AQUATIC ECOSYSTEM RESEARCH
A Freshwater Conservation Company

LAKE WONONSCOPOMUC

2015 Summary Water Quality Report

CONTENTS

EXECUTIVE SUMMARY

The water quality of Lake Wononscopomuc was found to be in line with other contemporary studies. Our results indicate that the trophic status of the lake was mesotrophic as previously suggested by other authors. During the summer of 2015, water clarity averaged ~4.0m. Water clarity was lowest early in the season; it increased to a maximum in the month of July and subsequently diminished through October. Furthermore, the diatom group dominated the algal community for most of the 2015 summer season; however, a shift in dominance occurred during the months of September and October with an increase in the blue-green algae group. That shift occurred concordantly with a change in the aqueous nitrogen to phosphorus ratio. Between May and July, the amount of nitrogen available was significantly higher than the amount of phosphorus, which benefited the diatom group to a greater extent than the blue-green group. As more phosphorus became available to algae later in the season due to internal generation, the relative ratio of nitrogen to phosphorus promoted the blue-green algal group.

In summary, the water quality during the summer 2015 was good. However, there is a significant internal production of phosphorus from the deep water, deoxygenated sediments later in the summer season. This may result in late season algal blooms in the future; water quality management strategies should be investigated for lake management planning purposes.

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INTRODUCTION

Lake Wononscopomuc is a natural 348ac water body located in Salisbury, Connecticut. This lake has a maximum depth of 31m, a mean depth of 11m, and contains approximately 4,735,317,783 gallons of water in two distinct basins. The lake's watershed is 1,621ac of sparse residential development. The resulting lake to watershed ratio is 4.65. Sucker Brook and one other small stream feed Lake Wononscopomuc; it flows out in to Factory Brook, a tributary of Salmon Creek, which ultimately feeds to the Housatonic River. Furthermore, Lake Wononscopomuc is a marl-type lake, which is characterized by calcium rich water and high specific conductance, due to its proximity to the geological feature known as Connecticut's Marble Valley (Frink and Norvell 1984, Canavan and Siver 1995). This type of water chemistry results in unique features such as marl deposits and lake whitening events. Finally, this type of water chemistry supports specialized algae and plant communities.

In 2015, Aquatic Ecosystem Research was engaged to examine the summer season water quality features of Lake Wononscopomuc. Historically, this lake has been characterized as mesotrophic with a high degree of water clarity. However, there has been some question as to whether Lake Wononscopomuc has suffered from cultural eutrophication and nutrient loading from dense aquatic vegetation. This initiative was not designed to look at long-term changes in water quality; rather, it was designed to establish a high quality contemporary database of water quality information. The 2015 water quality assessment established a repeatable design and allowed for a general examination of current water quality for use in future water quality comparisons.

This report summarizes those data collected during the summer 2015 season and makes recommendations for future lake management initiatives.

METHODOLOGY

During the year of 2015, Lake Wononscopomuc's water quality was assessed at two points (41°57'17.62"N/73°26'50.65W and 41°57'29.26"N/73°26'34.72"W), one in each basin (fig. 1). These assessments took place over a six-month period (i.e. May through October). At each sample point, during each month, a transparency measurement was taken using a standard Secchi Disk. Also, temperature, oxygen, conductivity, specific conductance, and pH were assessed at the surface and at every meter to the bottom using a YSI ® Professional meter. Water samples were taken at a depth of 1.0m from the surface and 0.5m from the bottom using a Van Dorn sampler. Furthermore, algae samples were taken at each site with a Van Dorn sampler at the depth of greatest oxygen concentration (usually 7m of depth). These samples were processed by a state certified laboratory. The surface/algae water samples were analyzed for genus-level algal cell counts, alkalinity, ammonia, nitrite, nitrate, Total Kjeldahl Nitrogen, and total phosphorus. Bottom water samples were analyzed for alkalinity, ammonia, nitrite, nitrate, Total Kjeldahl Nitrogen, and total phosphorus. Algal samples were enumerated using a Whipple Grid technique where the sample was subsampled and counted. The cell enumerations were done by counting a subset of the Whipple Grid and corrected to be representative of the whole slide. The results of all these tests were stored in a database managed by Aquatic Ecosystem Research.

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Using the aforementioned data, resistance to mixing, which is an assessment of the ability of two different water volumes – that differ in temperature – to mix, was calculated using the Relative Thermal Resistance to Mixing (RTRM) formula: **$(D^1 - D^2)/(D' - D^o)$**, where D^1 is the density of upper water volume, D^2 is the density of the lower water volume, D' is the density of water at 5°C, and D^o is the density of water at 4°C.

RESULTS

Water Clarity:

Secchi depth averages for sites 1 and 2 in 2015 were 4.21 and 3.95m, respectively. The maximum water clarity at both sample sites was encountered in July; site 1 and 2 maximum water clarity measurements were 5.57 and 5.60m, respectively (figs 2/3, Tables 1/2).

The patterns in water clarity were congruent between both sites. The water clarity was lowest in May; it increased to the maximum in July, which sustained through August. The clarity of Lake Wononscopomuc then decreased through September and remained constant until the end of October (figs 2/3). These dynamics in water clarity can be directly related to the changes in aqueous nutrients and the pelagic algal community.

Algal Community:

Diatoms dominated the pelagic algal community for the majority of the season at both sites. Only in the months of September and October was there a distinct shift in the dominance of the diatoms, which yielded to the blue-green algae genera in regards to dominance (figs 4/5).

Total cell counts of the algal community at both sites were high in May; total cells then dropped significantly in June. Following, the number of cells encountered in each month increased throughout the remainder of the season (figs 4/5). These patterns are mirrored in the water clarity evaluations, where the clarity of the water decreased as the number of algal cells increased throughout the later parts of the season (figs 2/3). The most significant decreases in summer water clarity follow the increased dominance of the blue-green algal genera in September and October (figs 4/5). This is commonly the case; water clarity is directly related to the total number of algal cells per mL of lake water and even more closely related to the total number of cells of the blue green algal genera.

In general, the productivity of the algal community is related to the aqueous availability of nitrogen and phosphorus. The relative concentration of each nutrient (i.e. nitrogen vs. phosphorus) will dictate the total productivity of the community and the relative abundance of each algal genus.

Nutrients:

The relative concentrations of nitrogen (i.e. ammonia) and phosphorus in the surface waters have a distinct impact on the structure of the pelagic algal community. The diatom, green, dinoflagellate, and golden algae groups are generally limited by the availability of nitrogen (i.e. high nitrogen to phosphorus ratio) while blue-green algae are more competitive under phosphorus rich conditions (i.e. low nitrogen to

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phosphorus ratio). Throughout the entire season, Lake Wononscopomuc had a high nitrogen-to-phosphorus ratio (i.e. phosphorus limited and substantial ammonia) in the surface waters, which favored the algae genera not usually associated with compromised water quality (i.e. diatoms, dinoflagellates, and greens – figs 6/7, Tables 1/2). However later in the season, the concentration of phosphorus in the surface waters increased, which resulted in a benefit to the blue-green algae population (i.e. decreasing nitrogen to phosphorus ratio) and increased productivity in that group (fig 8/9). The relative concentrations of nutrients in the surface waters are driven by production of nutrients in the bottom waters during times of thermal stratification where diffusion sustains the surface concentrations until mixing occurs late in the season (i.e. October/November).

The influence of internal nutrient loading in Lake Wononscopomuc is probably more important compared to external watershed nutrient loading; however, this hypothesis should be investigated in future management initiatives. Assuming that the aforementioned is true, the internal production of nutrients from the deoxygenated hypolimnion (bottom waters) is critical to the overall water quality of Lake Wononscopomuc. Ammonia increased in the hypolimnion throughout the season at site 1, while it was relatively consistent at site 2 (figs 10/11, Tables 3/4). Total phosphorus production in the hypolimnion increased from May to July at both sites; its concentration then decreased throughout the remainder of the season (figs. 12/13, Tables 3/4). However, it should be noted that there is a significant internal production of phosphorus from the hypolimnion where the peak availability of phosphorus at sites 1 and 2 was 172 and 137μg/L, respectively (Tables 3/4). Internal loading of nutrients is driven by the state of the vertical thermal structure of the water body, which in turn affects the concentration of oxygen in the deeper reaches of the lake and whether nutrients remain bound to the lake sediments.

Thermal Structure and Oxygen:
The vertical structure of water temperature is influenced by the incident radiation of our sun hitting the surface of the lake and the diffusion of that energy through the vertical profile of the water volume. In short, the upper reaches of the lake are heated asymmetrically compared to the lower reaches of the water body. The result is a warm surface water volume (i.e. epilimnion), a transitional area of rapid temperature decline with depth (i.e. thermocline/metalimnion), and a cool bottom water volume (i.e. hypolimnion). Concordant with the establishment of the aforementioned thermal structure is a diminishment of oxygen in the hypolimnion. The reason for the decrease in oxygen is due to the inability of the epilimnion and hypolimnion to mix under thermally stratified conditions. The reason for this inhibited mixing is due to the differences in water density among layers; for all intents and purposes the epilimnion and hypolimnion can be considered oil and water in regards to their ability to mix. The result of the aforementioned is that oxygen is consumed by soil bacteria at a rate that is greater than the diffusion of oxygen from the surface waters and – ultimately – oxygen becomes depleted in the hypolimnion.

