Water Quality Conditions on the Williamson River Delta, Oregon: Three Years Post-Restoration

2010 Annual Data Report

Siana Wong and Heather Hendrixson
The Nature Conservancy
Klamath Basin Field Office
226 Pine St., Klamath Falls, Oregon

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SUMMARY OF RESULTS

- Site water depths were considerably lower during the 2010 sampling year compared to previous years, with seasonal maximum depths in the wetlands ranging 0.3–0.7 m lower in 2010 compared to 2009.

- Total phosphorus concentrations were highest in the seasonally flooded emergent wetlands of Tulana during the majority of the year, compared to all other locations in the project area. Within the emergent wetlands, considerable site variability in phosphorus concentrations was observed. Phosphorus concentrations in 2010 were generally comparable to concentrations 2009 but seasonally lower than in 2007 and 2008 in the permanently flooded areas of Tulana (open and deep water wetlands).

- Total nitrogen concentrations in the permanently flooded wetlands and in Upper Klamath and Agency Lake sites appeared to correspond positively with seasonal trends in chlorophyll-a concentration, with peaks in mid-July and mid/late August. Among years, total and dissolved nitrogen concentrations exhibited inter-year variability in the wetlands.

- Seasonal trends in dissolved oxygen and pH were comparable among permanently flooded wetland and lake sites. However, relative to open water and lake sites, the deep water wetland exhibited some noticeable seasonal variability and lower dissolved oxygen concentrations during the summer months.

INTRODUCTION

The Nature Conservancy (TNC) has been monitoring water quality at the Williamson River Delta (the Delta), Oregon since its restoration in 2007. The two fundamental goals of the wetland restoration are to: (1) restore habitat for two endangered sucker species endemic to the Upper Klamath Basin—the Lost River (*Deltistes luxatus)* and shortnose (*Chasmistes brevirostris*) sucker; and (2) facilitate improvement in water quality in Upper Klamath and Agency Lakes by eliminating a continuous agricultural source of nutrients into the lake, and by nutrient removal from surface waters through wetland ecosystem processes. A post-restoration effectiveness water quality monitoring effort was initiated in 2007 with the primary objectives of: (1) measuring the extent to which the wetlands provide a source or sink of nutrients; (2) assessing the effects of the restoration on surface water chemistry in the wetlands and in the adjacent lakes; and (3) evaluating water quality conditions in relation to sucker inhabitance of the wetlands. A two-year comprehensive report for the period 2007–2009 (Wong et al. 2010) and annual reports for 2008 (Doehring et al. 2009) and 2009 (Doehring et al. 2010) have been completed. This report summarizes water quality data collected at the Delta in 2010.

STUDY AREA

The 7,500-acre Delta is situated between Upper Klamath and Agency Lakes in southern Oregon, east of the Cascade Range (Figure 1). The wetlands straddle the last four miles of the

Williamson River, draining the river as it empties into Upper Klamath Lake. Historically a naturally functioning, freshwater wetlands system, the wetlands were drained and converted for agriculture beginning in the 1940s. The entire Delta was hydrologically disconnected from Upper Klamath and Agency Lakes and the Williamson River through the construction of levees on the Delta perimeter. The Nature Conservancy initiated the restoration effort in 1996 and recently completed the restoration with the breaching of levees on the perimeter of the Delta west of the Williamson River (known as Tulana) in October 2007 and on the perimeter of the Delta east of the river (known as Goose Bay) in November 2008. Approximately 5,500 acres were re-flooded, restoring the wetlands as an open and passively managed system.

Four breaches ranging about 2,100–2,700 feet in length are located on the northwest and southwest perimeters of Tulana. Three breaches ranging about 1,000–3,000 ft in length are located on the south perimeter of Goose Bay. Three breaches ranging 500–1,700 ft are also situated along the Williamson River on both the Tulana and Goose Bay sides. Between breaches, levees were lowered to a surface elevation ranging about 4,139–4,142 ft.

Hydrology of the Delta wetlands is influenced by that of Upper Klamath and Agency Lakes and the Williamson River. Lake levels are regulated by the US Bureau of Reclamation and fluctuate about five feet through the year, with highs (~4,143 ft surface water elevation) typically in April and lows (~4,138 ft surface water elevation) typically in October. At seasonally high water levels, water overflows the majority of remaining perimeter levees. During seasonally low water levels, the wetlands are largely cut off from lake and river flows except through the perimeter breaches. Considerable soil subsidence has occurred on western portions of the Delta such that current elevations in these areas are as much as eight feet below average lake elevations (David Evans and Associates, Inc. 2005). These areas currently resemble open water conditions year-round. The overall hydrologic effect is seasonal flooding and drying of emergent and riparian wetlands in eastern portions of Tulana and in the majority of Goose Bay, and year-round inundation in the western areas of Tulana.

Vegetation across the Delta wetlands is largely influenced by water depth and flooding tolerances of various plant species. Documentation of species composition and coverage are available in TNC's vegetation monitoring report for the Delta (Elseroad et al. 2011). Four distinct habitat zones comprised of different plant communities occur along a gradient across the Delta wetlands. From shallowest to deepest, these include: transitional wetlands, emergent wetlands, deep water wetlands, and open water (Elseroad 2004) (Figure 1). Transitional and emergent wetlands are the more vegetated habitat zones, and deep water wetland and open water are the less or non-vegetated zones. Within habitat zones, vegetation was patchy during the 2010 sampling season, with some areas more sparsely covered than other areas.

METHODS

Sampling Locations

All sampling sites were fixed sites which have been monitored for surface water quality since 2008 in Tulana and 2009 in Goose Bay. In 2010, water samples were not collected at seven of the transitional wetland monitoring sites because water depths were too shallow (<0.3 m) throughout most of the year to sample, with surface lake elevation reaching a seasonal high of 4,141.57 ft in mid-June (US Bureau of Reclamation data). In 2010 only, two emergent sites in South Marsh[1] were added to the sampling effort. In total, 22 sites were sampled in 2010, including four sites in three habitat zones in Tulana (open water, deep water, emergent wetlands), three sites in one habitat zone in Goose Bay (emergent wetlands), three sites near-shore of the Delta perimeter in Upper Klamath and Agency Lakes, two sites in the Williamson River (one upstream and one downstream of the project area), and two sites in South Marsh (Figure 1). Sampling sites in the emergent wetlands were dropped in late July/August 2010 as water levels declined and sites became too shallow to sample. Nutrients and parameters collected at each site are shown in Table 1.

Multi-probe instruments (YSI 600 XLM sondes) were deployed at a subset (nine) of the 22 fixed grab sampling sites, including one in three habitat zones in Tulana (open water, deep water, emergent), one in Goose Bay in the emergent wetlands, one in the Williamson River upstream of the project area, and three in the lakes near-shore of the Delta perimeter. One site in South Marsh was incorporated into the 2010 continuous monitoring effort.

Grab Sampling

Surface water grab samples were collected for constituents of nitrogen (N), phosphorus (P), carbon (C), chlorophyll-a, and algal speciation. Nitrogen and P samples were collected at all 22 sites sampled over 16 sampling events from March–November 2010. Carbon and chlorophyll-a samples were collected at 17 of the 22 sites over 12 sampling events from April–late September 2010. Algal speciation samples were collected at 14 sites during 3 sampling events from July–September.

Field methods were similar to previous monitoring years and followed protocols detailed in TNC's Quality Assurance Project Plan (The Nature Conservancy 2008). At sites less than 1 m water depth, water was collected at mid-depth in the water column. At sites between 1–2 m deep, water was collected at mid-depth in the water column and at 0.5 m below the water surface. Sites greater than 2 m deep were sampled at 0.5 and 1 m below the water surface. Water was collected with a Van Dorn and mixed using a churn splitter before being transferred to triple-rinsed sample bottles. Quality assurance samples were also collected during each sampling event. Quality assurance results for nutrients and chlorophyll-a are presented in Appendix A. All water samples were stored in a cooler on ice at about 4°C until further processed. Other site data collected included water depth, water transparency (secchi depth), surface algal bloom (algal density measured on a 0–5 scale), and vegetation composition. Water temperature, dissolved oxygen (DO) concentration, pH, and specific conductance were also measured instantaneously at each site using an YSI 600 XLM sonde.

[1] An early action restoration project in 2003 re-connected about 170 acres of wetland located in the southeast corner of the Delta, known as South Marsh, to Upper Klamath Lake.

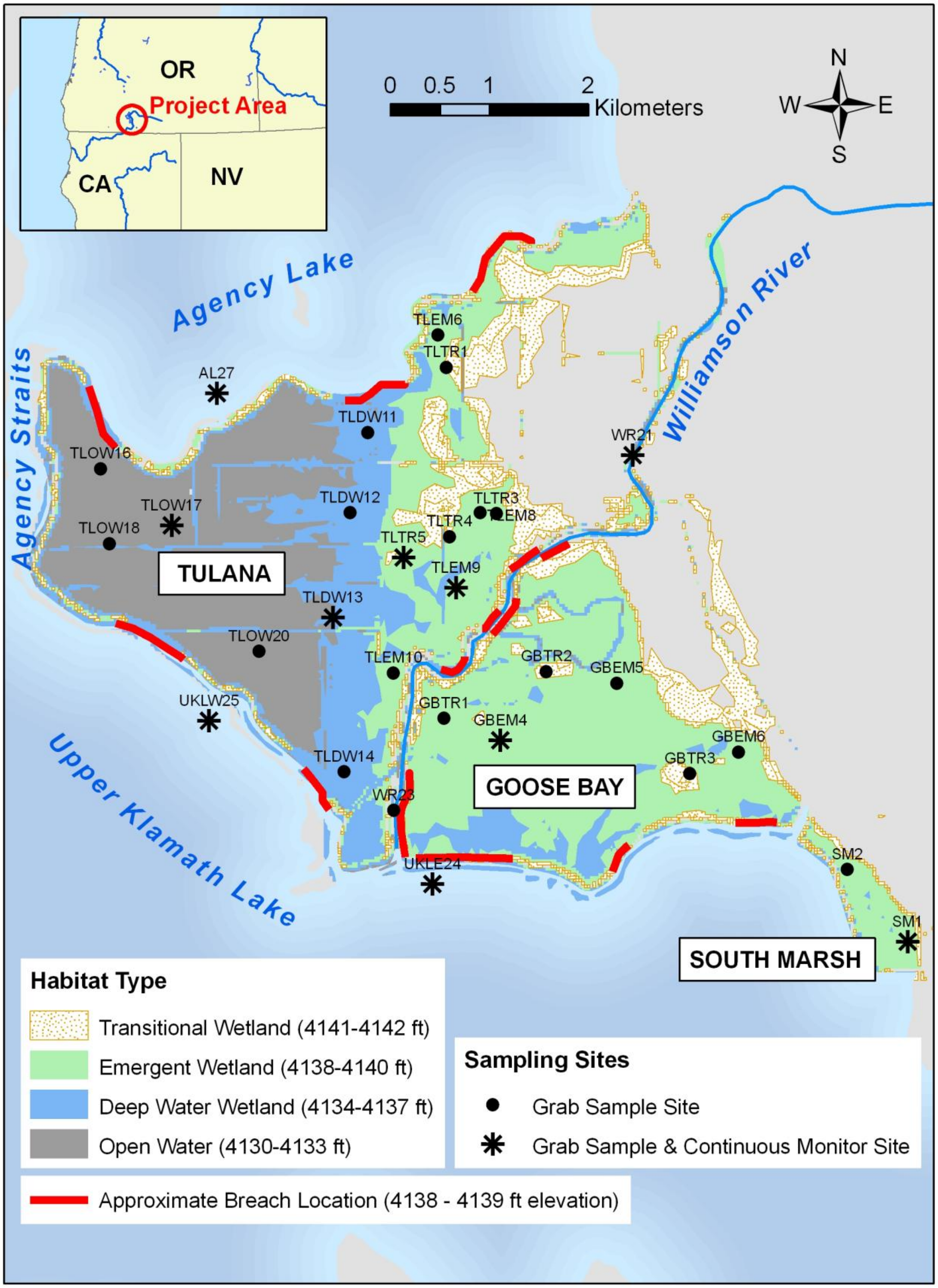

Figure 1. Map of the Williamson River Delta, Oregon showing wetland habitat types and water sampling sites. Transitional wetland sites were not sampled in 2010 because of shallow water depths (<0.3 m)

Table 1. Water quality data collected at each water sampling site in the Williamson River Delta project area in 2010. 'Sonde' denotes water temperature, dissolved oxygen concentration, pH, and specific conductance. 'X' denotes sample collected and '-' denotes sample not collected.

Location	Site ID	Habitat	Sonde	Nitrogen	Phosphorus	Carbon	Chlorophyll-a	Algal Speciation
			Hourly	16 events		12 events		3 events
			March-November			April-September		July-September
Tulana	TLTR1	Transitional Wetland	-	-	-	-	-	-
	TLTR3	Transitional Wetland	-	-	-	-	-	-
	TLTR4	Transitional Wetland	-	-	-	-	-	-
	TLTR5	Transitional Wetland	-	-	-	-	-	-
	TLEM6	Emergent Wetland	-	X	X	X	X	X
	TLEM8	Emergent Wetland	-	X	X	-	-	-
	TLEM9	Emergent Wetland	X	X	X	X	X	X
	TLEM10	Emergent Wetland	-	X	X	X	X	X
	TLDW11	Deep Water Wetland	-	X	X	X	X	X
	TLDW12	Deep Water Wetland	-	X	X	X	X	-
	TLDW13	Deep Water Wetland	X	X	X	X	X	X
	TLDW14	Deep Water Wetland	-	X	X	-	-	-
	TLOW16	Open Water	-	X	X	X	X	-
	TLOW17	Open Water	X	X	X	X	X	X
	TLOW18	Open Water	-	X	X	-	-	-
	TLOW20	Open Water	-	X	X	X	X	X
Goose Bay	GBTR1	Transitional Wetland	-	-	-	-	-	-
	GBTR2	Transitional Wetland	-	-	-	-	-	-
	GBTR3	Transitional Wetland	-	-	-	-	-	-
	GBEM4	Emergent Wetland	X	X	X	X	X	X
	GBEM5	Emergent Wetland	-	X	X	X	X	X
	GBEM6	Emergent Wetland	-	X	X	X	X	X
River	WR21	Williamson River, upstream	X	X	X	X	X	X
	WR23	Williamson River, downstream	-	X	X	-	-	-
Lake	UKLE24	Upper Klamath Lake, nearshore	X	X	X	-	-	-
	UKLW25	Upper Klamath Lake, nearshore	X	X	X	X	X	X
	AL27	Agency Lake, nearshore	X	X	X	X	X	X
South Marsh	SM1	Emergent Wetland	X	X	X	X	X	X
	SM2	Emergent Wetland	-	X	X	X	X	-

Laboratory Analysis

Samples for analysis of N and P were brought to the Klamath Tribes' Sprague River Water Quality Laboratory in Chiloquin, Oregon immediately from the field. Nitrogen and P constituents included total nitrogen (TN), nitrate+nitrite (NO_3+NO_2), ammonium (NH_4), total phosphorus (TP), and orthophosphate (PO_4). For analysis of TN and TP, approximately 120 mL of unfiltered sample water were transferred to triple-rinsed amber polyethylene bottles and acidified with 1 mL of 4.5N H_2SO_4. Samples for analysis of 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 N and P samples were stored at 4°C (±2°C) for less than 28 days. Total P and TN samples were digested using potassium persulfate, autoclaved, then analyzed on an automated spectrophotometer. Analyses of samples for PO_4, NO_3+NO_2, NO_2, and NH_4 were completed using the colorimetric method on an automated spectrophotometer (see Appendix B for Standard Method references).

