Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Water Management Study, Imperial Ponds
May 2011 through May 2013

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

August 2013

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Lower Colorado River Multi-Species Conservation Program

Water Management Study, Imperial Ponds May 2011 through May 2013

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Multi-Species Conservation Program
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ACRONYMS AND ABBREVIATIONS

ADEQ	Arizona Department of Environmental Quality
AIC_C	Akaike's Information Criterion
AM	ante meridiem
ANOVA	analysis of variance
ANTE	antedependence
AR	auto regressive
ARH	auto regressive unequal variance
ARMA	first-order auto regressive moving-average structure
BONY	bonytail
CI	confidence interval
CS	compound symmetry
CSH	compound symmetry unequal variance
cm	centimeter(s)
DO	dissolved oxygen
EC	electrical conductivity
EPA	United States Environmental Protection Agency
gpm	gallons per minute
hp	horsepower
INWR	Imperial National Wildlife Refuge
IPCA	Imperial Ponds Conservation Area
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
m	meter
mg/L	milligram(s) per liter
mL	milliliter(s)
NH_3-N	ammonia nitrogen
NO_3+NO_2-N	nitrate-nitrite
Ortho-P	Orthophosphorous
PM	post meridiem
RASU	razorback sucker
SAS	statistical analysis software
Se	selenium
TDS	total dissolved solids
Total -N	total nitrogen
Total -P	total phosphorous

Symbols

°C	degrees Celsius
<	less than
>	greater than
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter
µm	micrometer(s)
±	plus – minus
%	percent

CONTENTS

Page

Introduction 1
Background 1
Purpose and Intent 3
Methods 4
  Water Physico-Chemical Profiles 4
  Data Preparation 4
  Data Analysis 5
  Water Chemistry 6
  Water Elevation 7
  Phytoplankton and Zooplankton 7
Results 8
  AM/PM and Depth 8
  Comparing Pond Trends (Averaged Over AM/PM and Depth) 8
  Repeated Measures Analysis: Comparing 2010 with 2011 – 2012 8
  Water Chemistry 19
  Water Elevation 25
  Phytoplankton and Zooplankton 25
Discussion 27
Literature Cited 37

Tables

Table Page

1 Comparing water quality parameters before and after changes in water management for May – September, 2010 – 2012 20
2 Modified summary on numeric water quality standards by the Arizona Department of Environmental Quality and the United States Environmental Protection Agency (created by Jeanette Haegele) 21
3 Acute criteria for ammonia-nitrogen (NH_3-N) in freshwater designated for aquatic and wildlife use when salmonids are absent 24

Figures

Figure Page

1 Aerial photograph of Ponds 1 – 6, Imperial National Wildlife Refuge, Yuma, Arizona. 2
2 Water temperature by time of day and depth category for each pond, 2010 – present. 9
3 Water pH by time of day and depth category for each pond, 2010 – present. 10
4 Dissolved oxygen by time of day and depth category for each pond, 2010 – present. 11
5 Specific conductivity by time of day and depth category for each pond, 2010 – present. 12
6 Total dissolved solids by time of day and depth category for each pond, 2010 – present. 13
7 Monthly mean water temperature for each pond, 2010 – 2012. 14
8 Monthly mean pH for each pond, 2010 – 2012. 15
9 Monthly means of dissolved oxygen for each pond, 2010 – 2012. 16
10 Monthly mean specific conductivity for each pond, 2010 – 2012..... 17
11 Monthly mean total dissolved solids for each pond, 2010 – 2012..... 18
12 Arsenic concentrations (µg/L) in Ponds 1 – 6. 22
13 Selenium concentrations (µg/L) in Ponds 1 – 6..... 22
14 Ammonia nitrogen concentrations (mg/L) in Ponds 1 – 6..... 23
15 Total nitrogen concentrations (mg/L) in Ponds 1 – 6. 23
16 Total phosphorus concentrations (mg/L) in Ponds 1 – 6. 26
17 Nitrate-nitrite concentrations (mg/L) in Pods 1 – 6. 26
18 Orthophosphorous concentrations (mg/L) in Ponds 1 – 6. 27
19 Surface water elevations of the Colorado River and Ponds 1 – 6..... 28
20 Log10 cyanobacteria cell densities (cells per liter)..... 29
21 Log10 bacillariphyta cell densities (cells per liter)..... 29
22 Log10 chlorophyta cell densities (cells per liter)..... 30
23 Log10 cryptophyta cell densities (cells per liter)..... 30
24 Log10 pyrrophyta cell densities (cells per liter). 31
25 Total biomass profile for Pond 1 (micrograms dry weight per liter)..... 31
26 Total biomass profile for Pond 2 (micrograms dry weight per liter)..... 32
27 Total biomass profile for Pond 3 (micrograms dry weight per liter)..... 32
28 Total biomass profile for Pond 4 (micrograms dry weight per liter)..... 33
29 Total biomass profile for Pond 5 (micrograms dry weight per liter)..... 33
30 Total biomass profile for Pond 6 (micrograms dry weight per liter)..... 34

