lake Samish chlorophyll data for Sites A–D, June 20, 2006.

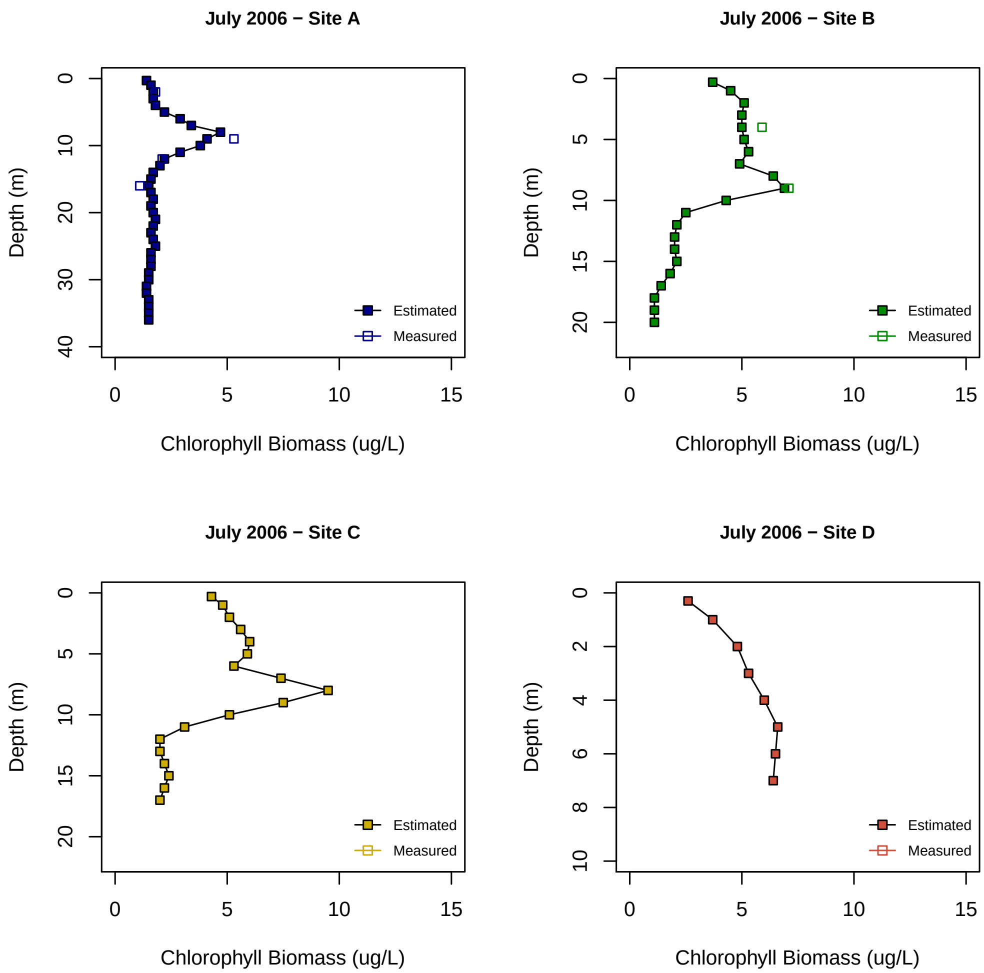


Figure 74: Lake Samish chlorophyll data for Sites A–D, July 19, 2006.

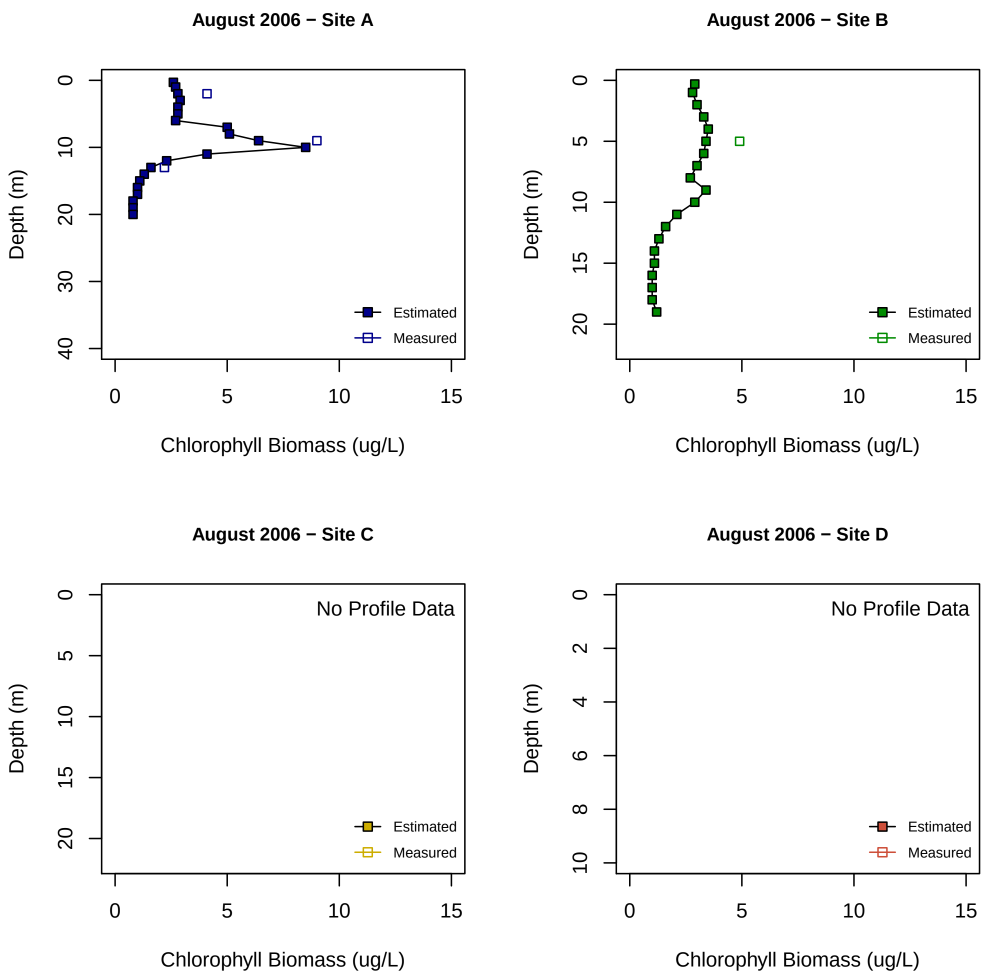


Figure 75: Lake Samish chlorophyll data for Sites A and B, August 24, 2006. Sites C and D were not sampled on this date.

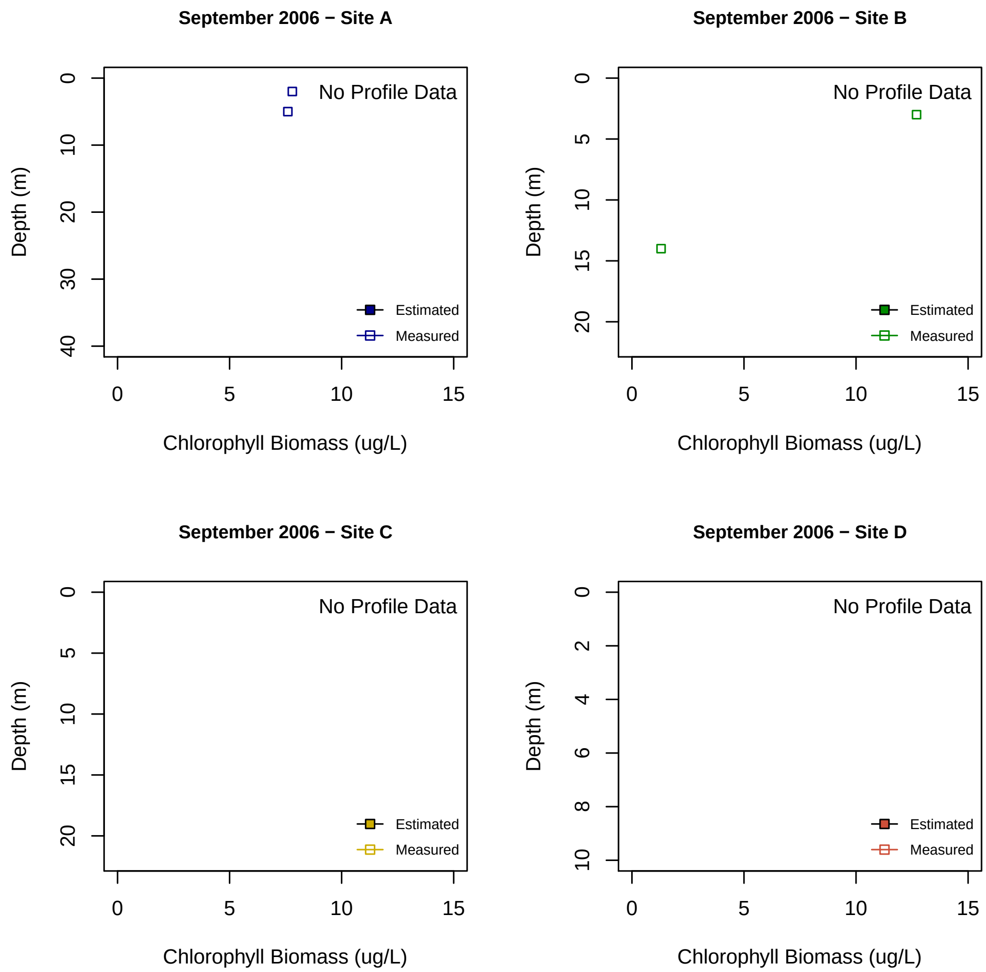


Figure 76: Lake Samish chlorophyll data for Sites A and B, September 18, 2006. Sites A and B had two measured water column samples; Sites C and D were not sampled on this date.

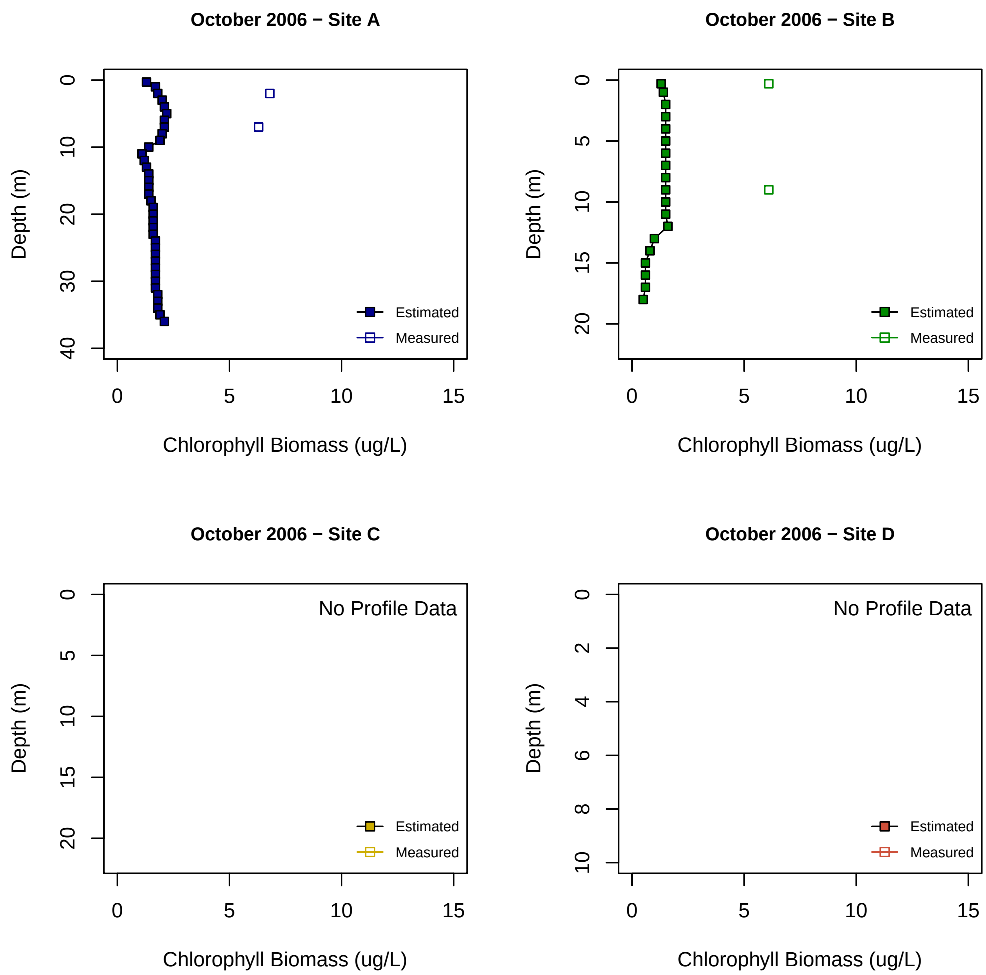


Figure 77: Lake Samish chlorophyll data for Sites A and B, October 22, 2006. Sites C and D were not sampled on this date.