Carbon samples were shipped on ice overnight and analyzed by Basic Laboratory, Inc. in Redding, California. Carbon constituents included total organic carbon (TOC) and dissolved organic carbon (DOC). Total organic C samples were pre-preserved with 4.5N H_2SO_4, and DOC samples were filtered prior to analysis. Carbon samples were analyzed using the persulfate-ultraviolet oxidation method (see Appendix B). Chloropyll-a samples were pre-preserved with 4.5N H_2SO_4 and shipped on ice overnight to be analyzed by Aquatic Research, Inc. in Seattle, Washington. Algal speciation samples were preserved with Lugol's solution on the day of sampling and analyzed by PhycoTech, Inc. in St. Joseph, Michigan.

Detection and reporting limits for nutrient constituents and chlorophyll-a are shown in Appendix B. Concentrations less than the detection limit were analyzed at half the detection limit value.

Continuous Monitoring

Hourly water temperature, DO, pH, and specific conductance data were collected using YSI 600XLM sondes deployed at nine fixed sites in the project area from March–November 2010. Sondes were placed at mid-depth in the water column or at 1 m below the water surface if water depth exceeded 2 m.

In order to reduce overlap of monitoring efforts by different entities, data collected and presented in this report during the period May 13–September 28, 2010 at TNC's Upper Klamath lake West site (UKLW25; Figure 1) were collected by the US Geological Survey (USGS), which had approximately the same site location in Upper Klamath Lake (USGS site WDW) as TNC. These water quality data were obtained from the US Geological Survey online database system for Upper Klamath Lake (US Geological Survey) and are provisional, subject to revision.

Quality assurance checks included weekly calibration of instruments, weekly site visits, and post-calibration checks. Calibration was performed the day prior to deployment of individual sondes. Weekly site visits included the following: precision checks of deployed sondes against a newly calibrated reference sonde; cleaning of deployed sondes; and re-deployment or replacement of sondes such that an individual sonde was deployed at a site for no longer than two-week intervals. Post-calibration checks were performed to verify accuracy of each sonde following a deployment. Data quality objectives adhered to requirements defined in the Quality Assurance Project Plan (The Nature Conservancy 2008). TNC's quality assurance criteria for acceptable continuous monitor data are shown in Appendix C, and quality assurance results are reported in Appendix D. All raw data were quality-checked before being accepted for statistical analysis. Daily statistics were computed only for days in which at least 20 hours of acceptable data were recorded. Statistics were generated using SAS® System for Windows, Release 9.1.3 (SAS Institute).

RESULTS

In total, 272 N and P samples, 160 C and chlorophyll-a samples, and 22 algal speciation samples were collected in 2010. Measured site water depths ranged from 0.3–1.0 m in the emergent wetlands, 1.0–2.3 m in the deep water wetlands, 1.2–2.7 m in open water, and 0.7–2.3 m in the lakes over the sampling year. Maximum water depths within all wetland habitat types in 2010 were about 0.3–0.7 m lower than maximum water depths in 2009 (1.3 m in the emergent wetlands, 3.0 m in the deep water wetlands, and 3.4 m in open water in 2009). Seasonal trends and ranges in nutrients, chlorophyll-a, and continuous monitoring parameters are reported, as well as results from algal speciation sampling. Nutrient and chlorophyll-a concentrations are also depicted spatially across the wetlands in Appendix E. Inter-annual trends in nutrient concentrations are shown in Appendix F.

Grab Sampling

Phosphorus

Total P concentrations ranged from 0.06–1.96 mg/L among wetland sites, 0.05–0.86 mg/L among lake sites, and 0.07–0.15 mg/L among river sites during the sampling period March–November 2010 (Table 2). On average over the year, PO_4 comprised about 44% TP in the wetlands, 33% TP in lakes, and 72% TP in the river.

Among habitat types, mean TP concentrations were highest in the Tulana emergent wetlands during most sampling events from March–August, while TP concentrations were lowest in the Williamson River (Figure 2a). Among emergent wetland locations, mean TP concentrations were highest in Tulana and lowest in South Marsh for most sampling events. Mean TP concentrations in the lakes, open water, and deep water wetland habitats increased noticeably beginning about early July and peaked two times in late July and late August, declining thereafter. In the Tulana and Goose Bay emergent wetlands, mean TP concentrations increased noticeably beginning about early April and peaked in late July, with some seasonal variability through the course of the sampling period. Within the Tulana emergent wetlands, noticeable site variability in TP concentration occurred during the period May–August (Figure 2a; Appendix E).

Compared to previous years of monitoring, ranges in TP and PO_4 concentrations in the deep water wetland and open water habitats were similar to ranges observed in 2009, but were seasonally lower than concentrations in 2007 and 2008 (Appendix F1). In 2010, orthophosphate concentrations at the near-shore lake sites were comparable to concentrations in 2009, but appeared seasonally lower than in 2008.

Nitrogen

Total N concentrations ranged from 0.31–6.89 mg/L among wetland sites, 0.14–9.87 mg/L among lake sites, and 0.11–1.08 mg/L among river sites (Table 2). On average over the year, dissolved inorganic N (sum of NO_3+NO_2 and NH_4 concentration) comprised about 8–10% TN among wetland, lake and river sites.

Mean TN concentrations in the lakes, open water, and deep water wetlands peaked two times in late July and late August, similar to TP. In the Tulana and Goose Bay emergent wetlands, TN concentrations appeared to peak slightly in late April/mid-May and at the end of

July before emergent sites were dropped (Figure 2a). Ammonium and NO_3+NO_2 concentrations in the wetlands and lakes generally peaked in late July and increased again beginning early September to the end of the sampling period in November. During October–November, dissolved inorganic N comprised a greater majority of TN (19–31% among all wetland, lake, and river sites) compared to the average range over the year.

Total N concentrations in 2010 were within range of values observed in 2008 and 2009; however concentrations appeared to peak later in the summer in the deep water wetland and open water habitats compared to 2008 and 2009 (Appendix F2). Ranges and trends in NO_3+NO_2 concentrations in 2010 were within range of values and similar to trends observed in 2008 and 2009 (Appendix F3). Ranges in NH_4 concentration in 2010 were comparable to previous years, except in the deep water wetland, where NH_4 concentrations in 2010 were comparable to 2009, but noticeably lower than in 2008 (Appendix F3).

Carbon

Total organic C concentrations ranged from 3.5–24.1 mg/L among wetland sites, 3.6–15.5 mg/L among lake sites, and 1–5.4 mg/L among river sites (Table 2). Carbon concentrations were below 14 mg/L among all habitats, except for a one-time occurrence in the Goose Bay emergent wetlands in mid-June (site GBEM6; 24.1 mg/L) and in Agency Lake in mid-August (site AL27; 15.5 mg/L). On average over the year, DOC comprised the majority of TOC in all habitats: 87% TOC in the wetlands; 84% TOC in the lakes; and 91% TOC in the river. Carbon concentrations were lower in the river compared to all other habitats from July–October (Figure 2b). Carbon concentrations were generally comparable among wetland and lake habitats, except in the South Marsh emergent wetlands, which had slightly higher C concentrations compared to all other habitats from July–August. The general seasonal trend in C concentration among wetland and lake habitats was an increase beginning in June toward seasonal highs in August–September.

Both total and dissolved organic C concentrations in 2010 were generally within range of values observed in 2009 in the emergent, deep water, and open water habitats; however concentrations in 2010 appeared slightly lower than in 2008 in all habitat types (Appendix F4)

Chlorophyll-a

Chlorophyll-a concentrations ranged from 0.1–454 µg/L in the wetlands, 6–1143 µg/L in the lakes, and 0.1–2.7 µg/L in the river (Table 2). Among lake sites, chlorophyll-a concentrations were below 300 µg/L, except for a one-time occurrence in late August (site AL27; 1143 µg/L). Among wetland habitats, concentrations were lower in the emergent wetlands compared to the open water and deep water wetlands beginning in July, and concentrations in the open water and deep water wetlands were overall comparable to concentrations in the near-shore lakes (Figure 2a). In the open water, deep water wetland, and lake habitats, chlorophyll-a concentration peaked two times (mid-July and mid/late August) during the sampling period. Among all habitats, TN concentration followed trends in chlorophyll-a concentration and was positively correlated to chlorophyll-a ($R=0.9$, $p<0.0001$) (Figure 2a; Appendix G). Peak timings in dissolved inorganic N concentrations generally corresponded to lows in chlorophyll-a during the period July–September (Figure 2a). Water transparency appeared to inversely correspond to chlorophyll-a concentrations during the period July–September at open water, deep water wetland, and lake sites (Figure 2b). This was not always the case in the shallow emergent wetlands, for example in South Marsh, where lower ranges in chlorophyll-a concentrations were observed and where secchi depth measurements reached the surface bottom on most sampling dates (Figure 3).

Algal Speciation

During three sampling events in July, August, and September, a total of 128 phytoplankton species were identified among all sampled sites, including 119 in the wetlands, 22 in the near-shore lakes, and 36 in the river. Phytoplankton samples collected from the lake, open water, and deep water wetland sites, and at site TLEM10 in the Tulana emergent wetlands were dominated by cyanophytes during all three events (Figure 4). At other sites, greater representation among taxonomic groups was generally observed. At site TLEM6 and WR21, samples were composed predominately of diatoms (making up >70% of the algal assemblage) during the two events sampled. At sites GBEM4, TLEM9, and SM1, samples collected in July were dominated by cyanophytes, while samples collected in August were composed primarily of diatoms. *Microcystis aeruginosa* was observed in a total of three samples collected at sites TLDW11, TLDW13, and TLOW17 on August 25, 2010 (cell concentration 18,932 cells/mL, 6,583 cells/mL, and 272 cells/mL, respectively). A list of the top 10 dominant species by major phytoplankton group (taxonomic division) is provided in Appendix H.

Above: Joanna Long conducting field work

Below: Example of bio-fouling on continuous monitors deployed in Upper Klamath Lake

Table 2. Median, minimum, and maximum concentrations of grab sampling constituents by location during the 2010 sampling year, Williamson River Delta, OR.

	Total Phosphorus (mg/L)			Orthophosphate (mg/L)		
Location/Habitat	**Med**	**Min**	**Max**	**Med**	**Min**	**Max**
Tulana- Emergent Wetland	0.33	0.09	1.96	0.17	0.02	1.27
Tulana- Deep Water Wetland	0.12	0.06	0.57	0.04	0.01	0.25
Tulana- Open Water	0.13	0.06	0.56	0.04	0.01	0.21
Goose Bay- Emergent Wetland	0.22	0.08	0.73	0.08	0.04	0.56
South Marsh Emergent Wetland	0.13	0.10	0.36	0.08	0.01	0.20
Williamson River	0.08	0.07	0.15	0.07	0.02	0.10
Lake Sites	0.09	0.05	0.86	0.02	0.00	0.25
	Total Nitrogen (mg/L)			**Nitrate+Nitrite (mg/L)**		
Location/Habitat	**Med**	**Min**	**Max**	**Med**	**Min**	**Max**
Tulana- Emergent Wetland	1.21	0.39	3.39	0.004	<0.008	0.150
Tulana- Deep Water Wetland	1.14	0.46	4.97	0.019	<0.008	0.360
Tulana- Open Water	1.24	0.50	6.89	0.018	<0.008	0.392
Goose Bay- Emergent Wetland	0.69	0.31	2.70	0.004	<0.008	0.614
South Marsh- Emergent Wetland	1.06	0.48	1.96	0.004	<0.008	0.011
Williamson River	0.28	0.11	1.08	0.008	<0.008	0.064
Lake Sites	1.02	0.14	9.87	0.009	<0.008	0.284
	Ammonium (mg/L)			**Total Organic Carbon (mg/L)**		
Location/Habitat	**Med**	**Min**	**Max**	**Med**	**Min**	**Max**
Tulana- Emergent Wetland	0.013	<0.006	0.433	5.9	3.8	10.3
Tulana- Deep Water Wetland	0.019	<0.006	0.311	7.2	4.1	12.0
Tulana- Open Water	0.022	<0.006	0.290	7.6	4.6	13.0
Goose Bay- Emergent Wetland	0.007	<0.006	0.121	5.6	3.5	24.1
South Marsh- Emergent Wetland	0.014	<0.006	0.175	8.1	4.7	12.6
Williamson River	0.013	<0.006	0.023	1.6	1.0	5.4
Lake Sites	0.020	<0.006	0.489	6.1	3.6	15.5
	Dissolved Organic Carbon (mg/L)			**Chlorophyll-a (µg/L)**		
Location/Habitat	**Med**	**Min**	**Max**	**Med**	**Min**	**Max**
Tulana- Emergent Wetland	5.4	3.7	9.2	14	2.1	84
Tulana- Deep Water Wetland	6.1	3.8	9.1	46	4.8	417
Tulana- Open Water	6.6	4.3	9.4	55	2.1	454
Goose Bay- Emergent Wetland	4.9	3.5	9.5	8.5	0.1	93
South Marsh- Emergent Wetland	8.1	4.5	12.7	14.5	0.1	33
Williamson River	1.6	0.9	4.8	0.8	0.1	2.7
Lake Sites	6.1	3.7	8.3	55	6	1143

