# 2009 Water Quality Conditions on the Williamson River Delta, Oregon: Two Years Post-Restoration


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## CONTENTS

## EXECUTIVE SUMMARY

This report summarizes results from The Nature Conservancy's (TNC) second full year of water quality monitoring on the Williamson River Delta (the Delta) in southern Oregon after initial restoration of the Delta in fall 2007. Subsequent to restoration, long term water quality monitoring was initiated with the objective of quantifying and describing the effects of restoration on surface water chemistry within and surrounding the Delta. Specific questions currently being addressed by TNC's monitoring effort include: (1) the extent to which the Delta wetlands provide a source or sink for nutrients; (2) the effects of the restoration on water quality in Upper Klamath Lake and *vice versa*; and (3) the effects of water quality in relation to endangered sucker inhabitance of the Delta wetlands.

From March to November 2009 we collected surface water grab samples for nitrogen and phosphorus at 27 sites, carbon and chlorophyll *a* samples at 21 sites, and continuous water chemistry parameters including temperature, dissolved oxygen, pH, and specific conductance at nine sites within the Delta, Upper Klamath and Agency Lakes, and the Williamson River. Sampling sites were modified from the previous year (2008) to incorporate sampling in the newly restored Goose Bay portion of the Delta (east of the Williamson River), which was flooded in fall 2008.

Phosphorus concentrations in emergent and transitional wetlands within the Delta were generally higher than concentrations in adjacent lake and river sites in 2009. In Goose Bay, phosphorus concentrations were generally lower than in emergent and transitional wetlands within Tulana. Chlorophyll *a* concentrations were lower inside Goose Bay compared to lake and Tulana wetland sites. Chlorophyll *a* concentrations in open and deep water wetlands within Tulana followed trends in the lake with two distinct peaks in late June/early July and late August, representing the bloom periods of cyanobacteria in Upper Klamath and Agency Lakes. Peaks in dissolved inorganic nitrogen concentrations in open and deep water wetlands appeared to coincide with declines in chlorophyll *a* concentrations. Continuous monitoring indicated that trends in dissolved oxygen and pH within Tulana wetlands followed trends in chlorophyll *a* concentrations. Seasonal trends in dissolved oxygen and pH within Goose Bay generally followed trends in the river. Based on analysis of high stress threshold water quality conditions for endangered suckers (Loftus 2001), the delta wetlands provided suitable habitat for suckers during the larval period from May-June.

Results from 2009 water quality monitoring on the Delta provide important information for assessing future trends in water chemistry and, combined with previous and future datasets, are a key component to answering the fundamental questions of the project. As wetland ecosystem processes are restored to the system, changes in surface water chemistry are expected. Documenting these long term changes is vital and will provide valuable information, especially considering the wide-ranging effort by multiple agencies and organizations in the Upper Klamath Basin to restore and manage wetlands. A comprehensive report comparing results for sampling years 2007 – 2009 on the Delta will be completed later this year.

## INTRODUCTION

The loss of wetlands in the Upper Klamath Basin in southern Oregon is widely cited as one of the underlying factors contributing to the degradation of water quality in Upper Klamath and Agency Lakes (Natural Research Council 2004). Over the past one-hundred years, expansion of development and agricultural activities has increased nutrient loading into the lake and has shifted the lake's classification from eutrophic to hyper-eutrophic. Currently, the lake is dominated seasonally by the cyanobacteria, *Aphanizomenon flos-aquae* (AFA). Blooms of AFA in Upper Klamath and Agency Lakes drive poor water quality conditions including highly variable dissolved oxygen concentrations (anoxic to supersaturated), elevated pH (9-10), and high un-ionized ammonia concentrations (above 0.5 mg/L) (Lindenberg et al. 2008). Poor water quality conditions and the loss of lake-fringe wetland habitats have contributed to the decline of two endangered fish species which are endemic to the Upper Klamath Basin – the Lost River sucker (*Deltistes luxatus*) and shortnose sucker (*Chasmistes brevirostris*).

Multiple wetland restoration and management projects are currently underway in the Upper Klamath Basin, including those at Wood River Wetland, Agency Lake Ranch, Running Y Ranch, and the Williamson River Delta (the Delta). Project objectives vary by agency/organization and include improved water quality, habitat for fish and wildlife, and water storage. The 5,500-acre Williamson River Delta Restoration Project was initiated by The Nature Conservancy (TNC) in 1996 with the fundamental goals of providing habitat for endangered suckers and contributing to improved water quality in Upper Klamath Lake. Pertaining to the second goal, the specific restoration objective is to facilitate nutrient removal from surface waters through plant uptake and soil accretion process by restoring habitat for perennial emergent vegetation.

In October 2007 levees surrounding the western half of the Delta were breached and a long term water quality monitoring project was established by TNC and project collaborators to assess the effectiveness of wetland restoration as a strategy for improving water quality. The objective of water quality monitoring is to quantify and describe the effects of the restoration on surface water chemistry within and surrounding the Delta. The fundamental questions being investigated are: (1) the extent to which the Delta wetlands provide a source or sink of nutrients; (2) the effects of the restoration on water quality in Upper Klamath Lake and *vice versa*; (3) the effects of water quality on sucker inhabitance of the Delta wetlands.

The focus of this report is to highlight results from TNC's second full year of long term water quality monitoring on the Delta. The report is divided into two major chapters: (1) surface water grab sample collection for nitrogen, phosphorus, carbon, and chlorophyll *a*, and (2) continuous water quality monitoring including temperature, dissolved oxygen, pH, and specific conductance.

## STUDY AREA DESCRIPTION

### Geographic location

The Williamson River Delta is located at the mouth of the Williamson River in the Upper Klamath Basin of southern Oregon and is situated between Upper Klamath and Agency Lakes (Figure i). The Delta straddles the last four miles of the Williamson River before emptying into Upper Klamath Lake. Historically the Delta was a functional freshwater wetland ecosystem and probably provided a considerable nutrient sink for the Sprague and Williamson River watersheds, which account for about 50% of the inflow to Upper Klamath Lake. Beginning in the 1940s the Delta was leveed, drained, and cultivated for crops such as potatoes, alfalfa, and barley. As a result, the Delta became hydrologically disconnected from Upper Klamath and Agency Lakes and the Williamson River.

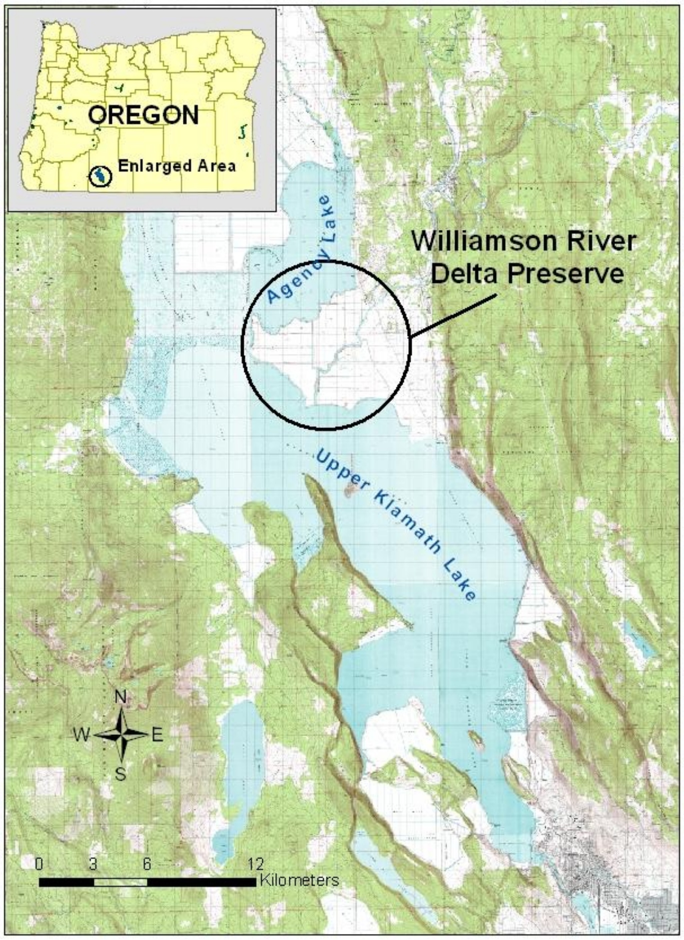


**Figure i. Location of The Nature Conservancy's Williamson River Delta Preserve in southern Oregon.**

## Restoration background

In 2000 and 2003, TNC restored several small portions of the Delta to improve hydrologic connection between the Delta wetlands and surrounding lake and river water. In fall 2007, larger scale restoration occurred with the breaching of levees surrounding the western half of the Delta (known as Tulana), flooding approximately 3,500 acres. In fall 2008, levees surrounding the eastern half of the Delta (known as Goose Bay) were breached, flooding approximately 2,000 acres.

Breach locations were strategically selected based on hydrologic modeling conducted by the U.S. Bureau of Reclamation, which determined the minimum number and location of breaches required for adequate reconnection of the Delta to surrounding lake and river waters (Daraio et al. 2004). On Tulana, four breaches ranging approximately 2,100-2,700 ft in length are located on the northern and southwest perimeter of the Delta in Agency and Upper Klamath Lakes, and three breaches ranging 500 – 1,700 ft in length are on the Williamson River. On the Goose Bay portion of the Delta, three breaches ranging approximately 1,000-3,000 ft in length occur on the southern end of Goose Bay, and three breaches occur along the Williamson River. Levees between breaches were lowered to an elevation between 4,139 and 4,142 ft, allowing water to flow over them for part of the year.

**Hydrology**

Water levels vary seasonally and spatially across the Delta. Surface water levels are regulated by the U.S. Bureau of Reclamation and vary by approximately five feet through the year, with highs typically in April and lows near the end of October. At low water level, waters from Agency and Upper Klamath Lakes flow predominately through small openings within the main perimeter breaches, and wetland areas receiving water from the Williamson River are largely cut off from the river. At high water level, lake waters flow across vast portions of the Delta, and wetland areas along the river are flooded. The overall effect is seasonal flooding and drying of emergent and riparian wetlands along the Williamson River, which include eastern portions of Tulana and the majority of Goose Bay, and year-round inundation of areas on the western portion of Tulana. Repeated draining and flooding of the Delta during cultivation resulted in the subsidence of soils on the western portion of Tulana due to organic matter decomposition and compaction. Current elevations on western portions of Tulana are as much as eight feet below average lake levels (David Evans and Associates, Inc. 2005) such that the western portions of Tulana now resemble open water. On Goose Bay and eastern portions of Tulana, emergent and transitional wetland conditions prevail.

**Vegetation**

Vegetation varies across the Delta and is largely influenced by water depth and flooding tolerances. In Goose Bay, flooded upland vegetation was most commonly observed during the sampling period. Beginning in early July, sparse emergent and submerged vegetation was observed in portions of Goose Bay. Eastern portions of Tulana resemble emergent and riparian wetland conditions. On the western most portions of the Delta, deep water conditions prevent the establishment of substantial vegetation. As of 2003, over 100 plant species were identified on the Williamson River Delta Preserve which included 80 native species and 38 introduced species (Elseroad 2004). Dominant riparian species include golden dock (*Rumex maritimus*) and Norwegian cinquefoil (*Potentilla norvegica*). Emergent and submerged macrophytes commonly present include hardstem bulrush (*Schoenoplectus acutus*), water smartweed (*Polygonum amphibium*), creeping spike-rush (*Eleocharis palustris*), and common mare's tail (*Hippuris vulgaris*), among others.

**Stratification of Monitoring Sites**

Water quality sampling sites were stratified based on predicted wetland type and water movement patterns across the Delta. Predicted wetland types were established based on estimated surface water elevations of the Delta once restored and the potential wetland plant communities found within those specific depth ranges (Elseroad 2004). A hydrodynamic circulation model developed by the U.S. Geological Survey (USGS) was used to predict water flow patterns through the Delta (T. Wood, USGS, personal communication). The predicted wetland types are, from shallowest to deepest: transitional wetland; emergent wetland; deep water wetland; and open water wetland (Elseroad 2004). Emergent and transitional wetlands are the two distinct vegetative zones and occur on the eastern portion of Tulana and the majority of Goose Bay. The two less-vegetative zones are open water and deep water which occur in the western portion of Tulana. Mean seasonal water depths for transitional, emergent, deep water, open water, lake, and river locations in 2009 were respectively 0.5 m, 0.85 m, 2.0 m, 2.4 m, 1.9 m, and 3.6 m.

# CHAPTER 1: GRAB SAMPLE COLLECTION

## METHODS

### Sample Locations

In 2009, a total of 27 sites within and surrounding the Delta were selected for grab sample collection (Figure 1.1). Six sites that were sampled in 2008 were moved to the newly restored Goose Bay in 2009: four sites within Tulana, as well as one site in Agency Straits and one site in the Williamson River. Sixteen sites occur within Tulana (four in each wetland type – transitional, emergent, deep water, and open water) and six sites occur within Goose Bay (three in each wetland type – transitional and emergent). Five sites occur in water bodies surrounding the Delta. These include two in the Williamson River: one upstream of the project area (~RM 2.5) and one near the river mouth (~RM 0.2). The other three sites occur in near-shore areas of Upper Klamath and Agency Lakes surrounding the Delta: south and east of the river mouth (referred to as Upper Klamath Lake East); near the southwest shore of Tulana (referred to as Upper Klamath Lake West); and Agency Lake.

### Sample Collection

Analytes from surface grab samples included several constituents of phosphorus [orthophosphate ($PO_4$) and total phosphorus (TP)] and nitrogen [nitrate+nitrite ($NO_3$+$NO_2$), ammonium nitrogen ($NH_4$), and total nitrogen (TN)] as well as carbon [dissolved organic carbon (DOC) and total organic carbon (TOC)], chlorophyll *a*, and algal speciation.

Nitrogen and phosphorus samples were collected at all 27 sampling sites during a maximum of 16 sampling events from March to November 2009. Carbon, chlorophyll *a*, and algal speciation samples were collected at 21 of the 27 sites during up to 12 sampling events, although algal speciation sampling results are not discussed in this report (data are in the process of being analyzed). Transitional and emergent wetland sites were only inundated seasonally and therefore samples were only collected when water was present at the site. Sampling in transitional wetlands began during the second sampling event, April 8$^{th}$ and 9$^{th}$. Table 1.1 lists the parameters collected at each individual site.

Grab sampling in 2009 was similar to the previous sampling years. Site parameters such as water depth, water transparency (measured with a secchi disk), density of surface algal bloom measured on a 0 – 5 scale, and presence or absence of vegetation were recorded at all 27 sampling sites during grab sample collection. Water temperature, pH, specific conductance, and dissolved oxygen concentration (DO) were also measured instantaneously at each site using a water quality multi-probe instrument (YSI 600 XLM).


**Figure 1.1. Map of the Williamson River Delta, Oregon showing predicted wetland types and grab sample collection sites sampled from March - November, 2009.**

For sites that were less than one meter deep, water was collected at mid-depth in the water column. For sites that were between one and two meters deep, water was collected at mid-depth in the water column and at 0.5 meters. For sites that were greater than one meter deep, water was collected at one meter and 0.5 meters below the water surface. Water was collected using a 3.2 liter Van Dorn and homogenized using an eight liter churn splitter. All constituents (nitrogen, phosphorus, chlorophyll *a*, and carbon) were measured from the same churn splitter. Data reported during one sampling week were collected over a consecutive two day period. At the end of each sampling day, the Van Dorn was rinsed with 500 mL of dilute hydrochloric acid, rinsed five times with distilled water, and stored with distilled water. The churn splitter was also rinsed at the end of each sampling day with 500 mL of dilute hydrochloric acid and distilled water, air dried, and stored in a plastic bag. Grab sample precision and accuracy were assessed by collecting equipment and laboratory blanks, splits at 10% of the total number of samples, and duplicate samples at least once per sampling event. Number of quality control samples, reporting levels, and sample corrections are included in Appendix B and follow methods described in the Williamson River Delta Water Quality Monitoring Project Plan (The Nature Conservancy 2008).

Immediately after field collection, samples were brought to the Sprague River Water Quality Laboratory in Chiloquin, Oregon for further processing and analysis. Approximately 120 mL of unfiltered water to be analyzed for TN and TP were transferred to triple rinsed amber polyethylene bottles and acidified with 1 mL of 4.5N $H_2SO_4$. Samples for $NO_3$+$NO_2$, $NH_4$, and $PO_4$ were filtered through 47 mm, 0.45 µm sterile membrane filters (Millipore®) using a vacuum pump and 300 mL magnetic filter funnel (Pall Gelman ®). All nitrogen and phosphorus samples were stored at 4°C (±2°C) for no longer than 28 days. Total organic carbon and chlorophyll *a* samples were acidified with 4.5N $H_2SO_4$ and shipped on ice overnight to the respective laboratories. Dissolved organic carbon samples were also shipped on ice overnight and were filtered prior to laboratory analysis.

**Laboratory Analysis**

Nitrogen and Phosphorus samples were analyzed by the Sprague River Water Quality Laboratory. Total phosphorus and total nitrogen samples were digested using potassium persulfate, autoclaved, then analyzed on an automated spectrophotometer. All other nitrogen and phosphorus analyses were completed using the colorimetric method on the same automated spectrophotometer. Carbon samples were sent to Basic Laboratory in Redding, California and analyzed using the persulfate-ultraviolet oxidation method. Chlorophyll *a* analysis was conducted by Aquatic Research, Inc. in Seattle, Washington. Refer to Appendix A for standard method numbers used.

**Table 1.1. Sampling sites, locations, and constituents sampled from March-November, 2009 in and surrounding the Williamson River Delta, Oregon. (Sampled when water was present: 1- April-July, 2-March-August).**

| Site ID | Location | Nitrogen | Phosphorus | Carbon | Chlorophyll *a* | Algal Speciation* |
|---|---|---|---|---|---|---|
| | | March-November | | April-October | April-October | |
| | | 16 events | | 12 events | 12 events | |
| TLTR1 | Transitional Wetland[1] | X | X | X | X | X |
| TLTR3 | Transitional Wetland[1] | X | X | X | X | X |
| TLTR4 | Transitional Wetland[1] | X | X | NA | NA | NA |
| TLTR5 | Transitional Wetland[1] | X | X | X | X | X |
| TLEM6 | Emergent Wetland[2] | X | X | X | X | X |
| TLEM8 | Emergent Wetland[2] | X | X | X | X | X |
| TLEM9 | Emergent Wetland[2] | X | X | X | X | X |
| TLEM10 | Emergent Wetland[2] | X | X | X | X | X |
| TLDW11 | Deep Water Wetland | X | X | X | X | X |
| TLDW12 | Deep Water Wetland | X | X | X | X | X |
| TLDW13 | Deep Water Wetland | X | X | X | X | X |
| TLDW14 | Deep Water Wetland | X | X | NA | NA | NA |
| TLOW16 | Open Water Wetland | X | X | X | X | X |
| TLOW17 | Open Water Wetland | X | X | X | X | X |
| TLOW18 | Open Water Wetland | X | X | NA | NA | NA |
| TLOW20 | Open Water Wetland | X | X | X | X | X |
| GBTR1 | Transitional Wetland | X | X | X | X | X |
| GBTR2 | Transitional Wetland | X | X | X | X | X |
| GBTR3 | Transitional Wetland | X | X | X | X | X |
| GBEM4 | Emergent Wetland | X | X | X | X | X |
| GBEM5 | Emergent Wetland | X | X | X | X | X |
| GBEM6 | Emergent Wetland | X | X | X | X | X |
| WR21 | Williamson River (N. of Delta) | X | X | X | X | X |
| WR23 | Williamson River (RM ~ 0.2 ) | X | X | NA | NA | NA |
| UKLE24 | Upper Klamath Lake (E. of Williamson River) | X | X | NA | NA | NA |
| UKLW25 | Upper Klamath Lake (W. of Williamson River) | X | X | X | X | X |
| AL27 | Agency Lake | X | X | X | X | X |

## Data Analysis

Results from nitrogen, phosphorus, and carbon analyses are reported if they occurred above the reporting limit or between the reporting limit and detection limit. Concentrations less than the detection limit were reported at half the detection limit value. Reporting and detection limits for all constituents can be found in Appendix A. Un-ionized ammonia concentrations were calculated based on water temperature and pH collected concurrently with the sample and were determined using an equation provided by the USGS (T. Wood, USGS, personal communication). We used SAS® System for Windows, Release 9.1.3 (SAS Institute Inc. 2004) for all data analysis including the calculation of means and standard errors.