The thermally stratified structure of Lake Wononscopomuc was established by the month of May in 2015 at both sites (figs. 14). This condition was sustained at both sites through September (figs. 15-18). Reviewing those Relative Thermal Resistance to Mixing (RTRM) data, which characterizes the ability of two water layers to mix (i.e. high RTRM indicates that two layers are not mixing), shows that the separation of the epilimnion and hypolimnion become more separated from May to September at both

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sites (figs. 14-18). The result is that mixing between those layers is minimal and that oxygen is not being introduced to the lower reaches of Lake Wononscopomuc. Finally, this separation between the epilimnion and hypolimnion only began to break down in October of 2015 (fig. 19).

Despite the early season separation of the epilimnion and hypolimnion of Lake Wononscopomuc, there was no significant zone of deoxygenation at either site until June (figs. 14/15). The size of the deoxygenated zones of site 1 and 2 hit their maxima during the months of September and August, respectively (figs. 18/17). The maximum sizes of the deoxygenated zone were 15m for site 1 and 5m for site 2 (figs. 18/17). The state of deoxygenation in the hypolimnion remained – in some form – through October (fig. 19). In short, there was a protracted period of deoxygenation that resulted in a significant internal production of nutrients; and, this condition was sustained by the thermal structure of the lake through October when there was some evidence for the degradation of thermal stratification.

SUMMARY DISCUSSION OF RESULTS

Overall, the water quality of Lake Wononscopomuc was good and the water chemistry parameters were in line with other contemporary studies of this lake (See Frink and Norvell 1984, Canavan and Siver 1995, & Jacobs and O'Donnell 2002. Diatoms dominated the algal community for the majority of the 2015 summer season, which is concordant with the high degree of water clarity of Lake Wononscopomuc; however, the protracted state of deoxygenation in the hypolimnion fueled the aqueous concentration of phosphorus in the epilimnion. This phenomenon resulted in a decrease in the N:P-ratio, which ultimately led to an increased productivity in the blue green algae populations later in the season (i.e. September/October). This is not an unusual finding for deep, dimictic lakes in Connecticut; however, it should be noted that this could result in a significant late season blue green algal bloom if the future summer season weather conditions promote higher epilimnetic water temperatures that further thwart mixing of the epilimnion and hypolimnion.

WATER QUALITY MANAGEMENT RECOMMENDATIONS

The following are recommendations for future water quality management initiatives:

1) Water Quality Monitoring
    a. Ideally, this should be conducted on a yearly basis to develop a comprehensive database for statistical modeling and real-time water quality management decision-making. <u>This should always be conducted following the protocol outlined in this report.</u>
        i. At minimum, this should be conducted every two years.
    b. Consider constructing a Quality Assurance Program Protocol to ensure the protocol is documented completely in case there is a change in the lake management entity.

2) EPA 9-Key Elements Watershed Study

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a. To establish the external nutrient loading and the relative influences of each part of the watershed, an EPA 9-Key Elements Watershed Study should be considered as part of your long-term lake management plan.
b. These types of studies are expensive; therefore, you should consider applying for grant funding. A few grant initiatives that may help you obtain funding for this type of study are:
    i. EPA 319 Grant Program
    ii. Connecticut STEAP
    iii. Connecticut Aquatic Invasive Species Grant Program

3) Historical Water Quality Data Analysis
    a. There is a long history of water quality monitoring for Lake Wononscopomuc. All of these data are spread among entities without a full summary analysis. These data hold a wealth of information; therefore, all of these data should be compiled and analyzed using advanced statistical techniques.
        i. The major advantage to doing this is to determine what the long-term dynamics of Lake Wononscopomuc's water quality have been. Furthermore, it will provide insight as to what the anthropogenic influences on the lake have been and to what degree these influences require remediation.

4) Examination of Water Quality Management Strategies
    a. Since there is a significant internal source of nutrients being produced in Lake Wononscopomuc in each summer season, the strategies for managing internal nutrient sources should be explored and quantified.
        i. This type of examination will allow for prudent fiscal planning should an internal water quality management strategy be required.
        ii. Types of nutrient management to be explored:
            1. Aeration
            2. Mixing
            3. Alum

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Canavan RW and Siver P. 1995. *Connecticut Lakes: A study of the chemical and physical properties of fifty-six Connecticut Lakes.* Connecticut College Arboretum – Connecticut College; New London, CT

Frink CR and Norvell WA. 1984. *Chemical and physical properties of Connecticut Lakes.* The Connecticut Agricultural Experiment Station, Bulletin 817; New Haven, CT

Jacobs RP and O'Donnell EB. 2002. *A fisheries guide to lakes and ponds of Connecticut.* Connecticut Department of Environmental Protection Bulletin 35; Hartford, CT.

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TABLES

Table 1: Site 1 – Surface water chemistry parameters for the summer 2015 season.

Site 1: Surface Water Quality Parameters						
	May	**June**	**July**	**August**	**September**	**October**
Alkalinity (mg/L)	138.00	132.00	134.00	128.00	118.00	122.00
Ammonia (mg/L)	0.56	2.80	0.56	0.56	0.84	0.84
Nitrate (mg/L)	0.05	0.00	0.00	0.00	0.00	0.00
Nitrite (mg/L)	0.00	0.00	0.00	0.00	0.00	0.00
TKN (mg/L)	1.10	3.40	6.70	3.90	7.30	1.40
Total P (ug/L)	0.00	0.00	21.20	48.00	63.00	20.00
N:P Ratio	NA	NA	26.42	11.67	13.33	42.00
Secchi (m)	2.65	4.10	5.57	5.37	3.54	4.00

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Table 2: Site 2 – Surface water chemistry parameters for the summer 2015 season.

Site 2: Surface Water Quality Parameters						
	May	**June**	**July**	**August**	**September**	**October**
Alkalinity (mg/L)	144.00	148.00	128.00	120.00	126.00	128.00
Ammonia (mg/L)	0.84	0.56	0.56	0.84	0.56	0.84
Nitrate (mg/L)	0.00	0.00	0.05	0.00	0.00	0.00
Nitrite (mg/L)	0.00	0.00	0.00	0.00	0.00	0.00
TKN (mg/L)	6.20	2.80	8.40	2.80	3.90	10.10
Total P (ug/L)	0.00	0.00	0.00	18.00	64.00	11.00
N:P Ratio	NA	NA	NA	46.67	8.75	76.36
Secchi (m)	2.92	3.90	5.60	4.23	3.33	3.69

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Table 3: Site 1 – Hypolimnetic water chemistry parameters for the summer 2015 season.

	Site 1: Bottom Water Quality Parameters					
	May	**June**	**July**	**August**	**September**	**October**
Alkalinity (mg/L)	144.00	148.00	145.00	164.00	160.00	146.00
Ammonia (mg/L)	0.84	1.10	1.10	2.10	4.20	0.28
Nitrate (mg/L)	0.26	0.28	1.22	0.00	0.00	0.00
Nitrite (mg/L)	0.00	0.00	0.00	0.00	0.00	0.00
TKN (mg/L)	4.50	3.40	7.30	2.20	3.40	6.20
Total P (ug/L)	15.00	0.00	172.00	143.00	79.00	51.00

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Table 4: Site 2 – Hypolimnetic water chemistry parameters for the summer 2015 season.

Site 2: Bottom Water Quality Parameters

	May	June	July	August	September	October
Alkalinity (mg/L)	144.00	150.00	150.00	274.00	146.00	158.00
Ammonia (mg/L)	1.70	0.00	1.40	1.90	1.40	1.10
Nitrate (mg/L)	0.06	0.00	0.85	0.00	0.00	0.00
Nitrite (mg/L)	0.00	0.00	0.00	0.00	0.00	0.00
TKN (mg/L)	5.60	5.60	7.30	6.70	10.60	16.80
Total P (ug/L)	31.00	15.00	137.00	114.00	90.00	71.00

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FIGURES

Figure 1: Map of Lake Wononscopomuc indicating sample points.