INTRODUCTION

The Lower Colorado River Multi-Species Conservation Program (LCR MSCP) is a partnership of Federal and non-Federal stakeholders responding to the need to balance the use of lower Colorado River (LCR) water resources and the conservation of native species and their habitats in compliance with the Endangered Species Act. Implementation of the LCR MSCP is accomplished partially through the creation of conservation areas within the LCR basin in order to restore and construct habitat for LCR MSCP covered species, to include 360 acres of backwater habitat for bonytail(*Gila elegans*) (BONY) and razorback sucker (*Xyrauchen texanus*) (RASU). The Imperial Ponds Conservation Area (IPCA) is an example of one such conservation area. The IPCA is located within the Imperial National Wildlife Refuge (INWR), which is owned and managed by the U.S. Fish and Wildlife Service. The conservation area encompasses a total project footprint of 132 acres: 80 acres of backwater, the Imperial Ponds, 12 acres of managed marsh, Field 18, and 34 acres of fields planned for cottonwood-willow development (figure 1).

BACKGROUND

A 200-horsepower (hp) pump was installed onsite in the Martinez Lake Inlet Channel (identified as the South Channel in previous reports) to supply water at a rate of 6,000 gallons per minute (gpm), or 1,000 gpm per pond (Reclamation 2008). These flows were estimated to be adequate to maintain all six ponds at a water elevation of 186 feet above mean sea level and to maintain adequate water quality within the ponds. Physico-chemical parameters, dissolved oxygen (DO), pH, temperature, specific conductivity, and total dissolved solids (TDS) for BONY and RASU have been identified as important parameters that the species require for their life cycle. The LCR MSCP is required to manage habitat for BONY and RASU. Understanding the acceptable range of each of these parameters is essential for management. Currently, the LCR MSCP staff is developing minimum management guidelines using existing information regarding habitat and site conditions for each of the LCR MSCP conservation areas. The Imperial Ponds currently operate within a set of physico-chemical standards agreed upon by the Imperial Ponds Fisheries Team: pH < 9.0, DO > 4 milligrams per liter (mg/L), and temperature < 33.3 degrees Celsius (°C) (Kesner et al. 2008). No standards were set for conductivity or TDS. Water quality became the leading factor in water management – if a physico-chemical parameter was nearing or exceeded a standard, water quality was considered to be poor, and additional water was added regardless of water elevation. The addition of water appears to be the factor that alleviated poor water quality; however, water input records only included monthly flows until 2011 and did not identify the source of water (e.g., Martinez Lake Inlet Channel or the well). The limited data prevent making inferences about the amount of water that was needed to alleviate poor water quality or if the water input source had an influence.

Figure 1.—Aerial photograph of Ponds 1 – 6, Imperial National Wildlife Refuge, Yuma, Arizona.

After construction of the Imperial Ponds, common carp (*Cyprinus carpio*) and western mosquitofish (*Gambusia affinis*) were documented within one or more of the ponds (Kesner et al. 2008). During the following sampling years, threadfish shad (*Dorosoma petense*), bluegill (*Lepomis macrochirus*), warmouth (*Lepomis gulosus*), and redear sunfish (*Lepomis microlophus*) were documented within one or more of the ponds (Kesner, et al. 2010a, 2010b). An entrainment study was performed in 2009 on the wedge-wire screen, the Martinez Lake Inlet Channel, and the ponds to identify the limits of the wedge-wire screen at excluding nonnative fish. The study revealed that over 97 percent (%) of the entrainment samples contained nonnative fish larvae (Normandeau Associates, Inc. 2010). The wedge-wire screen could not exclude 100% of nonnative fish species from the Imperial Ponds without secondary filtration (Karcheskey and McDonald 2011). The entrainment study results prompted the Imperial Ponds Fisheries Coordination Team to eliminate water supplied from the Martinez Lake Inlet Canal filtered through the 200-hp pump as the primary water source to the ponds. In 2010, the pump was disconnected. The primary water source is now supplied by well water.