Seasonal trends in mean nutrient concentrations were compared across eight locations: two wetland types in Goose Bay (transitional and emergent), four wetland types in Tulana (transitional, emergent, deep water, and open water), lake, and river locations. Carbon and chlorophyll *a* samples were only collected at one site in the Williamson River and therefore single values are reported.

## RESULTS

In 2009, a total of 331 phosphorus and nitrogen samples were collected from March to November and 190 carbon and chlorophyll *a* samples were collected from April to October within the Delta and adjacent water bodies. Seasonal trends by eight different locations are described for each sampled constituent (Figure 1.2-1.9). Seasonal trends at individual sampling sites can be found in Appendix C. Minimum and maximum concentrations for each sampled constituent and location are shown in Table 1.2.

**Table 1.2. Minimum and maximum concentrations by sampling location for grab sampling constituents collected March – November 2009 within and surrounding the Williamson River Delta, Oregon. Chlorophyll *a* is reported in µg/L; all other constituents are reported in mg/L.**

| | TN | | TP | | $NO_3$+$NO_2$ | | $NH_4$ | | $PO_4$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Location** | **Min** | **Max** | **Min** | **Max** | **Min** | **Max** | **Min** | **Max** | **Min** | **Max** |
| **Tulana-Transitional** | 0.475 | 2.550 | 0.132 | 0.892 | 0.004 | 0.054 | 0.007 | 0.482 | 0.065 | 0.684 |
| **Tulana-Emergent** | 0.448 | 3.200 | 0.083 | 1.400 | 0.004 | 0.157 | 0.006 | 0.796 | 0.014 | 0.894 |
| **Tulana-Deep Water** | 0.441 | 5.810 | 0.075 | 0.560 | 0.004 | 0.313 | 0.003 | 0.478 | 0.005 | 0.210 |
| **Tulana-Open Water** | 0.423 | 5.920 | 0.071 | 0.566 | 0.004 | 0.348 | 0.007 | 0.517 | 0.010 | 0.240 |
| **Goose Bay-Transitional** | 0.376 | 1.300 | 0.104 | 0.522 | 0.004 | 0.018 | 0.007 | 0.156 | 0.060 | 0.352 |
| **Goose Bay-Emergent** | 0.424 | 1.770 | 0.090 | 0.722 | 0.004 | 0.015 | 0.003 | 0.118 | 0.002 | 0.433 |
| **Williamson River** | 0.075 | 2.210 | 0.067 | 0.251 | 0.004 | 0.038 | 0.003 | 0.108 | 0.020 | 0.151 |
| **Lake Sites** | 0.079 | 3.590 | 0.041 | 0.406 | 0.004 | 0.292 | 0.007 | 0.445 | 0.004 | 0.176 |

| | TOC | | DOC | | Chlorophyll *a* | |
|---|---|---|---|---|---|---|
| **Location** | **Min** | **Max** | **Min** | **Max** | **Min** | **Max** |
| **Tulana-Transitional** | 5.9 | 13.1 | 4.4 | 11.9 | 6 | 148 |
| **Tulana-Emergent** | 5.8 | 11.6 | 4.8 | 10.3 | 3 | 221 |
| **Tulana-Deep Water** | 5.8 | 14.1 | 4.8 | 11.4 | 12 | 589 |
| **Tulana-Open Water** | 6.2 | 11.2 | 4.7 | 10.5 | 6 | 443 |
| **Goose Bay-Transitional** | 4.7 | 8.1 | 4.6 | 7.95 | 1 | 65 |
| **Goose Bay-Emergent** | 3.7 | 12.9 | 4 | 10.4 | 1 | 45 |
| **Williamson River** | 1.1 | 6.2 | 1 | 6 | 0 | 2 |
| **Lake Sites** | 4.3 | 9.1 | 4.2 | 8.5 | 6 | 246 |

**Seasonal Trends**

Phosphorus. Seasonal mean orthophosphate concentrations across all locations ranged from 0.011 – 0.544 mg/L (Figure 1.2). With the exception of the Williamson River, mean orthophosphate concentrations at all locations increased and peaked during the month of July with an individual emergent wetland site, TLEM8, peaking at 0.894 mg/L. After July, mean orthophosphate concentrations gradually decreased until the end of the sampling period. Emergent and transitional wetlands in Tulana generally had the highest mean orthophosphate concentrations compared to other sampling locations. Transitional and emergent wetlands within Goose Bay were fully inundated for the first time in early 2009, when lake and river elevations rose in the spring. During the sampling period from March to July, mean orthophosphate concentrations in Goose Bay were consistently higher than adjacent lake and river locations, though not by much (Figure 1.3). Averaged over the entire sampling period at all locations, orthophosphate concentrations accounted for approximately 53% of total phosphorus concentrations. Mean total phosphorus concentrations for all locations ranged from 0.051 – 0.0826 mg/L and followed a similar seasonal trend as orthophosphate (Figure 1.2). From March to the end of July, total phosphorus was highest in emergent and transitional wetland locations during the majority of sampling events. After July, total phosphorus concentrations were slightly higher in open and deep water wetlands compared to lake locations.

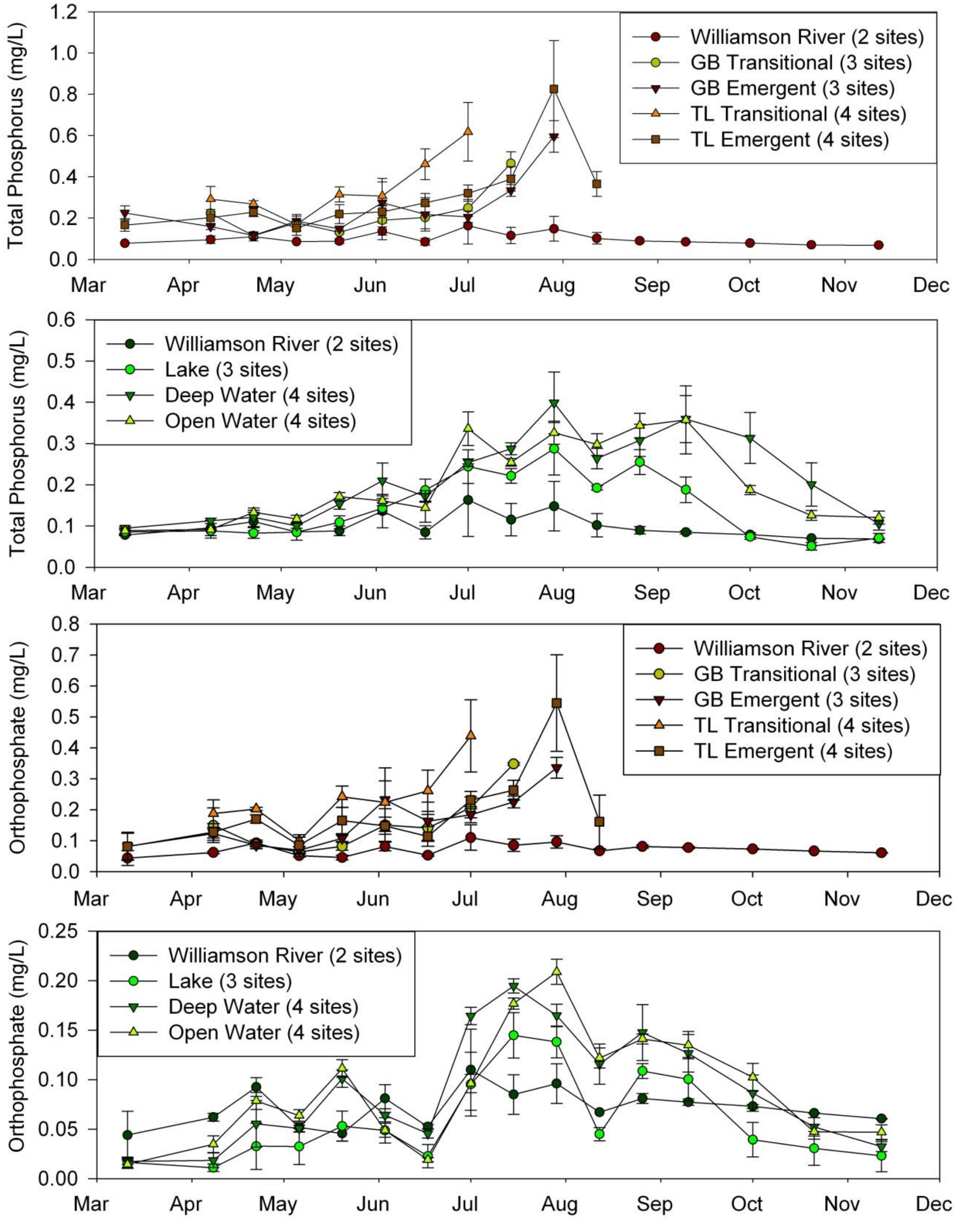


**Figure 1.2. Seasonal trends in total phosphorus and orthophosphate from March– November 2009 within and surrounding the Williamson River Delta. Shown are means (± standard error) within each location by sampling event, with the Williamson River shown in each graph for comparison. Note the scales are not the same.**

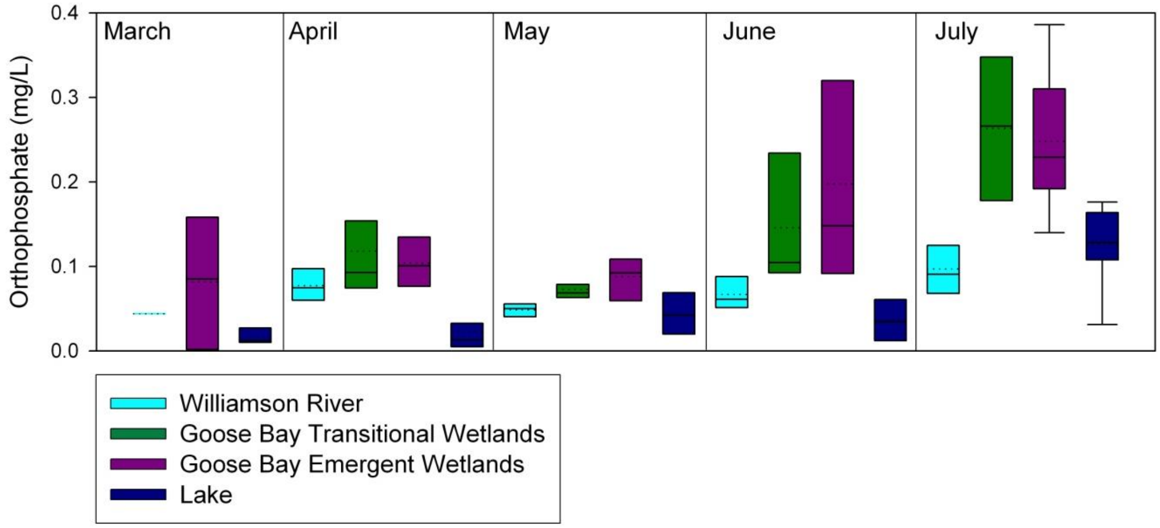


**Figure 1.3. Boxplots showing mean and median orthophosphate concentrations in Goose Bay wetlands, the Williamson River, and lake locations from March - July, 2009. Transitional wetlands did not have sufficient water to sample during the month of March. Both transitional and emergent wetlands were dried out by August. Boxes represent the interquartile range with the median marked by a solid line and the mean marked by a dotted line. Whiskers show 10$^{th}$ and 90$^{th}$ percentiles.**

Nitrogen. Mean nitrate + nitrite concentrations were below 0.016 mg/L at all locations at the beginning of the sampling period and increased in mid-July (Figure 1.4). In late October and November, mean nitrate + nitrite concentrations peaked at 0.235, 0.278, 0.196 mg/L in deep water, open water, and lake locations, respectively. Mean ammonia concentrations were variable throughout the sampling period with peaks during the month of July and September (Figure 1.5). Mean ammonia concentrations ranged from 0.006 to 0.33 mg/L for all locations with highest values in open water and Tulana emergent wetland sites (Figure 1.5). Un-ionized ammonia concentrations were lower than 0.010 mg/L except at one site where concentrations reached 0.168 mg/L (site TLTR05). Dissolved inorganic nitrogen made up approximately 7.4% of total nitrogen averaged over the entire sampling period at all locations. From October to November this percentage increased to approximately 25% of total nitrogen. Mean total nitrogen concentrations were variable between sampling sites and locations, particularly within deep and open water wetlands, and ranged from to 0.653 – 3.99 mg/L for all locations.

Chlorophyll *a*. Mean chlorophyll *a* values ranged from 1 – 139 µg/L in transitional and emergent wetlands, 12.7 – 318 µg/L in open and deep water wetlands, 8 – 201 µg/L in lake sites, and 0 – 2 µg/L in the Williamson River (Figure 1.5). Trends in mean chlorophyll *a* concentrations in Goose Bay transitional and emergent wetlands followed trends in the Williamson River with mean concentrations in Goose Bay peaking at 33.7 µg/L (Table 1.2). Tulana wetland and lake sites generally had higher chlorophyll *a* concentrations with the highest concentrations occurring in deep and open water wetlands (maximum concentrations of 589 and 443 µg/L, respectively) (Table 1.2). With the exception of the Williamson River and Goose Bay locations, there were two seasonal peaks in chlorophyll *a* that occurred in late June/early July and August, followed by abrupt declines that occurred in mid-July and then again in early October (Figure 1.5).

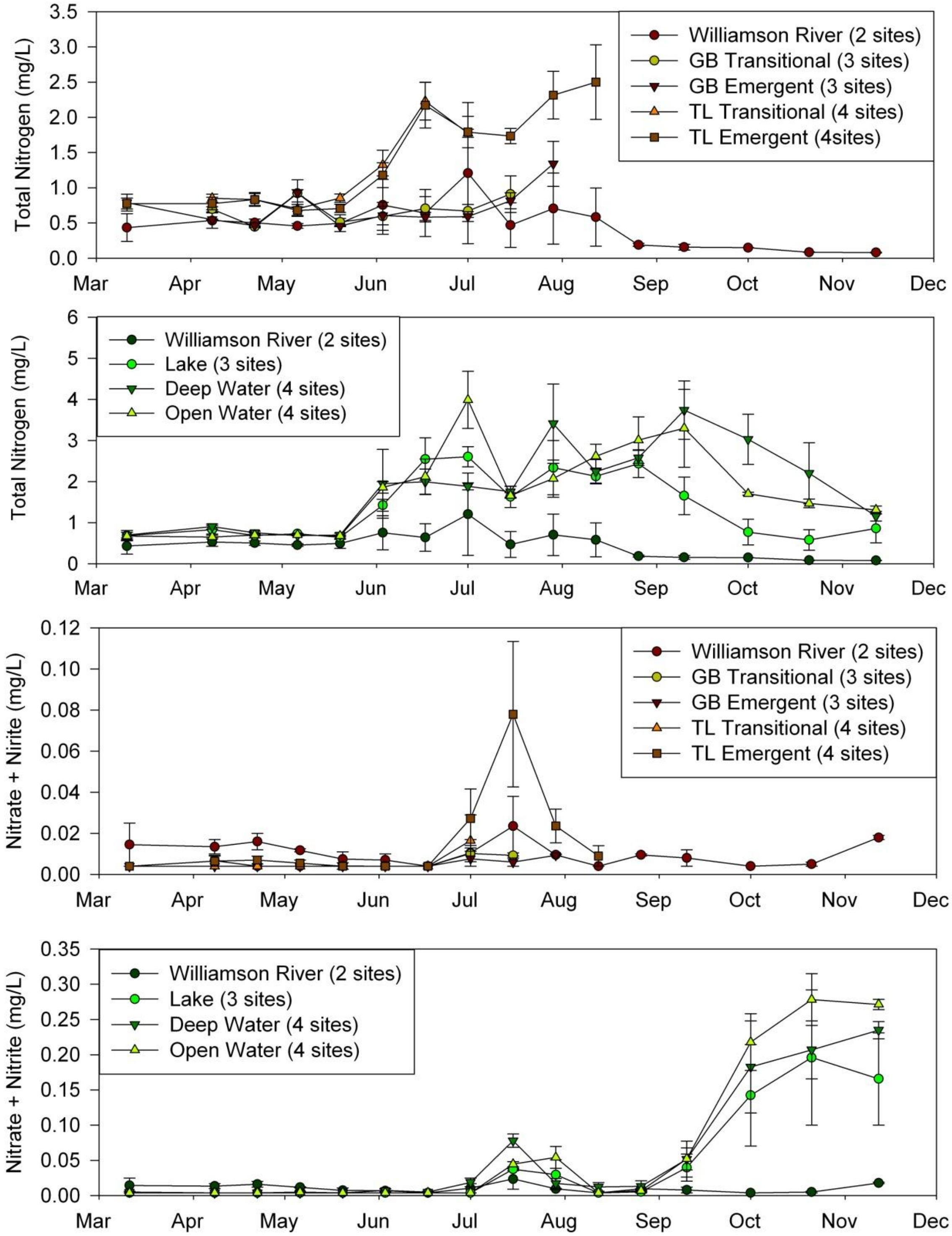


**Figure 1.4. Seasonal trends in total nitrogen and nitrate + nitrite from March– November 2009 within and surrounding the Williamson River Delta. Shown are means (± standard error) within each location by sampling event.**