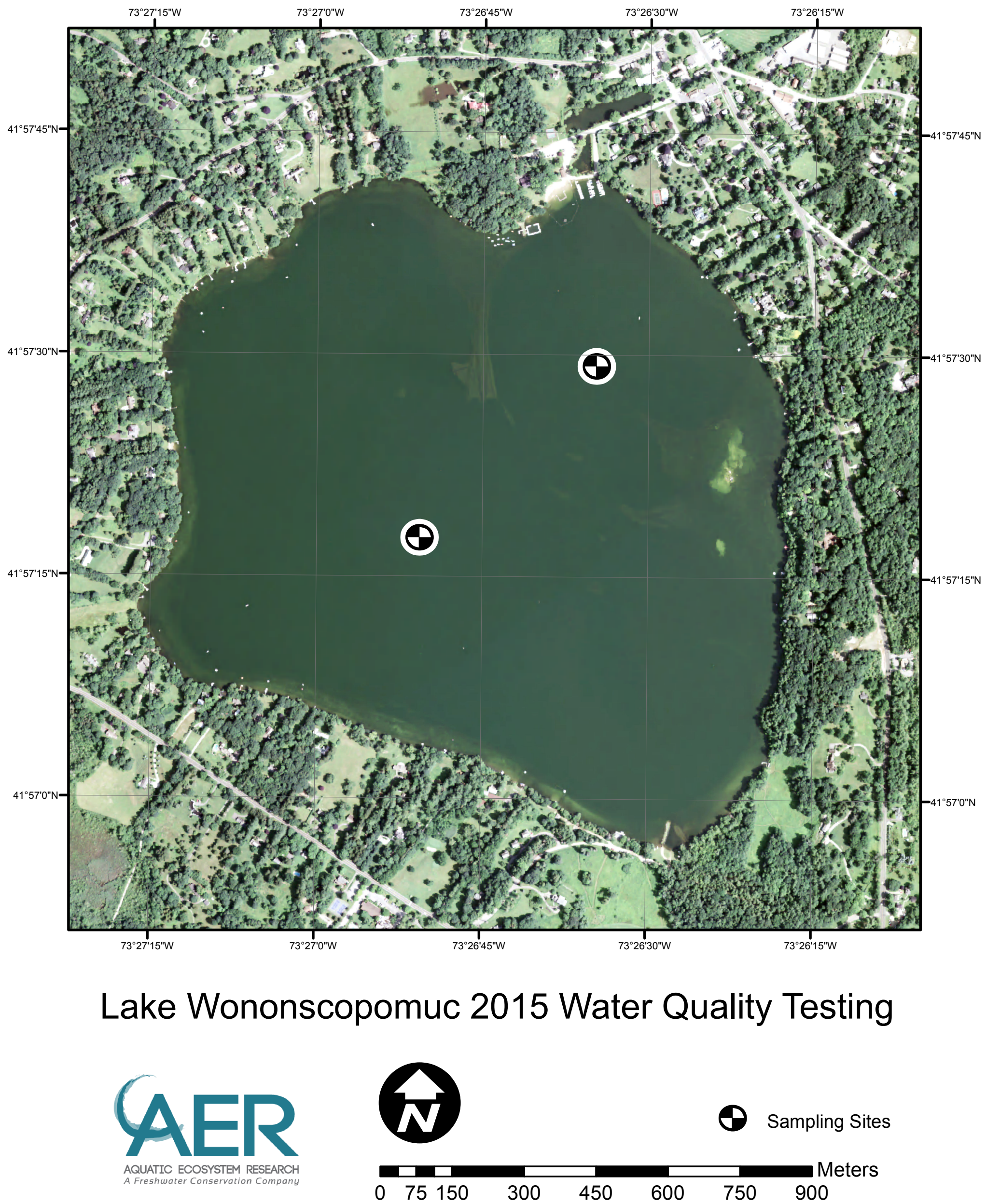

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Figure 2: Site 1 – Water clarity measurements for the summer 2015 season.

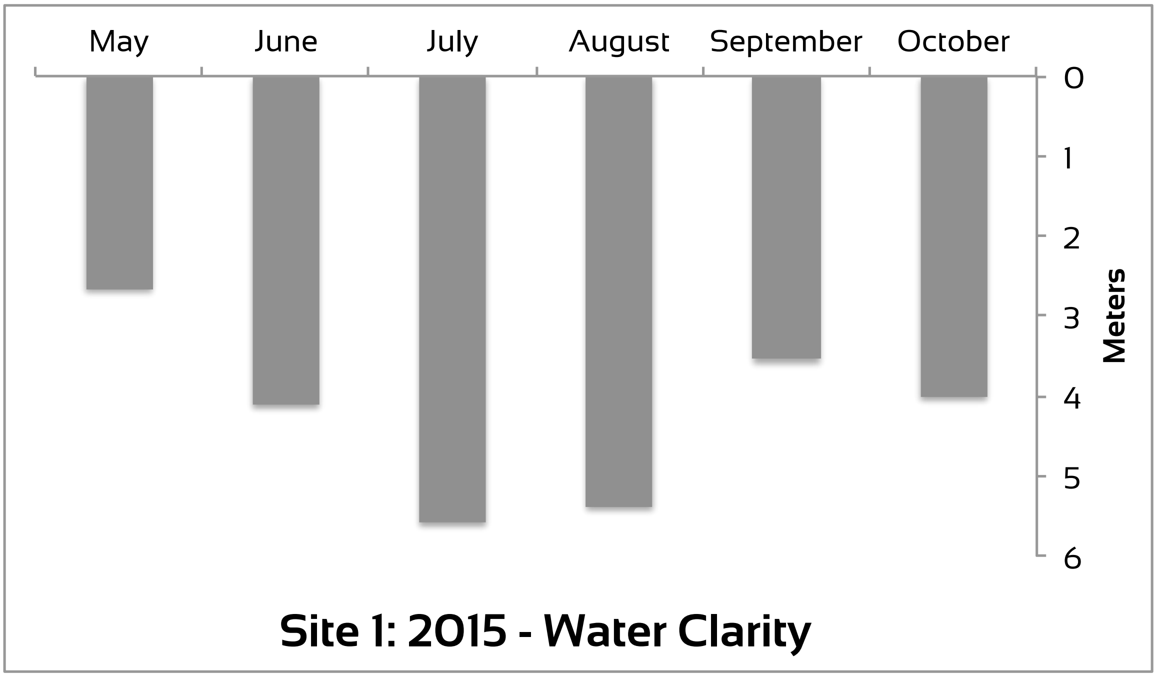

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Figure 3: Site 2 – Water clarity measurements for the summer 2015 season.

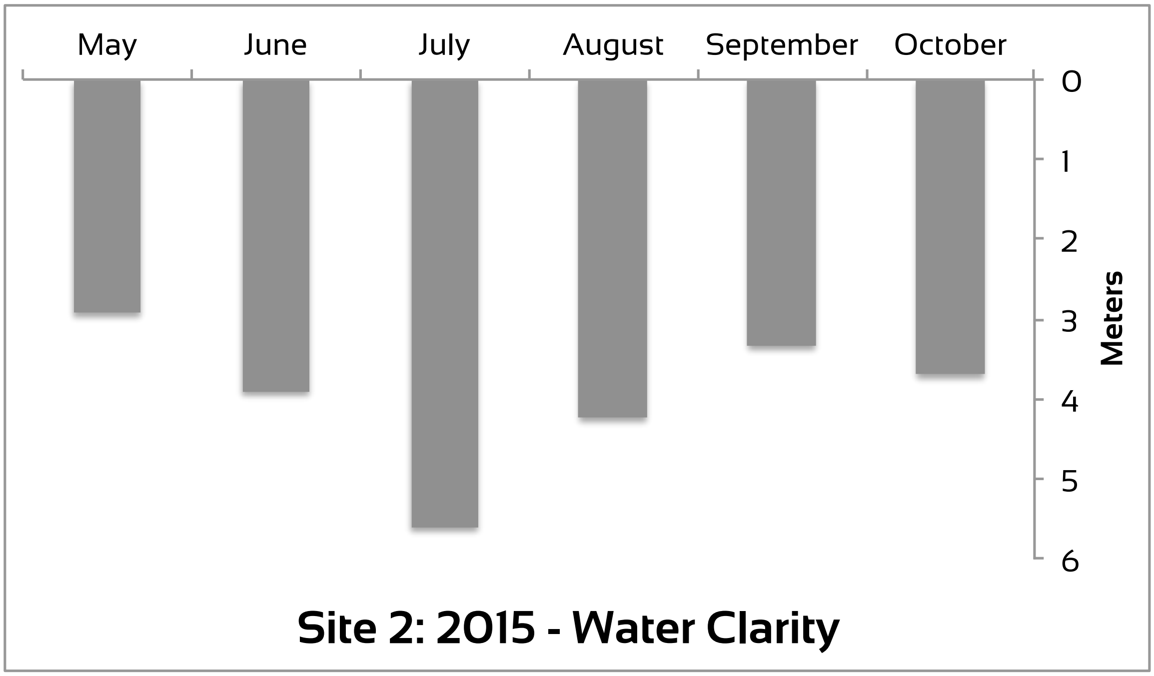

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Figure 4: Site 1 – Algal cell counts organized by algae class and month for the summer 2015 season.