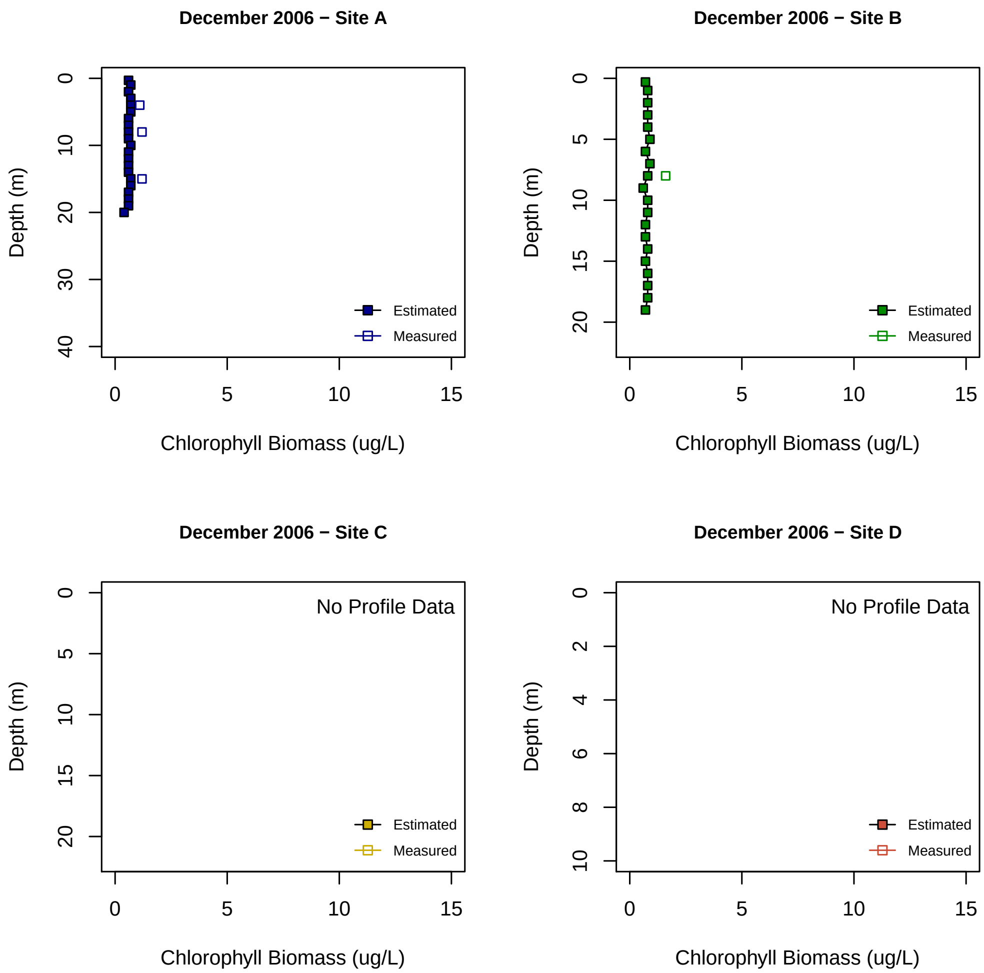


Figure 78: Lake Samish chlorophyll data for Sites A and B, December 18, 2006. Sites C and D were not sampled on this date.

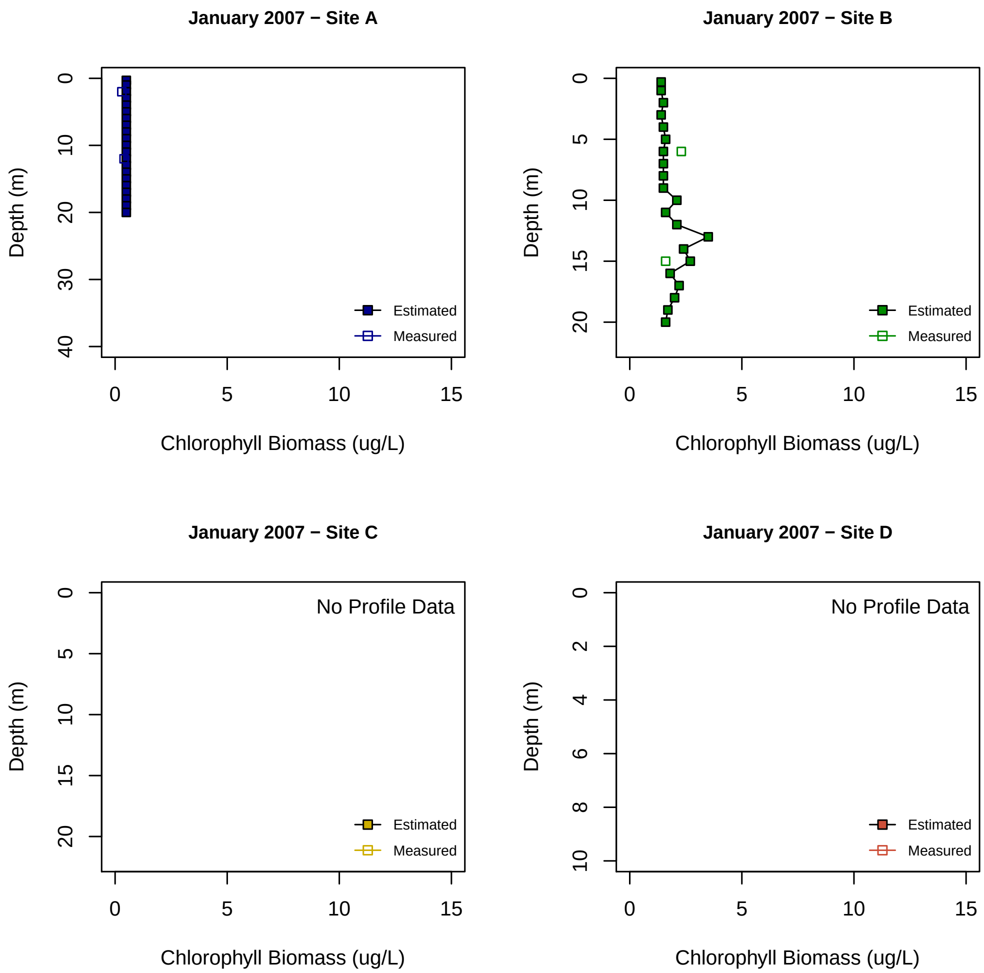


Figure 79: Lake Samish chlorophyll data for Sites A and B, January 30, 2007. Sites C and D were not sampled on this date.

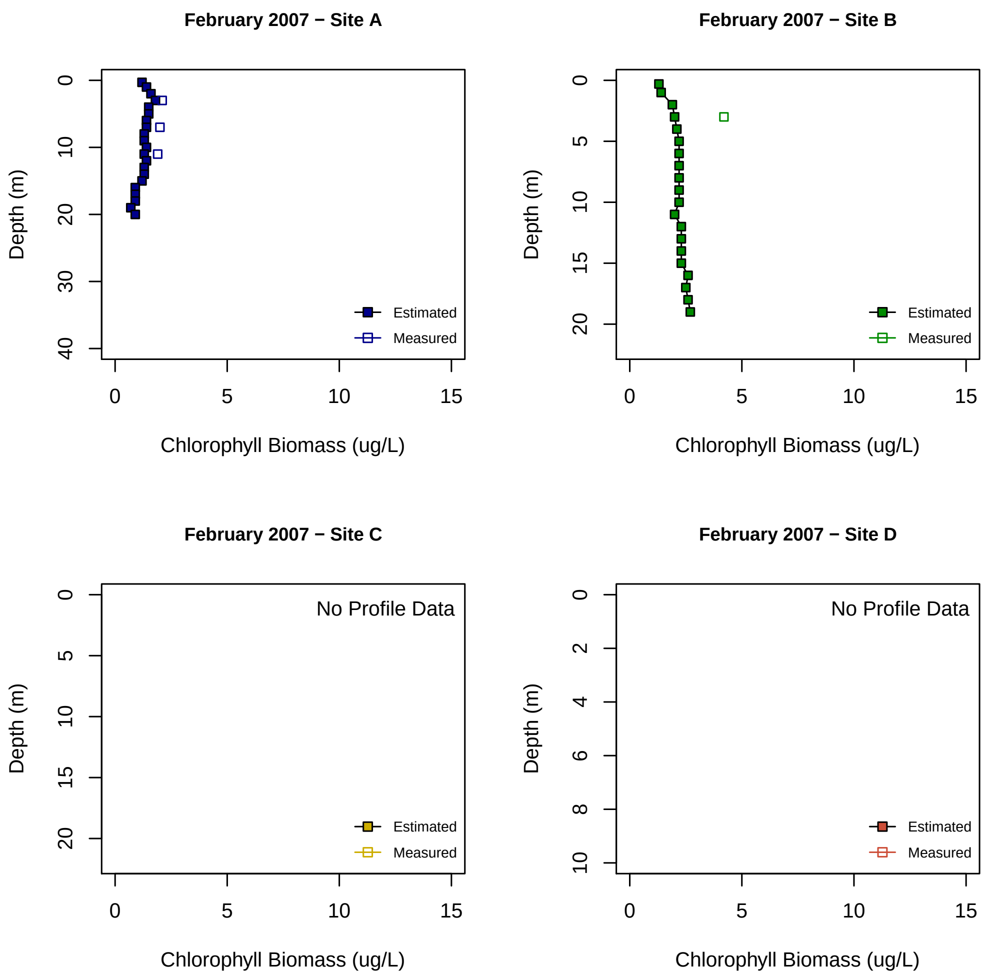


Figure 80: Lake Samish chlorophyll data for Sites A and B, February 27, 2007. Sites C and D were not sampled on this date.