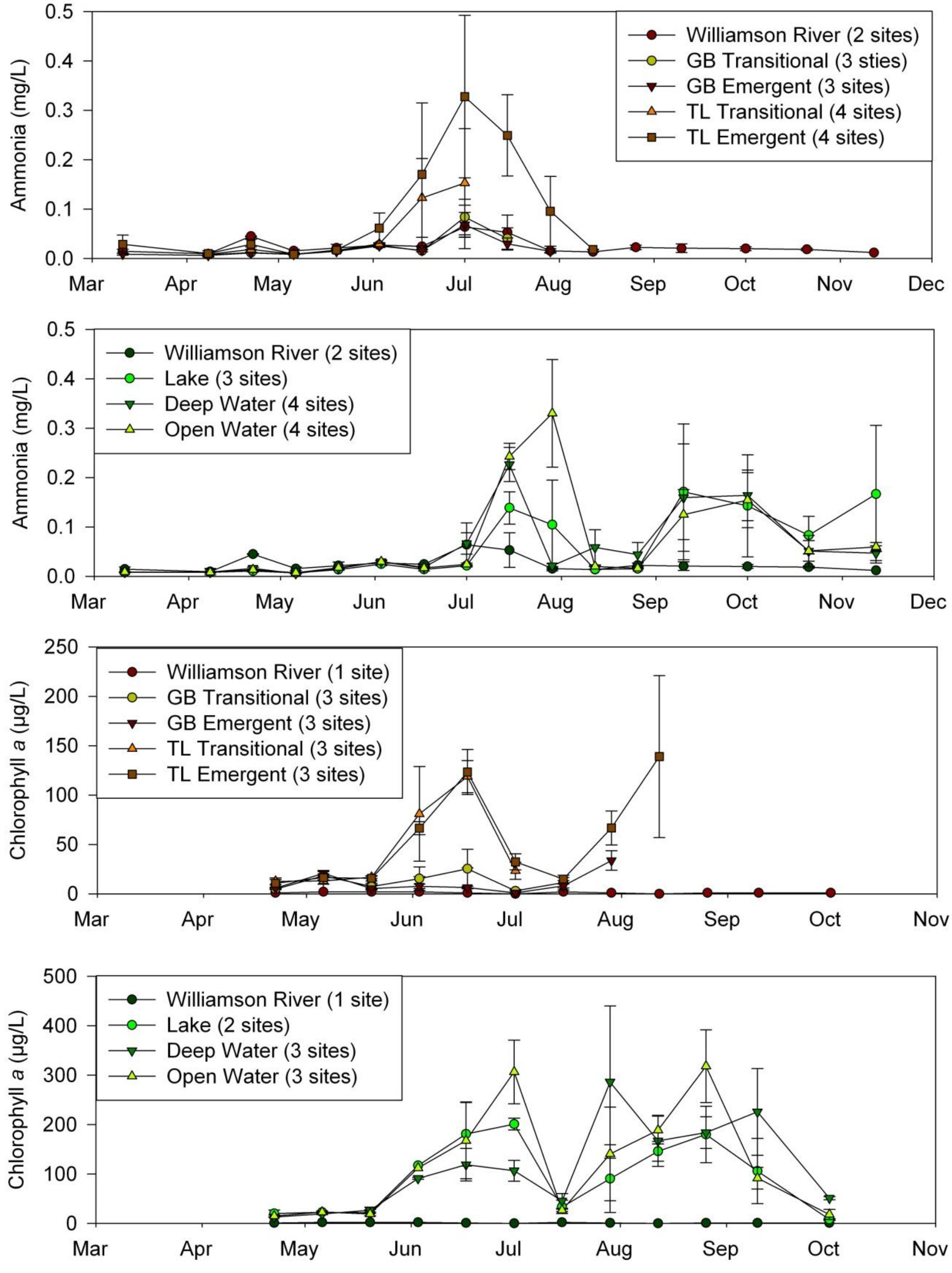


**Figure 1.5. Seasonal trends in ammonia and chlorophyll *a* from March– November 2009 within and surrounding the Williamson River Delta. Shown are means (± standard error) within each location by sampling event, except in the Williamson River when only one sample was collected during each event.**

Carbon. Mean dissolved organic carbon concentrations ranged from 1 – 10.87 mg/L among all locations (Figure 1.6). During April and May, mean dissolved organic carbon at all locations tracked closely with the Williamson River. After May, dissolved organic carbon concentrations in open and deep water locations slightly increased and concentrations in the Williamson River slightly decreased until November. Transitional and emergent sites within Tulana generally had higher dissolved organic carbon concentrations compared to Goose Bay locations. Average dissolved organic carbon made up approximately 91% of total organic carbon for all locations. Mean total organic carbon concentrations followed similar trends as dissolved organic carbon and ranged from 1.1 – 11.3 mg/L (Figure 1.7).

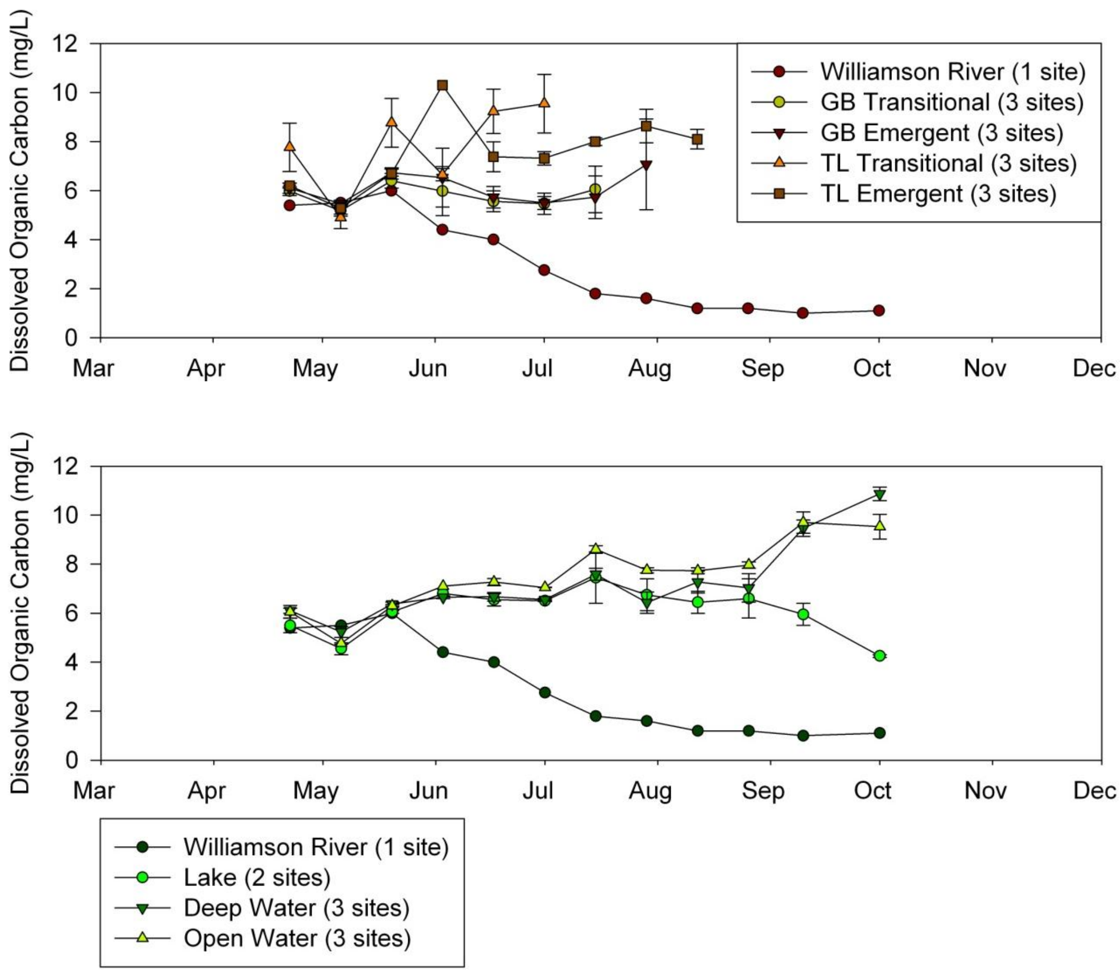


**Figure 1.6. Seasonal trends in dissolved organic carbon from April–October 2009 within and surrounding the Williamson River Delta. Shown are means (± standard error) within each location by sampling event, except in the Williamson River where only one sample was collected during each event.**

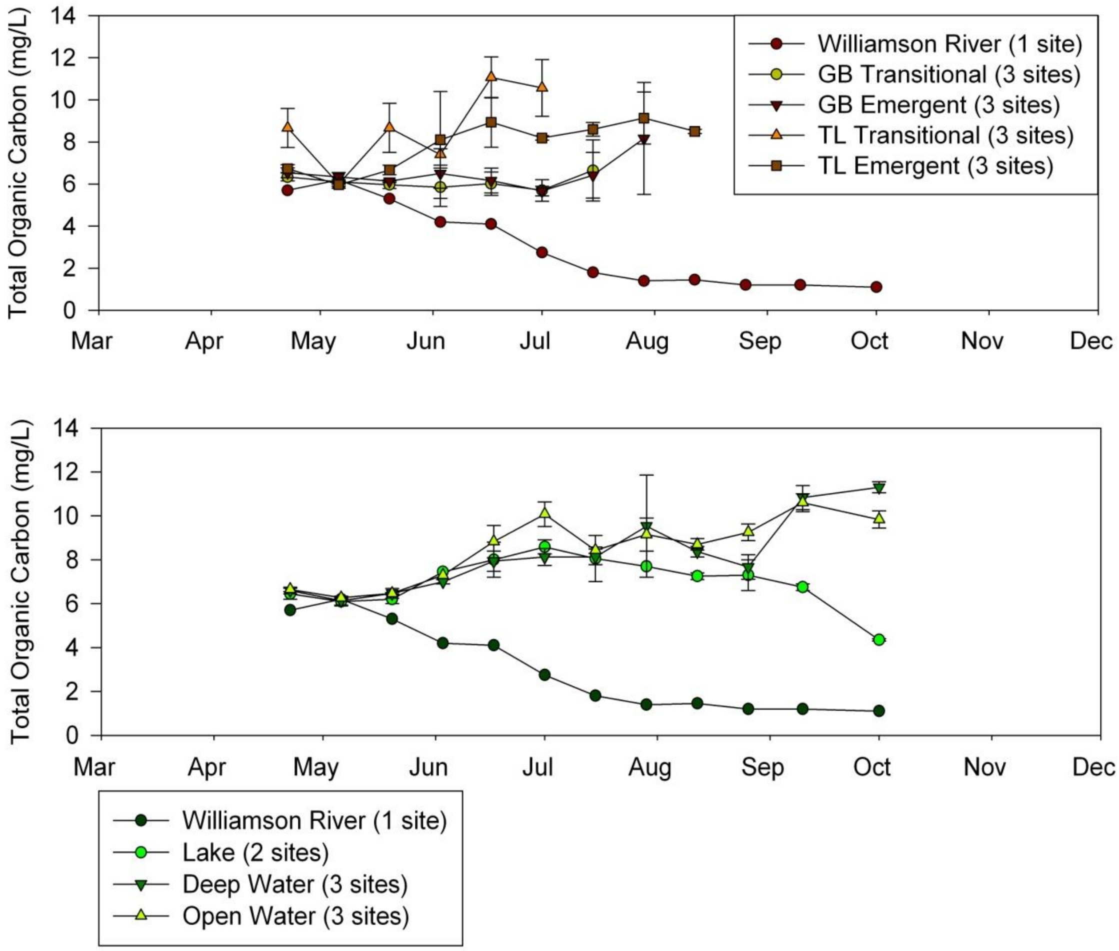


**Figure 1.7. Seasonal trends in total organic carbon from April–October 2009 within and surrounding the Williamson River Delta. Shown are means (± standard error) within each location by sampling event, except in the Williamson River where only one sample was collected during each event.**

Algal Dynamics. Chlorophyll *a* concentrations were examined in relation to dissolved nutrient concentrations. Seasonal variation in chlorophyll *a* concentrations followed opposite trends in dissolved inorganic nitrogen concentrations in deep and open water wetlands and lake locations (Figure 1.8). Declines in chlorophyll *a* concentrations generally corresponded with increases in ammonia and nitrate + nitrite concentrations. This trend was not as evident in transitional and emergent wetlands and river locations, possibly due to lower chlorophyll *a* concentrations at these locations (Appendix D). Seasonal fluctuations in orthophosphate concentrations at deep and open water wetlands and lake sites also followed opposite trends in chlorophyll *a* concentrations to some extent (Figure 1.9). This trend was again not as apparent in transitional and emergent wetlands (Appendix E). Dissolved organic carbon concentrations at all sites were also not strongly related to seasonal trends in chlorophyll *a* (Appendix F).

Instantaneous Water Chemistry. Mean daytime dissolved oxygen concentrations across all locations ranged from 2.9 – 13.2 mg/L from June to October with large variability between locations (Figure 1.10). Lowest mean dissolved oxygen concentrations occurred within emergent and open water wetlands in Tulana. Mean temperature ranged from 1.4 –25.1°C at all locations, with highest temperatures occurring in July. Seasonal average daytime temperature in the Williamson River from July to October was approximately 3.5°C cooler than all other locations. Mean pH values across all locations ranged from 7 to 10, varying seasonally, with highs occurring at the end of June and August coincident with peaks in chlorophyll *a* concentrations. Specific conductance at all locations ranged from 79 – 399 µS/cm (Figure 1.10). Values were generally higher within emergent and transitional wetlands in Tulana with mean specific conductance peaking at 231 and 207 µS/cm, respectively. Additional water chemistry results collected hourly from nine of the 27 sites can be found in Chapter 2.

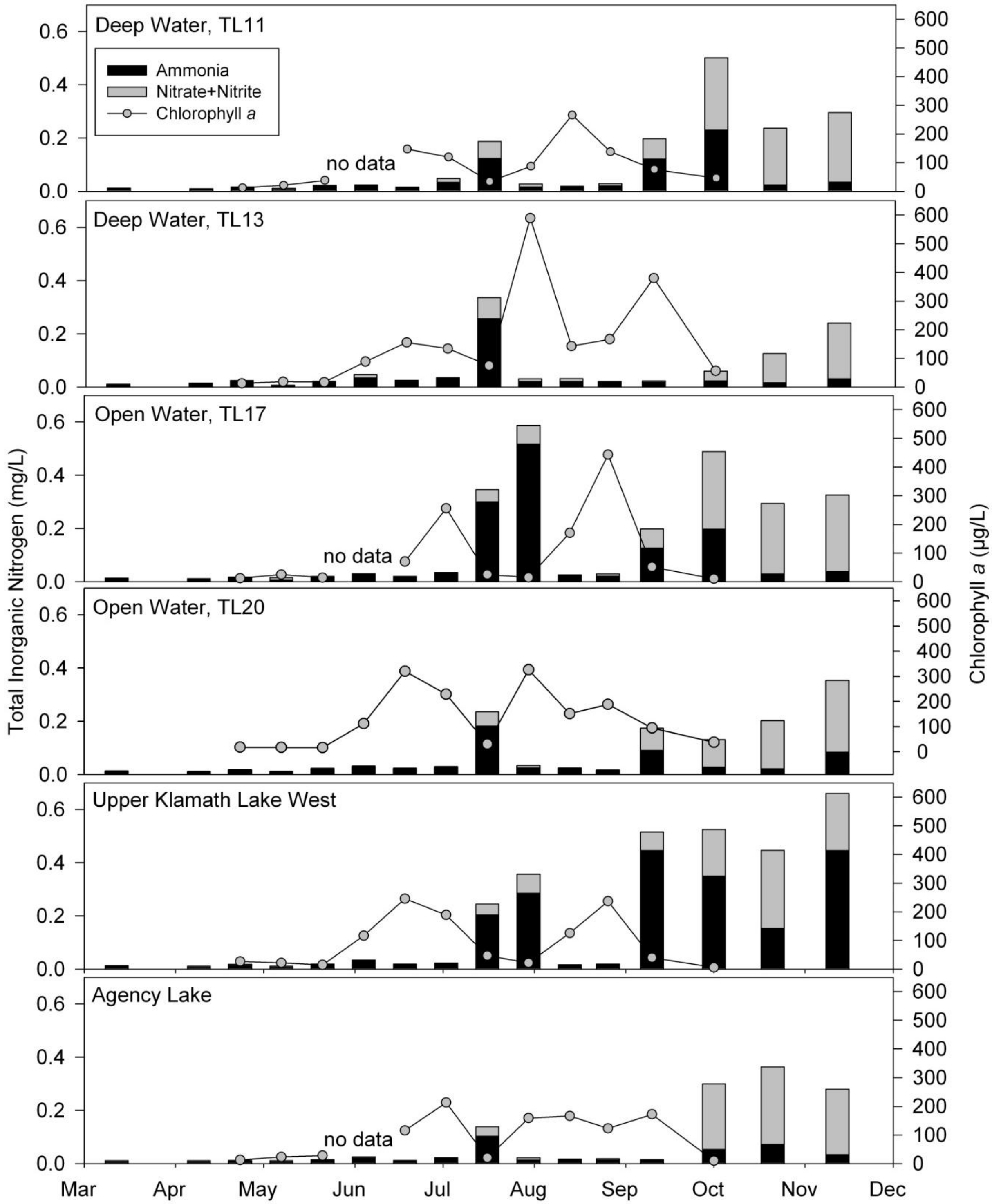


**Figure 1.8. Relationship between dissolved inorganic nitrogen and chlorophyll *a* concentrations at individual sampling sites in deep and open water wetland and lake locations from March - November 2009. Stacked bars represent ammonia and nitrate + nitrite concentrations and lines represent chlorophyll *a* concentrations.**

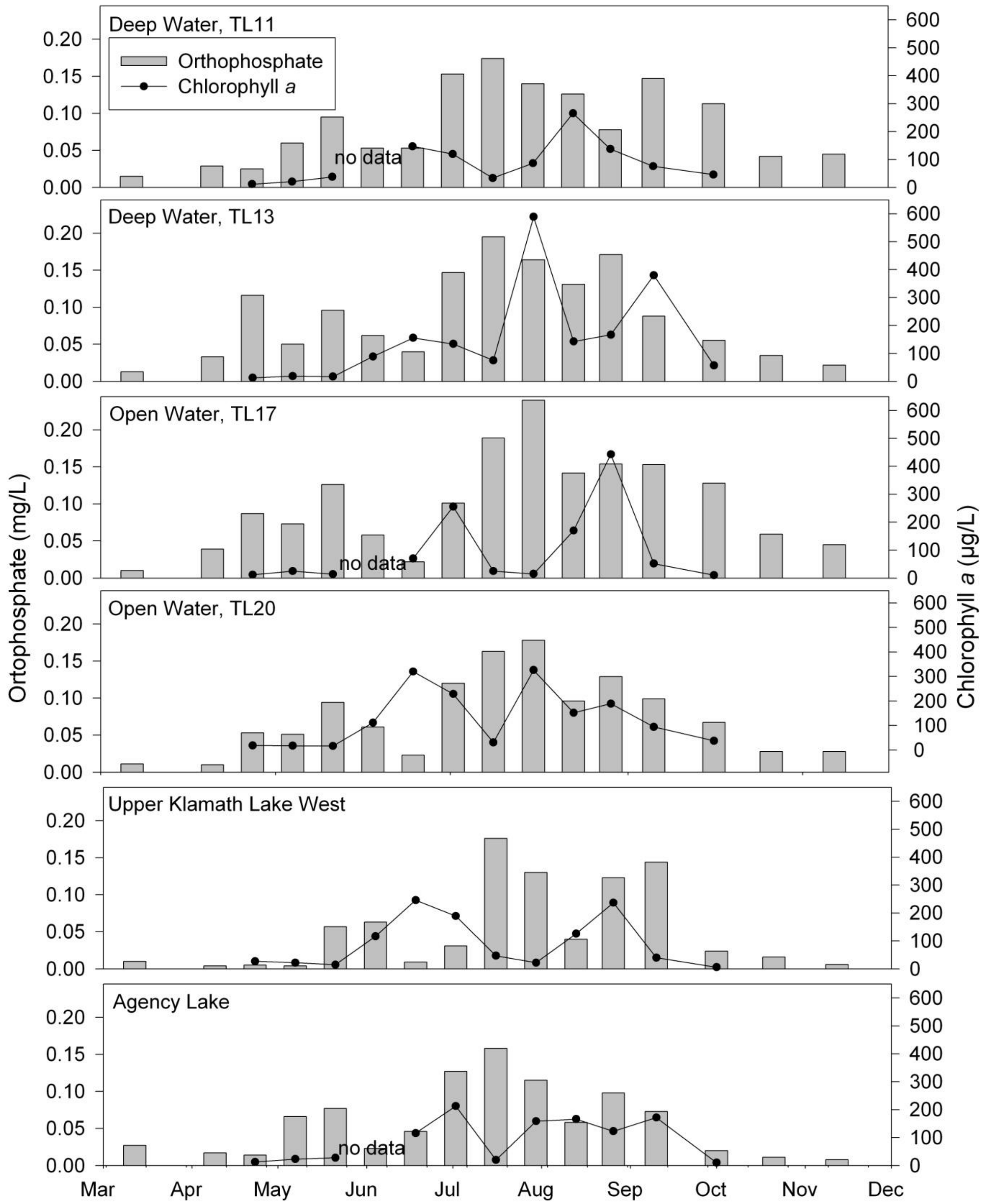


**Figure 1.9. Relationship between orthophosphate and chlorophyll *a* concentrations at individual sampling sites in deep and open water wetland and lake locations from March - November 2009. Bars represent orthophosphate concentrations and lines represent chlorophyll *a* concentrations.**