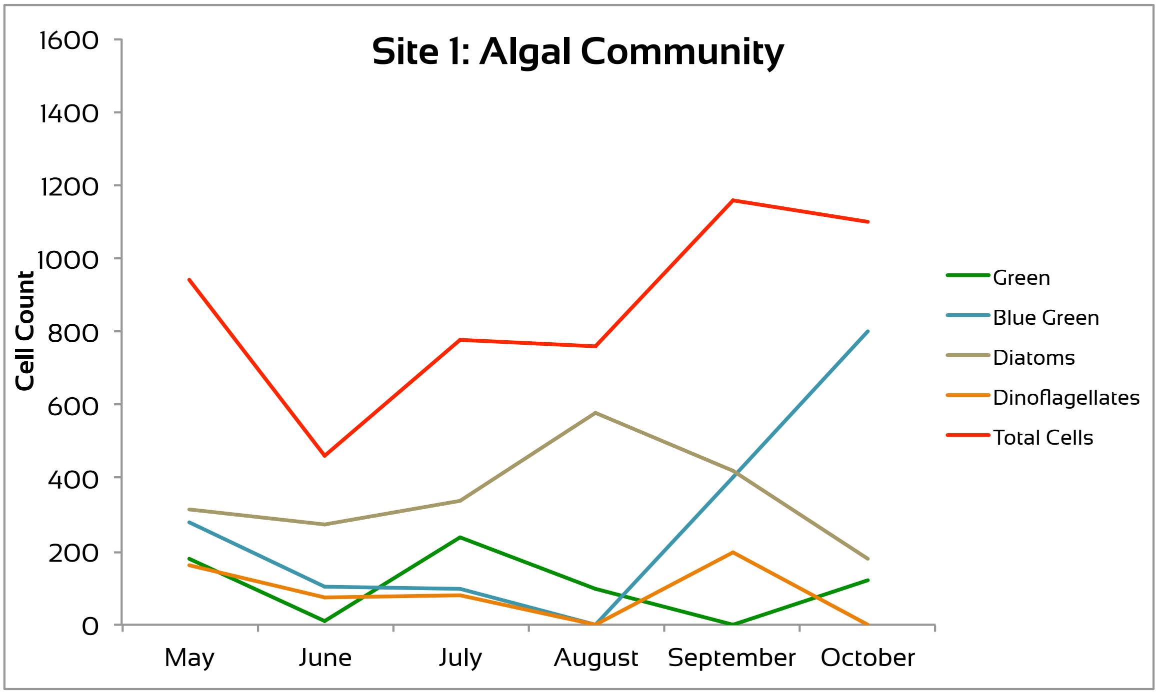

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Figure 5: Site 2 – Algal cell counts organized by algae class and month for the summer 2015 season.

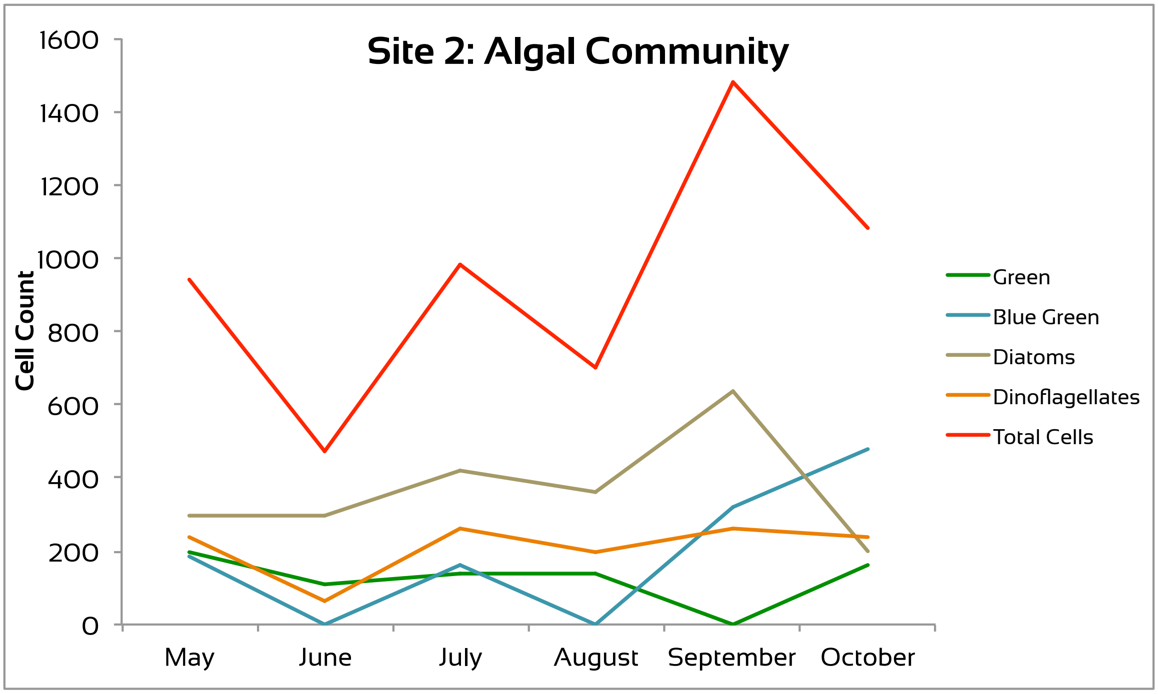

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Figure 6: Site 1 – Surface ammonia concentrations for the summer season of 2015.

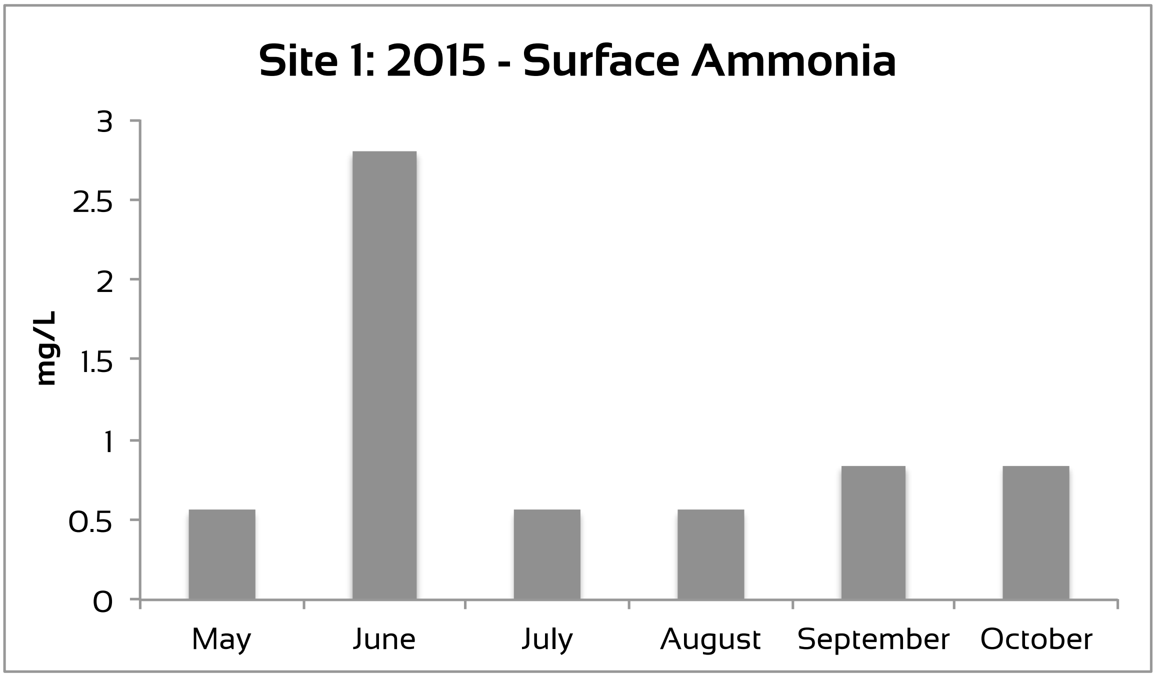

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Figure 7: Site 2 – Surface ammonia concentrations for the summer season of 2015.

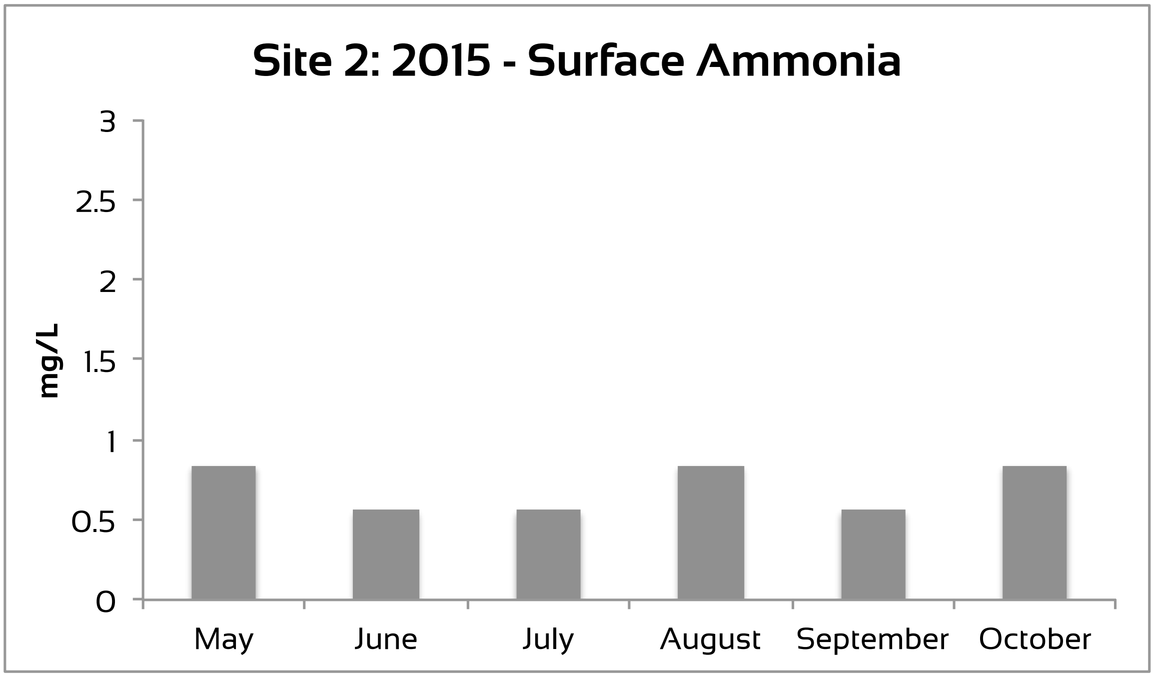

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Figure 8: Site 1 – Surface phosphorus concentrations for the summer season of 2015.