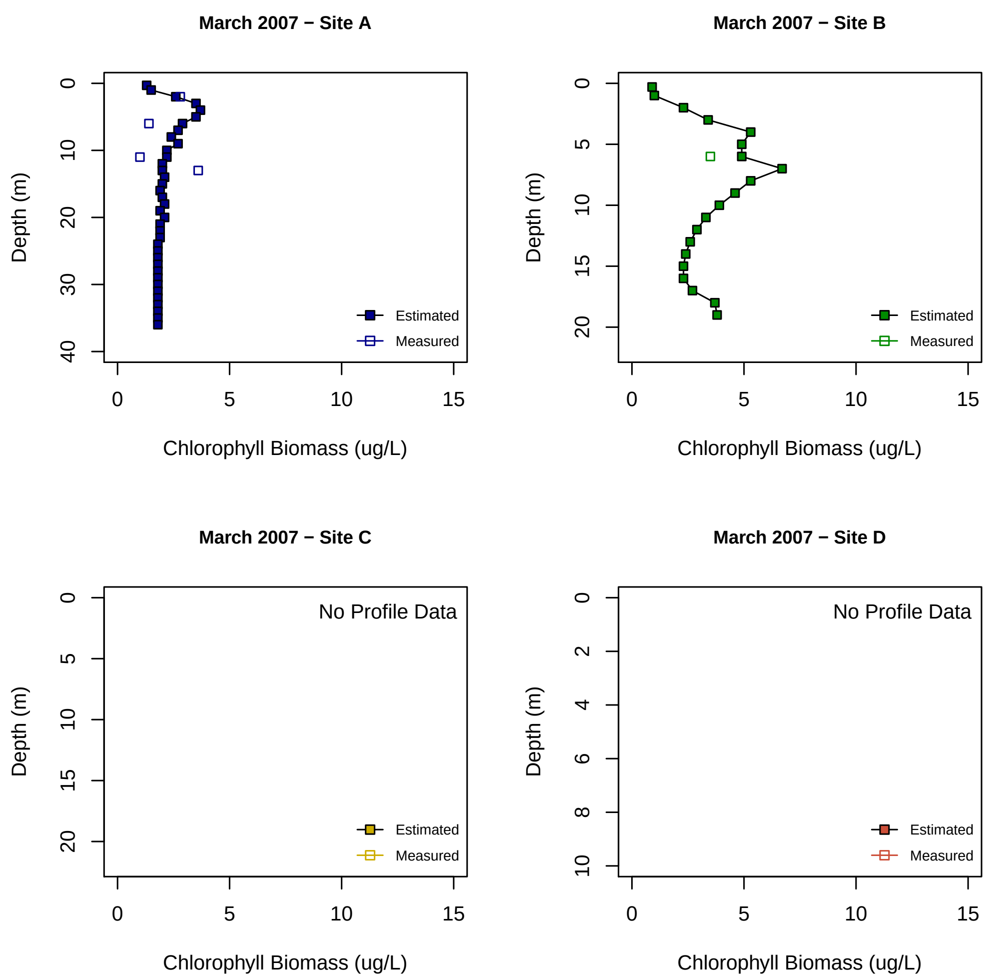


Figure 81: Lake Samish chlorophyll data for Sites A and B, March 29, 2007. Sites C and D were not sampled on this date.

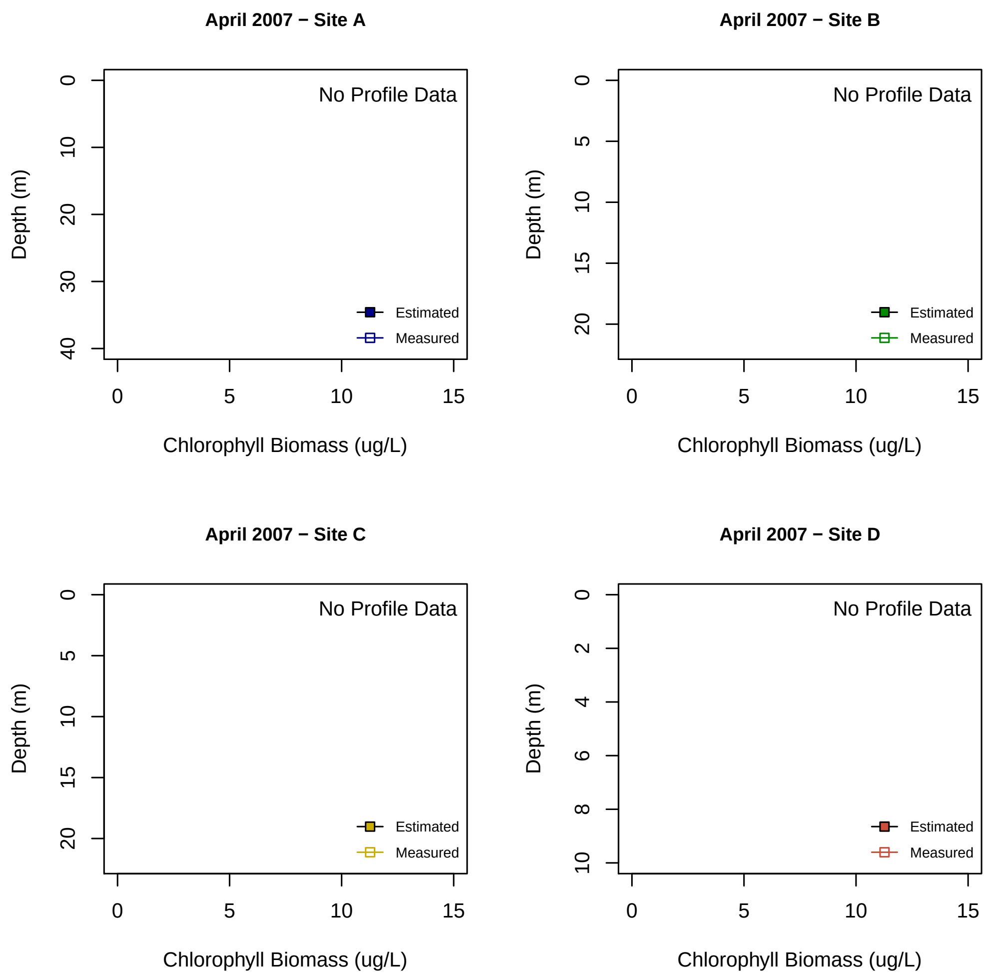


Figure 82: Lake Samish chlorophyll data for April 24, 2007 (no chlorophyll data were collected; the plot is included for information only).

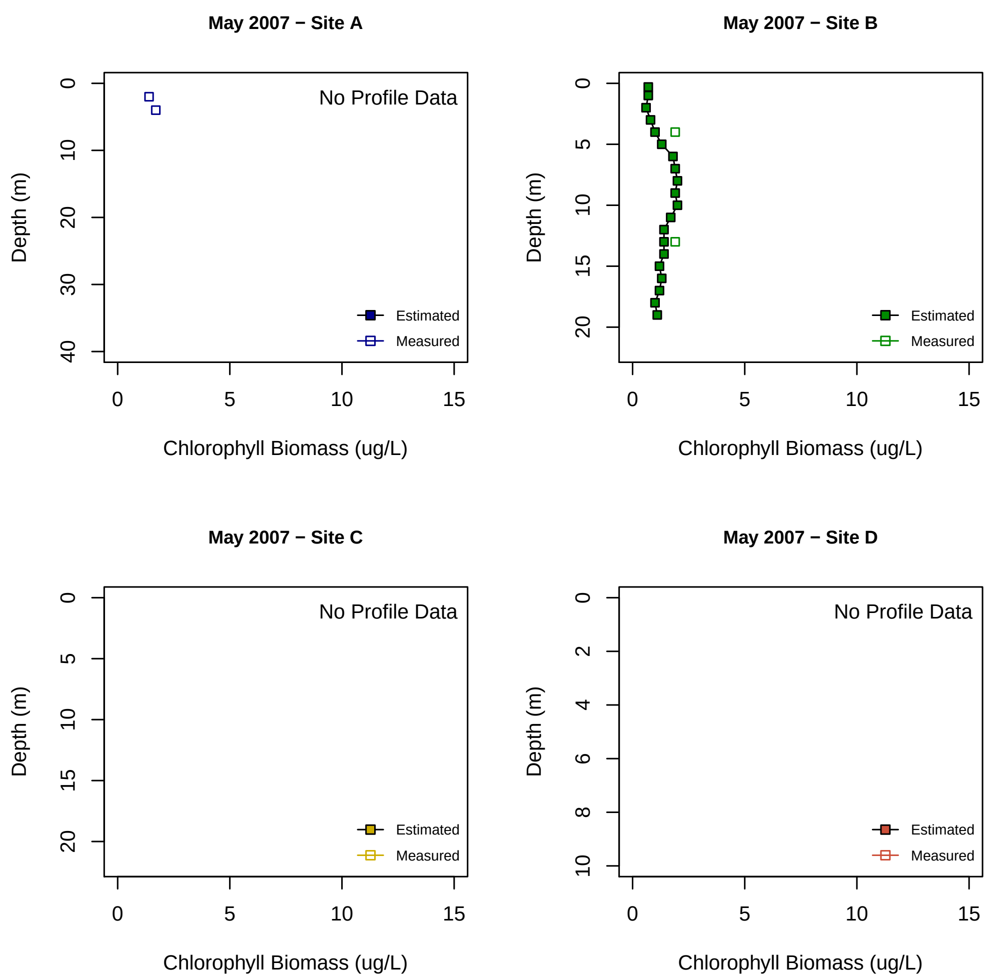


Figure 83: Lake Samish chlorophyll data for Site B, May 24, 2007. Sites C and D were not sampled on this date and only two samples were collected at Site A.

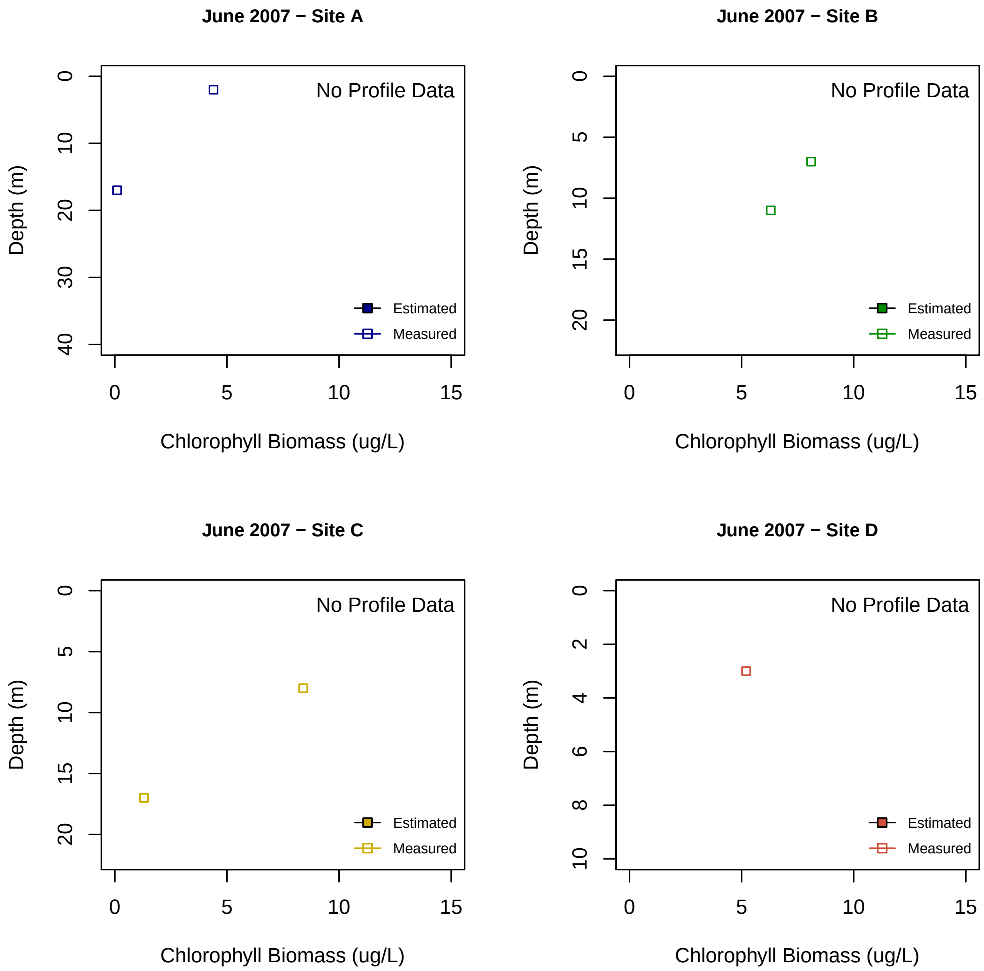


Figure 84: Lake Samish chlorophyll data for Sites A–D, June 21, 2007.