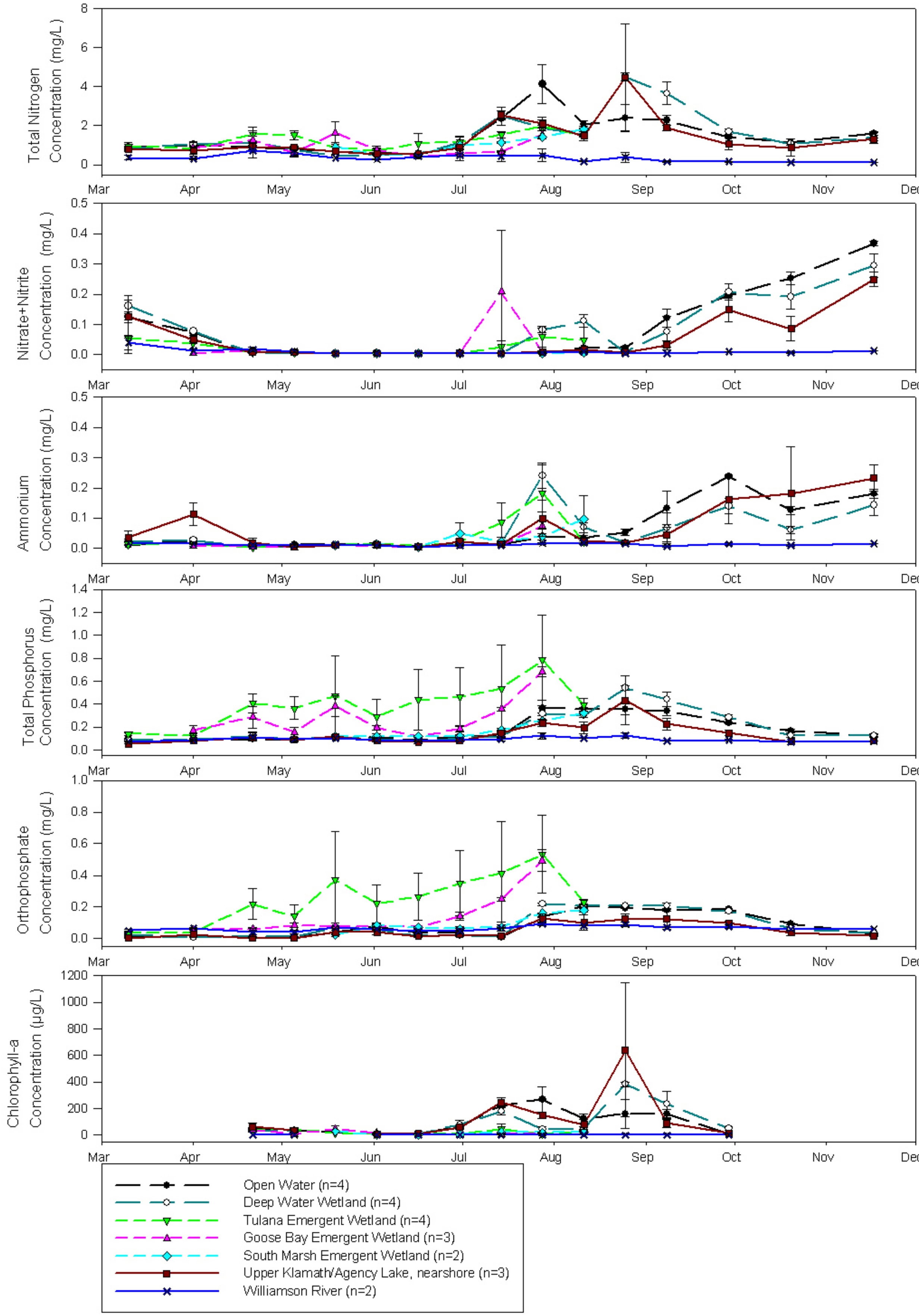

Figure 2a. Seasonal trends in grab sample constituents, Williamson River Delta, OR, 2010. Shown are means (± standard error) by location/habitat and sampling event.

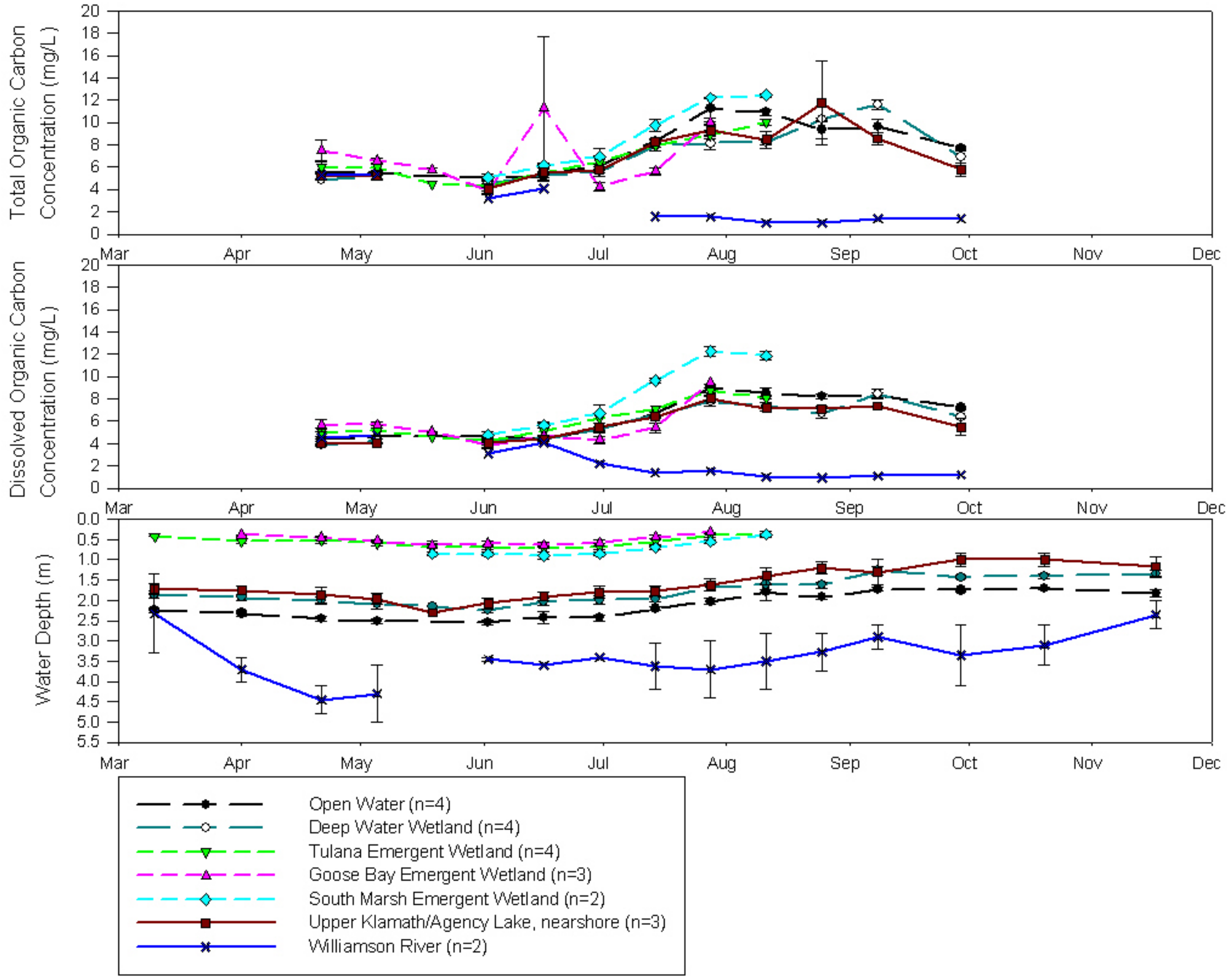

Figure 2b. Seasonal trends in grab sample constituents and water depth, Williamson River Delta, OR, 2010. Shown are means (± standard error) by location/habitat and sampling event.

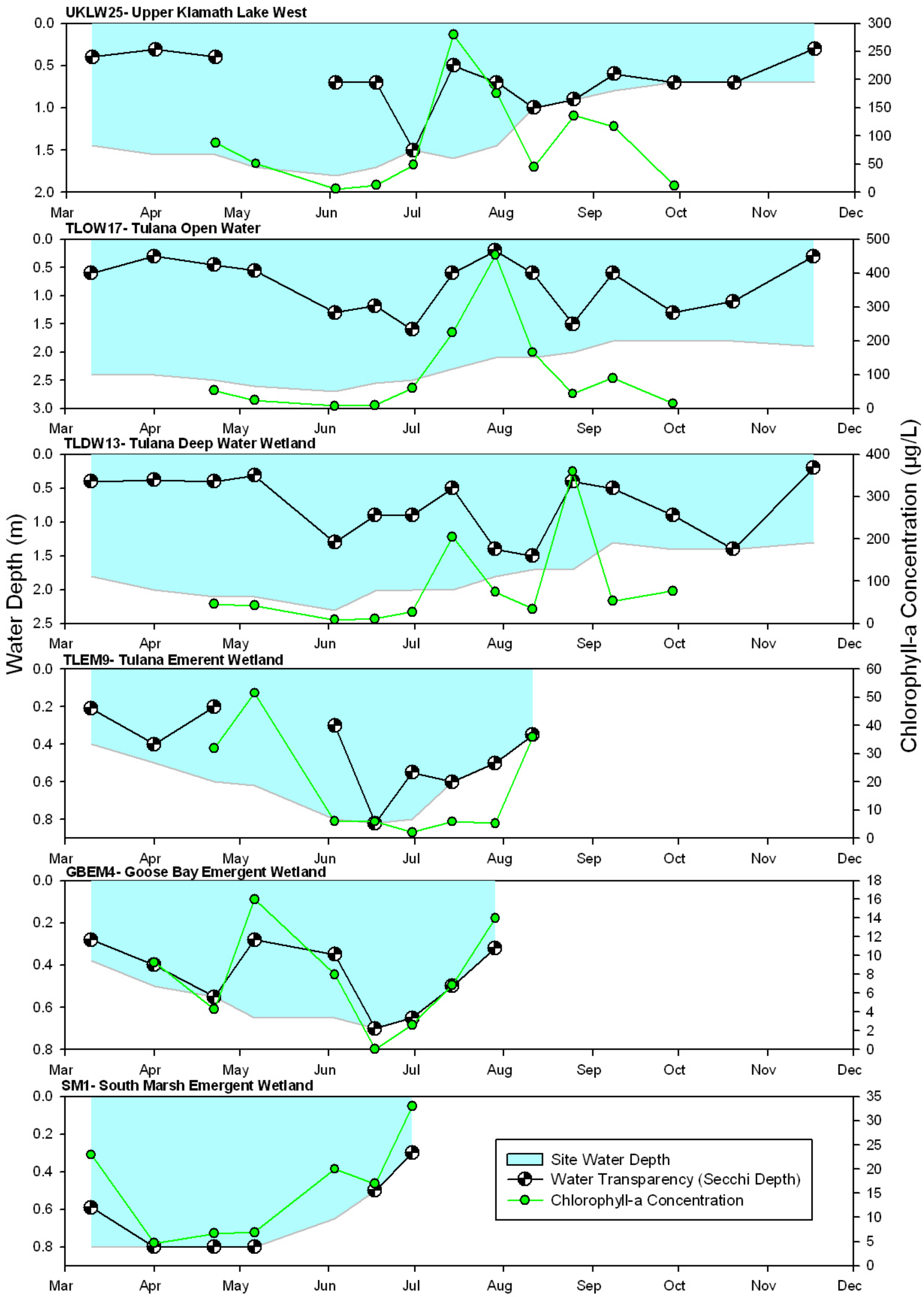

Figure 3. Seasonal trends in water transparency (secchi depth) in relation to chlorophyll-a concentrations at selected sites, Williamson River Delta, OR, 2010.

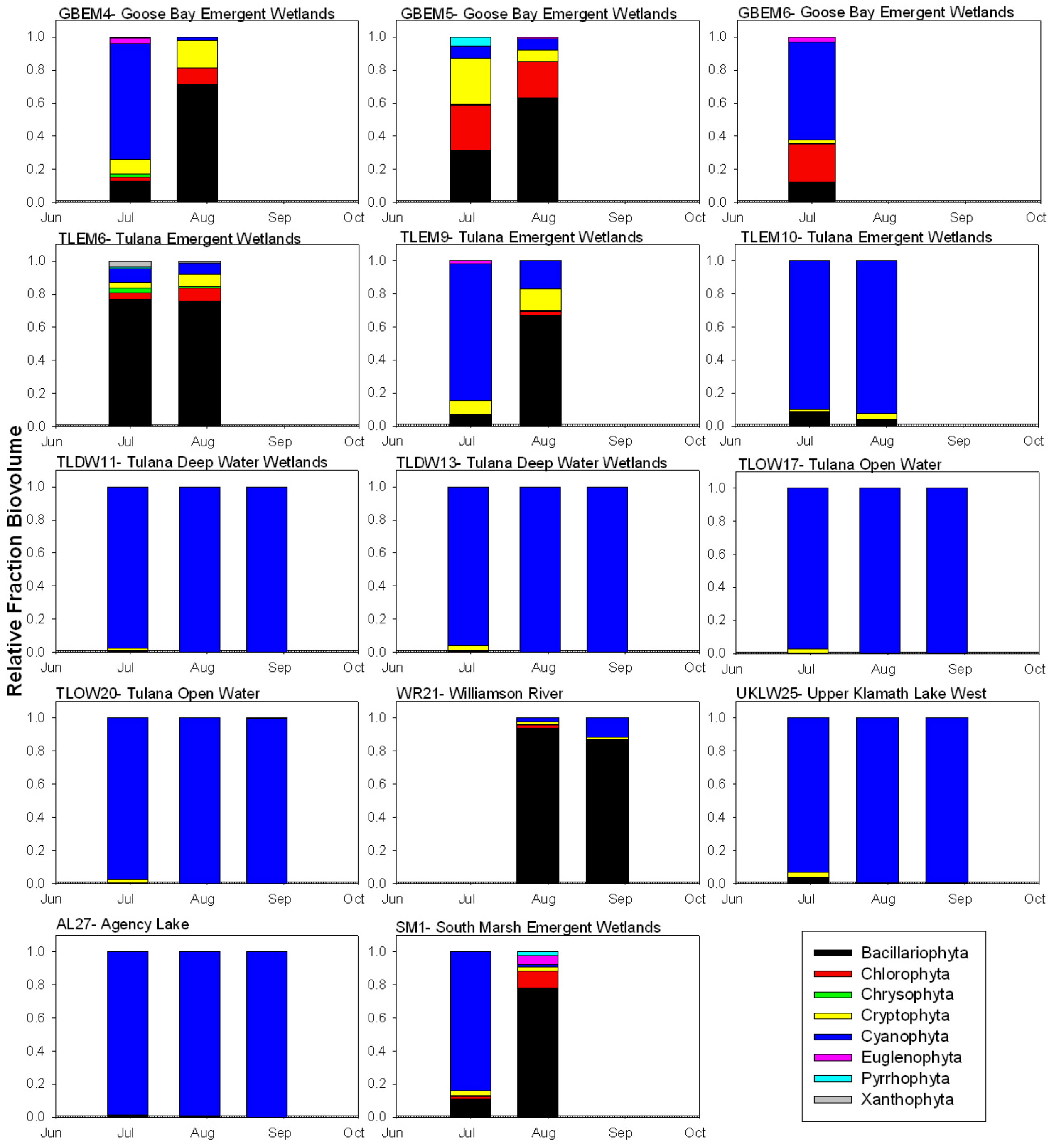

Figure 4. Relative fraction biovolume of major phytoplankton groups during 3 sampling events at sites sampled for algal speciation, Williamson River Delta, OR, 2010.