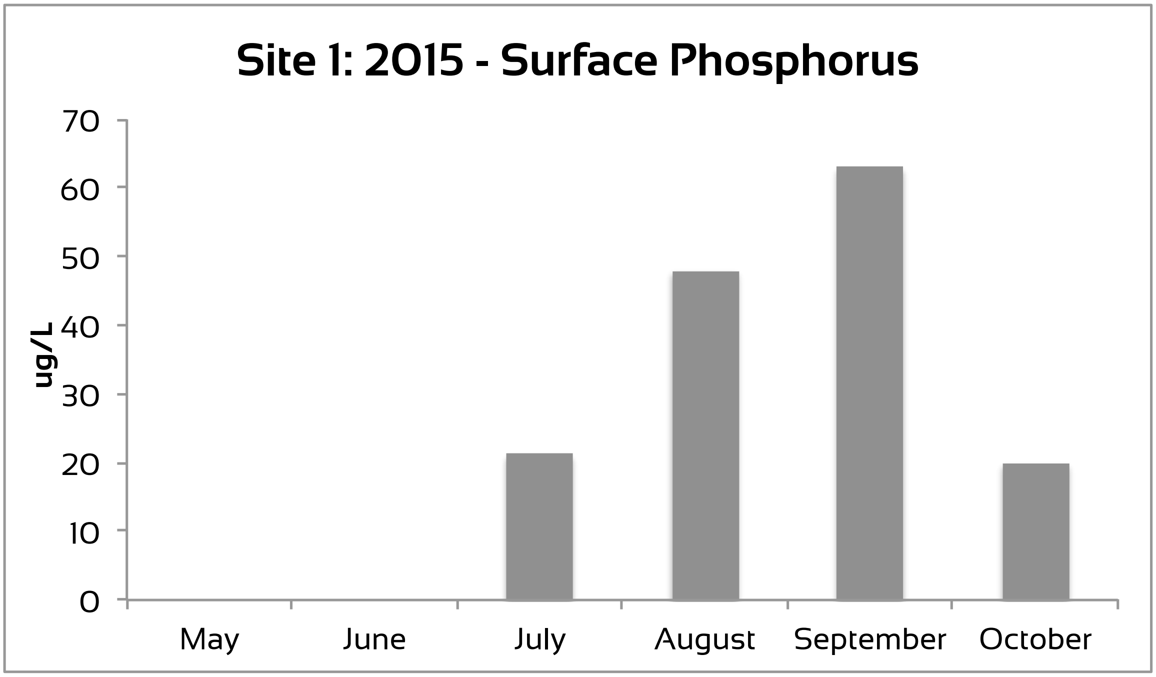

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Figure 9: Site 2 – Surface phosphorus concentrations for the summer season of 2015.

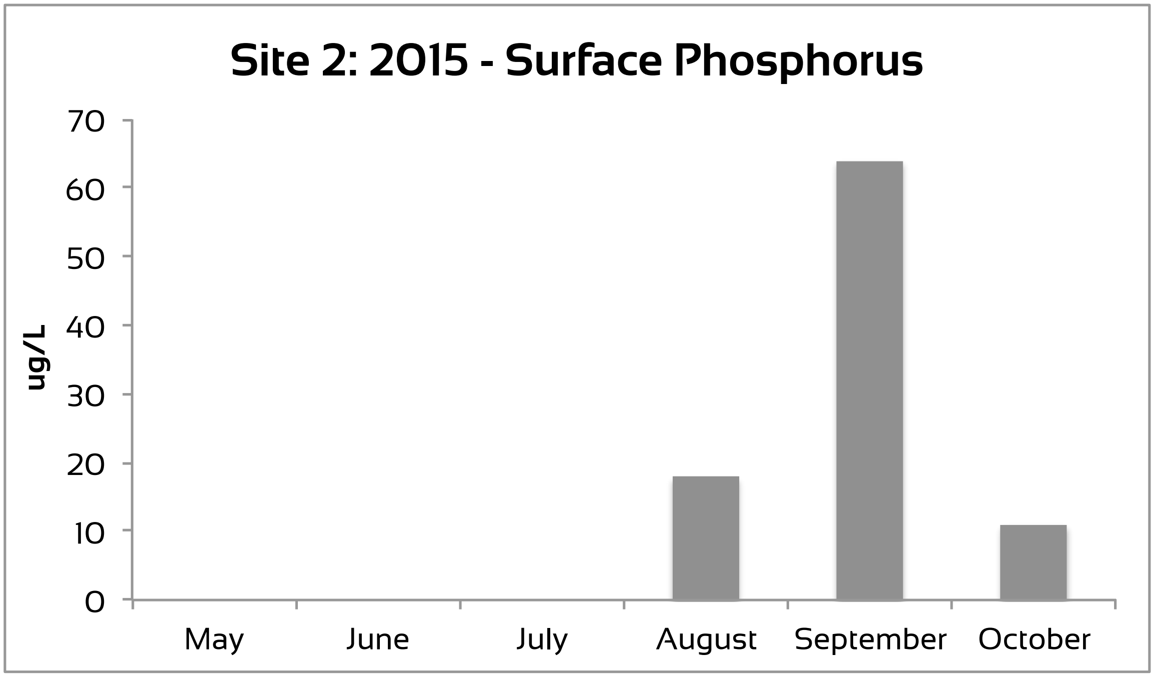

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Figure 10: Site 1 – Hypolimnetic ammonia concentrations for the summer season of 2015.

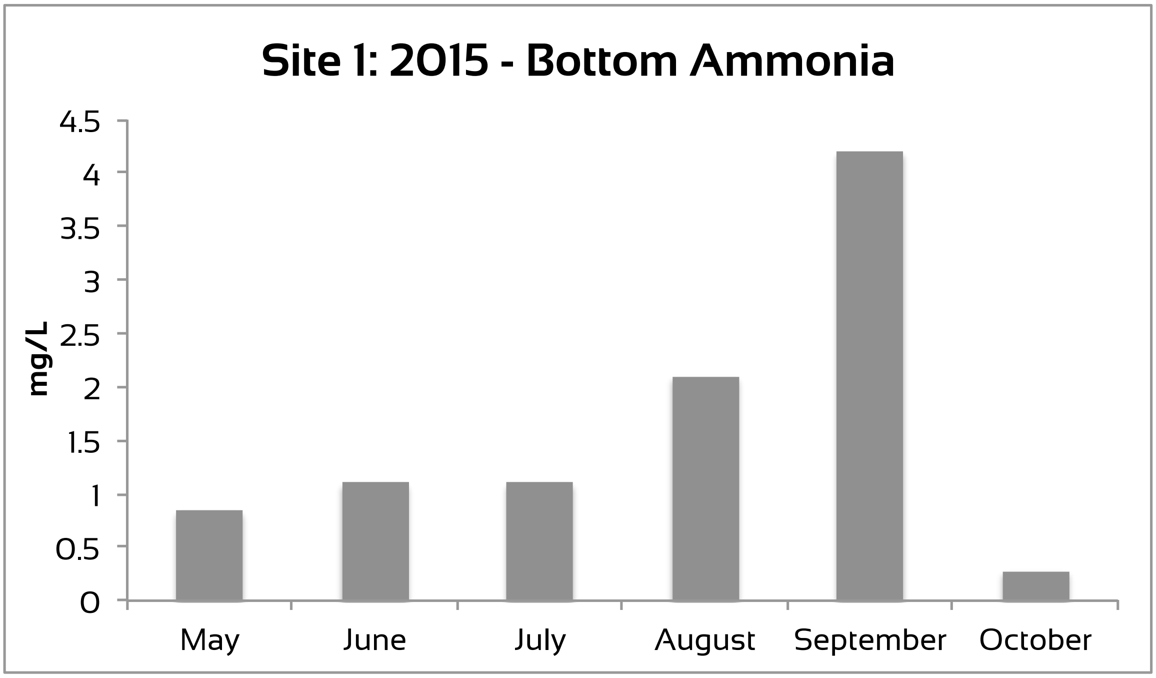

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Figure 11: Site 2 – Hypolimnetic ammonia concentrations for the summer season of 2015.