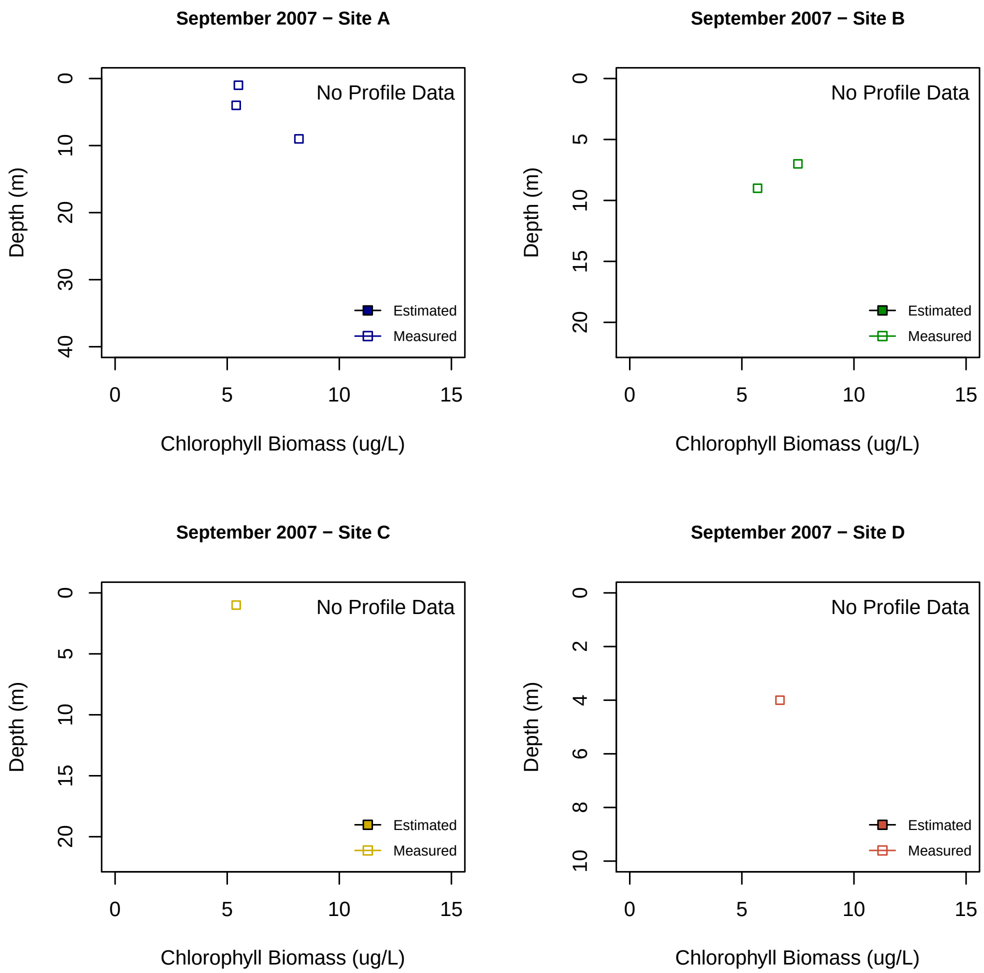


Figure 85: Lake Samish chlorophyll data for Sites A–D, September 13,2007.

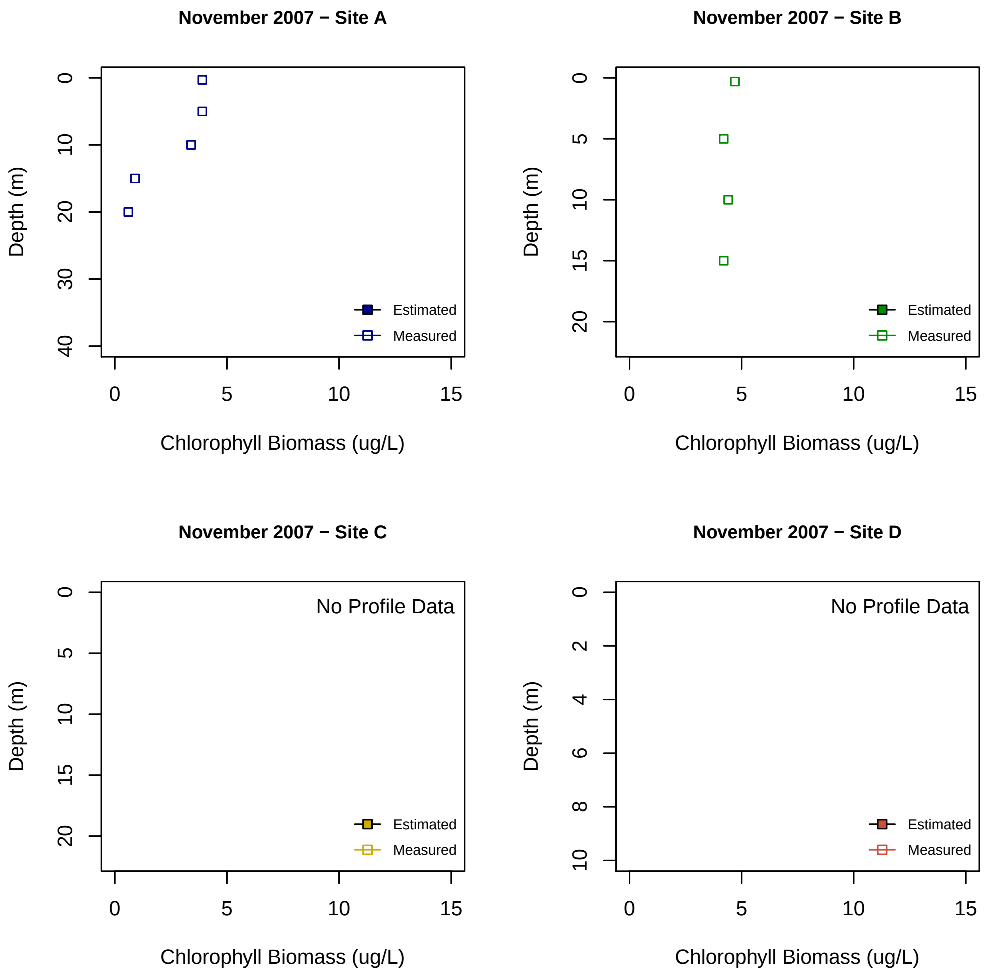


Figure 86: Lake Samish chlorophyll data for Sites A and B, November 15, 2007. Sites A and B were sampled at 5 meter depth intervals; Sites C and D were not sampled on this date.

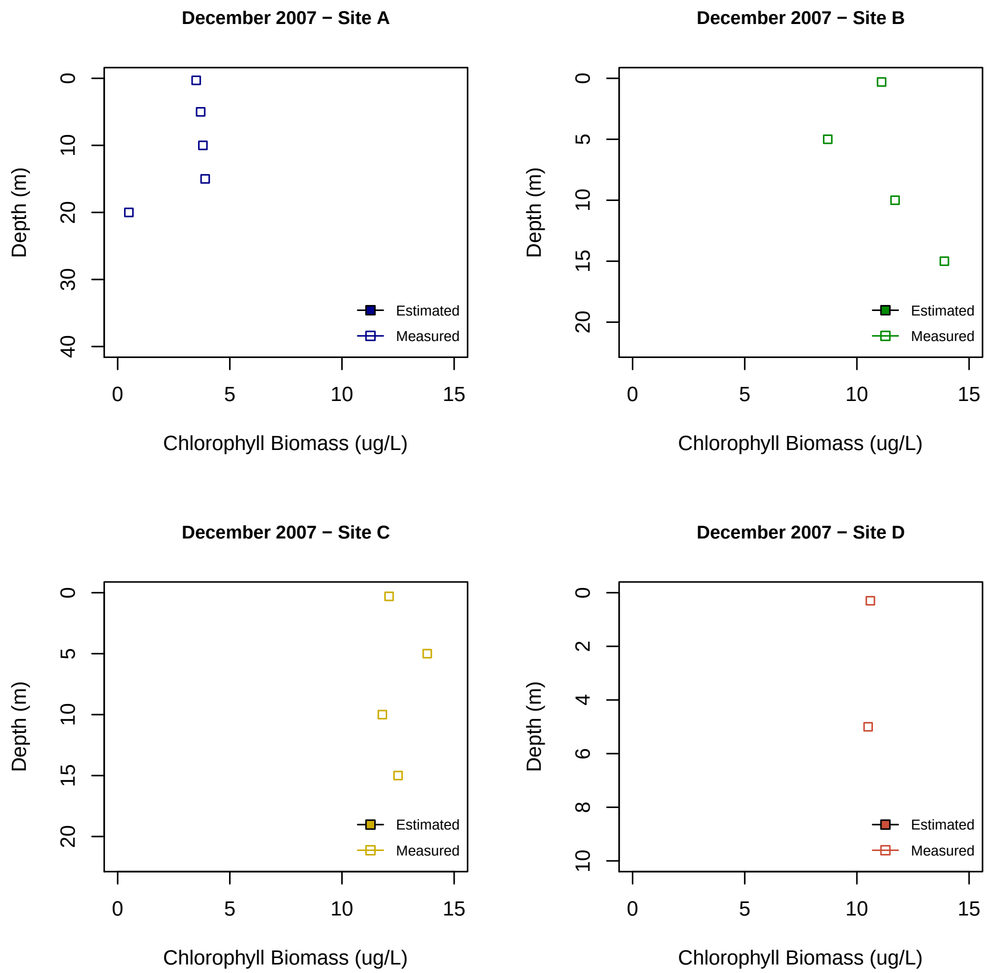


Figure 87: Lake Samish chlorophyll data for Sites A–D, December 20, 2007. All sites were sampled at 5 meter depth intervals.

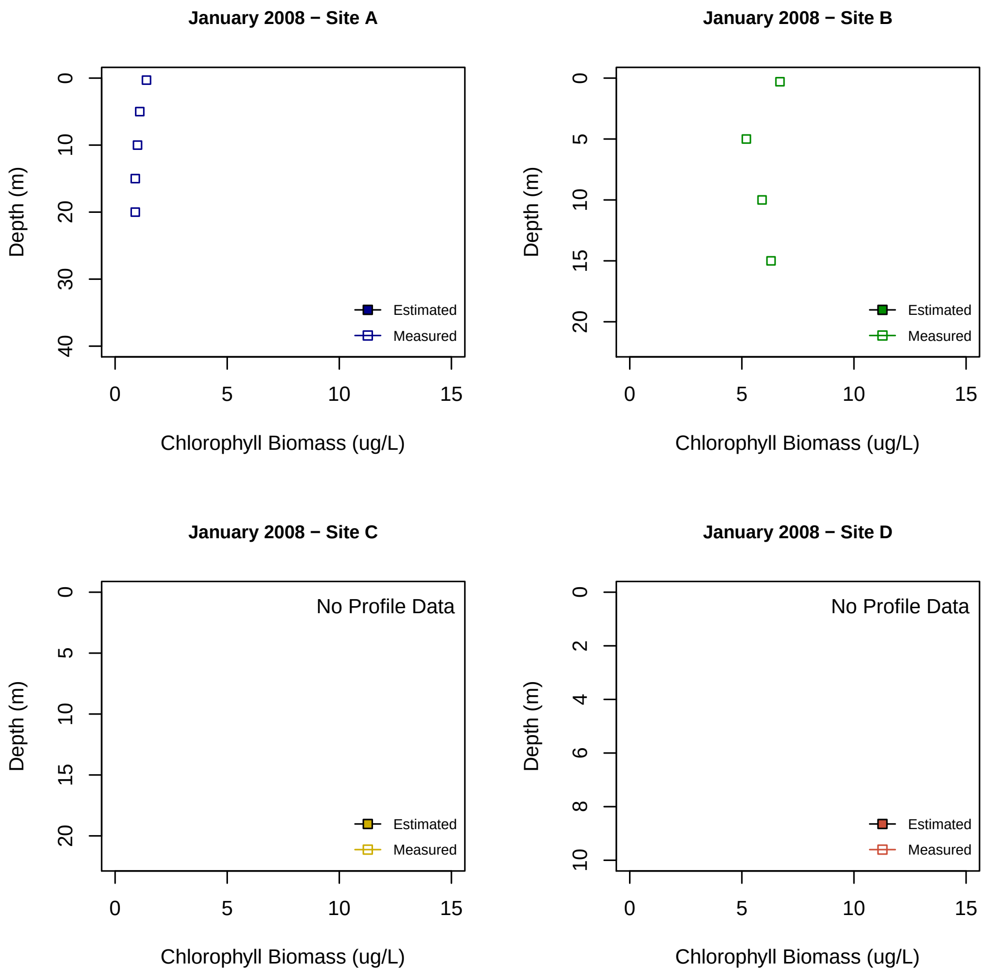


Figure 88: Lake Samish chlorophyll data for Sites A and B, January 29, 2008. Sites A and B were sampled at 5 meter depth intervals; Sites C and D were not sampled on this date.