Because of the presence of native fish in the ponds and the lack of water pumping records, implementing water management recommendations proved problematic as suggestions and possible management actions were not data driven, and it was difficult to evaluate in the context of long-term site management. An Imperial Ponds Fisheries Coordination Team meeting was held in April 2011 to discuss the possibility of using Ponds 2 – 6 for water management monitoring and research. The intent was to determine the range of variation in key physico-chemical parameters as an unmanaged system (without the addition of supplemental water). Fish had been previously consolidated into Pond 1 to alleviate pressure on the single well while continuing BONY and RASU management. Pond 1 was supplied with a water line plumbed directly from the well. Ponds 2 – 6 did not receive any water through managed surface flows.

PURPOSE AND INTENT

The purpose of this project was to monitor and evaluate water quality by the physical, chemical, and biological characteristics of Pond 1, with current water management protocols in progress, and Ponds 2 – 6, with no water management from May 2011 through May 2013. Water chemistry and water physico-chemical profiles were collected from all six ponds monthly to identify seasonal or intermittent changes that would adversely affect BONY and RASU. Pond and river elevations were recorded to verify a hydrologic connection between the ponds and main river channel. Zooplankton, a food source for BONY and RASU, were collected prior to this study when water was being actively managed. These data were also collected during the 2 years that surface water was not supplied to the ponds in order to document any changes in the aquatic communities.

METHODS

In May 2011, water input was shut off to Ponds 2 – 6 in order to monitor and evaluate natural water level fluctuations, water chemistry, and physico-chemical parameters in the absence of supplemental water. Pond 1 continued to receive well water from an independent line as described previously. BONY and RASU remained in Pond 1. Fisheries monitoring continued in Pond 1 to include larval sampling and monthly population estimates; however, that is not the focus of this report.

Water Physico-Chemical Profiles

Vertical profiles of the water column were collected using a hand-held multiparameter instrument (e.g., Hannah Instrument HI9829, November 1, 2011 – September 30, 2012, and YSI Professional Plus, October 1, 2012 – present) for all six ponds. Physico-chemical parameters, including specific conductivity in microsiemens per centimeter (µS/cm), DO (mg/L), pH, temperature (°C), and TDS (mg/L), were recorded near pond bottom, the mid-water column, and just below the surface of the water around the AM and PM crepuscular period. Physico-chemical parameters were collected from three preset monitoring buoys in each of the ponds once a month until water temperatures exceeded 27 °C; data were then collected twice a month.

Data Preparation

Data were standardized prior to analysis to account for variation in the number of depths sampled and a few dates with replicate samples taken at the same location (inlet, outlet, and mid-pond), time of day (AM/PM), and depth. Morning and afternoon sampling were initiated on different dates for each pond late in 2009; analysis was restricted to the period from 2010 – 2013. Before 2010, samples were taken at multiple depths (usually more than three and as many as eight to nine at higher water levels). Starting in February 2010, three depths were usually sampled (e.g., surface, mid-depth, and near the bottom), but additional depths were occasionally sampled. To account for multiple samples at the same time, location, and depth, means were calculated of all parameters by pond, date, time of day, location and depth. Since actual depth varied with water level, we categorized depths as surface, mid, and lower for graphing. When more than three depths were sampled, values were averaged for “mid” and “lower” depths (typically 0.5 – 2 meters [m] and 2 – 3 m, respectively).

In examining the data records for a few dates with depth values larger than the bank, the full depth of the ponds were identified. Based on data from other dates, it appeared that depth had been entered in feet rather than meters; these values were converted to meters prior to analysis.

Because pH is the negative logarithm of H+ ion concentration, summary statistics should be calculated in the untransformed scale (U.S. Food and Drug Administration, 2003). For standardizing pH data and the analysis described below, average pH was calculated by converting pH to H+ ion concentration, taking the mean and then back-transforming.