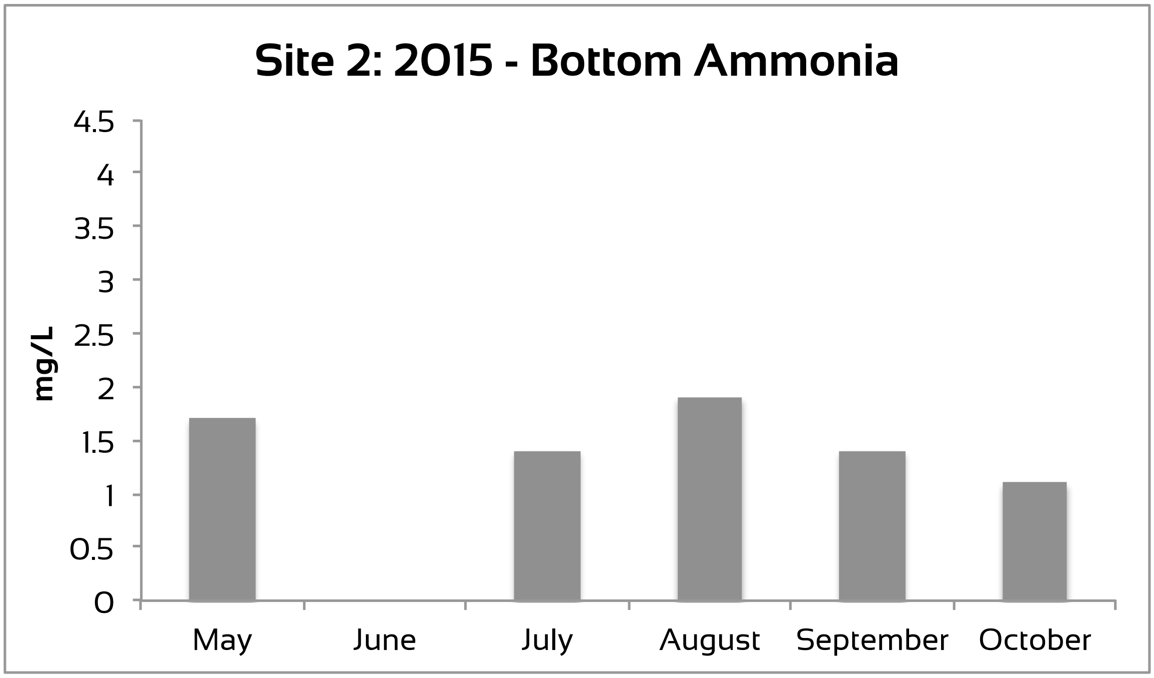

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Figure 12: Site 1 – Hypolimnetic phosphorus concentrations for the summer season 2015.

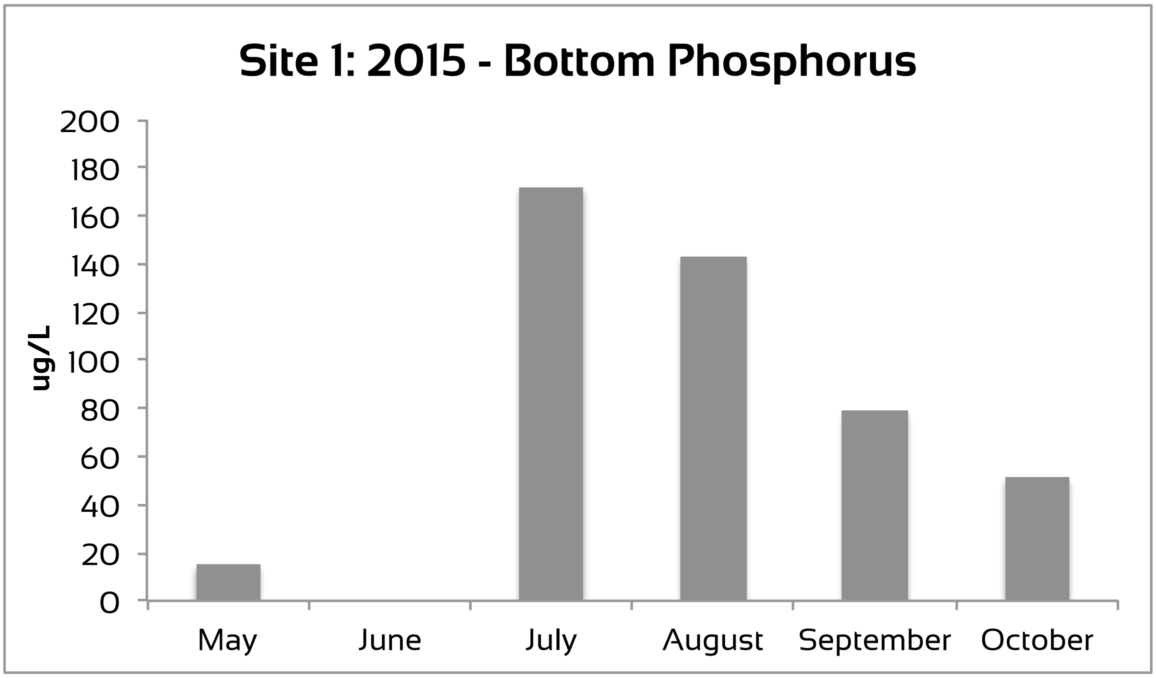

Figure 13: Site 2 – Hypolimnetic phosphorus concentrations for the summer season 2015.

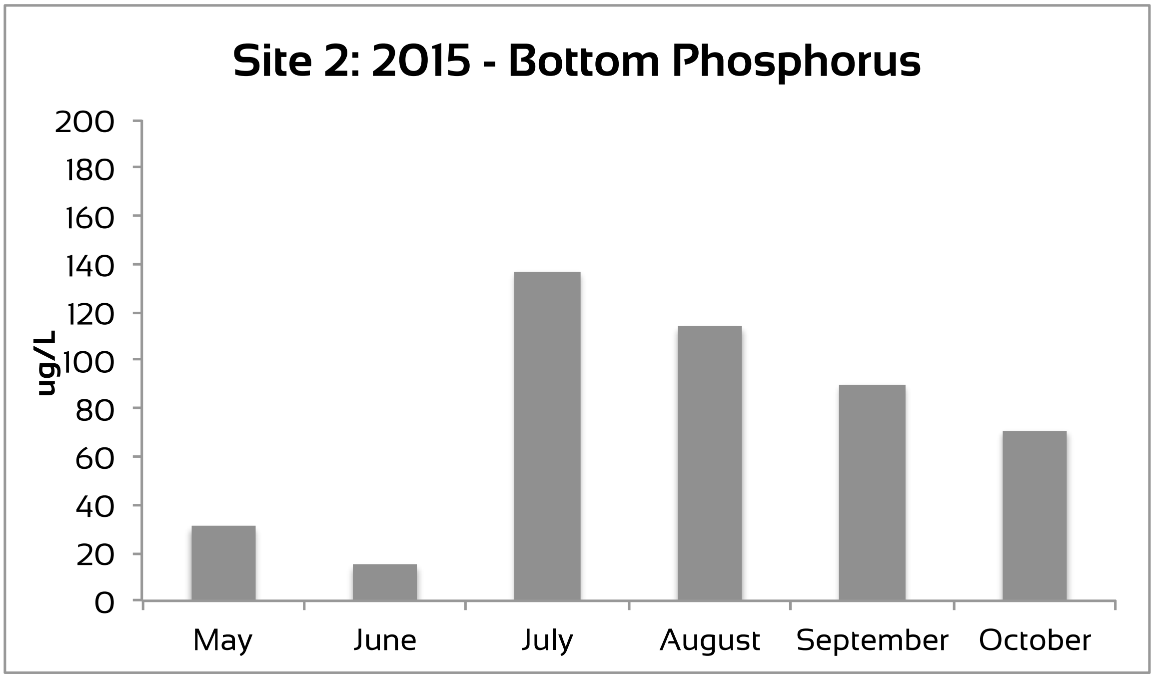

Figure 14: Sites 1 and 2 – Profiles of temperature, dissolved oxygen and RTRM for May 2015.