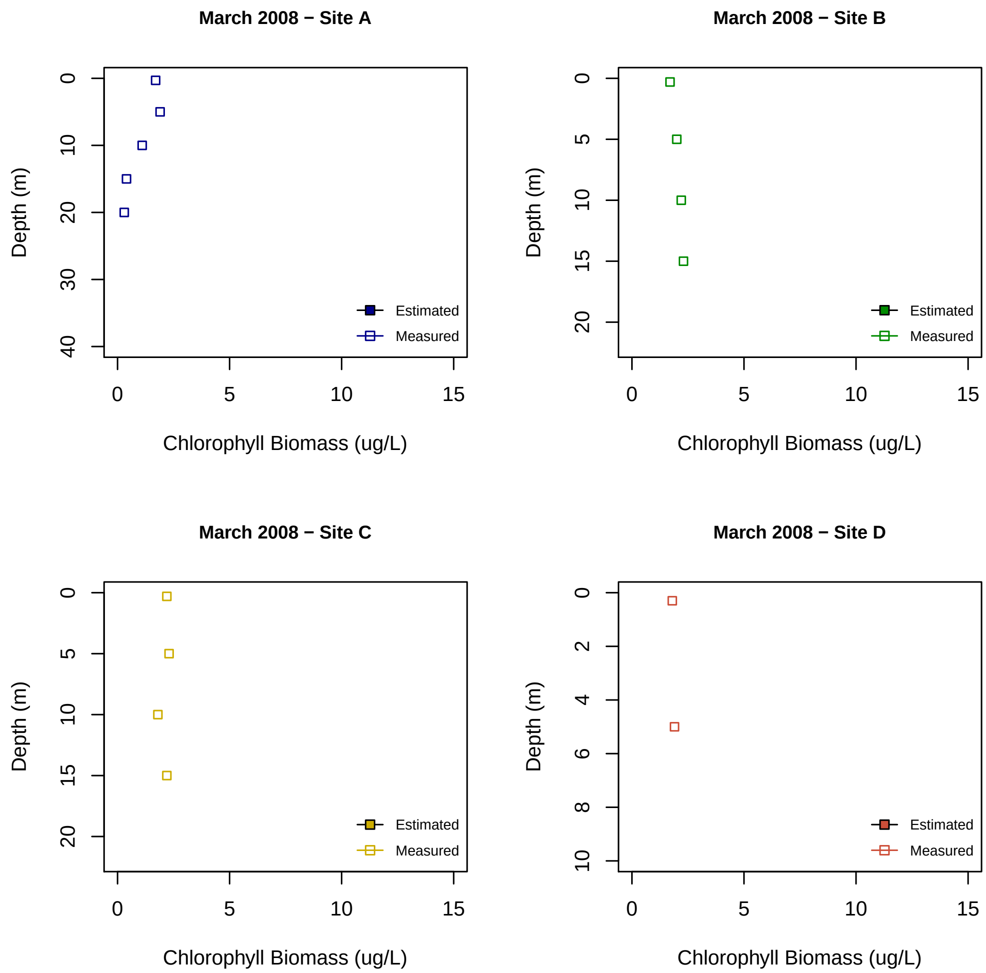


Figure 89: Lake Samish chlorophyll data for Sites A–D, March 25, 2008. All sites were sampled at 5 meter depth intervals.

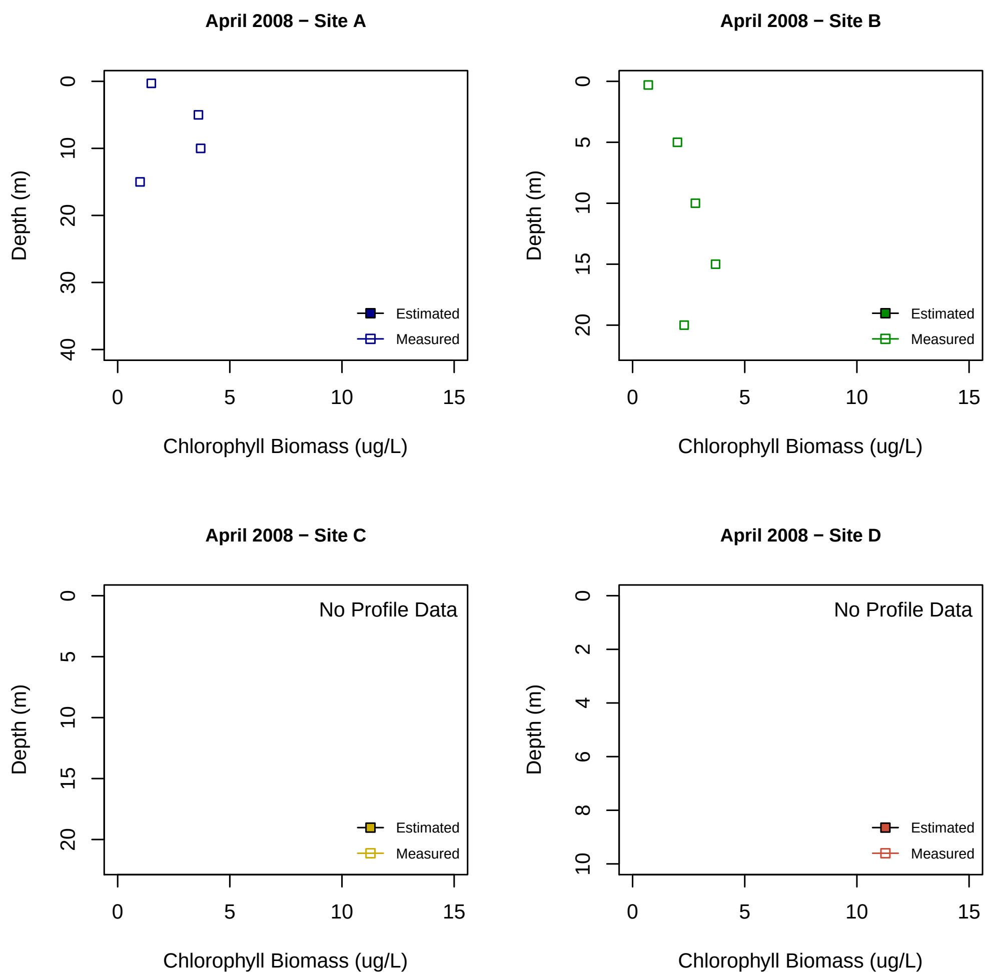


Figure 90: Lake Samish chlorophyll data for Sites A and B, April 21, 2008. Sites A and B were sampled at 5 meter depth intervals; Sites C and D were not sampled on this date.

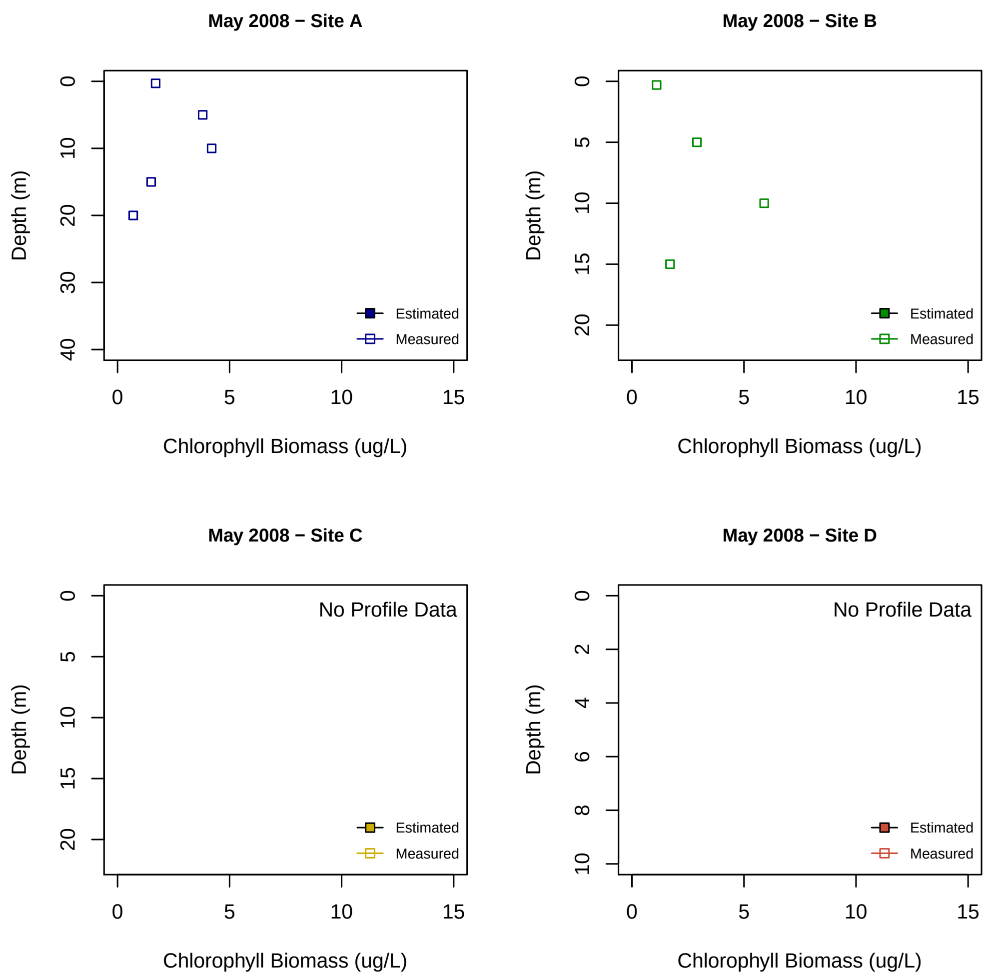


Figure 91: Lake Samish chlorophyll data for Sites A and B, May 15, 2008. Sites A and B were sampled at 5 meter depth intervals; Sites C and D were not sampled on this date.