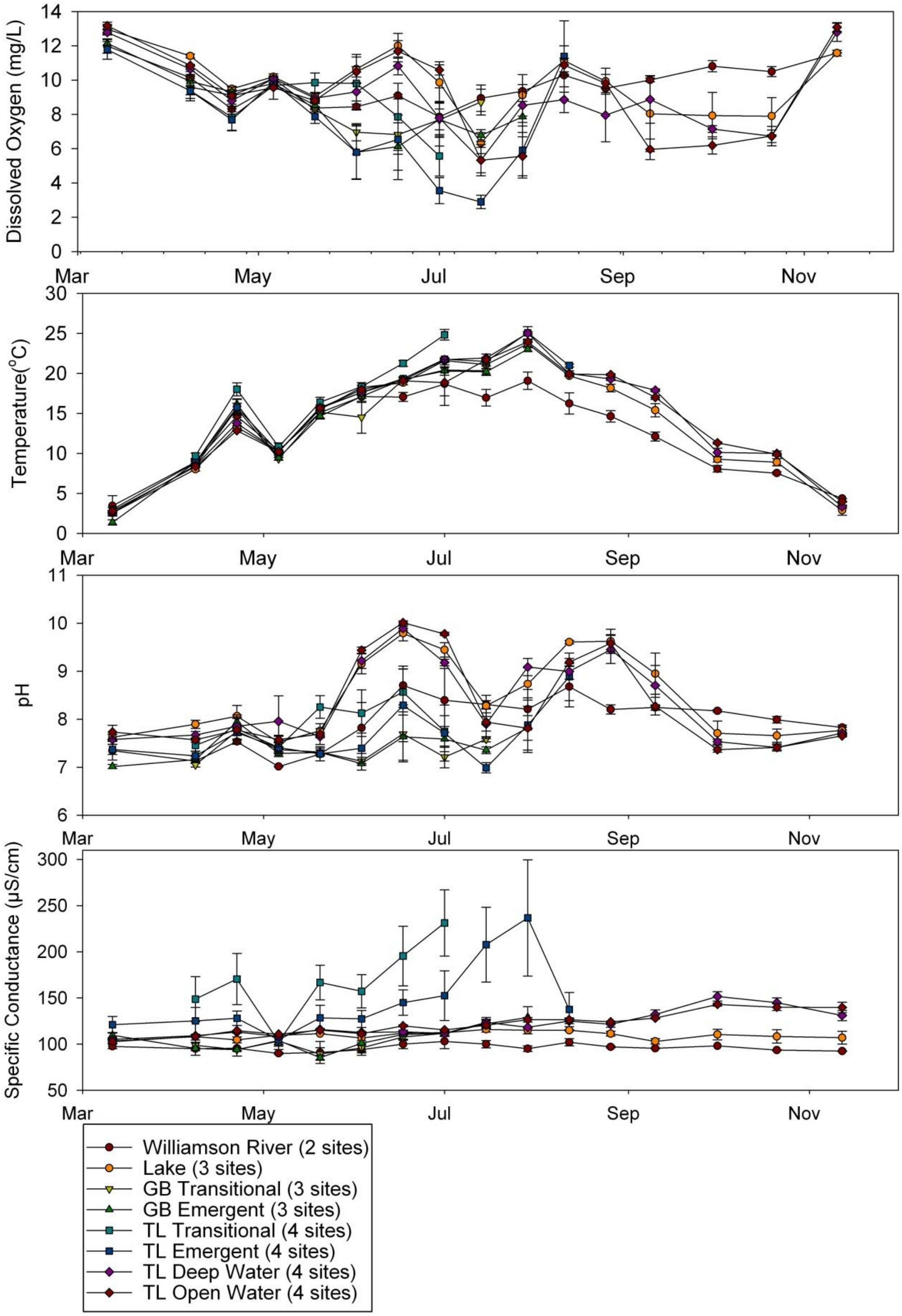


**Figure 1.10. Seasonal trends in instantaneous water chemistry parameters taken during grab sampling from March–November 2009 within and surrounding the Williamson River Delta. Shown are means (± standard error) within each location by sampling event.**

# <u>CHAPTER 2: CONTINUOUS WATER QUALITY MONITORING</u>

## METHODS

### Location of Continuous Monitoring Sites

Multi-probe instruments (YSI 600 XLM sondes) were deployed at nine fixed continuous monitoring sites within and surrounding the Delta in 2009 (Figure 2.1). Site locations were identical to the previous year (2008) except for the addition of one site inside the newly restored Goose Bay. Data from sondes were collected hourly and included temperature, dissolved oxygen concentration (DO), pH, and specific conductance. Sondes were placed at mid-depth in the water column at each site or one meter below the water surface if water depth exceeded two meters. Five sites were located inside the Delta and included the following: one in each of the four wetland types within Tulana (open water, deep water, emergent, and transitional wetland); and one inside Goose Bay in emergent wetland (referred to as Goose Bay emergent). The Goose Bay emergent site was added in 2009 following the restoration of Goose Bay in fall 2008. Four sites were located immediately surrounding the Delta and included the following: one in the Williamson River upstream of the project area (~RM 2.5); one in Upper Klamath Lake near the southwest shore of Tulana (referred to as Upper Klamath Lake West); one in Upper Klamath Lake south and east of the river mouth (referred to as Upper Klamath Lake East); and one near-shore in Agency Lake. Each site coincided with a grab sampling site.

### Monitoring Period

Continuous monitoring in 2009 began in mid-March and ended in mid-November. Sondes were pulled from transitional, Goose Bay emergent, and emergent sites in early July, mid-August, and late-August, respectively, due to declining water levels during the summer and insufficient water to continue monitoring at those sites. At the Upper Klamath Lake West site, data collected during the period June 10 – September 28 were provided by the USGS, which had approximately the same site location in Upper Klamath Lake as TNC. Data presented in this report which were collected by the USGS during this period at the Upper Klamath Lake West site are provisional and subject to revision.

### Quality Assurance

Calibrations were performed prior to sonde deployment to verify accuracy of each instrument. During weekly site visits, sonde performance was checked for precision against a recently calibrated reference sonde. Sondes were cleaned, rechecked, and either redeployed or replaced such that an individual sonde was deployed at a site for no longer than two weeks at a time. Following deployment, post calibration checks were performed to verify accuracy of each sonde. Data quality assurance objectives were defined in TNC's Water Quality Monitoring Project Plan (The Nature Conservancy 2008). Instances where data did not meet quality assurance criteria were reported and/or omitted. Quality assurance criteria for continuous monitoring are shown in Appendix F and outcomes are shown in Appendix G.


**Figure 2.1. Location of continuous monitoring sites at the Williamson River Delta Preserve in southern Oregon, March – November 2009.**

### Data Analysis

All raw data collected from sondes were quality-checked before computing statistics. Data that passed quality assurance criteria were deemed acceptable. Daily statistics were computed only for days in which at least 20 hours of acceptable data were recorded. All statistics were computed using SAS® System for Windows, Release 9.1.3 (SAS Institute).

## RESULTS

### Seasonal Trends

The warmest water temperatures in 2009 were recorded in the shallow wetland sites (emergent, transitional, and Goose Bay emergent wetlands) with maximum temperatures reaching 30.5 – 32°C (Table 2.1). Dissolved oxygen concentrations were highly variable through the year ranging from near-anoxic conditions to well above 100% saturation at lake and wetland sites. Ranges in pH were also variable in lake and Tulana wetland sites, with maximum pH reaching above 10 at those sites. The highest specific conductance values were recorded in shallow wetland sites.

**Table 2.1. Range values for water quality parameters collected hourly at nine continuous monitoring sites in the Williamson River Delta project area in southern Oregon, March – November 2009.**

| | Temperature (°C) | | Dissolved Oxygen (mg/L) | | pH | | Specific Conductance (µS/cm) | |
|---|---|---|---|---|---|---|---|---|
| | Min | Max | Min | Max | Min | Max | Min | Max |
| Agency Lake (AL27) | 1.02 | 26.95 | 1.64 | 20.93 | 6.85 | 10.56 | 95 | 151 |
| Upper Klamath Lake West (UKLW25) | 0.22 | 27.2 | 1.33 | 18.31 | 6.7 | 10.22 | 87 | 152 |
| Upper Klamath Lake East (UKLE24) | 0.78 | 26.81 | 1.31 | 17.91 | 6.94 | 10.24 | 80 | 139 |
| Williamson River (WR21) | 2.02 | 20.42 | 6.94 | 12.38 | 6.88 | 8.75 | 60 | 105 |
| Open Water (TLOW17) | 1.65 | 26.79 | 1.05 | 19.19 | 6.66 | 10.46 | 104 | 168 |
| Deep Water (TLDW13) | 0.99 | 27.57 | 1.47 | 23.4 | 6.73 | 10.38 | 87 | 164 |
| Emergent (TLEM9) | 3.96 | 30.58 | 0.91 | 24.09 | 6.86 | 10.19 | 75 | 261 |
| Transitional (TLTR5) | 1.2 | 31.3 | 0.23 | 19.26 | 6.78 | 10.45 | 81 | 265 |
| Goose Bay Emergent (GBEM4) | 2.45 | 31.92 | 2.4 | 15.17 | 6.64 | 9.43 | 77 | 169 |

Highs in daily median water temperatures among wetland and lake sites were reached in late July-early August 2009 (Figure 2.2). Seasonal trends in temperature at wetland and lake sites generally followed trends at the Williamson River site until early June, when temperatures at wetland and lake sites began to increase and diverge from river temperatures. From the period July – September, daily median temperatures in the river were on average 6.2°C cooler than wetland sites, and 4.3°C cooler than lake sites. From the period May – June, daily median temperatures at the Tulana emergent site were on average 1.7°C warmer than in the river, and 0.7°C warmer than at lake sites. During the same period, temperatures at the transitional site were on average 1.8° warmer than in the river and 0.8°C warmer than at lake sites. Also during this period, temperatures at the Goose Bay emergent site were 1.3°C warmer than in the river, and 0.3°C warmer than at lake sites.

Seasonal trends in DO at lake sites showed two distinct peaks and crashes in 2009 (Figure 2.2). Timings of peaks and crashes in DO at lake sites appeared to follow trends in the bloom and crash periods of cyanobacteria in Upper Klamath and Agency Lakes (see chlorophyll *a* section in Chapter 1 of this report). Peaks in daily median DO concentration at lake sites occurred in mid-June, followed by a period of low DO in mid-July. A second peak in DO occurred in mid-August followed by a second drop in DO in mid-September. In open water and deep water wetlands, seasonal trends in DO generally followed similar patterns as in lake sites, with peaks in mid-June and mid-August and lows in mid-July and mid-September. In emergent and transitional wetlands, DO concentrations began to drop in mid-June to lows in early July. In emergent wetland, DO concentrations began to rebound beginning late July. Daily median DO concentrations at the Goose Bay emergent site generally followed trends in the Williamson River, remaining relatively steady throughout the year.

Trends in pH were generally variable among all sites with minimum pH ranging from 6.7 – 6.9 and maximum pH of over 10 at most sites (Table 2.1). Seasonal trends in pH at lake sites showed two distinct peaks and declines in 2009 (Figure 2.2). Timings of peaks and declines in pH appeared related to trends in DO and associated cyanobacteria bloom and crash periods. The first peak in daily median pH occurred in mid-late June, which was followed by a drop in mid-late July. A second peak occurred in mid-late August and was followed by a second drop in mid-late September. Trends in pH in open water and deep water wetlands followed similar patterns as in lake sites with corresponding peaks and drops during the season. Trends in pH at emergent, transitional, and Goose Bay emergent sites also showed seasonal variability. At these shallow wetland sites, pH was generally highest during the month of June and lowest prior to June and in mid-July.

Specific conductance values at wetland sites ranged from 77 – 265 μS/cm and generally increased through the course of the year (Table 2.1; Figure 2.2). Values at lake and wetland sites were generally higher than the river throughout the year. Trends and values in open water and deep water were similar to lake values until mid-August, when specific conductance began to increase and diverge from the lake. Specific conductance values in emergent and transitional wetlands were the most variable of all the sites and began to increase and diverge from lake and river values in June. At the Goose Bay emergent site, trends and values were similar to those in the river until early-mid June, when values began to increase and diverge.

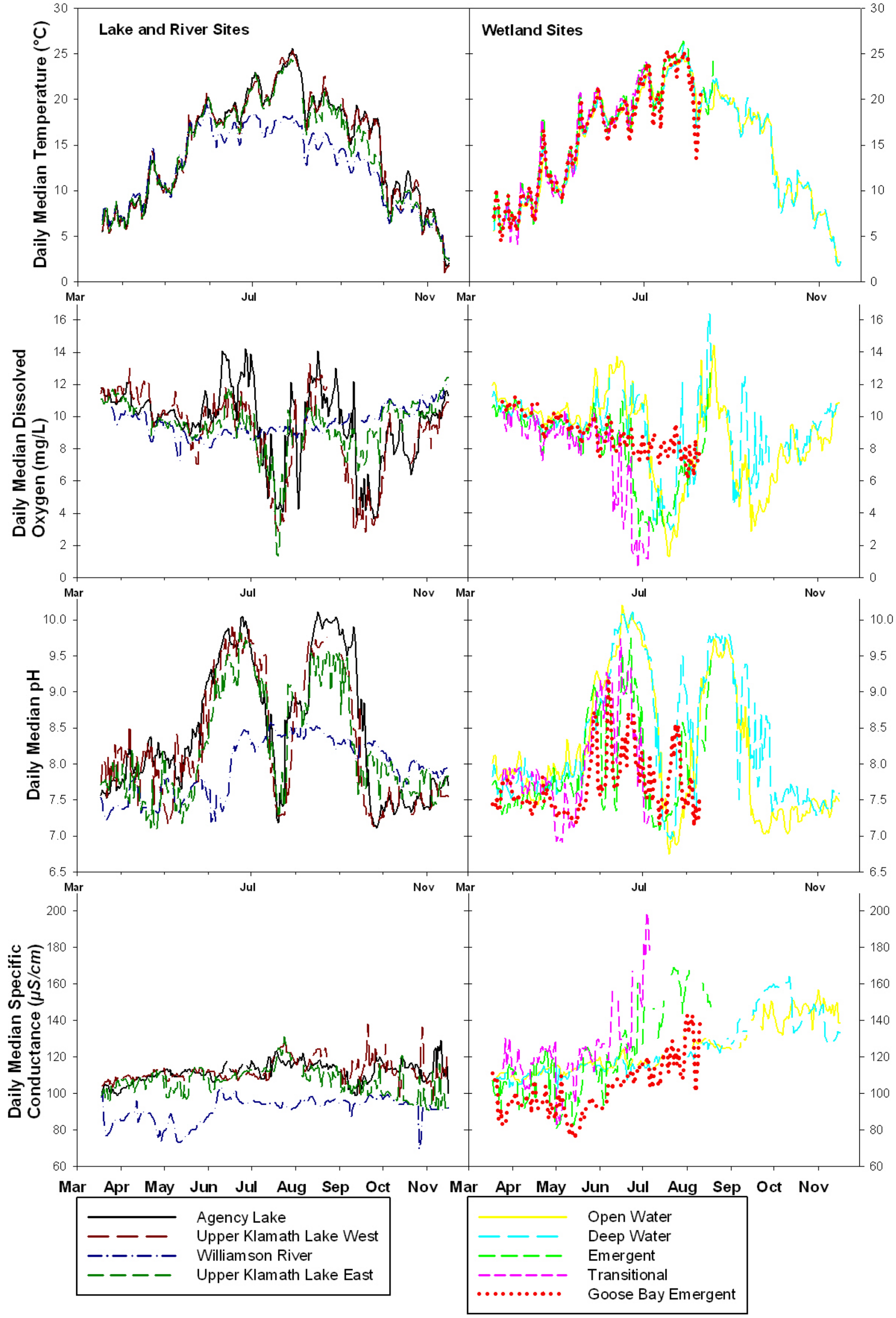


**Figure 2.2. Daily median temperature, dissolved oxygen, pH, and specific conductance at lake, river, and wetland sites at the Williamson River Delta in southern Oregon, March – November 2009. Left panels represent lake and river sites; right panels represent Delta wetland sites.**

**High Stress Threshold Conditions for Endangered Suckers**

In addition to seasonal trends, water quality was examined in relation to conditions potentially harmful to the health of endangered suckers in Upper Klamath Lake based on water temperature, DO concentration, and pH. High stress threshold conditions for suckers were characterized by temperature > 28°C, DO concentration < 4 mg/L, and pH > 9.7, and were selected based on research conducted by Loftus (2001). Investigation of water quality data included determining the seasonal timing, location, and duration of high-stress conditions within and surrounding the Delta. These results provide an indication of habitat quality for sucker in the Delta wetlands based on water quality.

In 2009, exceedances of threshold conditions for the three parameters were not observed in the Williamson River. In open and deep water wetlands, exceedances of DO and pH thresholds tended to occur when exceedances occurred at lake sites (Figure 2.3). Occurrences in the Goose Bay emergent wetlands generally did not follow these same trends.

At lake, open water, and deep water sites, exceedances of the pH threshold tended to occur at two distinct periods: early-season during the month of June, and late-season in late-August. Conditions in which pH > 9.7 lasted 100% of the day occurred at Agency and Upper Klamath Lakes, and at open and deep water wetland sites. In open water and deep water, these "100%-day" conditions lasted up to 12 and 15 days, respectively, from mid – late June. Minor occurrences of pH threshold exceedance were observed in emergent and transitional wetlands in June, and no occurrences were observed at the Goose Bay emergent wetland site.