Continuous Monitoring

Seasonal Trends

Water temperatures from March–November ranged from 1.6–29.6 °C among all sites (Table 3). Temperatures were generally highest in the shallow emergent wetlands and lowest in the river. During the period May–June, water temperatures were on average 1.1°C higher in the emergent wetlands compared to river temperatures, and 0.8°C higher than lake temperatures. From July–September, water temperatures in the emergent wetlands were on average 7.6°C higher than river temperatures, and 3.5°C higher than lake temperatures. The maximum recorded temperature among all sites was reached on July 24 in the Goose Bay emergent wetlands (29.6°C). Maximum temperature in the Williamson River was reached on June 28 (20.4°C) and at the lake sites in late July (26.1–27.6°C). In the deep water wetland, the maximum recorded temperature occurred on August 14, about 2–4 weeks later than in other habitat types.

Dissolved oxygen concentrations were variable throughout the year with concentrations ranging 0.1–21.0 mg/L in the wetlands, 1.2–23.8 mg/L in the lakes, and 7.9–12.2 mg/L in the river (Table 3). Dissolved oxygen concentrations below 1 mg/L were reached in the deep water wetland, Tulana emergent wetland, and South Marsh emergent wetland. At lake, open water, and deep water wetland sites, two peaks and crashes were observed during the year, with peaks in early-mid July and mid-late August corresponding to peaks in chlorophyll-a concentrations (Figures 5 & 2a). In the month of August, daily median DO concentration in the deep water wetland was on average about 3.3 mg/L lower than in the lake sites and about 2.7 mg/L lower than in open water.

Table 3. Median, minimum, and maximum values in continuous monitoring variables at continuous monitoring sites, Williamson River Delta, OR, 2010.

Location/Habitat	**Water Temperature (°C)**			**Specific Conductance (µS/cm)**			**Dissolved Oxygen (mg/L)**			**pH**		
	Med	**Min**	**Max**	**Med**	**Min**	**Max**	**Med**	**Min**	**Max**	**Med**	**Min**	**Max**
Agency Lake (AL27)	14.0	2.3	26.3	115	94	149	9.8	1.7	23.8	7.9	6.7	10.5
Upper Klamath Lake West (UKLW25)	14.3	1.6	27.6	114	89	158	9.9	1.2	23.6	8.0	6.6	10.5
Upper Klamath Lake East (UKLE24)	13.0	1.6	26.1	107	82	138	9.9	3.2	19.0	8.0	6.9	10.2
Williamson River (WR21)	11.6	3.7	20.4	92	76	102	10.0	7.9	12.2	7.9	7.2	8.7
Open Water (TLOW17)	14.4	2.6	26.0	121	99	151	9.2	1.7	21.0	7.9	6.7	10.4
Deep Water Wetland (TLDW13)	14.4	2.0	25.8	119	96	159	9.0	0.9	18.8	7.8	6.8	10.4
Tulana Emergent Wetland (TLEM9	15.7	3.4	29.2	113	80	174	9.1	0.7	18.7	7.7	7.1	10.0
Goose Bay Emergent Wetland (GBEM4)	14.8	2.9	29.6	96	79	140	9.8	2.9	17.1	8.0	7.1	9.8
South Marsh Emergent Wetland (SM1)	19.4	7.4	28.7	125	106	184	8.4	0.1	18.0	7.8	6.6	9.6

Among all sites, pH ranged from 6.6–10.5 throughout the year, with values reaching above 10.0 at all sites except in the Williamson River, Goose Bay emergent wetlands, and South Marsh (Table 3). At lake, open water, and deep water wetland sites, two distinct peaks were observed during the year (early-mid July and mid-late August), similar to peak timing in dissolved oxygen concentration (Figure 5). A noticeable increase in pH also was observed earlier in the year in April at lake, open water, and deep water wetland sites, with peaks occurring in late April. Peak values during this period were lower compared to later in the summer.

Specific conductance values ranged from 79–184 µS/cm in the wetlands, 82–158 µS/cm in the lakes, and 76–102 µS/cm in the river (Table 3). The lowest values and range in values occurred in the river, while the highest values and range in values occurred in the emergent wetlands. In general, specific conductance values in the emergent wetlands increased noticeably beginning about mid-late June, with maximum values reached just before the sites were dropped in July/August (Figure 5). Specific conductance values in the lakes, open water, and deep water wetlands gradually increased beginning in mid-April and peaked in mid-July and mid-October.

Diel Trends

Examination of diel trends in water quality parameters show wide fluctuations in DO concentrations within a 24-hour period in all habitats except in the river. Daily fluctuations in DO concentrations at lake and wetland sites were greatest during the summer months of July and August (Figure 6). Dissolved oxygen concentrations generally peaked later in the day (5–7 pm) at most sites, while low DO concentrations were observed in the morning (7–9 am). Wide fluctuations in water temperature were observed in the emergent wetlands, with mean daily fluctuations of about 7°C during the months of July and August (Figure 7). Water temperatures at lake, open water, and deep water wetland sites experienced daily fluctuations of roughly 1–3°C.

High Stress Threshold Conditions for Endangered Suckers

Water quality was examined in relation to conditions of water temperature, DO, and pH potentially threatening to the health of endangered Lost River and shortnose suckers in Upper Klamath Lake. Based on Loftus (2001), conditions in which high stress thresholds for suckers are reached include water temperature>28°C, DO<4 mg/L, and pH>9.7. The seasonal timing and duration, location, and severity of these conditions in the wetlands and near-shore lakes are described.

Threshold exceedances did not occur for any of the three parameters in the Williamson River. Temperature exceedances occurred only in the Tulana and Goose Bay emergent wetlands, reaching up to 21% and 25% of the day, respectively, in mid-late July.

Exceedances of the pH threshold were observed in all lake and wetland habitats except in South Marsh (Figure 8). However, conditions were not severe (prolonged during the day) nor did they persist through the season in the Tulana and Goose Bay emergent wetlands and the Upper Klamath Lake East site near the river mouth. Conditions were most severe at the Agency Lake, Upper Klamath Lake West, open water, and deep water wetland sites, with conditions of pH>9.7 persisting throughout the day (up to 100% of the day) and through the month of July. In

Agency Lake, conditions exceeded the pH threshold in late August, however this trend was not observed at the other lake or wetland sites.

Exceedances of the DO threshold were observed in all lake and wetland sites, although conditions were neither severe nor persistent through the season in the Upper Klamath Lake East and Goose Bay emergent wetland sites (Figure 9). Conditions were most severe in the lake, open water, and deep water wetland sites in late September, with conditions of DO<4 mg/L reaching 100% of the day in the open water and deep water wetland. In the deep water wetland, conditions of low DO (<4 mg/L for 50–100% of the day) persisted from late July to mid-August, different from the lake and open water sites. Severe low DO conditions also occurred in the emergent wetlands of Tulana and South Marsh from mid–late July.

Above: Vegetation at water quality sampling site, TLEM6 (photo taken 6/27/2008)

Below: Vegetation at water quality sampling site, TLEM8 (photo taken 6/29/2009)

Left: Water quality sampling site, TLTR5 (photo taken 5/19/2010)

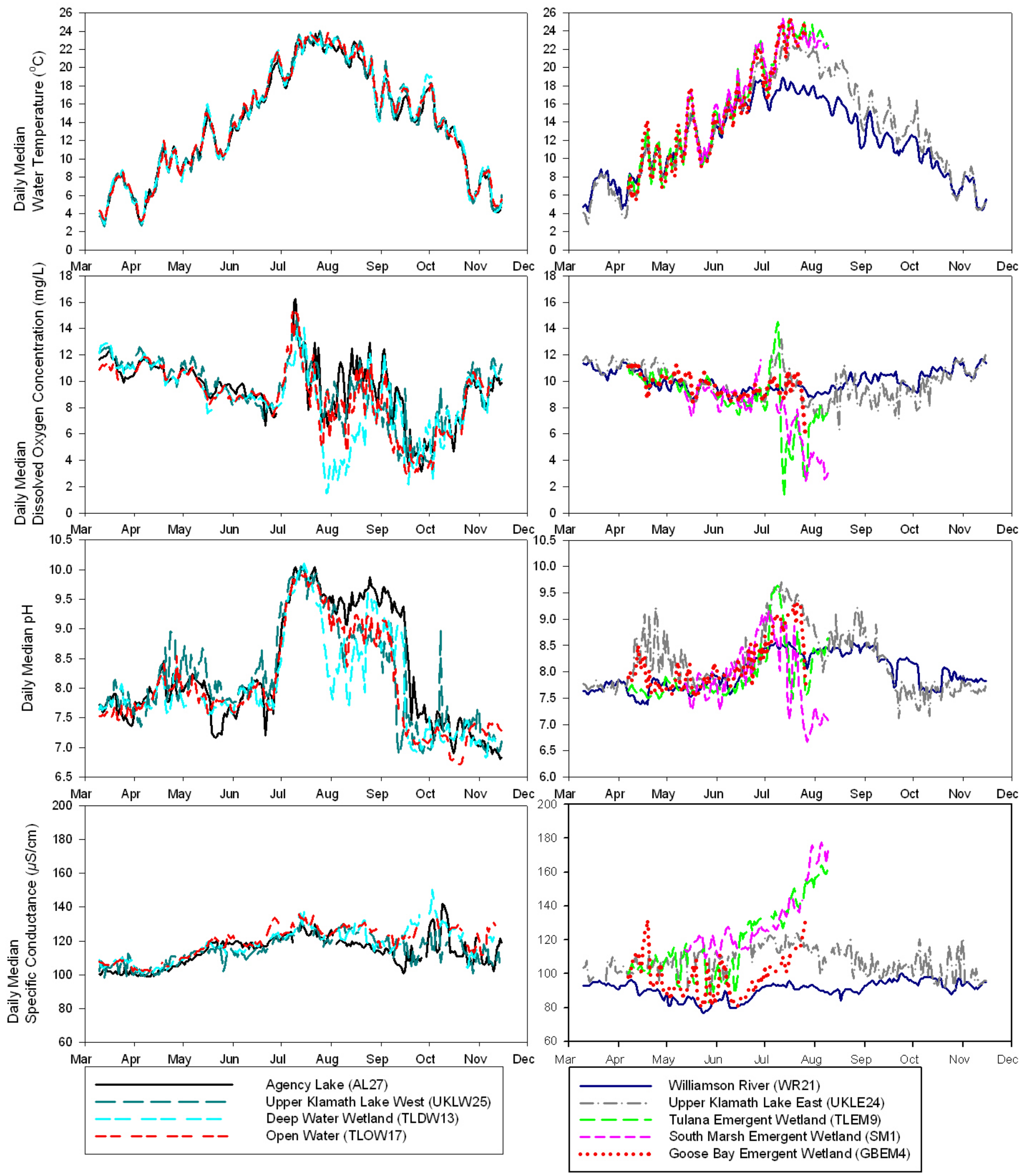

Figure 5. Seasonal trends in continuous monitoring variables at continuous monitoring sites, Williamson River Delta, OR, 2010.

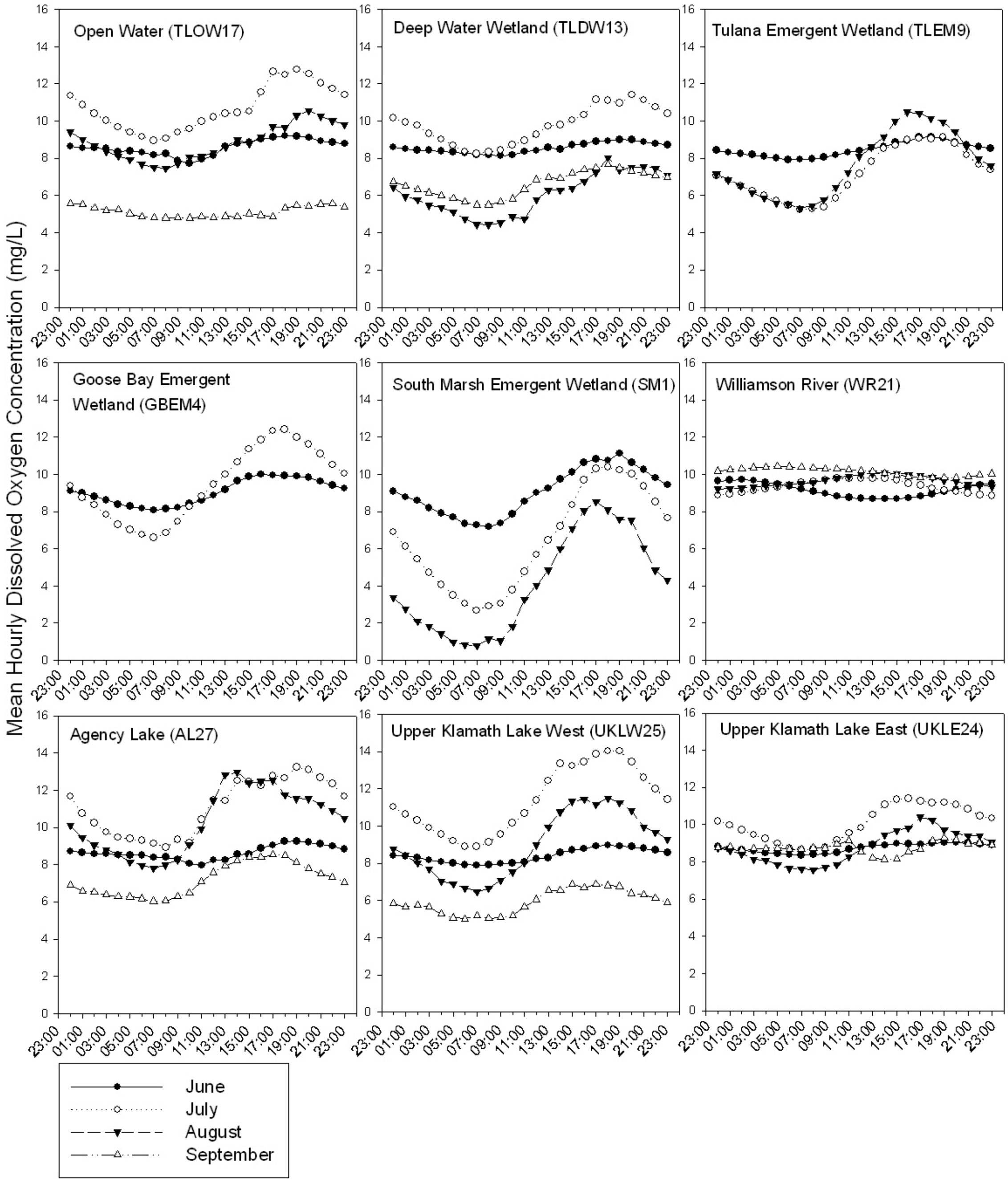

Figure 6. Diel trends in dissolved oxygen concentration at continuous monitoring sites during the period June–September 2010, Williamson River Delta, OR.