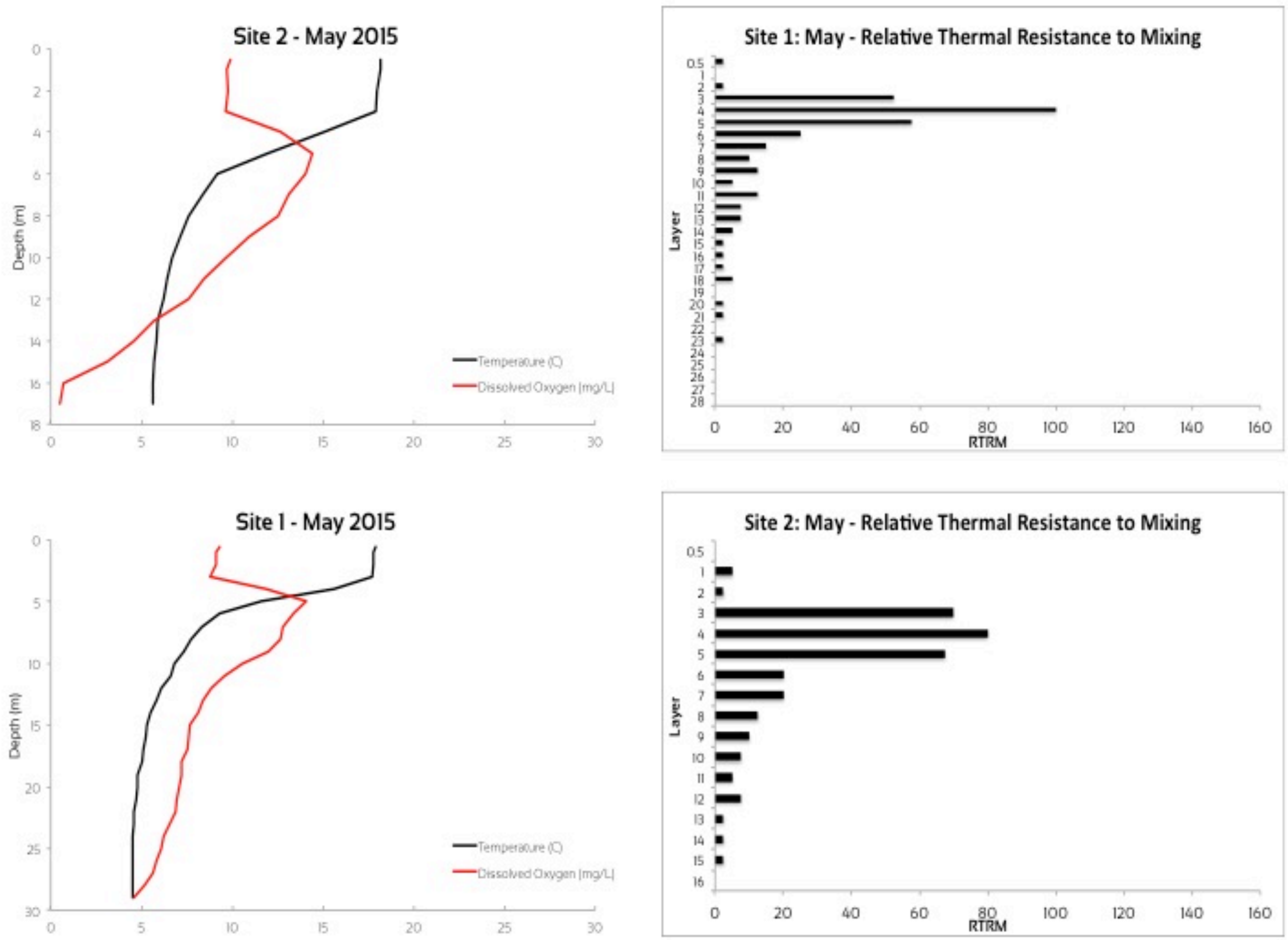

Figure 15: Sites 1 and 2 – Profiles of temperature, dissolved oxygen and RTRM for June 2015.

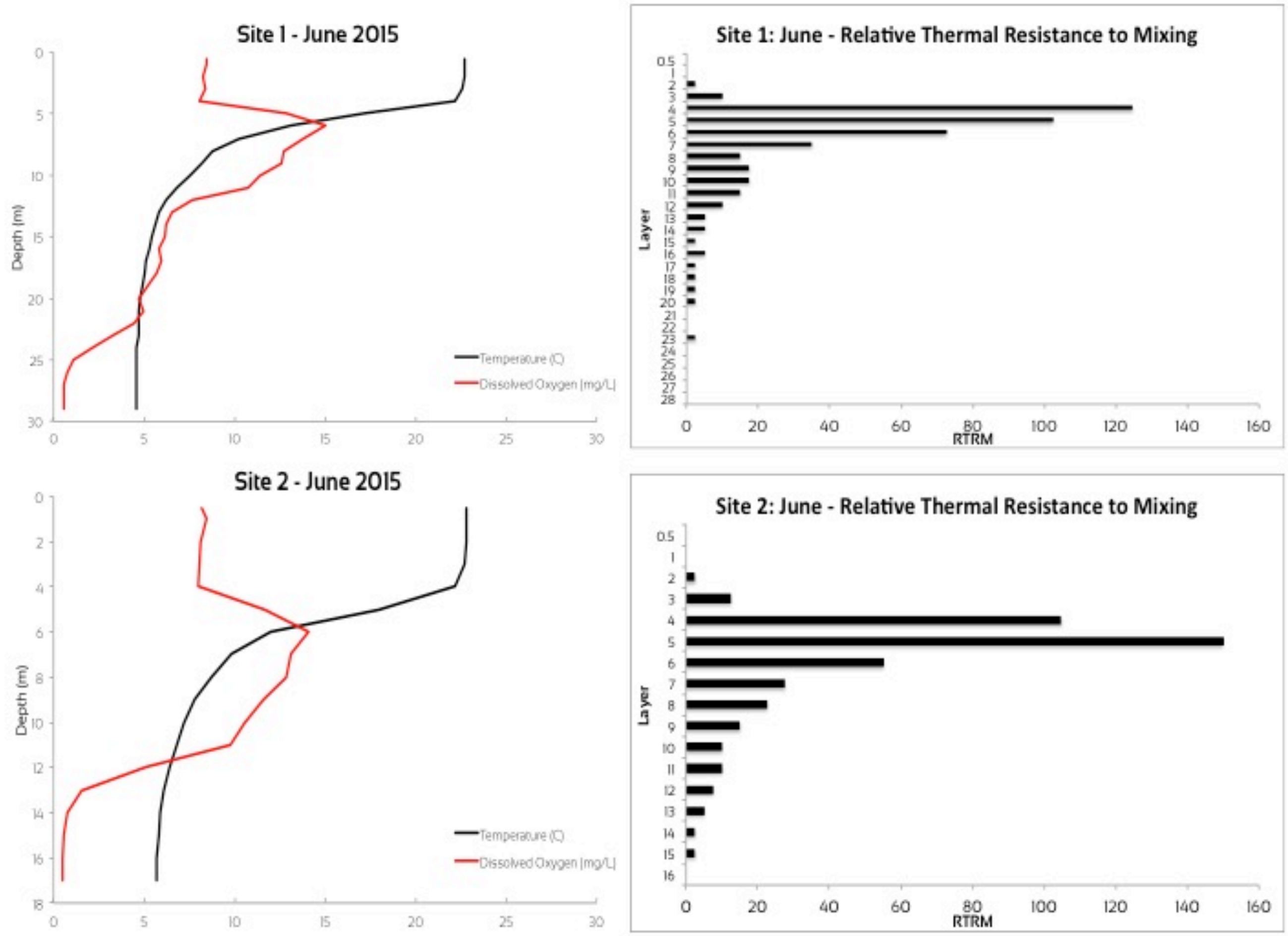

Figure 16: Sites 1 and 2 – Profiles of temperature, dissolved oxygen and RTRM for July 2015.