At lake, open water, and deep water wetland sites, exceedances of the DO threshold tended to occur at two distinct periods: mid-season in mid-late July, and late-season in September. At these sites, distinct periods of DO threshold exceedance occurred after distinct periods of pH threshold exceedance. In open water, conditions in which DO < 4 mg/L lasted 100% of the day occurred over a nine-day period in mid-late July. In emergent wetlands, exceedances of the DO threshold occurred for a prolonged period during the month of July: for seven days, these conditions lasted up to 100% of the day. In transitional wetland, exceedances of the DO threshold occurred in June and July with "100%-day" conditions occurring for three days in early July. DO thresholds were exceeded in Goose Bay emergent wetland in late July – early August, however these conditions were neither severe during the day (less than 37% of a day in Goose Bay), nor prolonged through the season (at most over nine consecutive days in Goose Bay emergent wetland).

Temperature exceedance occurred only in the shallow wetland sites. These conditions tended to occur in early June in transitional wetland and late July in emergent and Goose Bay emergent wetlands. When high temperature conditions occurred at these shallow wetland sites, they generally were not severe during the day (at most 33% of the day in transitional wetland), nor prolonged through the season (at most eight consecutive days in Goose Bay emergent wetland).

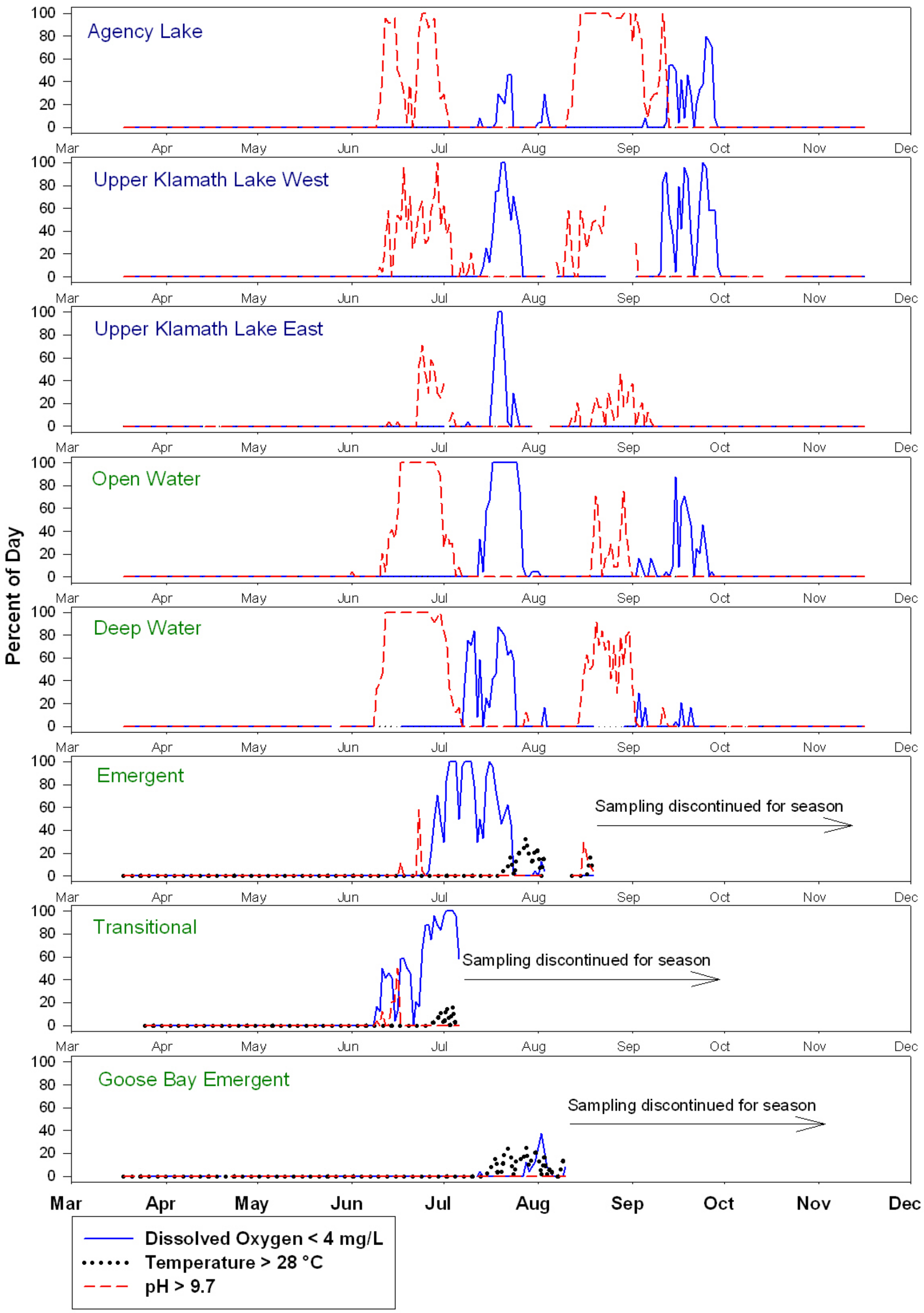


**Figure 2.3. Seasonal timing, location, and duration (percent of day) of water quality conditions exceeding high-stress thresholds for Lost River and shortnose suckers in Upper Klamath Lake, March – November 2009.**

**CONCLUSION**

This report highlights results from the second full year of water quality monitoring on the Williamson River Delta, including additional monitoring in the newly flooded Goose Bay wetlands. Samples were successfully collected as outlined in the grant proposal. Nitrogen and phosphorus samples were collected during sixteen events from mid-March through mid-November. Carbon, chlorophyll *a*, and algal speciation samples were collected during twelve events from mid-April to early October and physical in-situ water chemistry monitors were deployed from mid-March to mid-November. Laboratory analysis for 2008 and 2009 algal speciation samples were recently completed and data analysis will be forth coming. Comprehensive water quality results for all sampling years, 2007-2009, will be summarized in a final grant report later this year.

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# APPENDICES

**Appendix A. Detection and reporting limits for sample constituents, standard method number, and laboratory conducting the analysis.**

| Constituents | Detection Limit (mg/L) | Reporting Limit (mg/L) | Method | Laboratory |
|---|---|---|---|---|
| Total Phosphorus | 0.009 | 0.012 | SM4500-P H | Sprague River Water Quality Laboratory, OR |
| Orthophosphate | 0.003 | 0.006 | SM4500- PF | |
| Ammonia | 0.006 | 0.010 | MD Krom methods | |
| Nitrate + Nitrite | 0.008 | 0.010 | Enzymatic NO3; SM4500-NO2 | |
| Total Nitrogen | 0.010 | 0.030 | Enzymatic NO3 | |
| Total Organic Carbon | 0.300 | 0.500 | SM 5310 | Basic Laboratory, CA |
| Dissolved Organic Carbon | 0.300 | 0.500 | SM5310C | |
| Chlorophyll *a* | 0.0001 | NA | SM10200H | Aquatic Research, WA |

**Appendix B. Quality Assurance/Quality Control results for split, duplicate, lab blank, and equipment blank samples.**

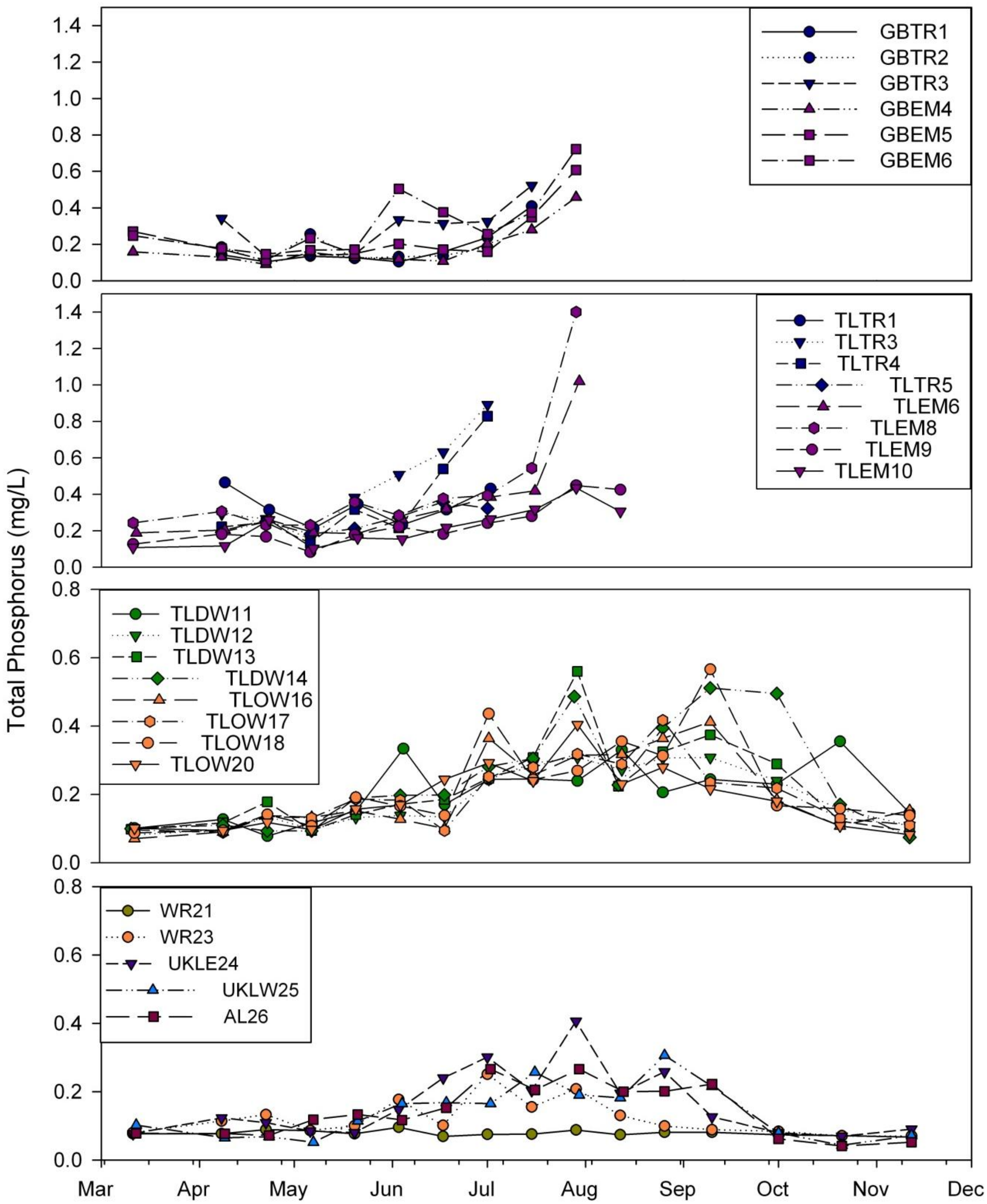
| Split Samples | Number of Samples | | % Split Samples | Difference btw. splits | |
|---|---|---|---|---|---|
| Analyte | Duplicates | Total | | Median (mg/L) | Median (%) |
| Total Phosphorus | 40 | 331 | 12% | 0.006 | 1 |
| Orthophoshate-P | 40 | 331 | 12% | 0.001 | 1 |
| Total Nitrogen | 40 | 331 | 12% | 0.022 | 1 |
| Ammonia | 40 | 331 | 12% | 0.002 | 2 |
| Nitrate + Nitrite | 40 | 331 | 12% | 0 | 0 |
| Chlorophyll *a* | 19 | 190 | 10% | 1.5 | 1 |
| Total Organic Carbon | 21 | 190 | 11% | 0.2 | 3 |
| Dissolved Organic Carbon | 21 | 190 | 11% | 0.1 | 3 |

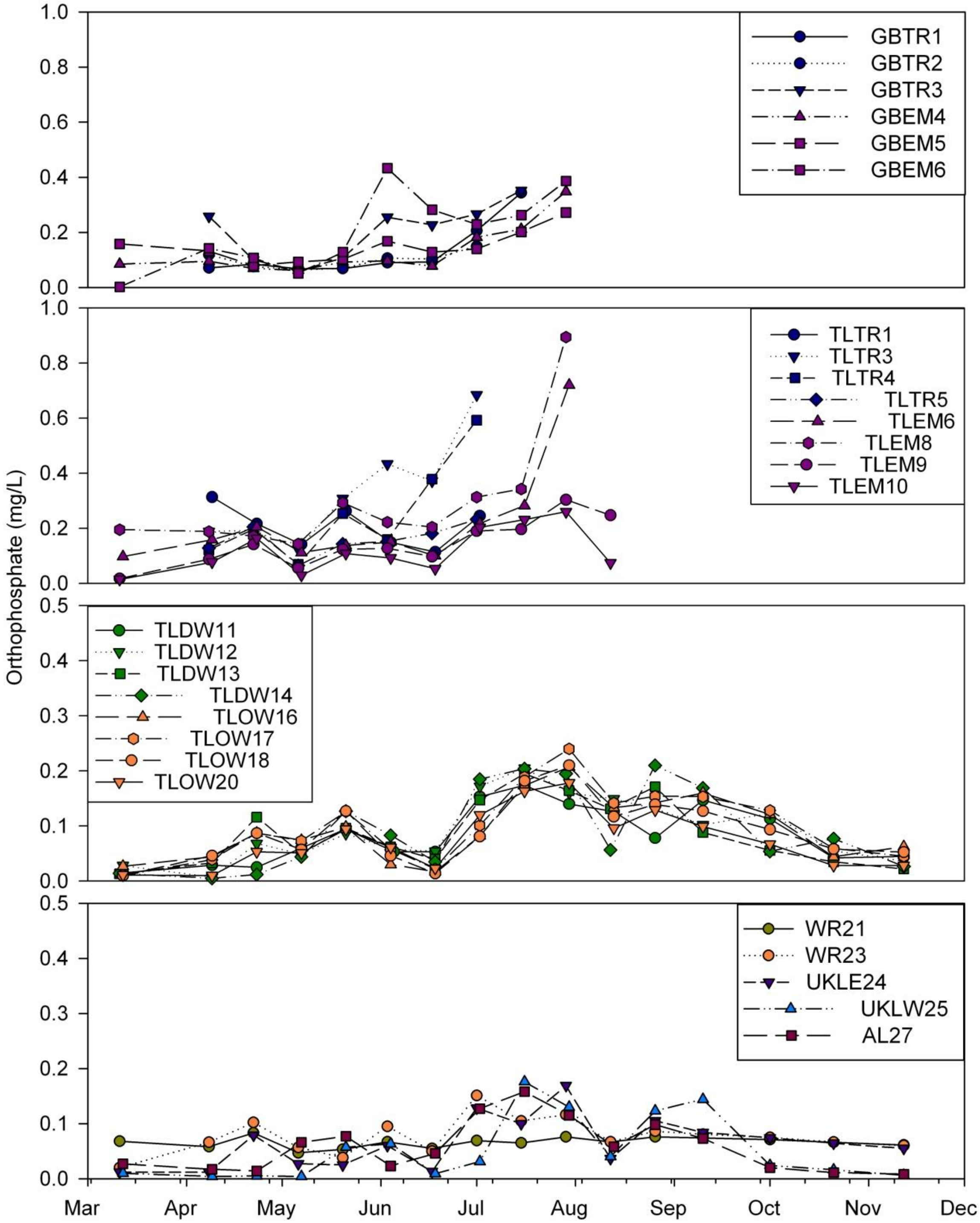
| Duplicate Samples | Number of Samples | | % Duplicate Samples | Difference btw. splits | |
|---|---|---|---|---|---|
| Analyte | Duplicates | Total | | Median (mg/L) | Median (%) |
| Total Phosphorus | 14 | 331 | 4% | 0.0045 | 3.28 |
| Orthophoshate | 14 | 331 | 4% | 0.001 | 7.14 |
| Total Nitrogen | 14 | 331 | 4% | 0.06 | 5.72 |
| Ammonia | 14 | 331 | 4% | 0.004 | 4.65 |
| Nitrate + Nitrite | 14 | 331 | 4% | 0.00 | 0.00 |

| Lab Blank | Number of Samples | | % of Blank Samples | Minimum Reporting Level (mg/L) | Value of Blank Samples greater than reporting limit |
|---|---|---|---|---|---|
| Analyte | Blank | Total | | | Maximum (mg/L) |
| Total Phosphorus | 3 | 331 | 1% | 0.036 | NA |
| Orthophoshate-P | 3 | 331 | 1% | 0.006 | NA |
| Total Nitrogen | 3 | 331 | 1% | 0.06 | NA |
| Ammonia | 3 | 331 | 1% | 0.012 | NA |
| Nitrate + Nitrite | 3 | 331 | 1% | 0.016 | NA |
| Chloropyhll a | 4 | 190 | 2% | 0.0001 | 1.1 |

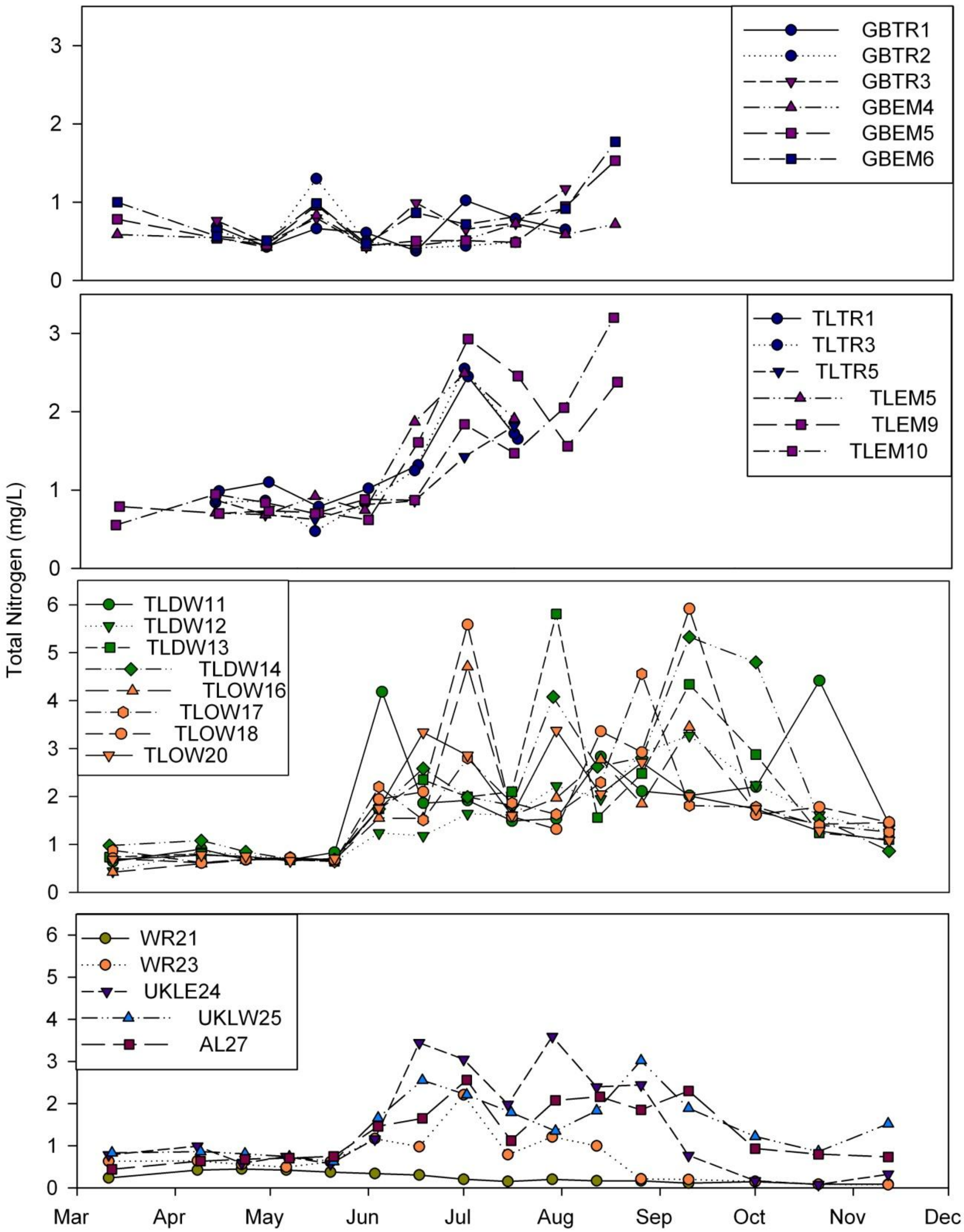
| Equipment Blank | Number of Samples | | % of Blank Samples | Minimum Reporting Level (mg/L) | Value of Blank Samples greater than reporting limit |
|---|---|---|---|---|---|
| Analyte | Blank | Total | | | Maximum (mg/L) |
| Total Phosphorus | 2 | 331 | 0.6% | 0.036 | NA |
| Orthophoshate-P | 2 | 331 | 0.6% | 0.006 | NA |
| Total Nitrogen | 2 | 331 | 0.6% | 0.06 | NA |
| Ammonia | 2 | 331 | 0.6% | 0.012 | 0.013 |
| Nitrate + Nitrite | 2 | 331 | 0.6% | 0.016 | NA |