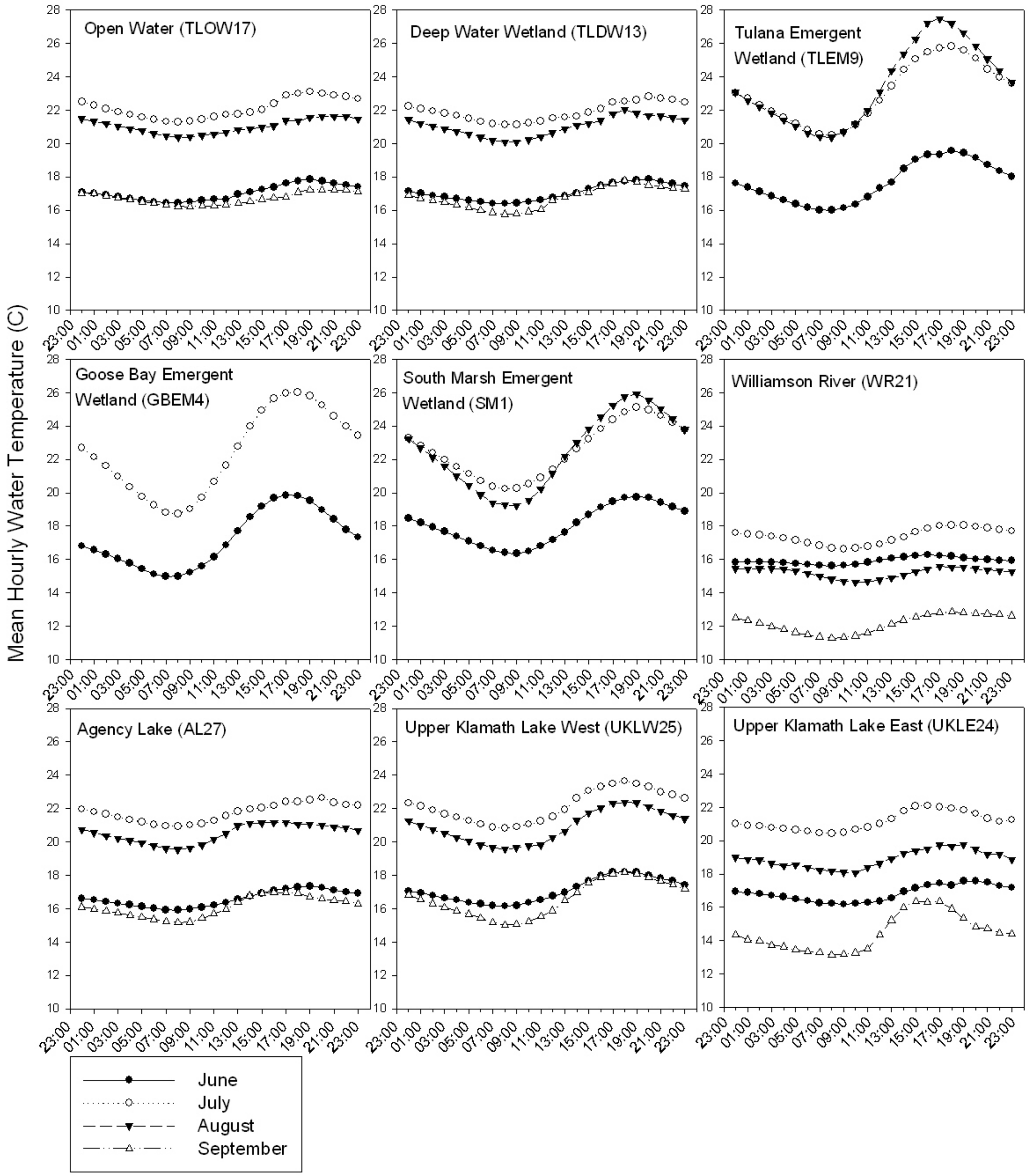

Figure 7. Diel trends in water temperature at continuous monitoring sites during the period June–September 2010, Williamson River Delta, OR.

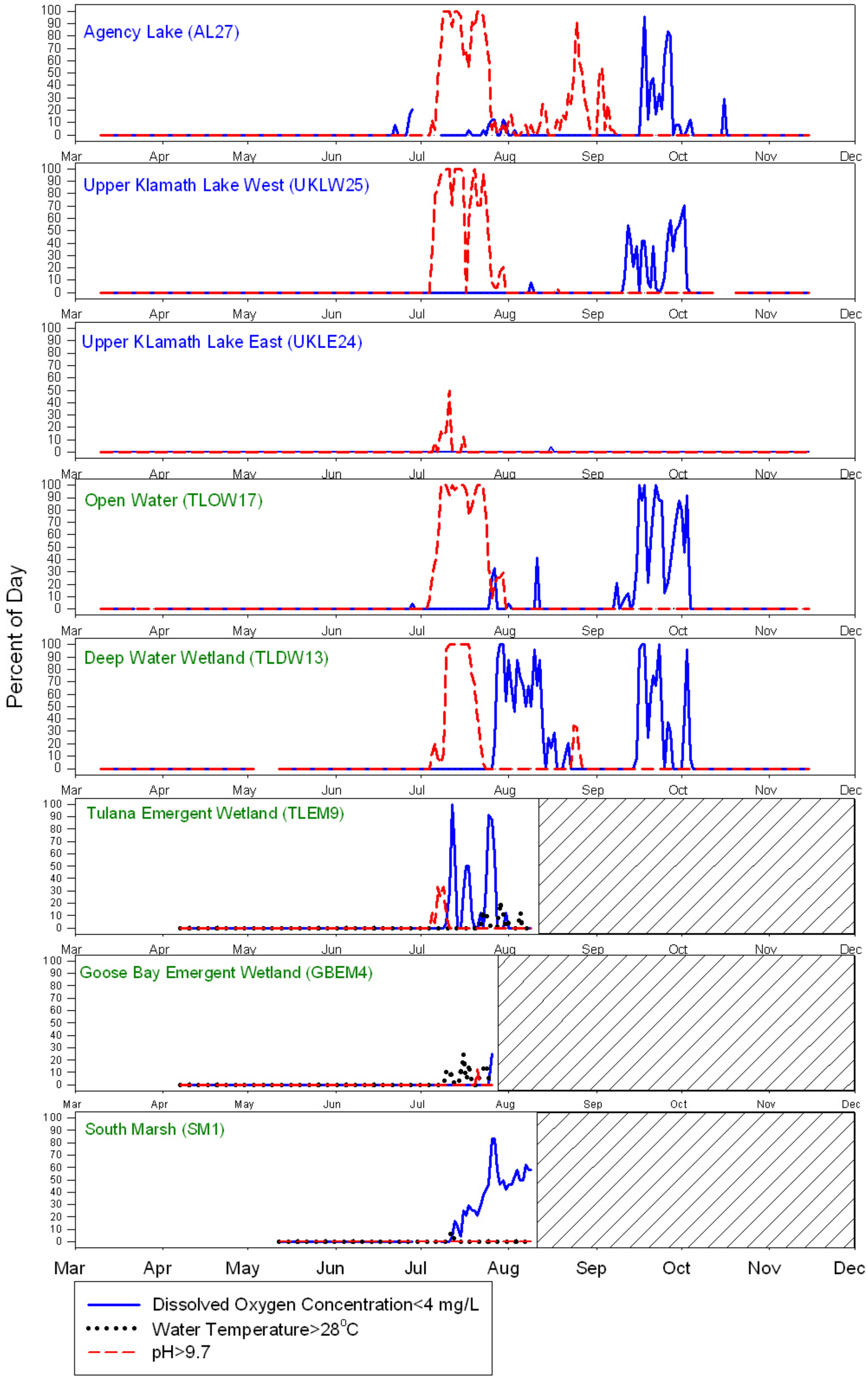

Figure 8. Location, timing, and duration of water quality conditions potentially harmful to Lost River and shortnose suckers (Loftus 2001), Williamson River Delta, OR, 2010. Hatched areas indicate discontinuation of monitoring for the season.

DISCUSSION & CONCLUSION

In general, trends in nutrient and chlorophyll-a concentrations in the permanently flooded wetlands exhibited seasonal variation typical of bloom and crash cycles of AFA, while trends in the shallow emergent wetlands exhibited seasonal and spatial variation that may be associated with various factors not discussed in this report (e.g. water depth, vegetation, soils, hydrology). Particularly in the permanently flooded wetlands, algal dynamics appeared to be a main factor exerting control on seasonal trends in water chemistry including DO and pH—trends typical of Upper Klamath and Agency Lakes (Lindenberg et al. 2008). Consequently, DO and pH values in the permanently flooded wetlands reached conditions potentially stressful to the health of endangered suckers during the summer and fall months, generally similar to conditions in the lakes (Loftus 2001). Dissimilar to the near-shore lakes and other wetland habitat types, low DO concentrations (<4/mg/L) persisting for over 50% of a 24-hour period were consistently observed in the deep water wetland from late July to mid-August. The exact cause is unknown, but may be related to the spatial and seasonal patterns of hydrologic flow through the Delta wetlands, the lingering effects of initially flooding the wetland soils in 2007, benthic influences on surface water quality, or some combination of these and other factors.

Compared to previous years of monitoring, seasonal trends and ranges in phosphorus concentration in 2010 were similar to those in 2009, but lower than in 2008 and 2007. It appears that the large, benthic pulse of nutrients associated with initially re-flooding the wetlands has diminished since 2007 and 2008 (Aldous et al. 2007, Wong et al. 2010). However, data collected by the USGS from pore-water samplers deployed at sites representing a small area of the wetlands have shown that the wetlands continued to exhibit a positive benthic flux of phosphorus in 2010 (J. Kuwabara, USGS, personal communication). Quantifying an accurate load from the wetlands as a whole since 2008 may be difficult or impossible because of the hydrologic connectivity and spatial complexity of the wetlands. Despite this, it is reasonable to speculate based on data collected from the past 3 ½ years of monitoring that the wetlands are continuing to transition toward a more equilibrium state with the surrounding lakes and river in terms of surface water chemistry.

This report summarizes results from the third full year of post-restoration water quality monitoring at the Williamson River Delta. A more comprehensive report will be presented upon project completion in 2012.

ACKNOWLEDGMENTS

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APPENDICES

Appendix A1. Quality assurance results for nutrient and chlorophyll-a samples collected in 2010.

Split Samples	Number of Samples		% Total Samples	Difference between splits	
Analyte	Splits	Total		Median (mg/L)	Median (Relative Percent Difference)
Total Phosphorus	25	272	9%	0.007	5.2
Orthophoshate	25	272	9%	0.001	3.0
Total Nitrogen	25	272	9%	0.03	4.2
Ammonia	25	272	9%	0.001	9.5
Nitrate + Nitrite	25	272	9%	0	0
Chlorophyll *a*	19	160	12%	0.002	6.6
Total Organic Carbon	17	160	11%	0.2	3.3
Dissolved Organic Carbon	17	160	11%	0.1	2.2

Duplicate Samples	Number of Samples		% Total Samples	Difference between duplicates	
Analyte	Duplicates	Total		Median (mg/L)	Median (Relative Percent Difference)
Total Phosphorus	16	272	6%	0.01	4.3
Orthophoshate	16	272	6%	0.001	2.2
Total Nitrogen	16	272	6%	0.06	4.2
Ammonia	16	272	6%	0.002	7.2
Nitrate + Nitrite	16	272	6%	0.00	0.0

Lab Blanks	Number of Samples		% Total Samples	Minimum Reporting Level (mg/L)	Value of blank samples greater than reporting limit
Analyte	Blank	Total			Maximum (mg/L)
Total Phosphorus	2	272	0.7%	0.036	NA*
Orthophoshate-P	2	272	0.7%	0.006	NA
Total Nitrogen	2	272	0.7%	0.06	NA
Ammonia	2	272	0.7%	0.012	NA
Nitrate + Nitrite	2	272	0.7%	0.016	NA
Chloropyhll a	2	160	1.3%	0.0001	NA
Total Organic Carbon	2	160	1.3%	0.5	NA
Dissolved Organic Carbon	2	160	1.3%	0.5	NA

*NA=Not applicable, values below RL

Appendix A1, continued.