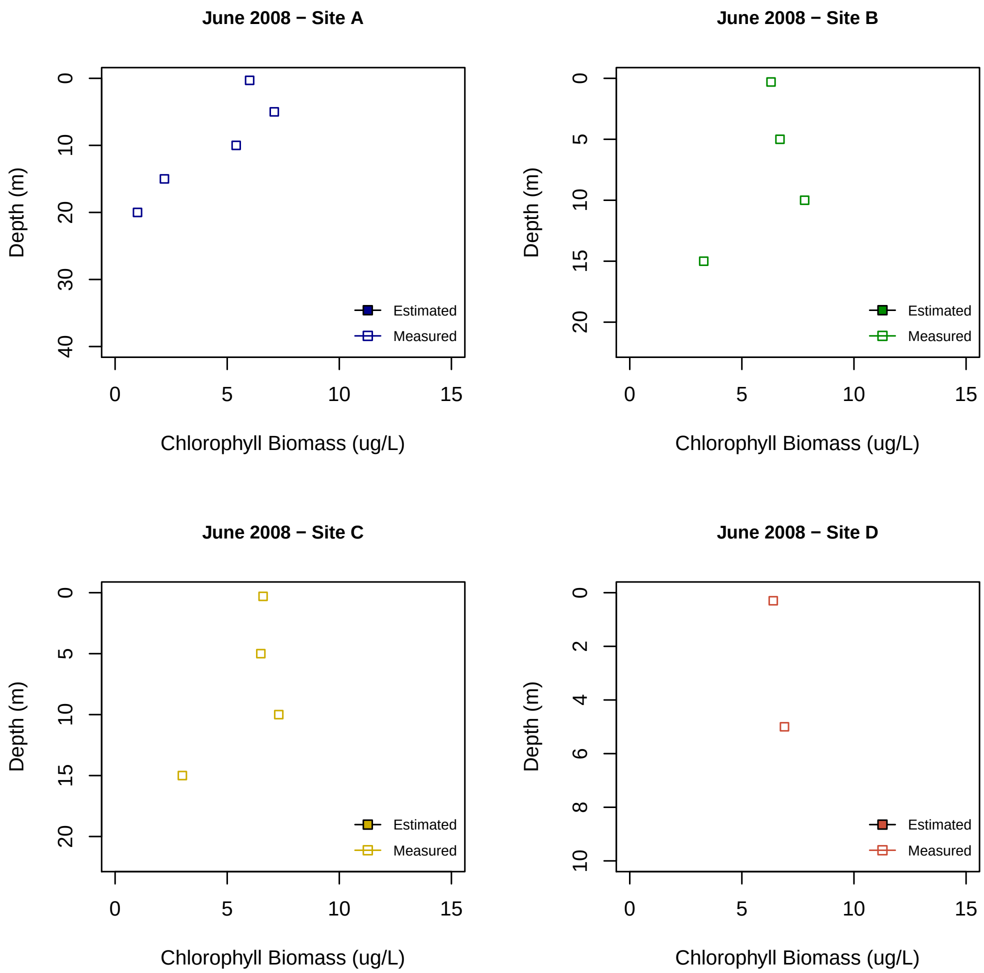


Figure 92: Lake Samish chlorophyll data for Sites A–D, June 10, 2008. All sites were sampled at 5 meter depth intervals.

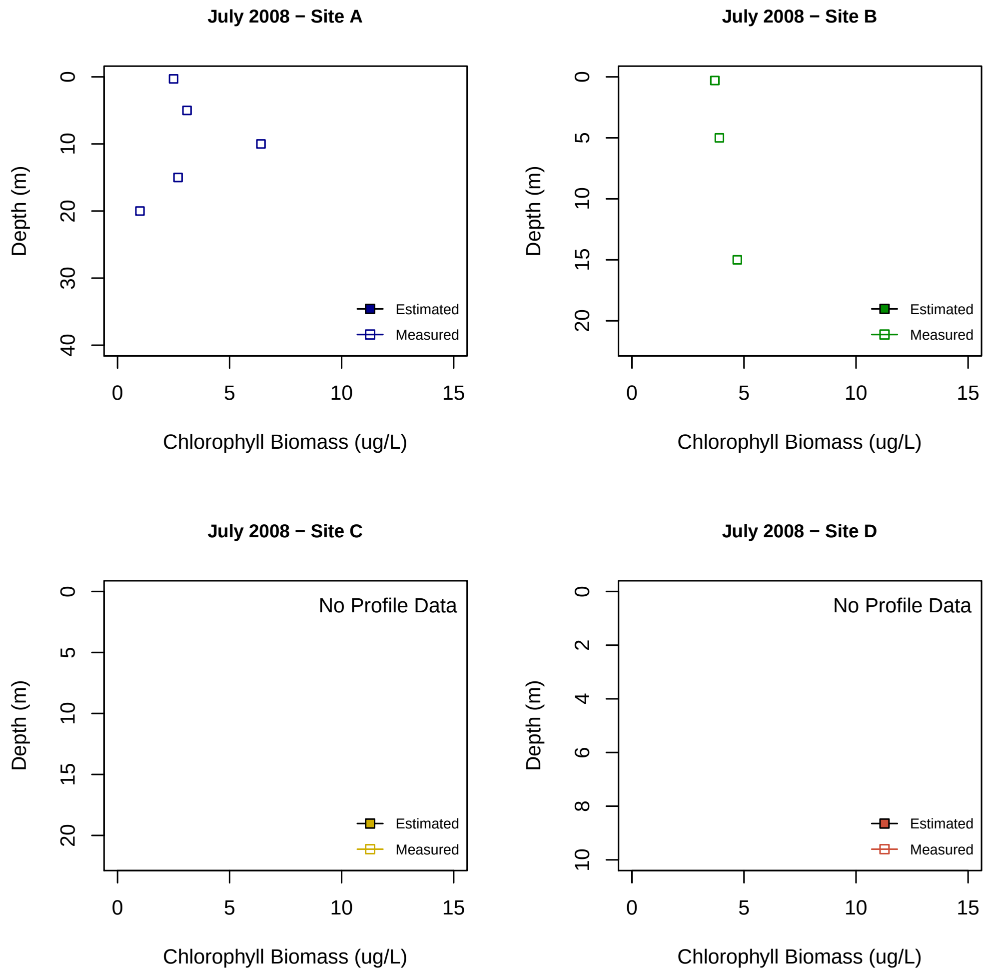


Figure 93: Lake Samish chlorophyll data for Sites A and B, July 22, 2008. Sites A and B were sampled at 5 meter depth intervals; Sites C and D were not sampled on this date.

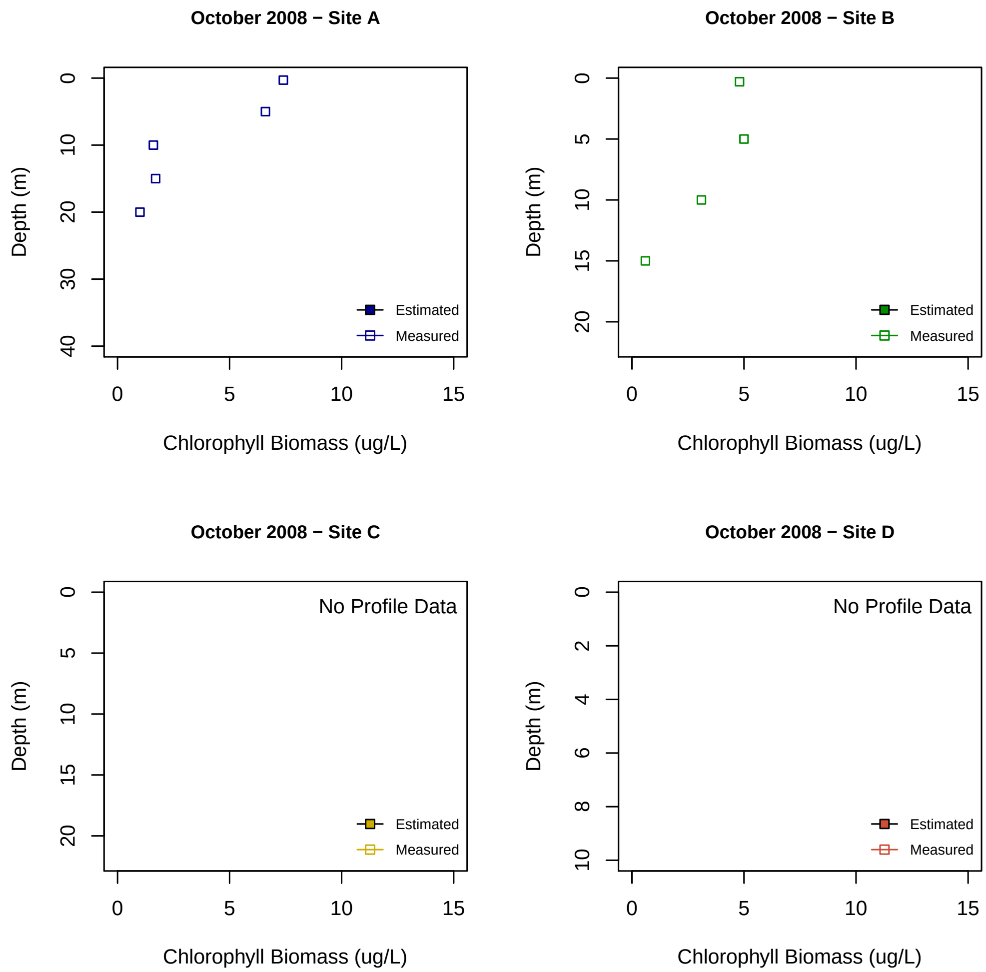


Figure 94: Lake Samish chlorophyll data for Sites A and B, October 23, 2008. Sites A and B were sampled at 5 meter depth intervals; Sites C and D were not sampled on this date.

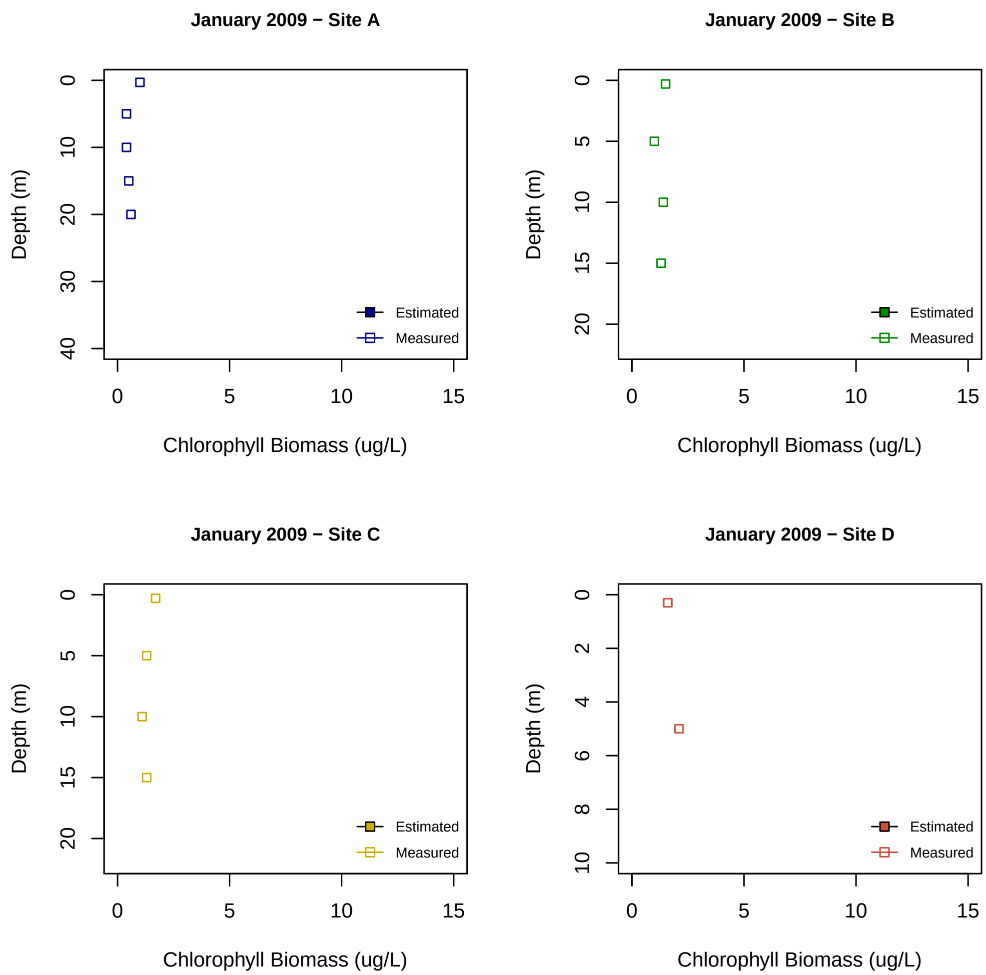


Figure 95: Lake Samish chlorophyll data for Sites A–D, January 25, 2009. All sites were sampled at 5 meter depth intervals.