**Appendix C. Seasonal trends for all grab sampling constituents collected at all lake, river, and Williamson River Delta sites from March – November 2009. See Figure 1.1 for locations of sampling sites.**

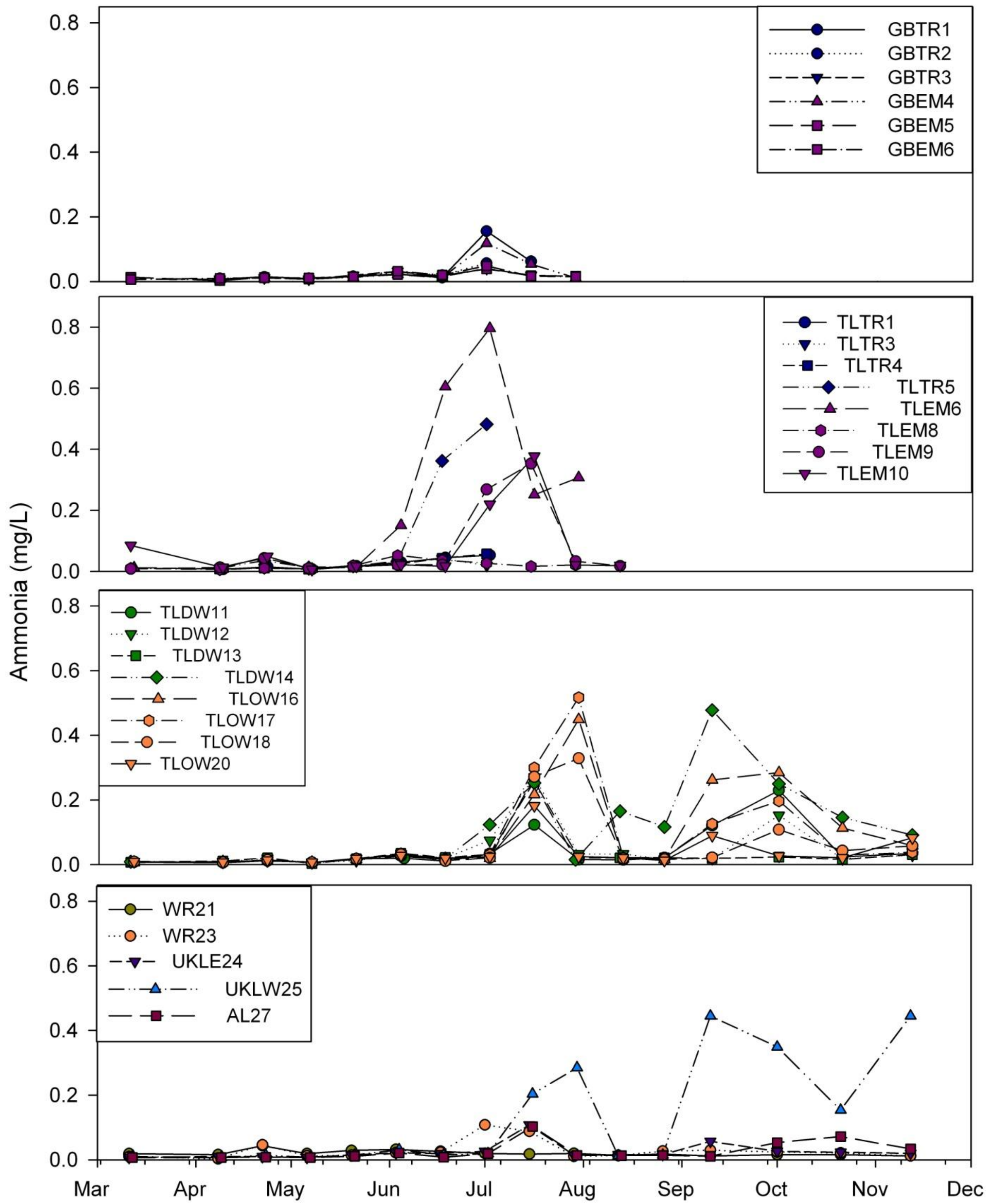




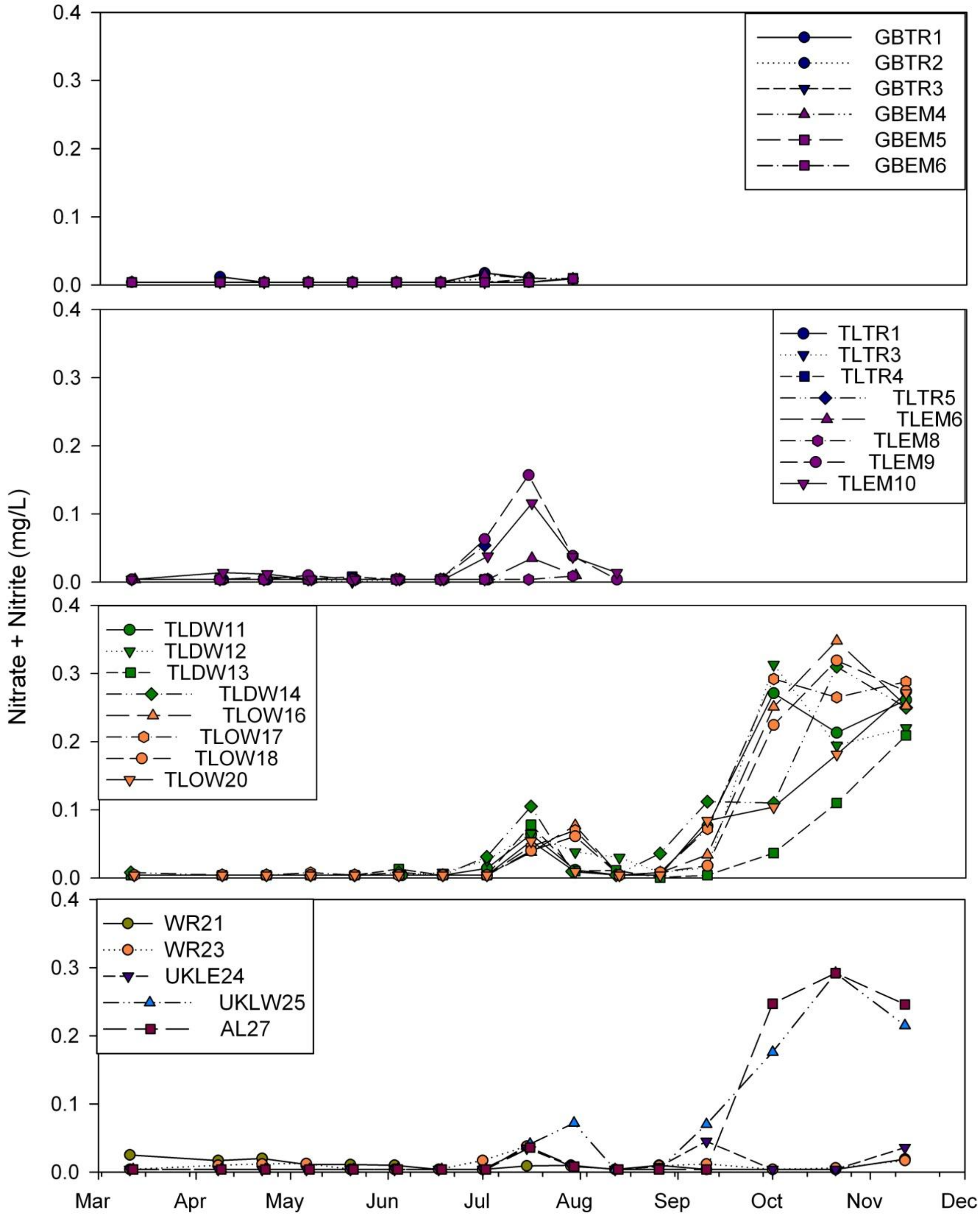
Orthophosphate (mg/L)
GBTR1
GBTR2
GBTR3
GBEM4
GBEM5
GBEM6
TLTR1
TLTR3
TLTR4
TLTR5
TLEM6
TLEM8
TLEM9
TLEM10
TLDW11
TLDW12
TLDW13
TLDW14
TLOW16
TLOW17
TLOW18
TLOW20
WR21
WR23
UKLE24
UKLW25
AL27
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

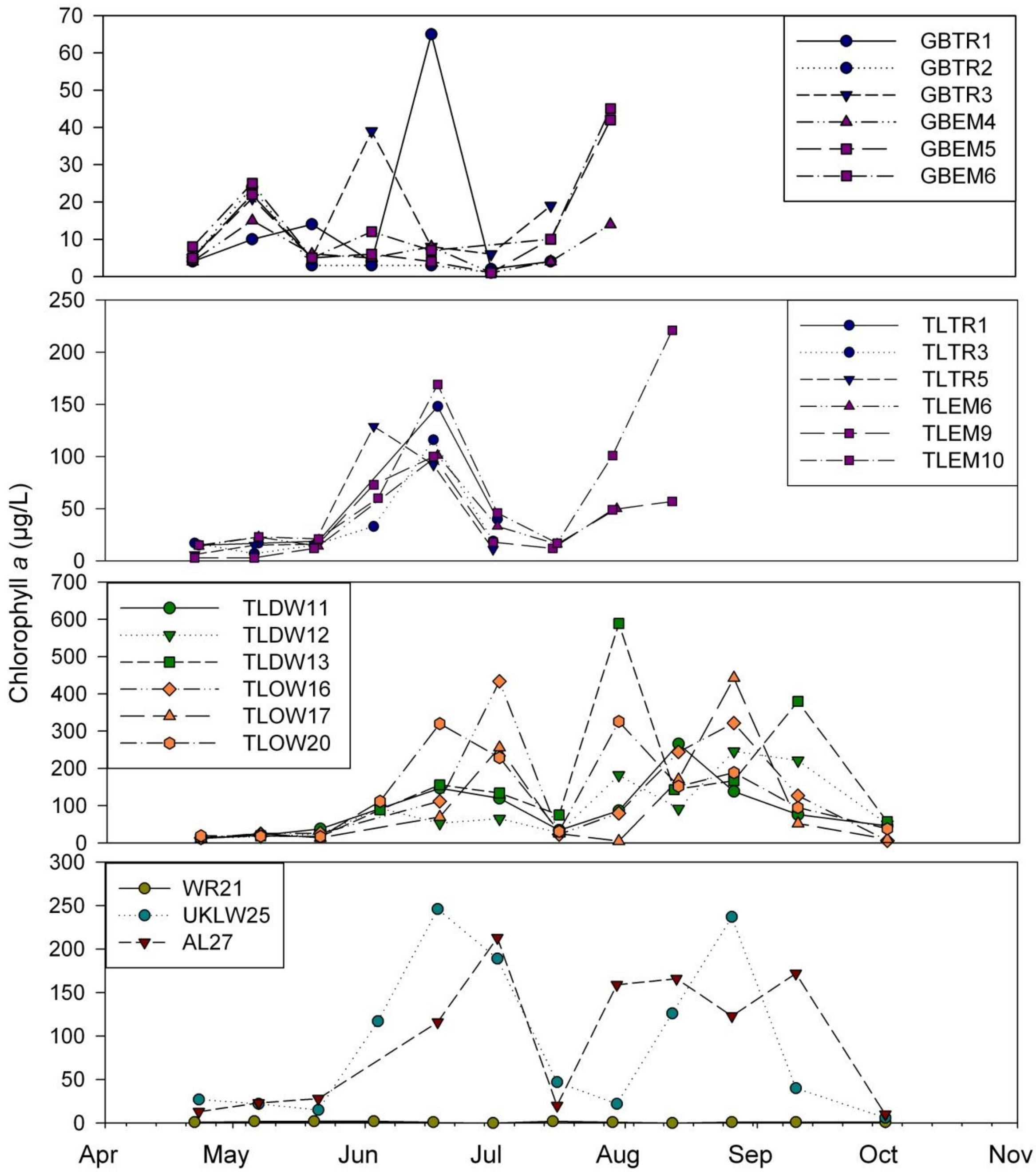


Total Nitrogen (mg/L)
GBTR1
GBTR2
GBTR3
GBEM4
GBEM5
GBEM6
TLTR1
TLTR3
TLTR5
TLEM5
TLEM9
TLEM10
TLDW11
TLDW12
TLDW13
TLDW14
TLOW16
TLOW17
TLOW18
TLOW20
WR21
WR23
UKLE24
UKLW25
AL27
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

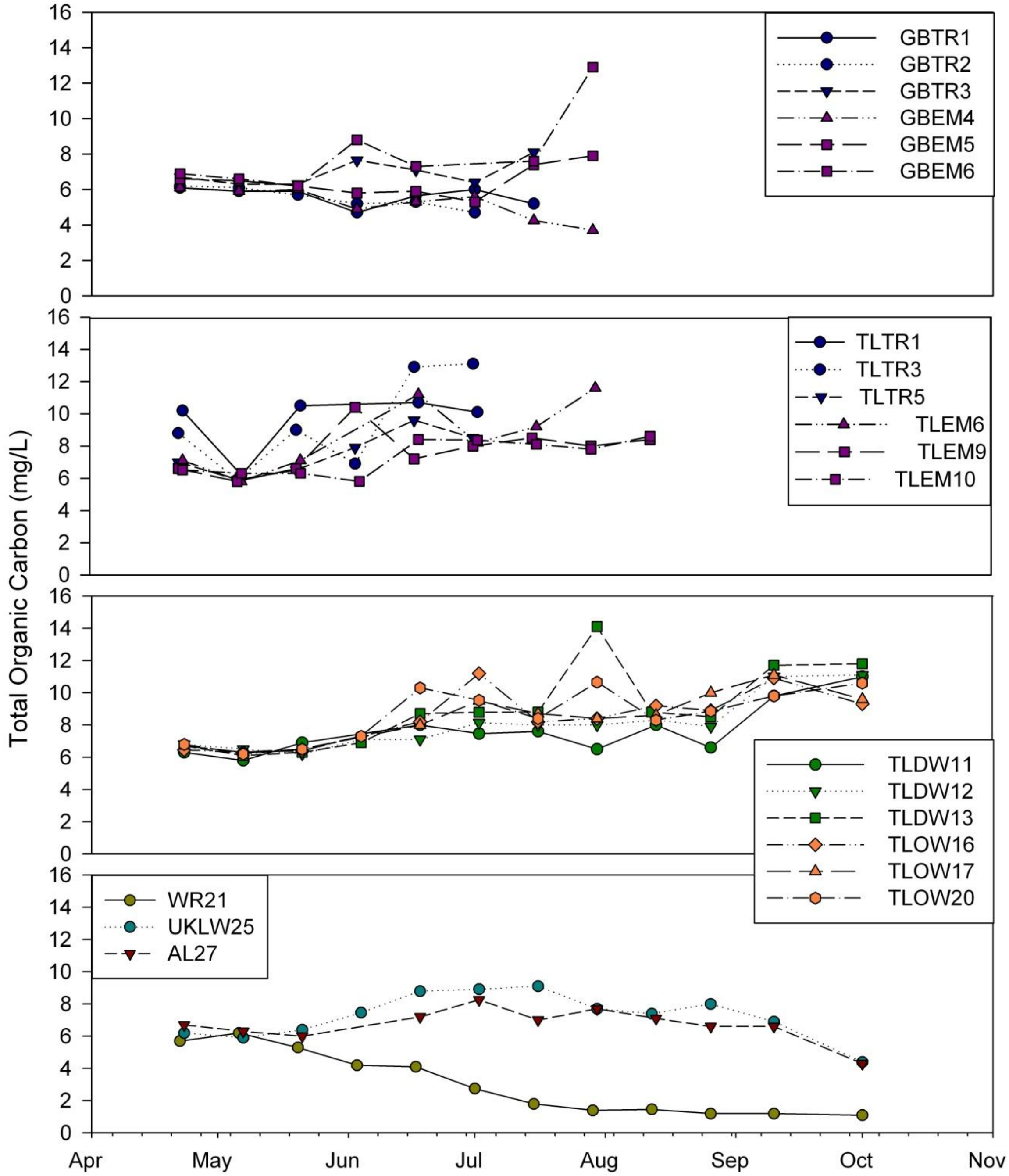


GBTR1
GBTR2
GBTR3
GBEM4
GBEM5
GBEM6
TLTR1
TLTR3
TLTR4
TLTR5
TLEM6
TLEM8
TLEM9
TLEM10
TLDW11
TLDW12
TLDW13
TLDW14
TLOW16
TLOW17
TLOW18
TLOW20
WR21
WR23
UKLE24
UKLW25
AL27
Ammonia (mg/L)
0.0
0.2
0.4
0.6
0.8
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