Equipment Blanks	**Number of Samples**		**% Total Samples**	**Minimum Reporting Level (mg/L)**	**Value of blank samples greater than reporting limit**
Analyte	**Blank**	**Total**			**Maximum (mg/L)**
Total Phosphorus	1	272	0.4%	0.036	NA*
Orthophoshate-P	1	272	0.4%	0.006	NA
Total Nitrogen	1	272	0.4%	0.06	NA
Ammonia	1	272	0.4%	0.012	NA
Nitrate + Nitrite	1	272	0.4%	0.016	NA

*NA=not applicable, values below RL

Rinsate Blanks	**Number of Samples**		**% Total Samples**	**Minimum Reporting Level (mg/L)**	**Value of blank samples greater than reporting limit**
Analyte	**Blank**	**Total**			**Maximum (mg/L)**
Total Phosphorus	3	272	1%	0.036	NA*
Orthophoshate-P	3	272	1%	0.006	NA
Total Nitrogen	3	272	1%	0.06	NA
Ammonia	3	272	1%	0.012	NA
Nitrate + Nitrite	3	272	1%	0.016	NA

*NA=not applicable, values below RL

Spike Samples	**Number of Samples**		**% Total Samples**	**Recovery < 80% (% Spike Samples)**	**Recovery>120% (% Spike Samples)**
Analyte	**Spikes**	**Total**			
Total Phosphorus	25	272	9%	48%	4%
Orthophoshate	25	272	9%	32%	4%
Total Nitrogen	25	272	9%	56%	4%
Ammonia	25	272	9%	28%	0%
Nitrate + Nitrite	25	272	9%	20%	0%

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

Constituents	Detection Limit (mg/L)	Reporting Limit (mg/L)	Standard Method	Laboratory
Total Phosphorus	0.018	0.036	SM4500-P H	Sprague River Water Quality Laboratory, OR
Orthophosphate	0.003	0.006	SM4500- PF	
Ammonia	0.006	0.012	MD Krom methods	
Nitrate + Nitrite	0.008	0.016	Enzymatic NO3; SM4500-NO2	
Total Nitrogen	0.03	0.06	Enzymatic NO3	
Total Organic Carbon	0.3	0.5	SM 5310	Basic Laboratory, CA
Dissolved Organic Carbon	0.3	0.5	SM5310C	
Chlorophyll-a	0.0001	NA	SM10200H	Aquatic Research, WA

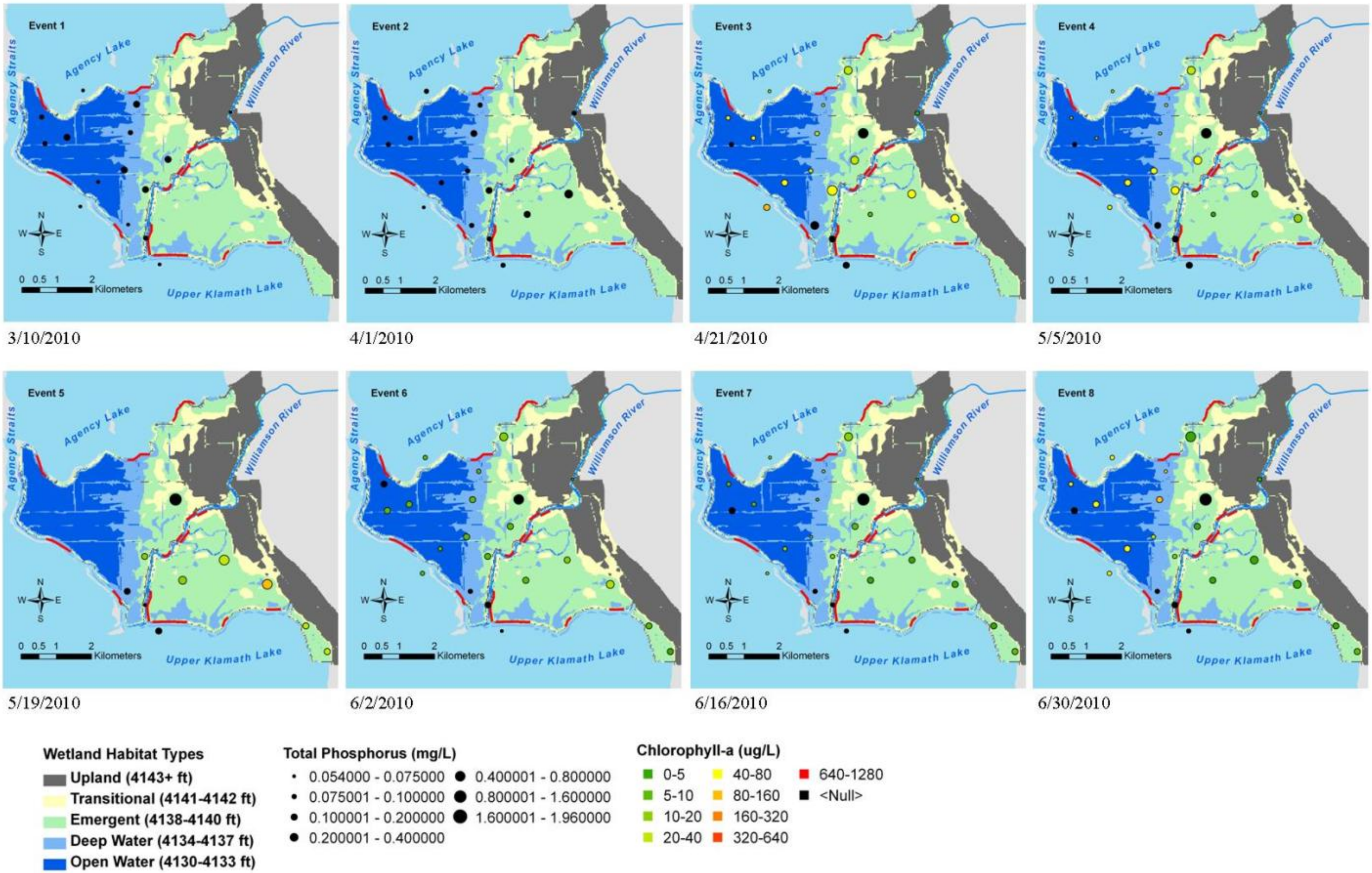
Appendix C. Quality assurance criteria for continuous monitoring data. Level A criteria represent the highest quality data as defined in TNC's Quality Assurance Project Plan. Level B criteria represent data outside Level A criteria, but deemed acceptable for statistical analysis. Level C criteria represent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

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

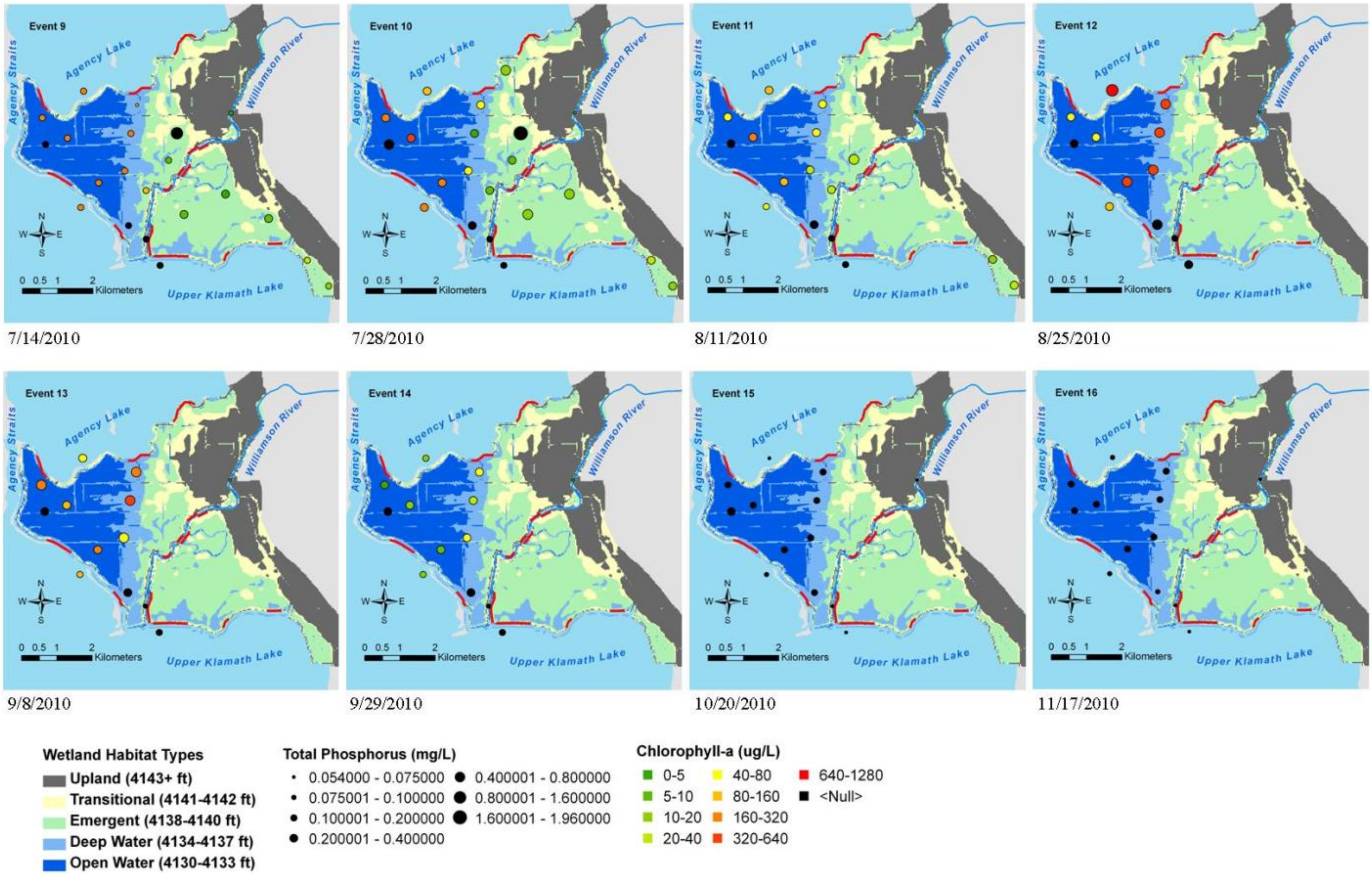
Appendix D. Quality assurance results for continuous monitoring in 2010. Data meeting Level A quality assurance criteria are not shown. 'No Data' indicates that no data were recorded for all four parameters due to equipment or other problems.

Continuous Monitor Site	Data Quality Level	Parameter	Dates	Continuous Monitor Site	Data Quality Level	Parameter	Dates
AL27	B	pH, DO	5/18/10 - 05/25/10	WR21	B	DO	09/14/10 - 09/21/10
AL27	B	DO	06/15/10 - 06/29/10	WR21	B	DO	09/28/10 - 10/05/10
AL27	C	DO	06/29/10 - 07/07/10	WR21	B	DO	10/13/10 - 10/19/10
AL27	B	DO	07/13/10 - 07/20/10	WR21	B	DO	10/26/10 - 11/02/10
AL27	B	DO	07/27/10 - 08/17/10	WR21	B	DO	11/09/10 - 11/16/10
AL27	B	DO	08/31/10 - 09/09/10	TLOW17	C	DO	03/23/10 - 03/31/10
AL27	B	DO	09/21/10 - 10/05/10	TLOW17	B	pH	05/04/10 - 05/11/10
AL27	B	DO	10/13/10 - 11/16/10	TLOW17	B	DO	05/18/10 - 05/25/10
UKLW25	B	DO	03/31/10 - 04/06/10	TLOW17	B	DO	06/15/10 - 06/22/10
UKLW25	B	DO	04/13/10 - 04/29/10	TLOW17	B	pH	06/22/10 - 06/29/10
UKLW25	B	DO	05/04/10 - 05/18/10	TLOW17	B	DO	08/17/10 - 08/31/10
UKLW25	B	DO	09/19/10 - 09/21/10	TLOW17	B	DO	09/21/10 - 09/28/10
UKLW25	B	DO	09/28/10 - 10/05/10	TLOW17	B	DO	10/19/10 - 10/26/10
UKLW25	NO DATA	NO DATA	10/13/10 - 10/19/10	TLOW17	C	DO	11/09/10 - 11/16/10
UKLW25	B	DO	11/02/10 - 11/16/10	TLDW13	B	DO	03/09/10 - 03/18/10
UKLE24	B	DO	03/08/10 - 03/18/10	TLDW13	B	DO	03/23/10 - 03/31/10
UKLE24	B	DO	03/23/10 - 03/31/10	TLDW13	B	DO	05/25/10 - 06/01/10
UKLE24	B	DO	04/20/10 - 04/29/10	TLDW13	B	DO	07/13/10 - 07/20/10
UKLE24	B	DO	07/07/10 - 07/13/10	TLDW13	B	DO	07/27/10 - 08/03/10
UKLE24	B	DO	07/27/10 - 08/03/10	TLDW13	B	DO	08/17/10 - 09/09/10
UKLE24	B	pH	08/10/10 - 08/17/10	TLDW13	B	DO	09/21/10 - 10/13/10
UKLE24	B	DO	08/17/10 - 08/24/10	TLDW13	B	DO	10/19/10 - 10/26/10
UKLE24	B	DO	09/28/10 - 10/13/10	TLDW13	B	DO	11/02/10 - 11/16/10
UKLE24	B	DO	10/26/10 - 11/02/10	TLEM9	B	DO	05/25/10 - 06/01/10
UKLE24	B	DO	11/09/10 - 11/16/10	TLEM9	B	DO	06/08/10 - 06/15/10
WR21	B	DO	03/18/10 - 03/23/10	TLEM9	B	DO	06/22/10 - 06/29/10
WR21	B	DO	03/31/10 - 04/06/10	TLEM9	B	DO	07/07/10 - 07/13/10
WR21	B	DO	04/13/10 - 04/20/10	TLEM9	B	DO	07/20/10 - 07/27/10
WR21	B	DO	05/25/10 - 06/01/10	GBEM4	B	pH	04/13/10 - 04/20/10
WR21	B	DO	06/22/10 - 06/29/10	GBEM4	B	DO	06/29/10 - 07/07/10
WR21	B	DO	07/07/10 - 07/13/10	GBEM4	B	DO	07/13/10 - 07/20/10
WR21	C	DO	07/13/10 - 07/20/10	SM1	B	DO	05/18/10 - 05/25/10
WR21	B	DO	07/20/10 - 07/27/10	SM1	C	DO	06/29/10 - 07/07/10
WR21	B	DO	08/10/10 - 08/24/10	SM1	B	DO	07/07/10 - 07/13/10
WR21	B	DO	08/31/10 - 09/09/10	SM1	B	DO	07/20/10 - 08/03/10

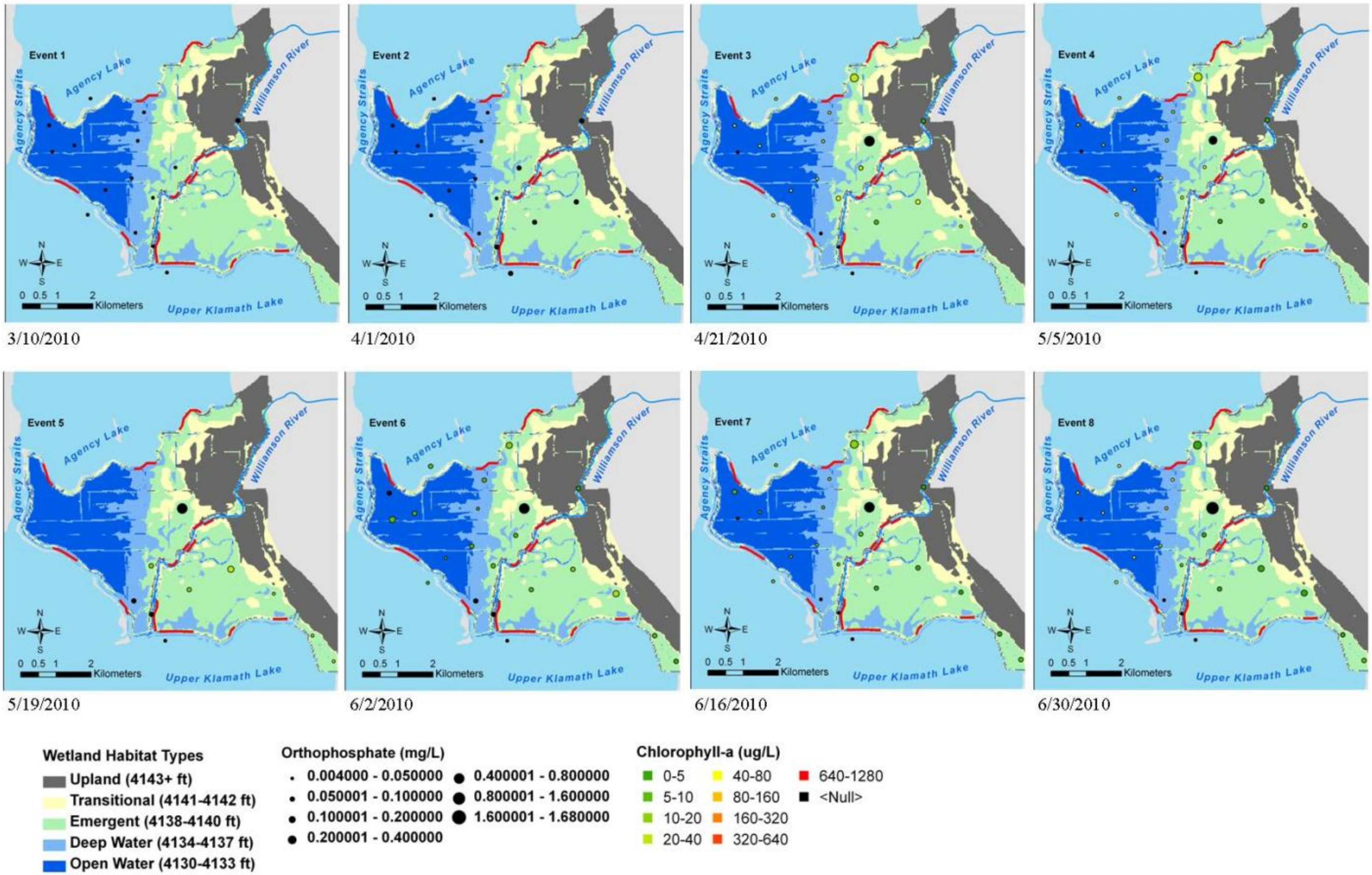
Appendix E1. Time series maps showing TP concentration (size of circles) and chlorophyll-a concentration (color of circles) for sampling events 1–8 at all water quality sampling sites on the Williamson River Delta and in the near-shore lakes and river. Black color circles indicate that TP sample was collected but chlorophyll-a sample not collected. No circles at a water quality site indicate that a sample was not collected.