Data Analysis

Physico-chemical parameters were analyzed within and among ponds. First-time trends were graphed to informally examine differences by time of day (AM/PM) and depth. The means for each sampling date (by depth and AM/PM over location) were overlaid on a grid of graphs for each year and pond. The monthly means were superimposed for each pond (over depth, AM/PM, and location) to better examine whether temporal trends in physico-chemical parameters were affected by changes in water management for Ponds 2 – 6 (see description of statistical analysis below). The grids of graphs by year and pond were created using the ggplot2 package (Wickham 2009) in R v. 3.0.1 (R Core Team 2013).

To evaluate whether changes in physico-chemical parameters were associated with changes in water management, physico-chemical parameters were compared for the period when all ponds received water (2010) to that after water management stopped for Ponds 2 – 6 (2011 –2012). Mixed model repeated measures analysis of variance (ANOVA) was used for this analysis because samples repeatedly taken from the same locations were correlated. Evidence of temporal autocorrelation was found in all variables (Durbin-Watson $D < 2$ and 1st order autocorrelations of residuals ranging from 0.3 to 0.8).

Mixed model ANOVA differs from standard ANOVA in that it does not assume that errors are independent and identically distributed or that variances or covariances are equal over time or among levels of other factors. Instead, mixed model analysis entails selecting a covariance structure (i.e., variances at each time interval and covariances among all time intervals) that best fits the data (Littell et al. 1998, 2006). Different covariance models assume varying types of dependence among measurements on the same subject and describe how variances and/or covariances vary over time. The references listed above, as well as Hamer and Simpson (2000) and Wolfinger and Chang (1996), provide good descriptions of how mixed models are used to analyze repeated measures data.

PROC MIXED in SAS/STAT® software 9.3 (SAS Institute, Cary NC) was used to compare models using different covariance structures generally appropriate for repeated measures data (AR = auto-regressive, CS = compound symmetry, ARMA = first-order autoregressive moving-average structure, and ANTE = antedependence and unequal variance versions of AR and CS, referred to as ARH

and CSH). The "best" covariance model was identified by using the small sample version of Akaike's Information Criterion (AIC_C) (i.e., the model with the lowest AIC_C value [Burnham and Anderson 2010]).

The monthly mean values over depth and time of day were analyzed to simplify the analysis. Monthly measures better met the assumption of equal time intervals for the compared covariance structures (i.e., measurements varied more on a weekly than on a monthly time scale). Graphs by depth and time of day confirmed that trends for several physico-chemical parameters varied seasonally among different levels of these factors, and including them in the ANOVA would have required making separate comparisons within levels of each factor. Finally, the average of physico-chemical parameters over natural monthly variations in depth and time of day is more easily applied to water management for native fish.

The ANOVA model was Y = Pond + Month + Pond*Month, where Y is the physico-chemical parameter, Month is the repeated measure factor, and Pond is treated as a fixed factor. The location within ponds was the subject measured at each month. Monthly measurements for each location are assumed to be correlated, but measurements across locations are assumed to be independent.

The analysis was restricted to data collected from 2010 – 2012. The best-fit covariance model was used to compare parameters for the time period when all ponds received water (2010) with the period when only Pond 1 was being managed (2011 – 2012). Separate comparisons were made for each pond and were limited to May through September of each year. This emphasized seasonal extremes for most parameters and ensured that no missing values complicated the analysis (i.e., there were data for all ponds in these months). For physico-chemical parameter changes to be associated with management changes, we expected to see differences in the magnitude and/or direction of change in Pond 1 versus the other ponds. We also compared 2010 versus 2011 and 2010 versus 2012 to determine whether temporal changes were consistent or larger in one year.

Water Chemistry

Surface grab samples were collected from Imperial Ponds 1 – 6 to measure lab electrical conductivity (EC), pH, TDS, arsenic, selenium (Se), Orthophosphorous (Ortho-P), nitrate-nitrate ($NO3+NO_2$-N), ammonia nitrogen (NH_3-N), total phosphorus (Total -P), and total nitrogen (Total -N). Samples were collected monthly at locations near each of the three preset buoys within each pond. The samples for each pond were mixed and decanted into the appropriate sample bottle. Water samples for general chemistry parameters were stored on ice immediately after collection. Samples collected for metals and Ortho-P were filtered with a 47-millimeter (0.45-micrometer [µm]) sterile membrane filter, and

metals were transferred to an acid-washed bottle acidified to pH < 2.0 and stored at 4 °C. Ortho-P was then frozen within 48 hours of collection. NO3+NO_2-N samples were preserved with 10% sulfuric acid and placed on ice. Samples for Total-N were frozen within 48 hours of collection.