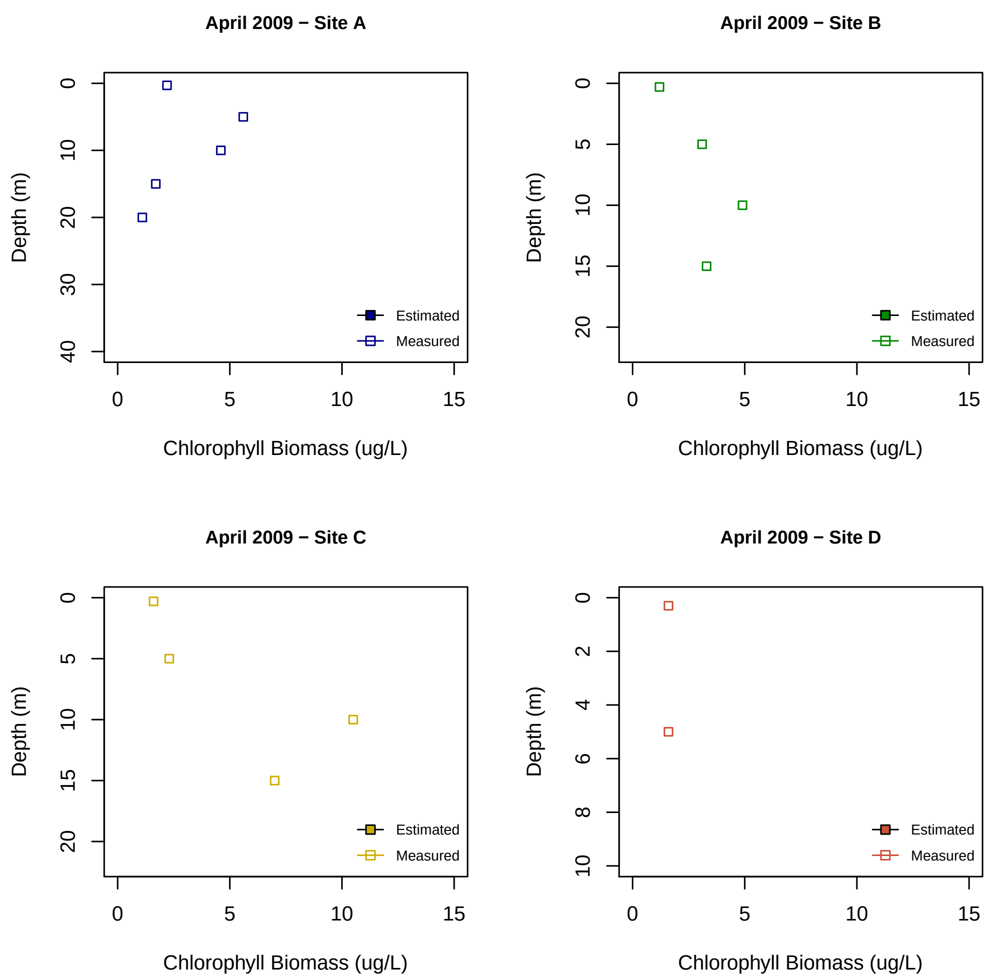


Figure 96: Lake Samish chlorophyll data for Sites A–D, April 27, 2009. All sites were sampled at 5 meter depth intervals.

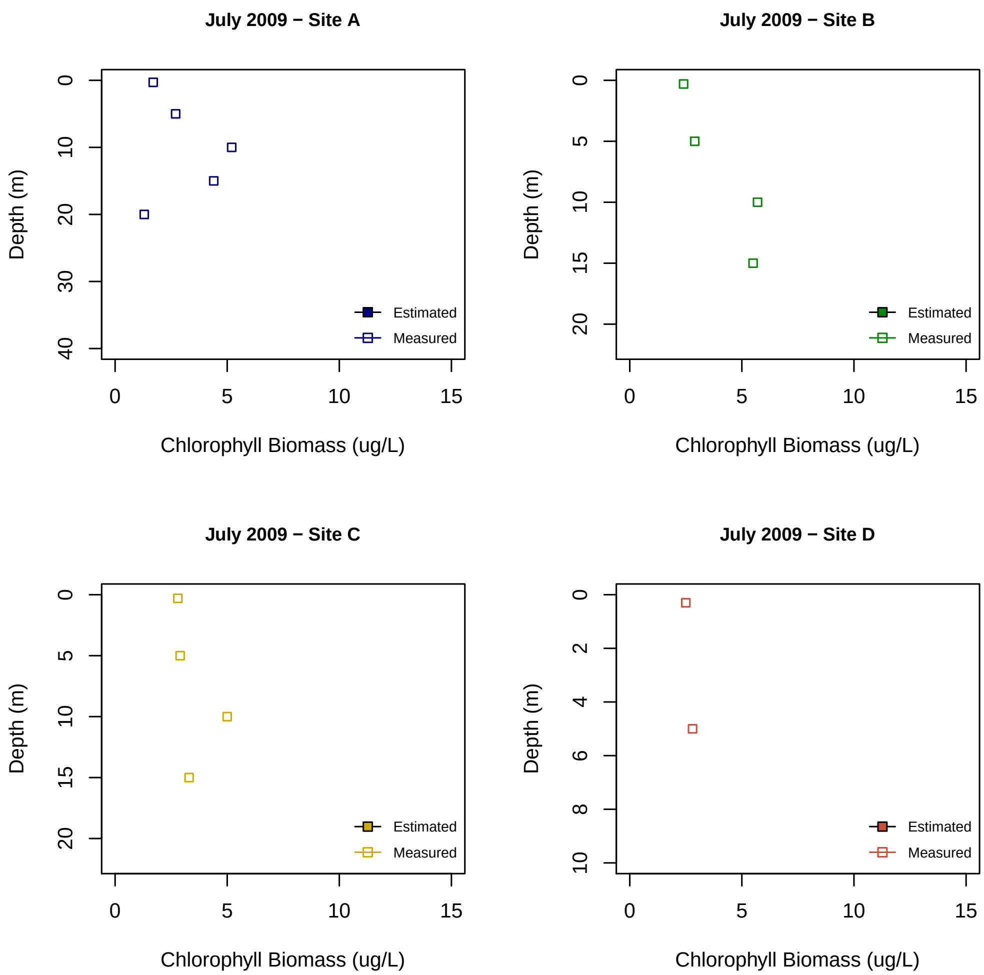


Figure 97: Lake Samish chlorophyll data for Sites A–D, July 1, 2009. All sites were sampled at 5 meter depth intervals.

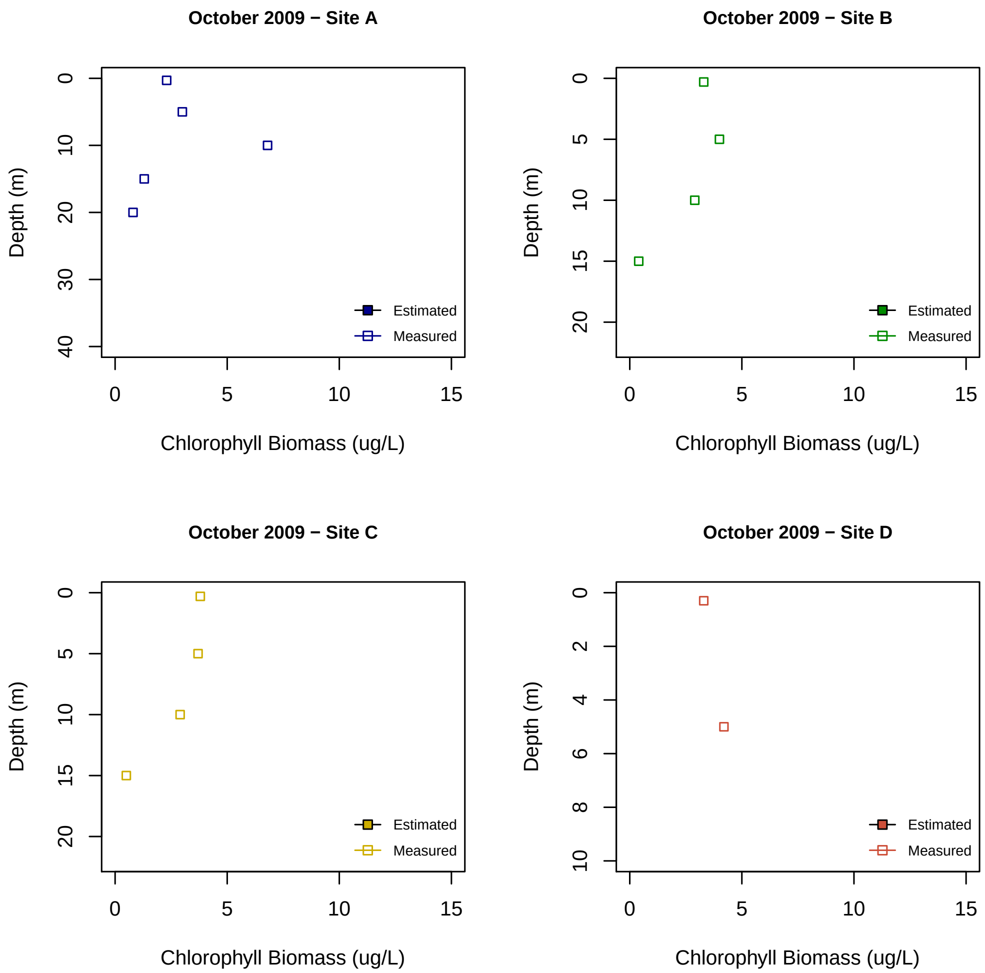


Figure 98: Lake Samish chlorophyll data for Sites A–D, October 20, 2009. All sites were sampled at 5 meter depth intervals.