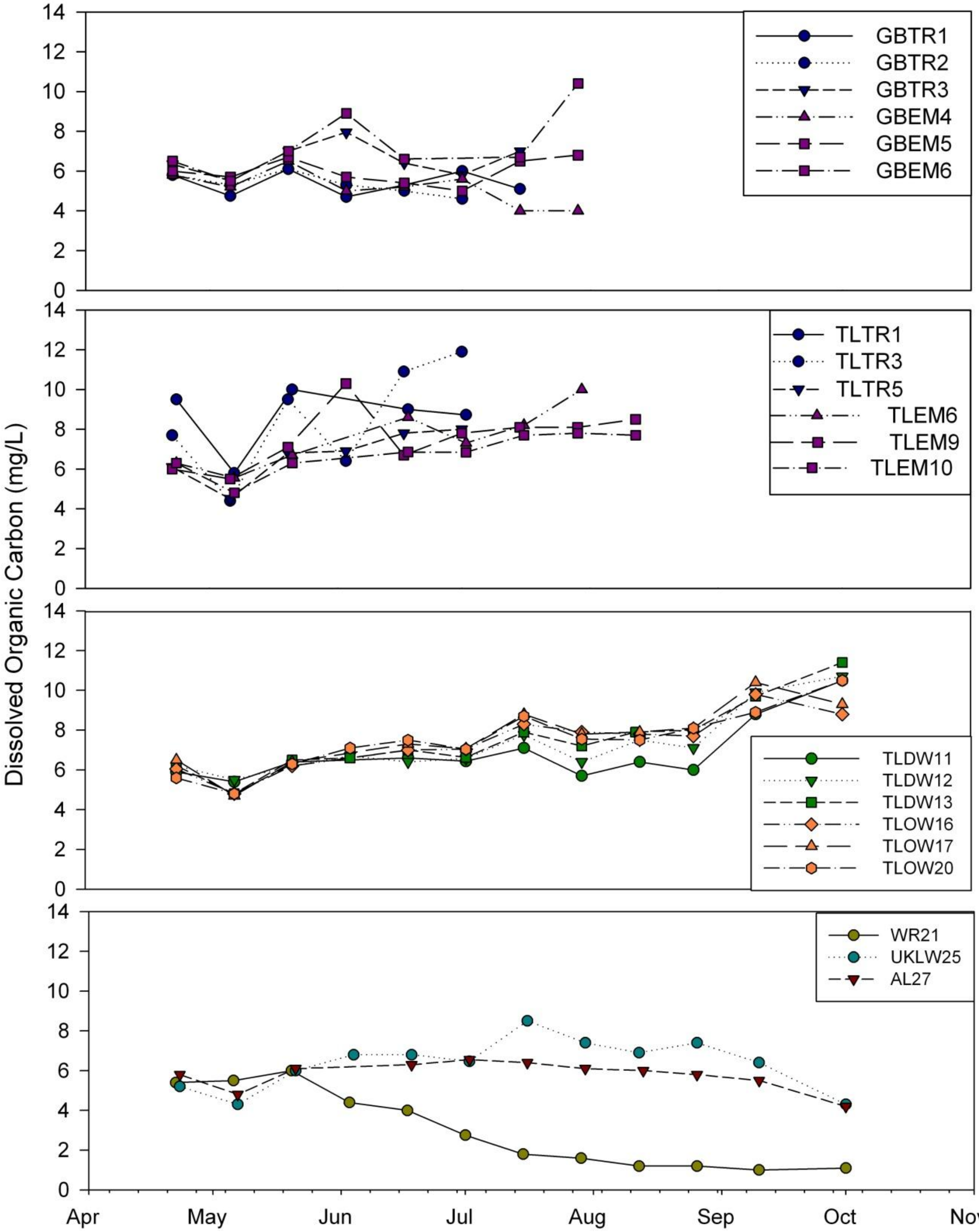

Nitrate + Nitrite (mg/L)
0.0
0.1
0.2
0.3
0.4
GBTR1
GBTR2
GBTR3
GBEM4
GBEM5
GBEM6
TLTR1
TLTR3
TLTR4
TLTR5
TLEM6
TLEM8
TLEM9
TLEM10
TLDW11
TLDW12
TLDW13
TLDW14
TLOW16
TLOW17
TLOW18
TLOW20
WR21
WR23
UKLE24
UKLW25
AL27
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec



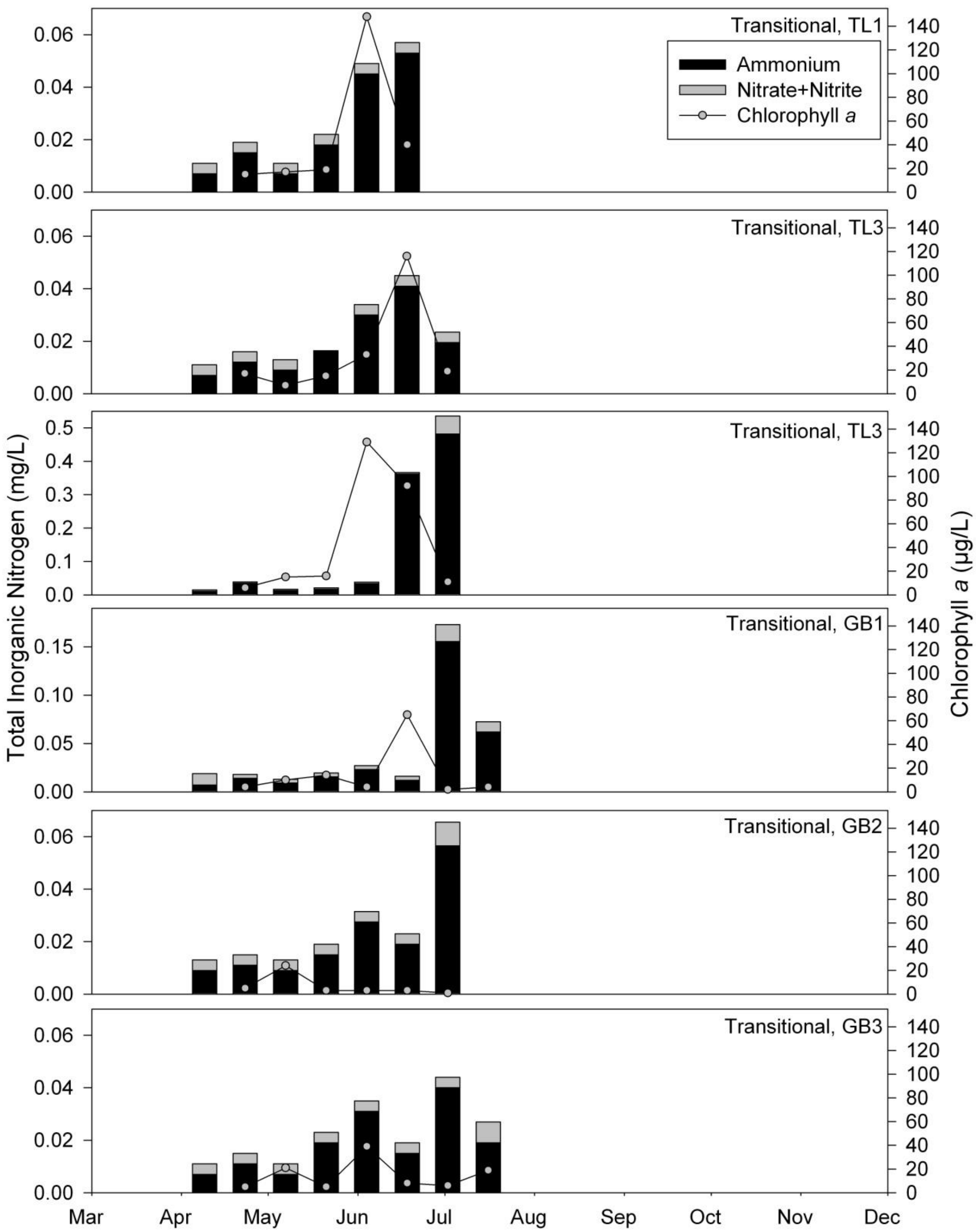
Chlorophyll a (µg/L)
GBTR1
GBTR2
GBTR3
GBEM4
GBEM5
GBEM6
TLTR1
TLTR3
TLTR5
TLEM6
TLEM9
TLEM10
TLDW11
TLDW12
TLDW13
TLOW16
TLOW17
TLOW20
WR21
UKLW25
AL27
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

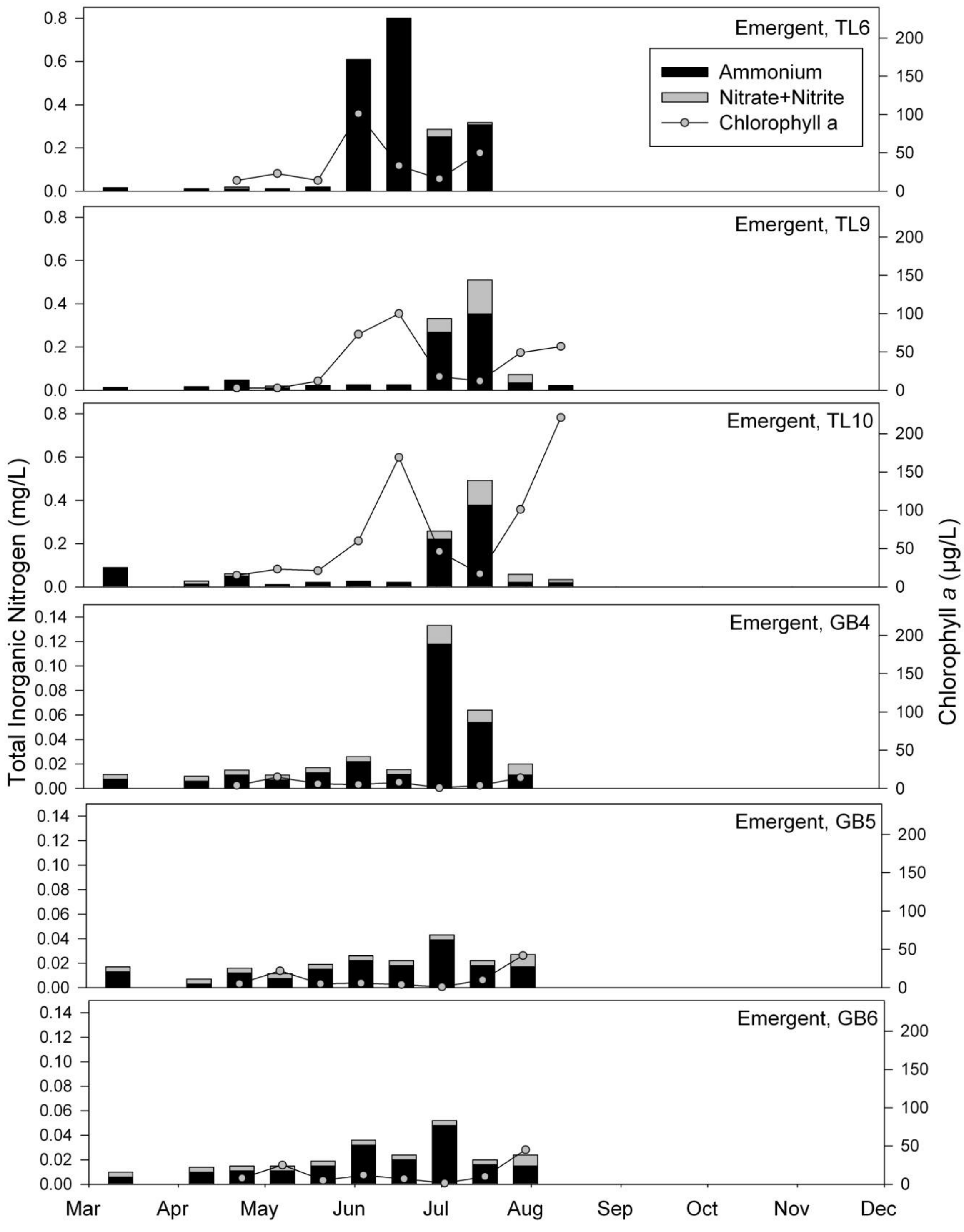


GBTR1
GBTR2
GBTR3
GBEM4
GBEM5
GBEM6
TLTR1
TLTR3
TLTR5
TLEM6
TLEM9
TLEM10
TLDW11
TLDW12
TLDW13
TLOW16
TLOW17
TLOW20
WR21
UKLW25
AL27
Total Organic Carbon (mg/L)
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

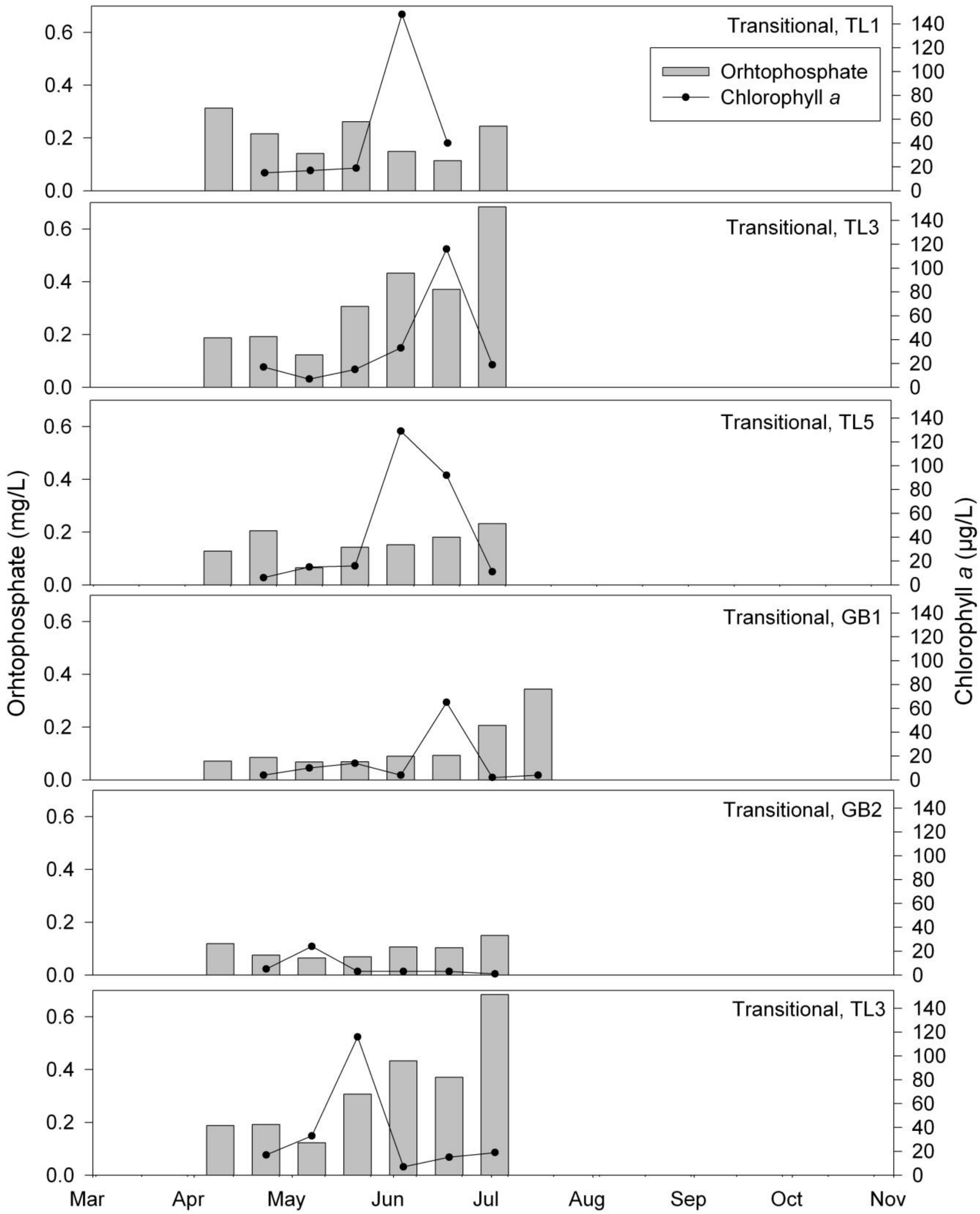

Dissolved Organic Carbon (mg/L)
GBTR1
GBTR2
GBTR3
GBEM4
GBEM5
GBEM6
TLTR1
TLTR3
TLTR5
TLEM6
TLEM9
TLEM10
TLDW11
TLDW12
TLDW13
TLOW16
TLOW17
TLOW20
WR21
UKLW25
AL27
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

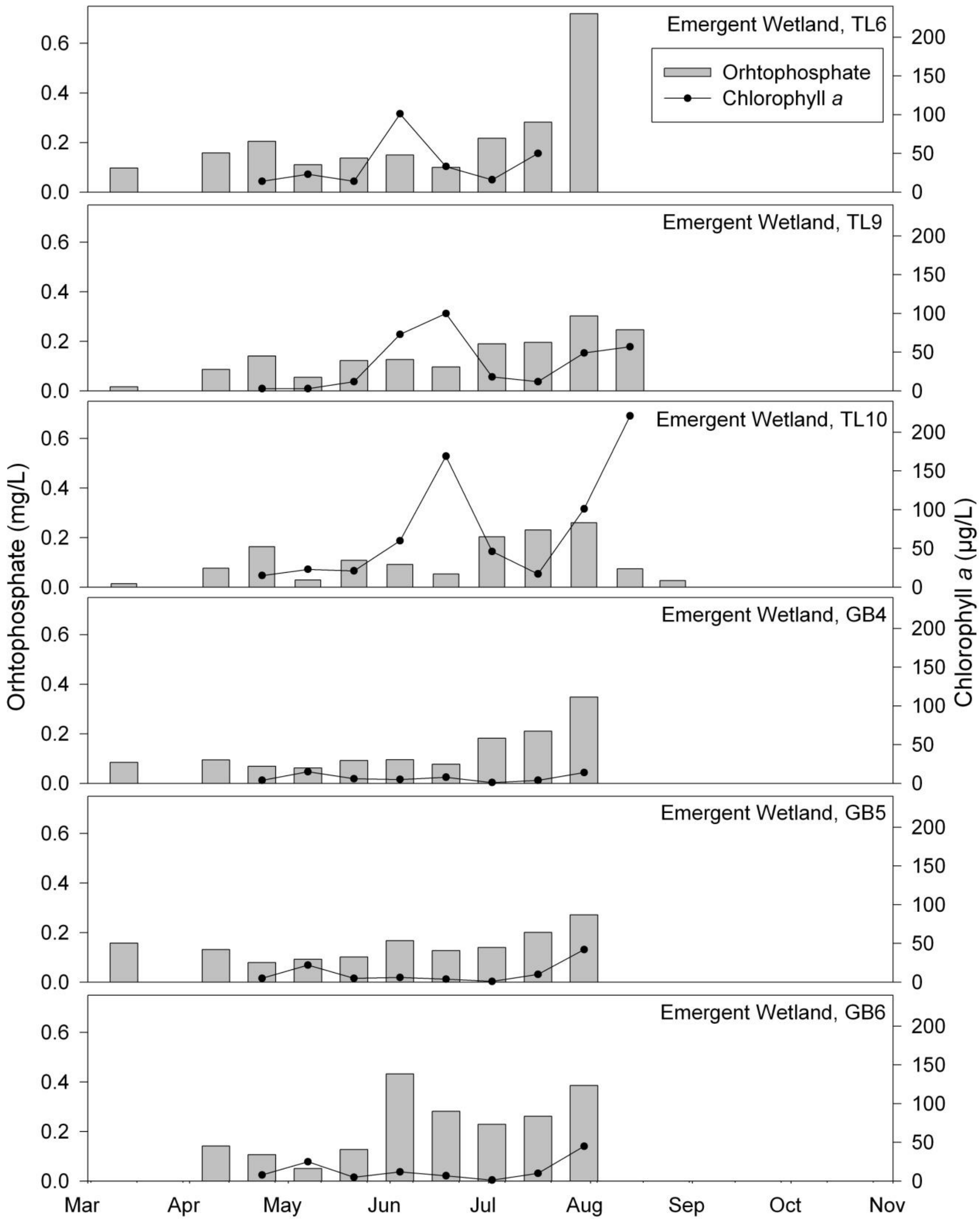
**Appendix D. Relationship between dissolved inorganic nitrogen and chlorophyll *a* concentrations at individual sampling sites in transitional and emergent wetlands from March - November 2009. Stacked bars represent ammonia and nitrate + nitrite concentrations and lines represent chlorophyll *a* concentrations. Note different scales.**