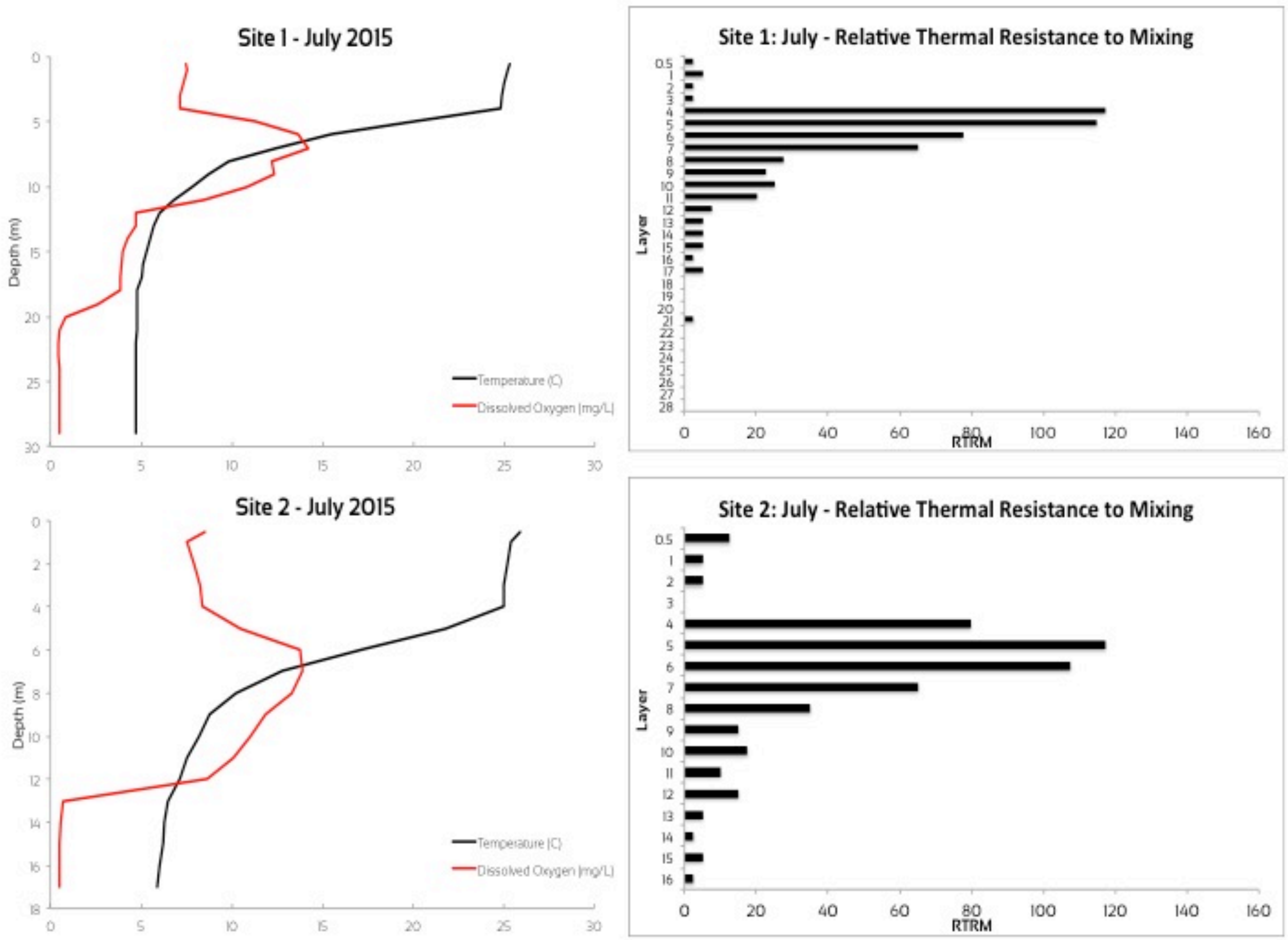

Figure 17: Sites 1 and 2 – Profiles of temperature, dissolved oxygen and RTRM for August 2015.

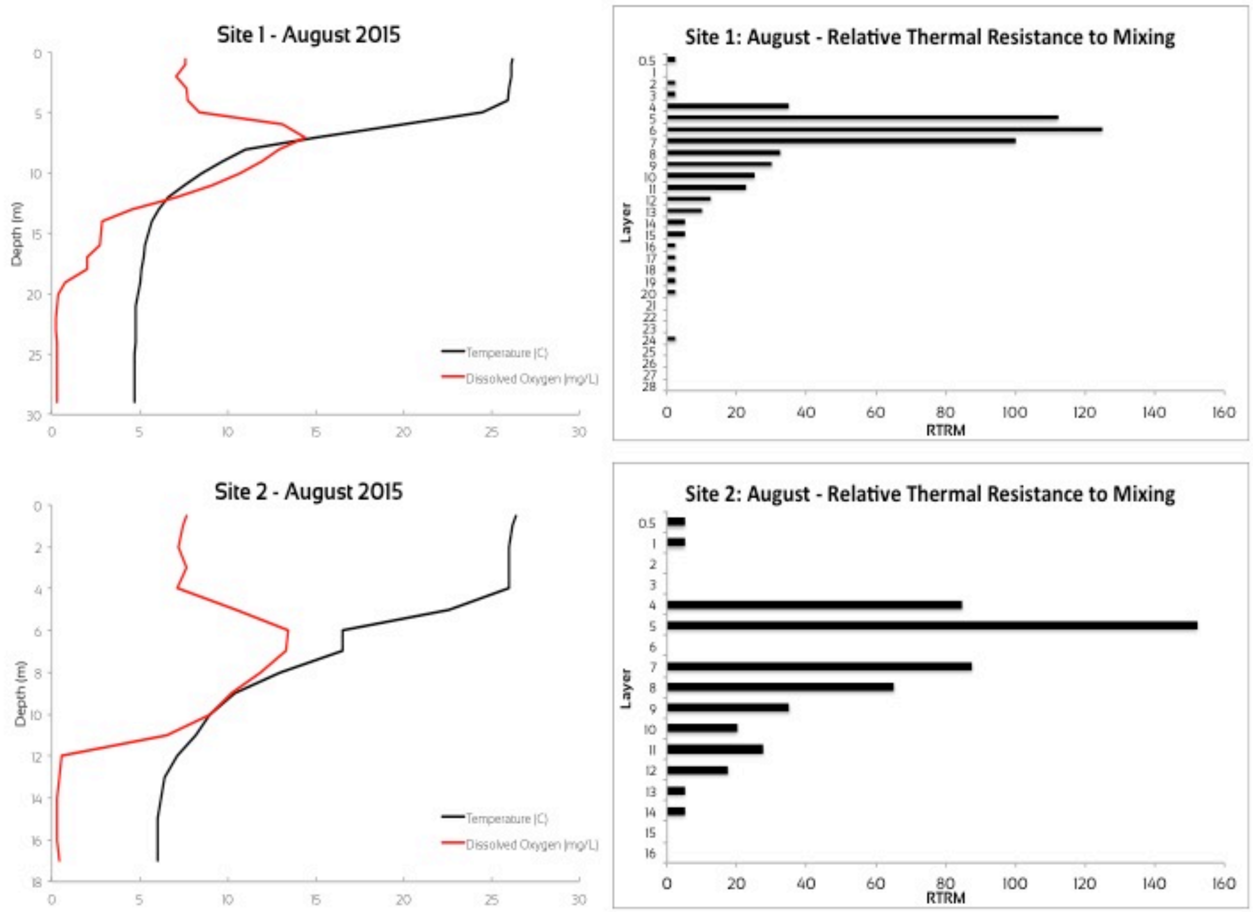

Figure 18: Sites 1 and 2 – Profiles of temperature, dissolved oxygen and RTRM for September 2015.

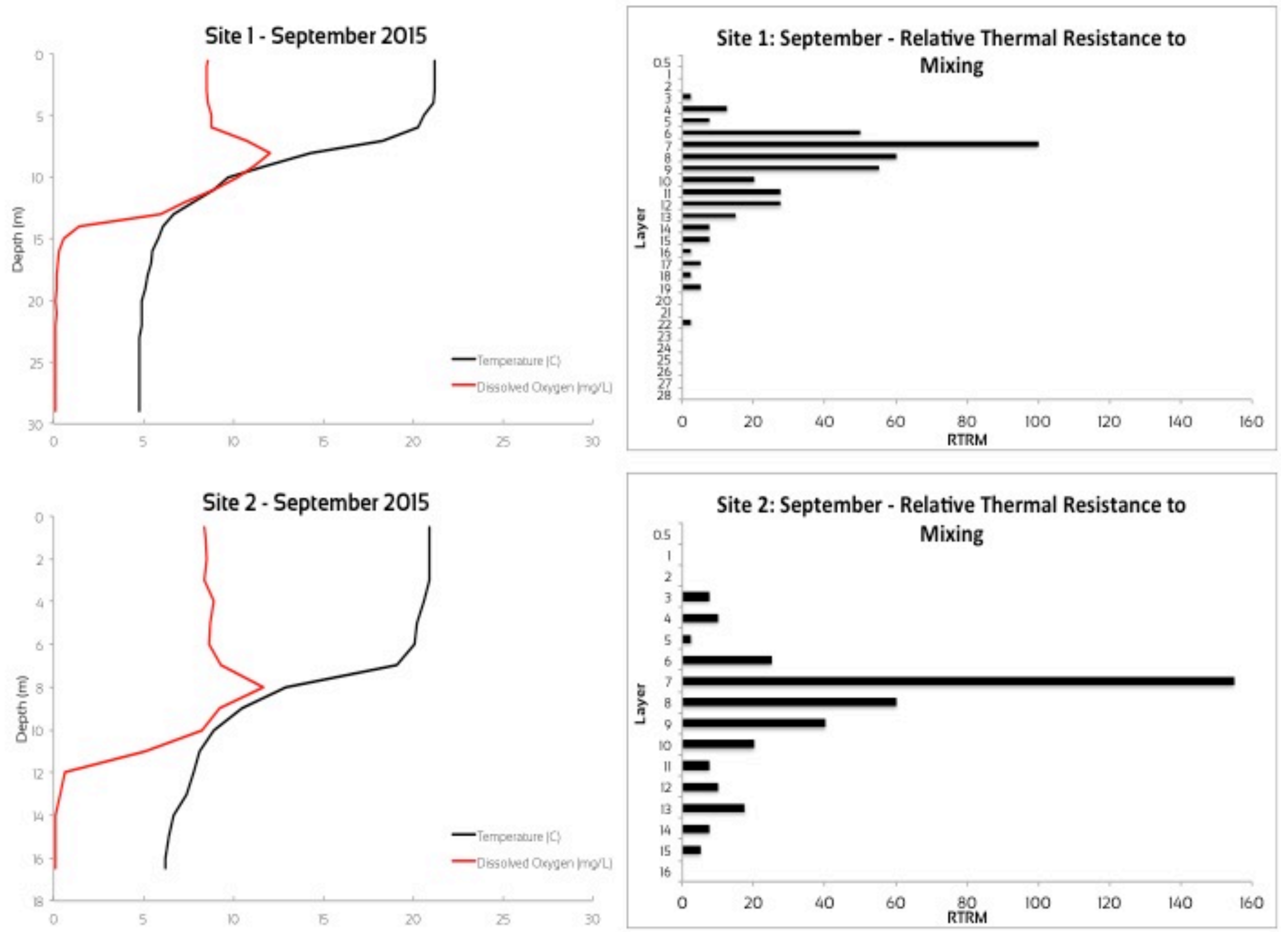

Figure 19: Sites 1 and 2 – Profiles of temperature, dissolved oxygen and RTRM for October 2015.