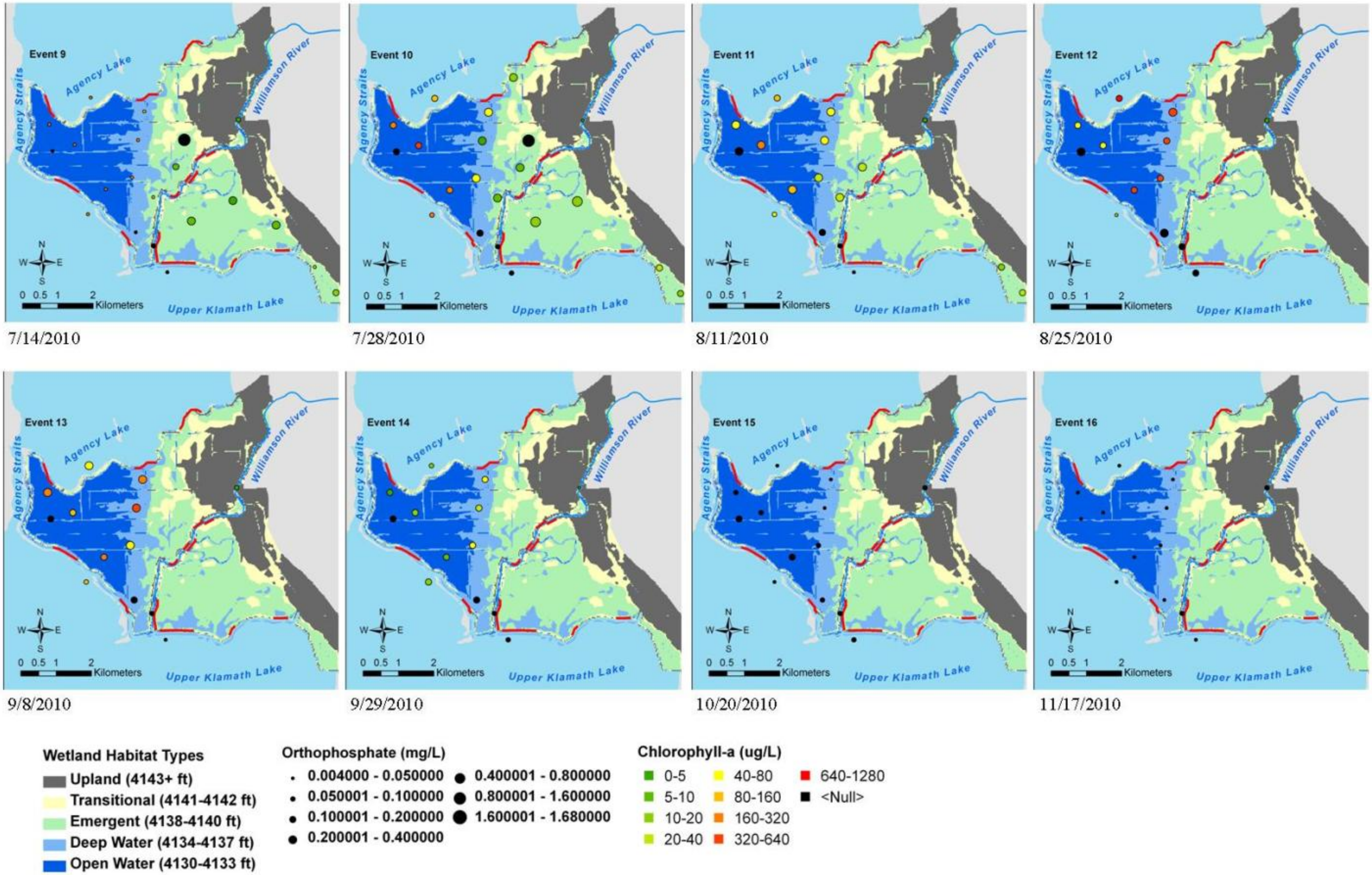
Appendix E2. Time series maps showing TP concentration (size of circles) and chlorophyll-a concentration (color of circles) for sampling events 9–16 at all water quality sampling sites on the Williamson River Delta and in the near-shore lakes and river. Black color circles indicate that TP sample was collected but chlorophyll-a sample not collected. No circles at a water quality site indicate that a sample was not collected.



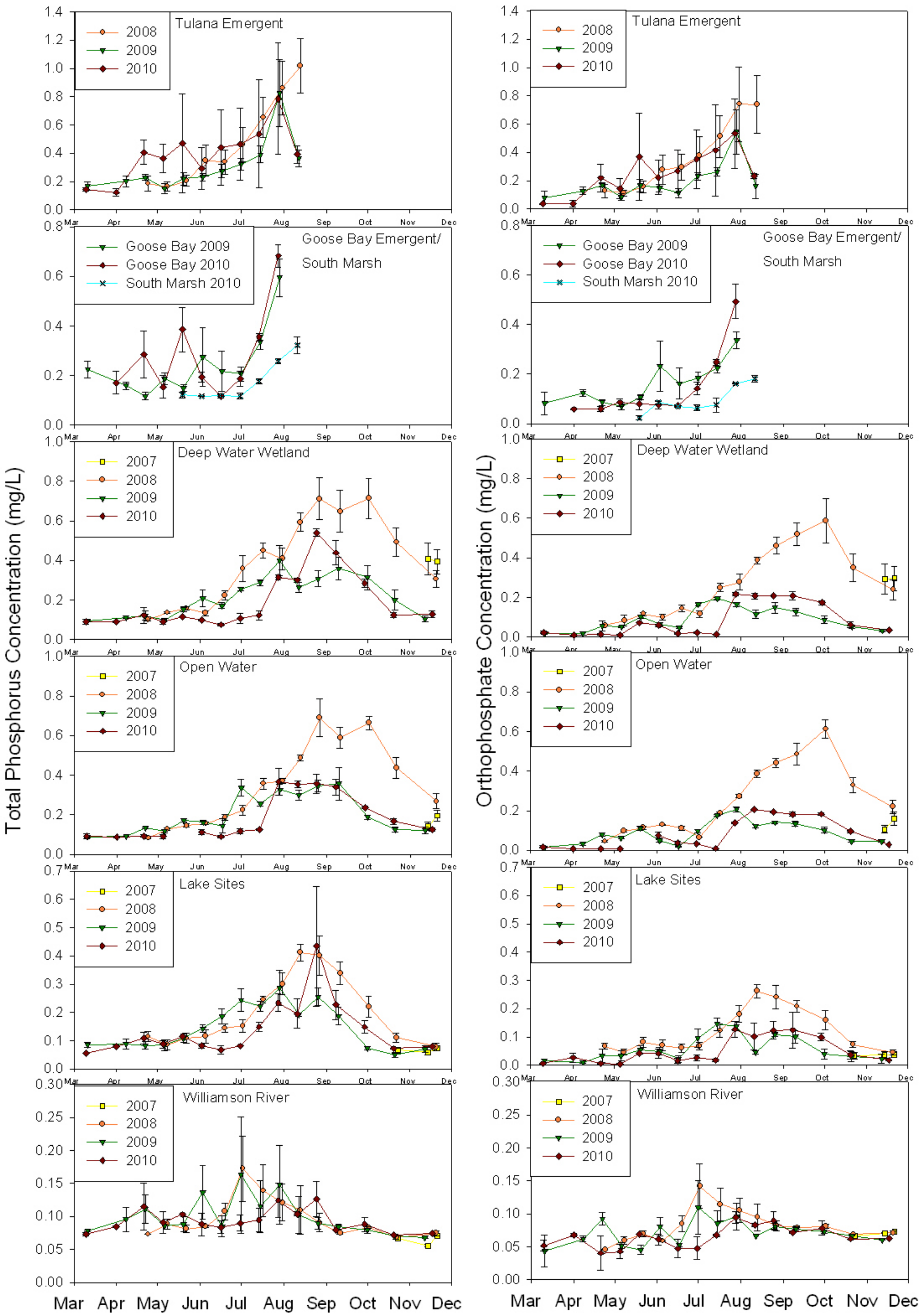
Appendix E3. Time series maps showing PO_4 concentration (size of circles) and chlorophyll-a concentration (color of circles) for sampling events 1–8 at all water quality sampling sites on the Williamson River Delta and in the near-shore lakes and river. Black color circles indicate that PO_4 sample was collected but chlorophyll-a sample not collected. No circles at a water quality site indicate that a sample was not collected.



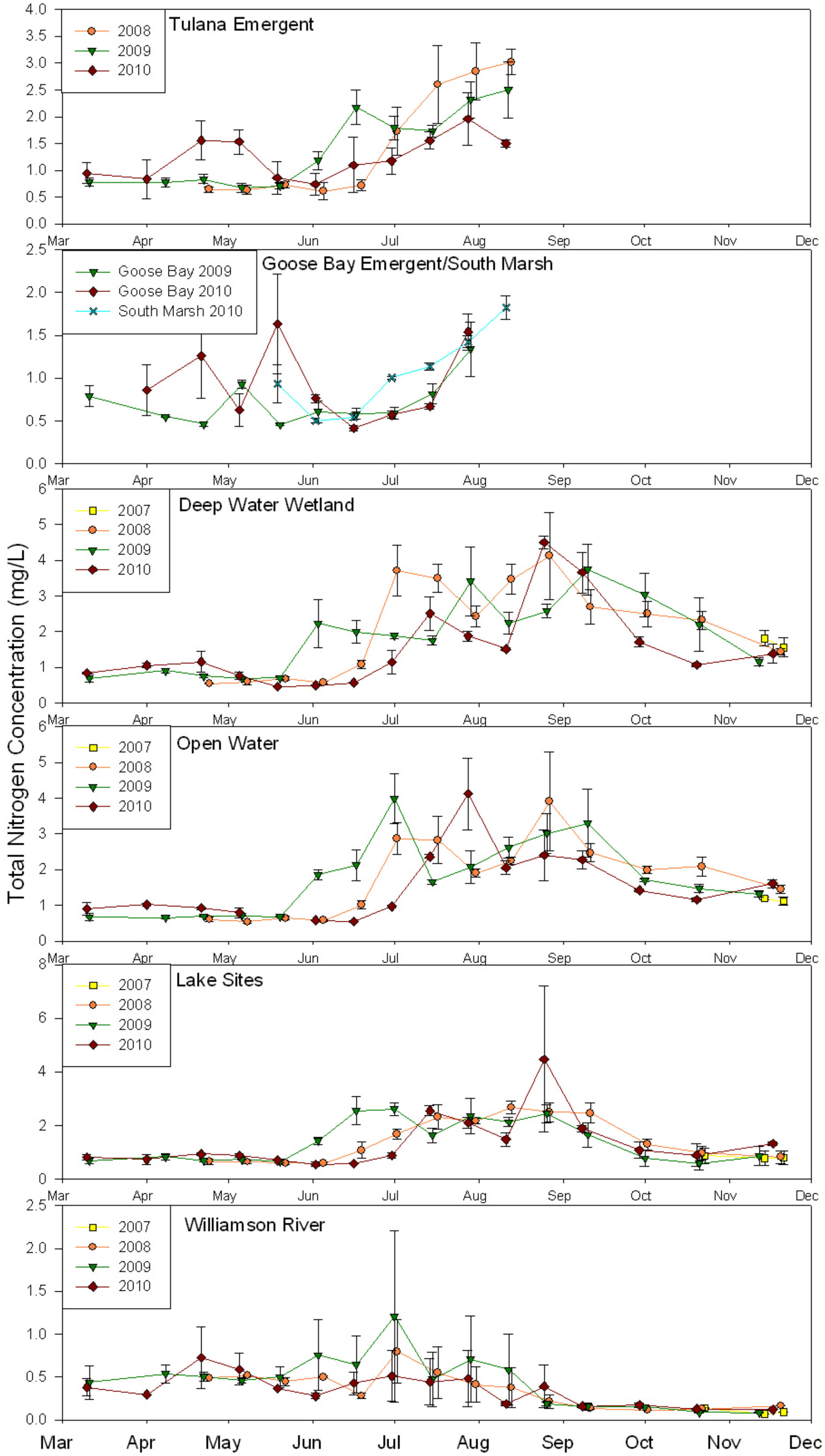
Appendix E4. Time series maps showing PO_4 concentration (size of circles) and chlorophyll-a concentration (color of circles) for sampling events 9–16 at all water quality sampling sites on the Williamson River Delta and in the near-shore lakes and river. Black color circles indicate that PO_4 sample was collected but chlorophyll-a sample not collected. No circles at a water quality site indicate that a sample was not collected.