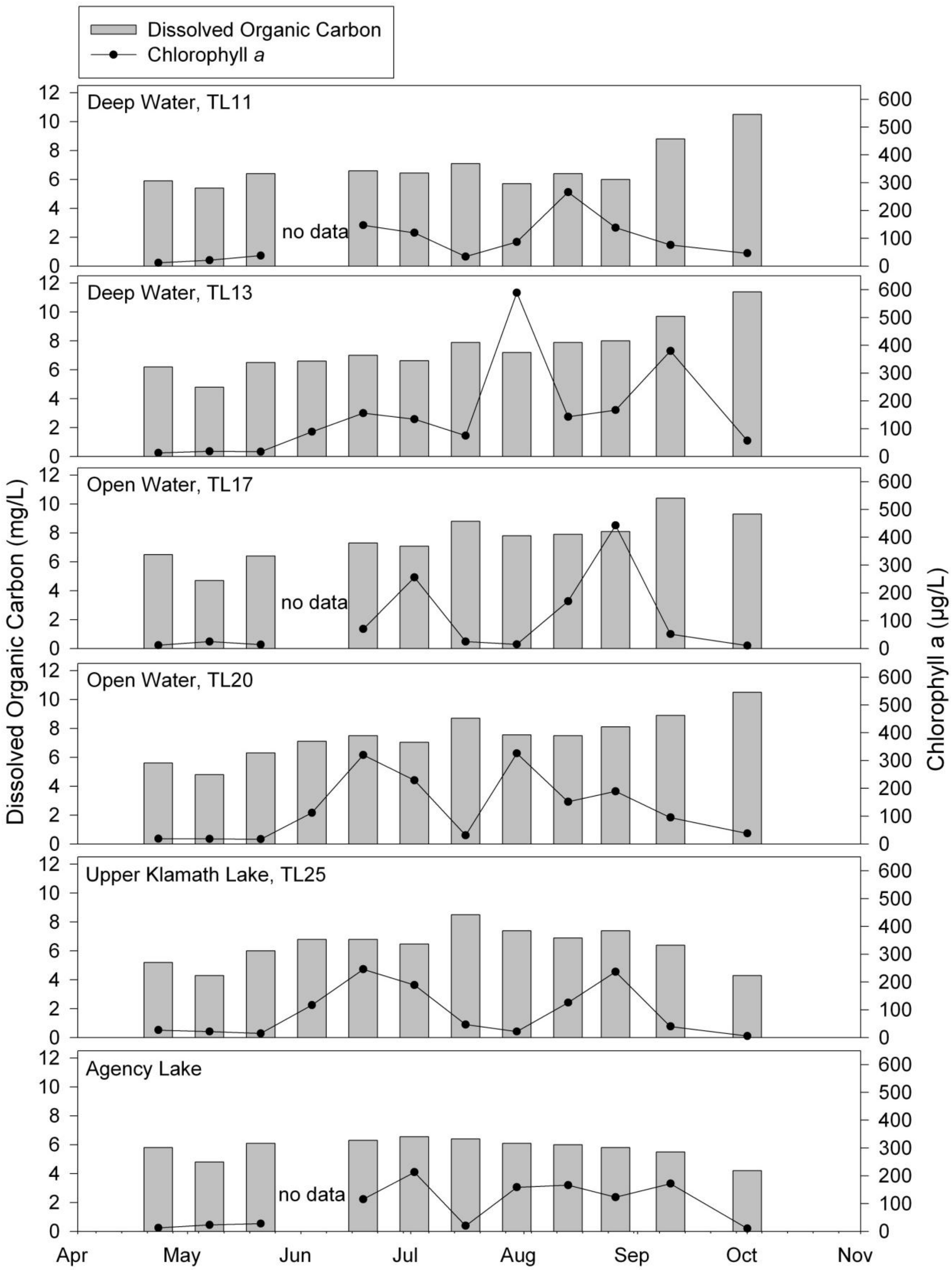

Emergent, TL6
Ammonium
Nitrate+Nitrite
Chlorophyll a
Emergent, TL9
Emergent, TL10
Emergent, GB4
Emergent, GB5
Emergent, GB6
Total Inorganic Nitrogen (mg/L)
Chlorophyll a (µg/L)
0.0
0.2
0.4
0.6
0.8
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0
50
100
150
200
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

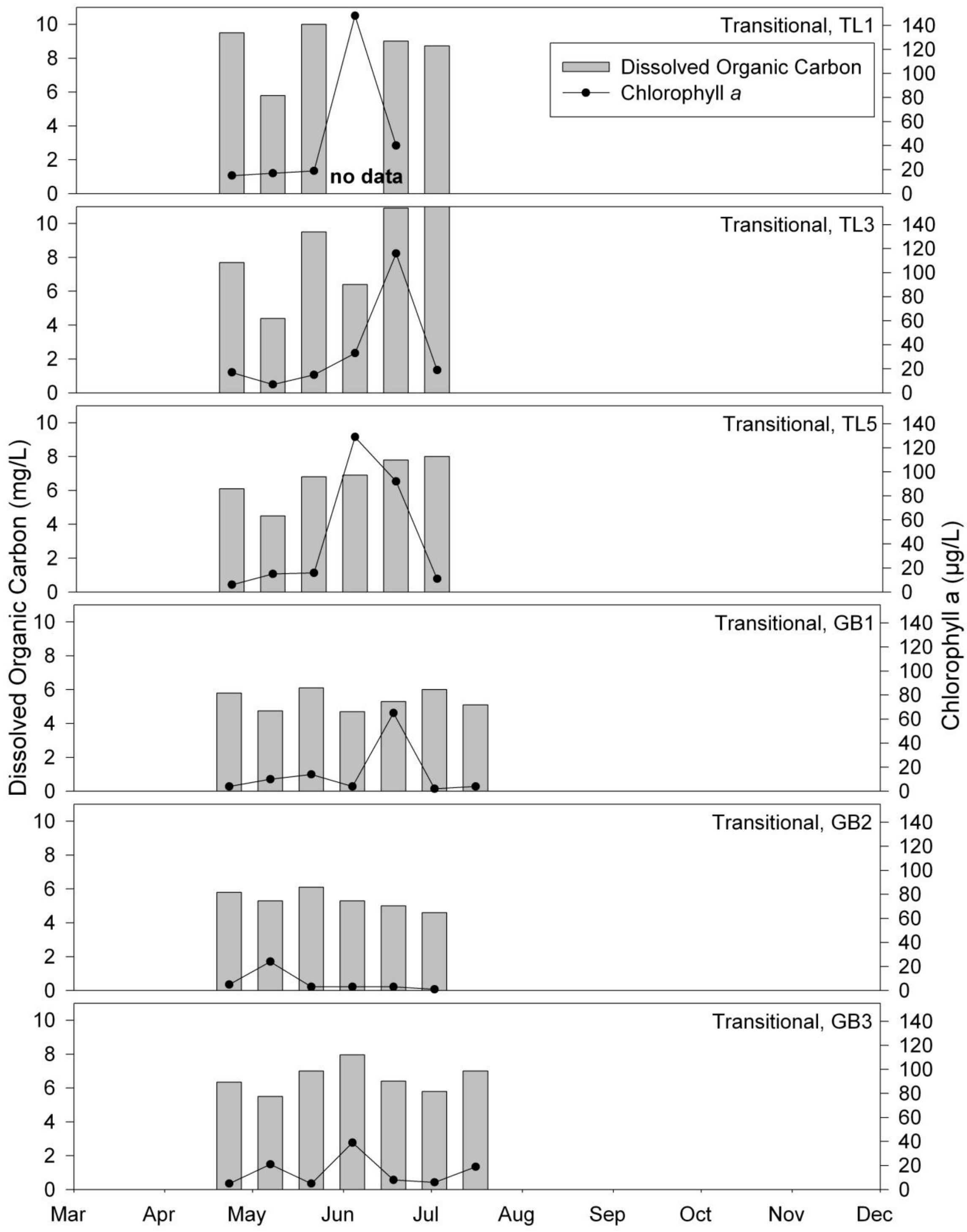
**Appendix E. Relationship between orthophosphate and chlorophyll *a* concentrations at individual sampling sites in transitional and emergent wetlands from March - November 2009. Bars represent orthophosphate concentrations and lines represent chlorophyll *a* concentrations. Note different scales.**

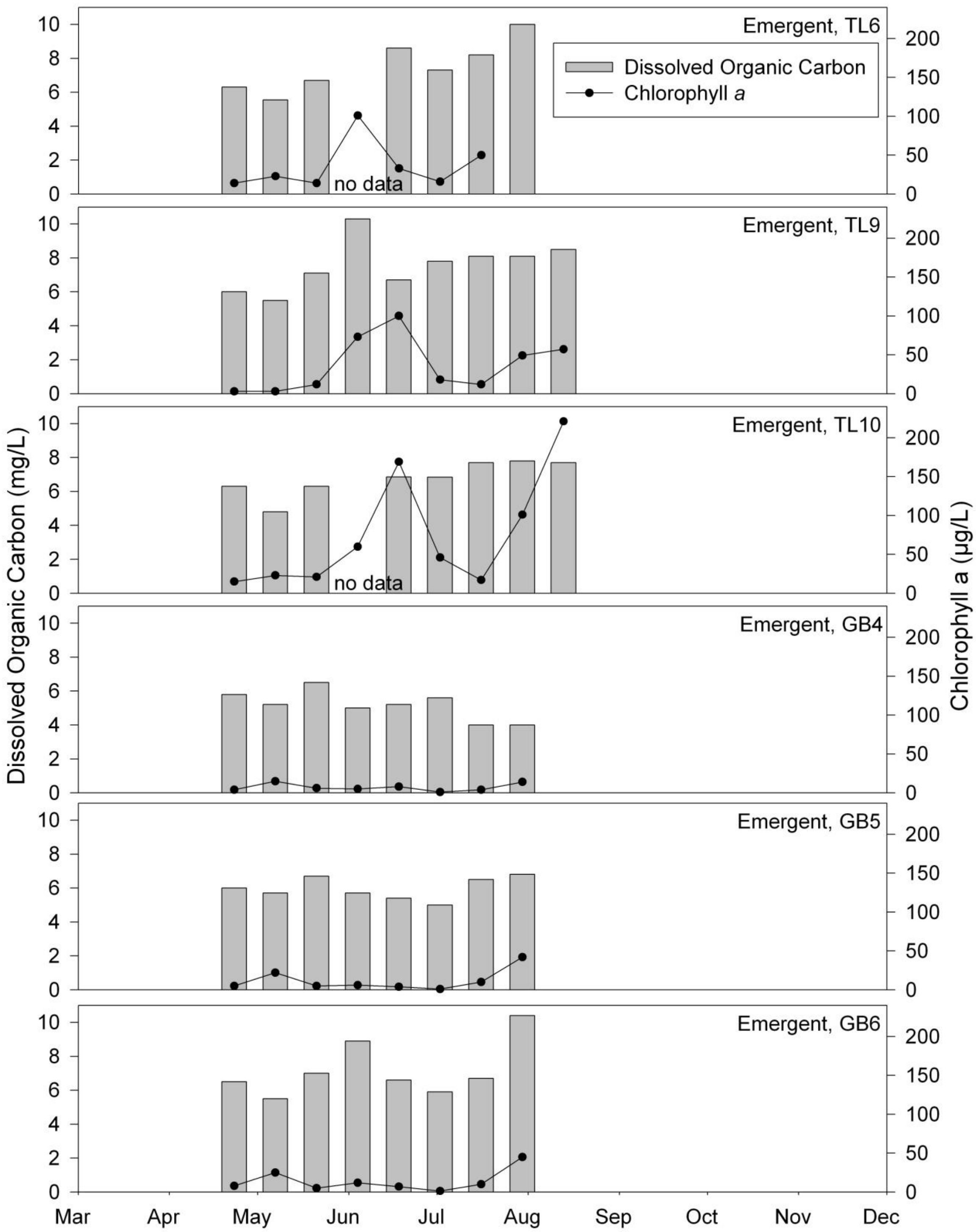



Emergent Wetland, TL6
Orhtophosphate
Chlorophyll a
Emergent Wetland, TL9
Emergent Wetland, TL10
Emergent Wetland, GB4
Emergent Wetland, GB5
Emergent Wetland, GB6
Orhtophosphate (mg/L)
Chlorophyll a (µg/L)
0.0
0.2
0.4
0.6
0
50
100
150
200
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

**Appendix F. Relationship between dissolved organic carbon and chlorophyll *a* concentrations at individual sampling sites in wetland and lake locations from March - November 2009. Bars represent dissolved organic carbon concentrations and lines represent chlorophyll *a* concentrations. Note different scales.**




Transitional, TL1
Dissolved Organic Carbon
Chlorophyll a
no data
Transitional, TL3
Transitional, TL5
Transitional, GB1
Transitional, GB2
Transitional, GB3
Dissolved Organic Carbon (mg/L)
Chlorophyll a (µg/L)
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Emergent, TL6
Dissolved Organic Carbon
Chlorophyll a
no data
Emergent, TL9
Emergent, TL10
no data
Emergent, GB4
Emergent, GB5
Emergent, GB6
Dissolved Organic Carbon (mg/L)
Chlorophyll a (µg/L)
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

**Appendix G. Quality assurance criteria for continuous water quality monitoring. Level A criteria represent the highest quality data as defined in TNC's Water Quality Monitoring Project Plan. Level B criteria represent data outside Level A criteria, but deemed acceptable for statistical analysis. Level C criteria represent data deemed unacceptable and omitted.**

| Data Quality Level | Quality Assurance Plan & Action Steps | Water Temperature | pH | Dissolved Oxygen | Specific Conductance |
|---|---|---|---|---|---|
| A | QA Criteria Met<br>Data Accepted | ± 0.5°C | ± 0.2 | ± 0.3 mg/L | ± 7% of std value |
| B | QA Criteria Not Met<br>Data Accepted; QA Reported | ± 2.0°C | ± 0.5 | ± 1.0 mg/L | ± 10% of std value |
| C | QA Criteria Not Met<br>Data Omitted; QA Reported | > ± 2.0°C | > ± 0.5 | > ± 1.0 mg/L | > ± 10% of std value |

**Appendix H. Quality assurance results for the 2009 continuous water quality monitoring season. Data meeting Level A quality assurance criteria are not shown. 'No Data' indicates that no data were recorded for all four parameters due to equipment problems.**

| Continuous Monitor Site | Data Quality Level | Parameter | Dates |
|---|---|---|---|
| Agency Lake | B | DO | 3/24/2009 - 4/7/2009 |
| Agency Lake | B | DO | 4/14/2009 - 4/21/2009 |
| Agency Lake | B | DO | 4/29/2009 - 5/8/2009 |
| Agency Lake | B | DO | 6/2/2009 - 6/9/2009 |
| Agency Lake | B | DO | 6/23/2009 - 6/30/2009 |
| Agency Lake | B | DO | 6/30/2009 - 7/7/2009 |
| Agency Lake | B | DO | 7/14/2009 - 7/21/2009 |
| Agency Lake | B | pH | 7/28/2009 - 8/4/2009 |
| Agency Lake | B | DO | 9/9/2009 - 9/15/2009 |
| Upper Klamath Lake West | B | DO | 4/29/2009 - 5/8/2009 |
| Upper Klamath Lake West | B | DO | 5/19/2009 - 5/27/2009 |
| Upper Klamath Lake West | C | DO | 10/8/2009 - 10/15/2009 |
| Upper Klamath Lake West | B | DO | 10/27/2009 - 11/3/2009 |
| Williamson River | C | DO | 3/17/2009 - 3/24/2009 |
| Williamson River | B | DO | 3/24/2009 - 3/31/2009 |
| Williamson River | B | DO | 4/7/2009 - 4/14/2009 |
| Williamson River | C | DO | 5/8/2009 - 5/13/2009 |
| Williamson River | B | DO | 6/9/2009 - 6/16/2009 |
| Williamson River | B | DO | 6/23/2009 - 6/30/2009 |
| Williamson River | B | DO | 7/21/2009 - 7/28/2009 |
| Williamson River | B | DO | 8/11/2009 - 8/20/2009 |
| Williamson River | B | DO | 8/20/2009 - 8/28/2009 |
| Williamson River | C | DO | 9/9/2009 - 9/15/2009 |
| Upper Klamath Lake East | B | DO | 3/24/2009 - 3/31/2009 |
| Upper Klamath Lake East | C | DO | 4/14/2009 - 4/21/2009 |
| Upper Klamath Lake East | B | DO | 4/21/2009 - 4/29/2009 |
| Upper Klamath Lake East | B | DO | 5/27/2009 - 6/2/2009 |
| Upper Klamath Lake East | B | DO | 6/16/2009 - 6/23/2009 |
| Upper Klamath Lake East | NO DATA | NO DATA | 7/30/2009 - 8/4/2009 |
| Upper Klamath Lake East | B | DO | 8/4/2009 - 8/11/2009 |
| Upper Klamath Lake East | B | DO | 8/20/2009 - 8/21/2009 |
| Upper Klamath Lake East | B | DO | 10/20/2009 - 10/27/2009 |
| Open Water | B | DO | 4/21/2009 - 5/8/2009 |
| Open Water | B | DO | 7/14/2009 - 7/21/2009 |
| Open Water | B | DO | 10/15/2009 - 10/20/2009 |
| Deep Water | B | DO | 4/29/2009 - 5/8/2009 |
| Deep Water | NO DATA | NO DATA | 5/26/2009 - 5/27/2009 |
| Deep Water | C | DO | 6/9/2009 - 6/16/2009 |
| Deep Water | B | DO | 7/7/2009 - 7/14/2009 |
| Deep Water | B | DO | 7/14/2009 - 7/21/2009 |
| Deep Water | B | DO | 7/21/2009 - 7/28/2009 |
| Deep Water | B | DO | 8/11/2009 - 8/20/2009 |
| Deep Water | C | DO | 8/20/2009 - 8/28/2009 |
| Deep Water | B | DO | 8/28/2009 - 9/9/2009 |
| Deep Water | B | DO | 9/22/2009 - 9/29/2009 |

| | | | |
|---|---|---|---|
| Deep Water | C | DO | 9/29/2009 - 10/8/2009 |
| Emergent | B | DO | 3/31/2009 - 4/7/2009 |
| Emergent | B | DO | 5/8/2009 - 5/13/2009 |
| Emergent | B | pH | 7/21/2009 - 7/28/2009 |
| Emergent | NO DATA | NO DATA | 8/4/2009 - 8/11/2009 |
| Transitional | B | DO | 3/31/2009 - 4/7/2009 |
| Transitional | B | DO | 4/14/2009 - 4/21/2009 |
| Transitional | B | DO | 6/23/2009 - 6/30/2009 |
| Goose Bay Emergent | C | DO | 3/17/2009 - 3/24/2009 |
| Goose Bay Emergent | B | DO | 4/14/2009 - 4/21/2009 |
| Goose Bay Emergent | B | DO | 5/19/2009 - 5/27/2009 |
| Goose Bay Emergent | B | DO | 6/2/2009 - 6/9/2009 |
| Goose Bay Emergent | B | SpC | 6/16/2009 - 6/23/2009 |
| Goose Bay Emergent | B | DO | 7/14/2009 - 7/21/2009 |