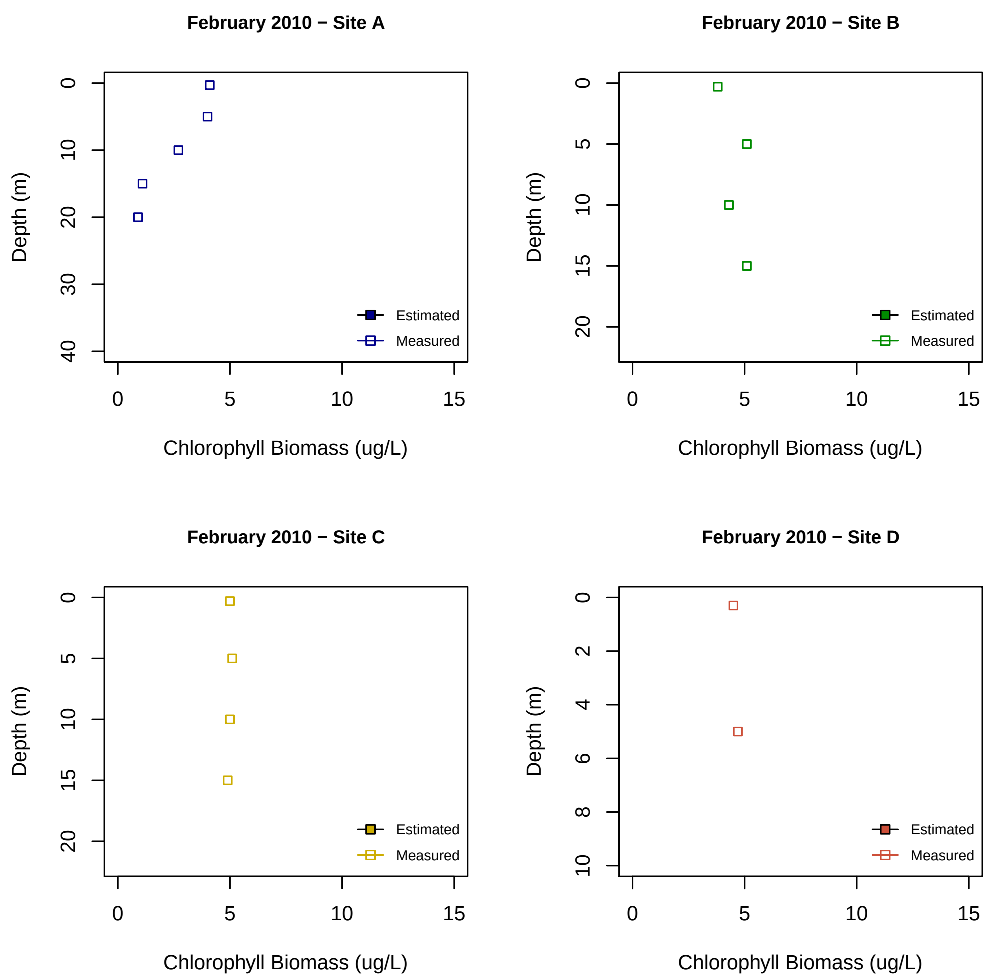


Figure 99: Lake Samish chlorophyll data for Sites A–D, February 17, 2010. All sites were sampled at 5 meter depth intervals.

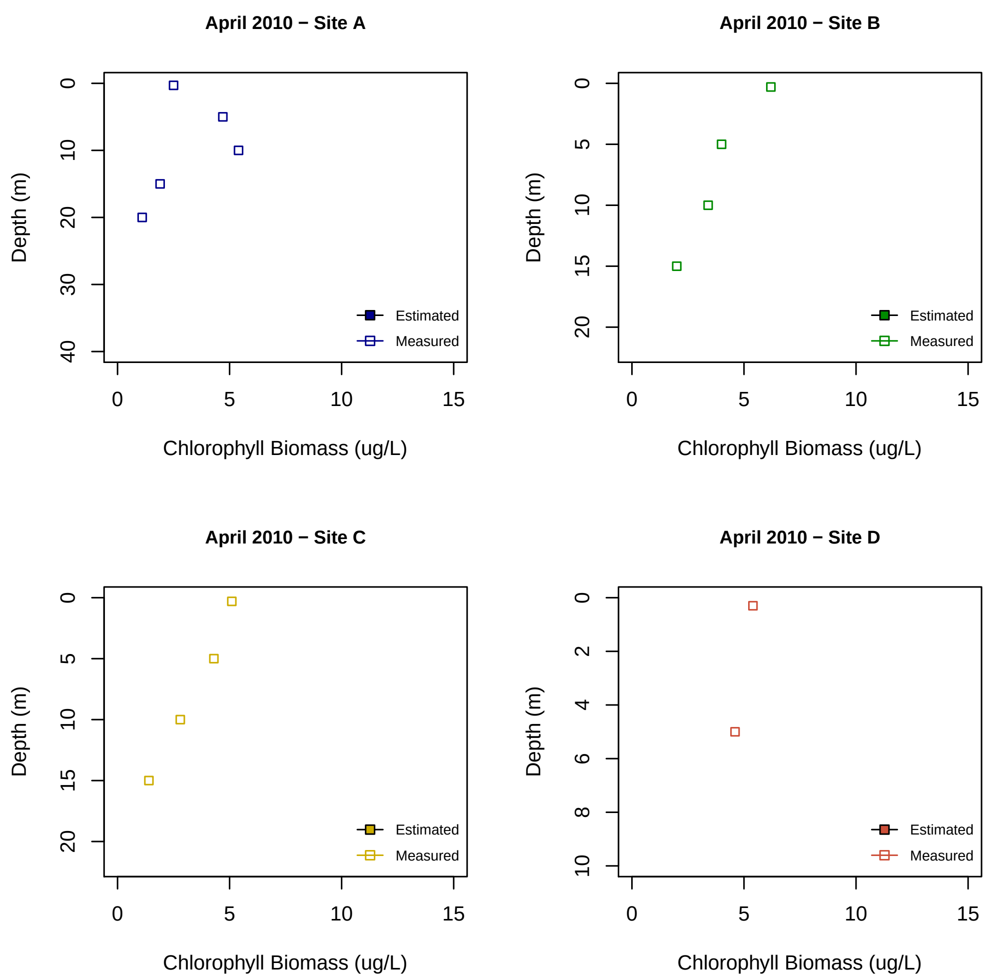


Figure 100: Lake Samish chlorophyll data for Sites A–D, April 22, 2010. All sites were sampled at 5 meter depth intervals.

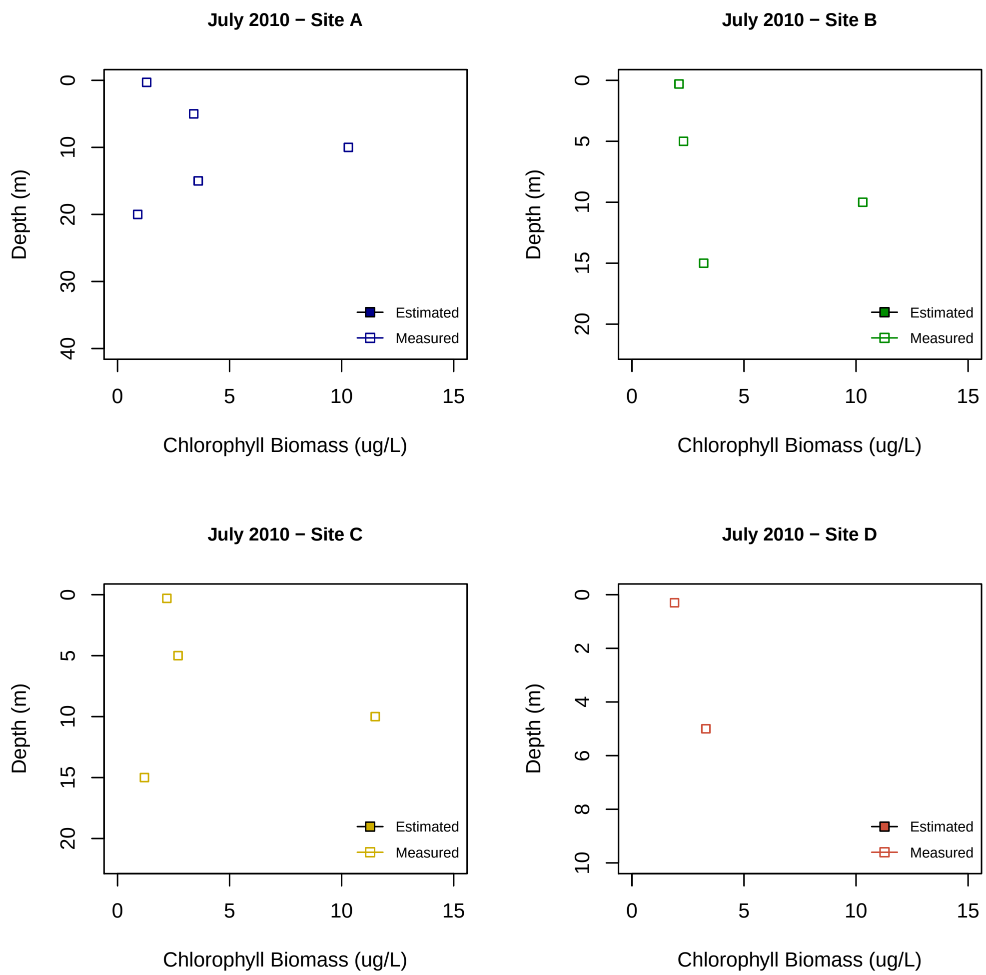


Figure 101: Lake Samish chlorophyll data for Sites A–D, July 15, 2010. All sites were sampled at 5 meter depth intervals.

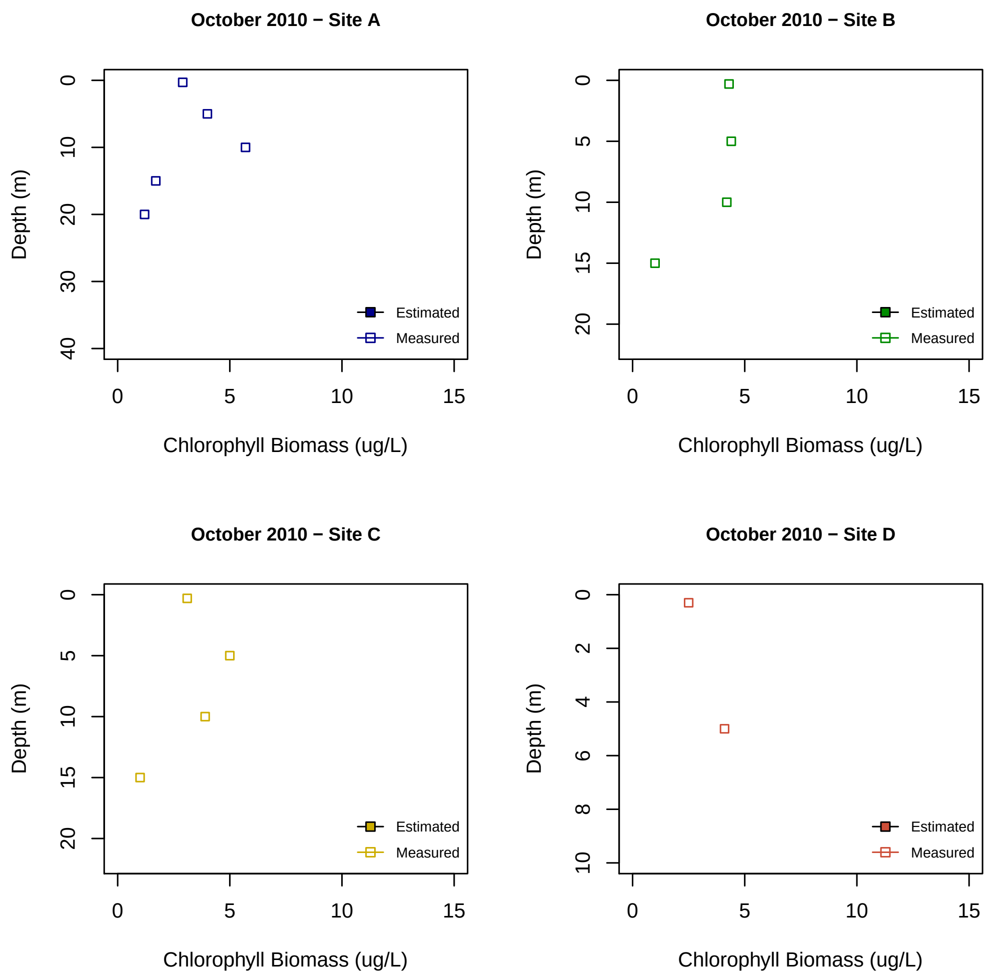


Figure 102: Lake Samish chlorophyll data for Sites A and B, October 19, 2010. All sites were sampled at 5 meter depth intervals.

C Lake Samish Monitoring Data

This appendix includes the lake data from 2005 through the current sampling year, edited to show detection limits and updated to include corrections or modifications made since the last summary report. All abbreviations are listed in Table 1 (page 27). Electronic copies of these files are available from the Institute for Watershed Studies.