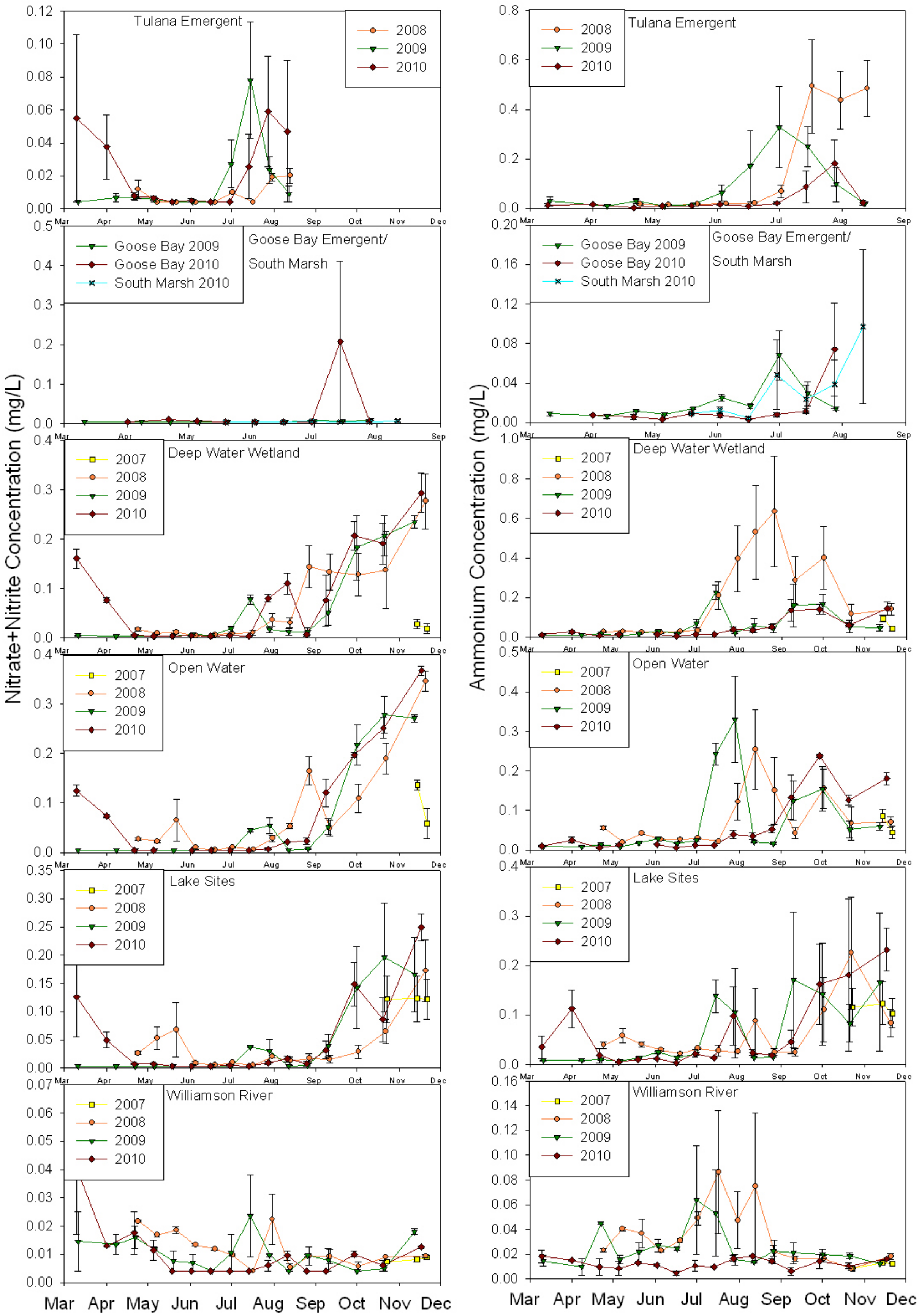
Appendix F1. Total phosphorus (left panels) and orthophosphate (right panels) concentrations from 2007–2010 by habitat type, Williamson River Delta, OR. Shown are means (± standard error) by location/habitat and sampling event.



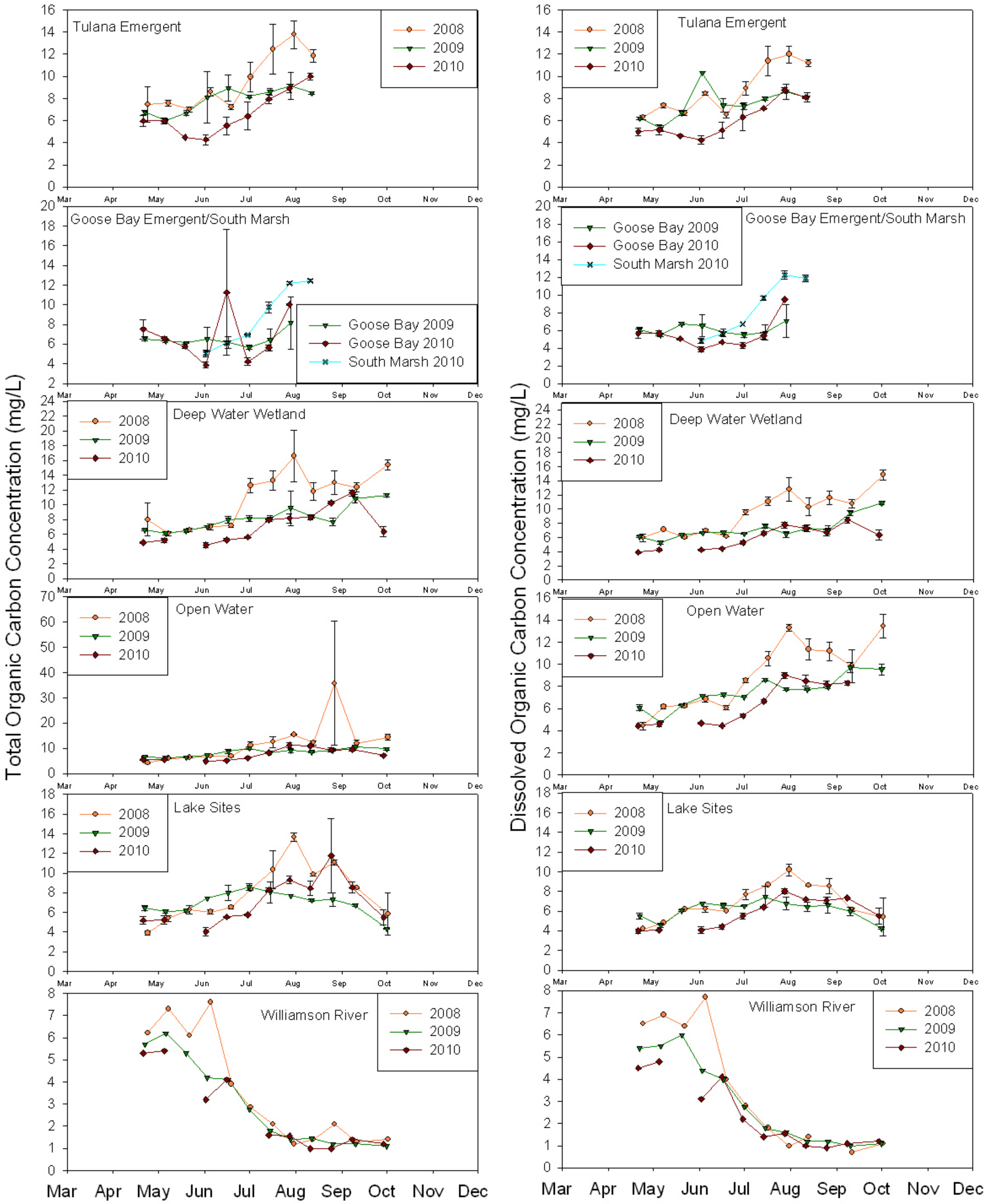
Appendix F2. Total nitrogen concentrations from 2007–2010 by location/habitat type, Williamson River Delta, OR. Shown are means (± standard error) by location/habitat and sampling event.



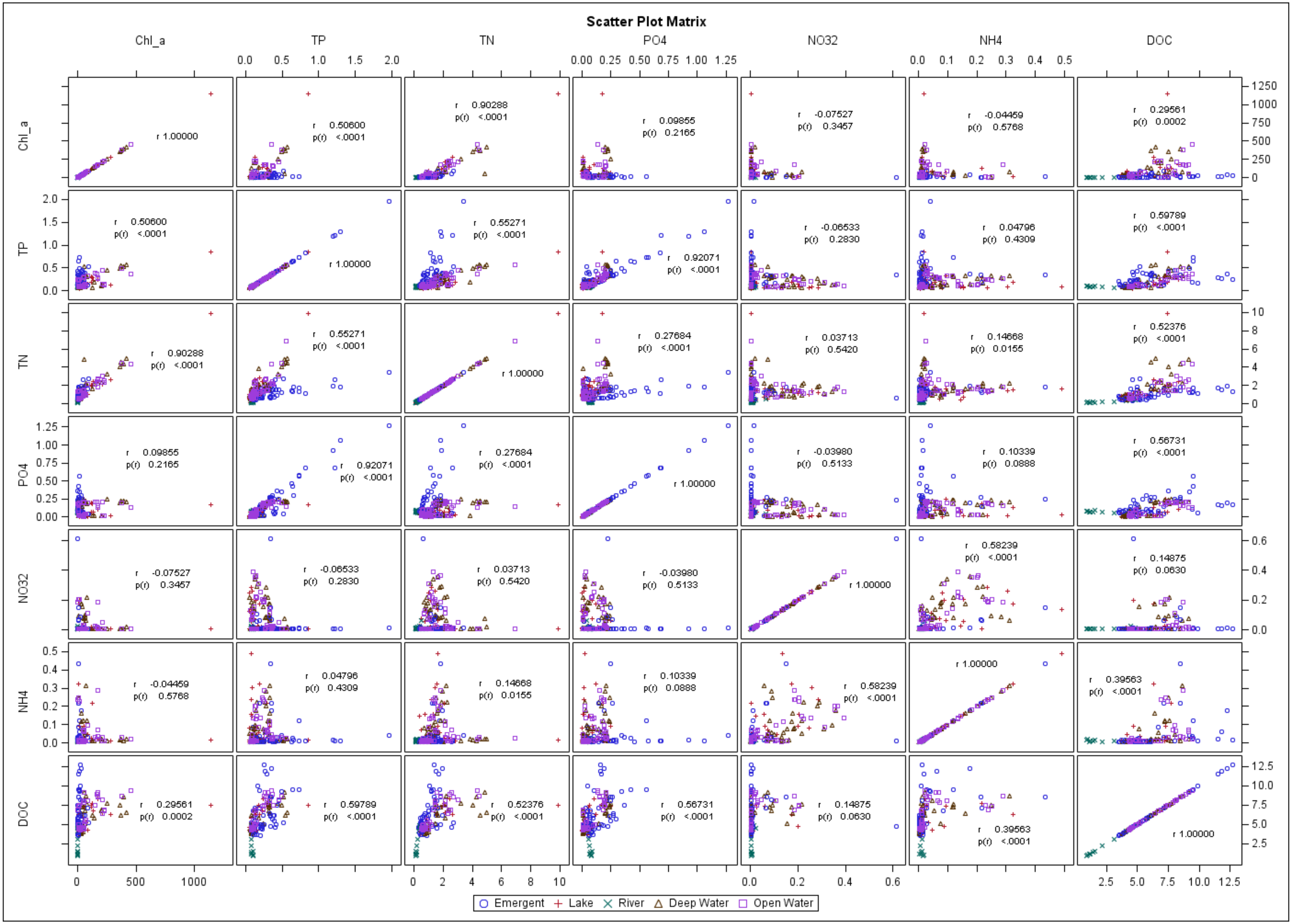
Appendix F3. Nitrate+Nitrite (left panels) and ammonium (right panels) concentrations from 2007–2010 by habitat type, Williamson River Delta, OR. Shown are means (± standard error) by location/habitat and sampling event.



Appendix F4. Total organic carbon (left panels) and dissolved organic carbon (right panels) concentrations from 2007–2010 by habitat type, Williamson River Delta, OR. Shown are means (± standard error) by location/habitat and sampling event.



Appendix G. Exploratory analysis results showing correlation (Pearson's) between various nutrient constituents and chlorophyll-a, Williamson River Delta, OR, 2010. Each dot represents an individual sample.



Appendix H. List of all identified phytoplankton species and the percent composition of the top ten dominant species within each major phytoplankton group (taxonomic division), Williamson River Delta, OR, 2010.

Taxonomic Division	Phytoplankton Species	Percent Composition
Bacillariophyta	*Fragilaria capucina*	18.6
	Aulacoseira granulata	14.0
	Fragilaria construens	12.6
	Synedra ulna	5.0
	Fragilaria virescens	3.4
	Cyclotella meneghiniana	3.3
	Nitzschia gracilis	3.0
	Amphora ovalis	2.9
	Rhopalodia gibba	2.8
	Nitzschia palea	2.8
	OTHER (58 species)	31.6
Chlorophyta	*Zygnema sp.*	36.7
	Chlamydomonas sp.	19.1
	Monomastix minuta	7.7
	Mougeotia sp.	5.0
	Pandorina morum	4.9
	Botryococcus braunii	4.1
	Pediastrum tetras	3.4
	Dictyosphaerium pulchellum	2.9
	Scenedesmus bijuga	1.9
	Monoraphidium arcuatum	1.6
	OTHER (34 species)	12.6
Chrysophyta	*Chromulina sp.*	83.8
	Synura sp.	6.3
	Erkenia subaequiciliata	3.0
	Dinobryon sociale	2.7
	Dinobryon sp.	1.6
	Mallomonas sp.	1.3
	Mallomonas akrokomas	1.3
Cryptophyta	*Cryptomonas erosa*	71.8
	Cryptomonas rostratiformis	17.4
	Rhodomonas minuta	10.6
	Cryptomonas ovata	0.1
Cyanophyta	*Aphanizomenon flos-aquae*	98.857
	Anabaena mendotae	1.015
	Microcystis aeruginosa	0.079
	Synechocystis sp.	0.011
	Pseudanabaena sp.	0.009
	Oscillatoria limnetica	0.008
	Anabaena augstumalis	0.005
	Anabaena macrospora	0.005
	Aphanocapsa elachista	0.002
	Anabaena sp.	0.002
	OTHER (11 species)	0.006
Euglenophyta	*Euglena sp.*	71.5
	Strombomonas sp.	26.2
	Trachelomonas sp.	1.4
	Phacus sp.	0.9
Pyrrhophyta	*Gymnodinium sp. 1*	56.2
	Glenodinium quadridens	23.5
	Gymnodinium sp. 3	8.5
	Gymnodinium sp. 2	6.6

	Peridinium umbonatum	5.2
Xanthophyta	*Tribonema sp.*	100