The monthly water chemistry concentrations for lab EC, pH, TDS, arsenic, Se, Ortho –P, NO3+NO_2-N, NH_3-N, Total -P and Total -N were represented graphically. Concentrations were compared to the standards or recommended concentrations set by the United States Environmental Protection Agency (EPA) and the Arizona Department of Environmental Quality (ADEQ).

Water Elevation

INWR staff recorded water elevations from all six ponds on a weekly basis. The elevation of the river was downloaded from the water monitoring gage north of the ponds, and provisional records were provided for May 2011 through May 2013.

Phytoplankton and Zooplankton

Phytoplankton and zooplankton samples were collected quarterly (winter, spring, summer, and autumn) during daylight hours. The samples were collected at the deepest know location in the ponds.

Phytoplankton samples were collected using a single, vertical plankton tow from January 2012 – July 2012, and an integrated hose-style vertical sampler technique was used for all other samples to collect the phytoplankton at the deepest area in each pond. A 3.5-centimeter (cm) pool hose was modified to collect the composite sample. The hose was lowered vertically into the water column to just above the maximum depth to prevent sediment contamination. The surface end was capped and held higher than the rest of the hose to prevent contamination during ascent. The sample was released into a bucket and mixed thoroughly. The samples were rinsed into a 250-milliliter (mL) amber collection bottle and preserved with Lugol's iodine solution at a rate of 0.3 mL solution per 100 mL of sample. The samples were kept on ice for later analysis by BSA Environmental Services, Inc. Samples collected January 2012 – July 2012 were not preserved and were kept on ice for later analysis by Aquatic Consulting and Testing, Inc. Phytoplankton were reported in cells per liter.

Zooplankton samples were collected using a 64-µm plankton net. The net was lowered to just above pond bottom and raised at a slow, steady rate to not exceed the filtration rate of the net. The samples were rinsed into a 250-mL amber collection bottle and preserved with Lugol's iodine solution at a rate of 0.3 mL

solution per 100 mL of sample. Samples were kept on ice for later analysis by BSA Environmental Services, Inc. Zooplankton were reported as total biomass (dry weight µg/L), summed at the division level. Samples collected January 2012 – July 2012 were analyzed by Aquatic Consulting and Testing, Inc.

RESULTS

AM/PM and Depth

Water temperature trended higher in surface and PM samples in the spring and summer, exceeding the fish standard of 33.3 °C in August in most ponds (figure 2). Temperature varied somewhat more over depth in Ponds 2 – 6, especially after water management stopped. pH and DO trended much lower at the lowest depth, especially in the summer (figures 3 – 4). The highest pH values were observed in 2011, but the standard was commonly exceeded in the summer of both 2011 and 2012 in Ponds 2 – 6 (figure 3). DO occasionally fell below 4 µg/L at the lowest depth in July – September, but was also often higher at mid and lower depths than at the surface in PM samples in June/July. Specific conductance and TDS varied little by time of day or depth and trended consistently higher over time in Ponds 2 – 5 (figures 5 – 6).

Comparing Pond Trends (Averaged Over AM/PM and Depth)

Mean water temperature was similar across ponds, but also increased over time for most ponds (figure 7). This trend was most evident for Pond 1. pH also appeared to trend upward over years. Differences in pH among ponds were most prevalent in 2011 – 2012. pH was lowest and exhibited less temporal variation in Pond 1. Pond 6 had the highest pH during the summer, although Ponds 2, 3, and 4 commonly exceeded the standard (figure 8). DO was highly variable over time and across ponds, but appeared to trend lower in Pond 1 in 2012 (figure 9). Specific conductivity and TDS were highest in Pond 5 and lowest in Pond 6, except in 2012 – 2013, when Pond 1 had the lowest salinity (figures 10 – 11). Both of these parameters exhibited a general increasing trend over time in most ponds, except Pond 1.

Repeated Measures Analysis: Comparing 2010 with 2011 – 2012

The Pond*Month interaction was statistically significant for all parameters ($p < 0.0001$), meaning that time trends varied among ponds. The direction and

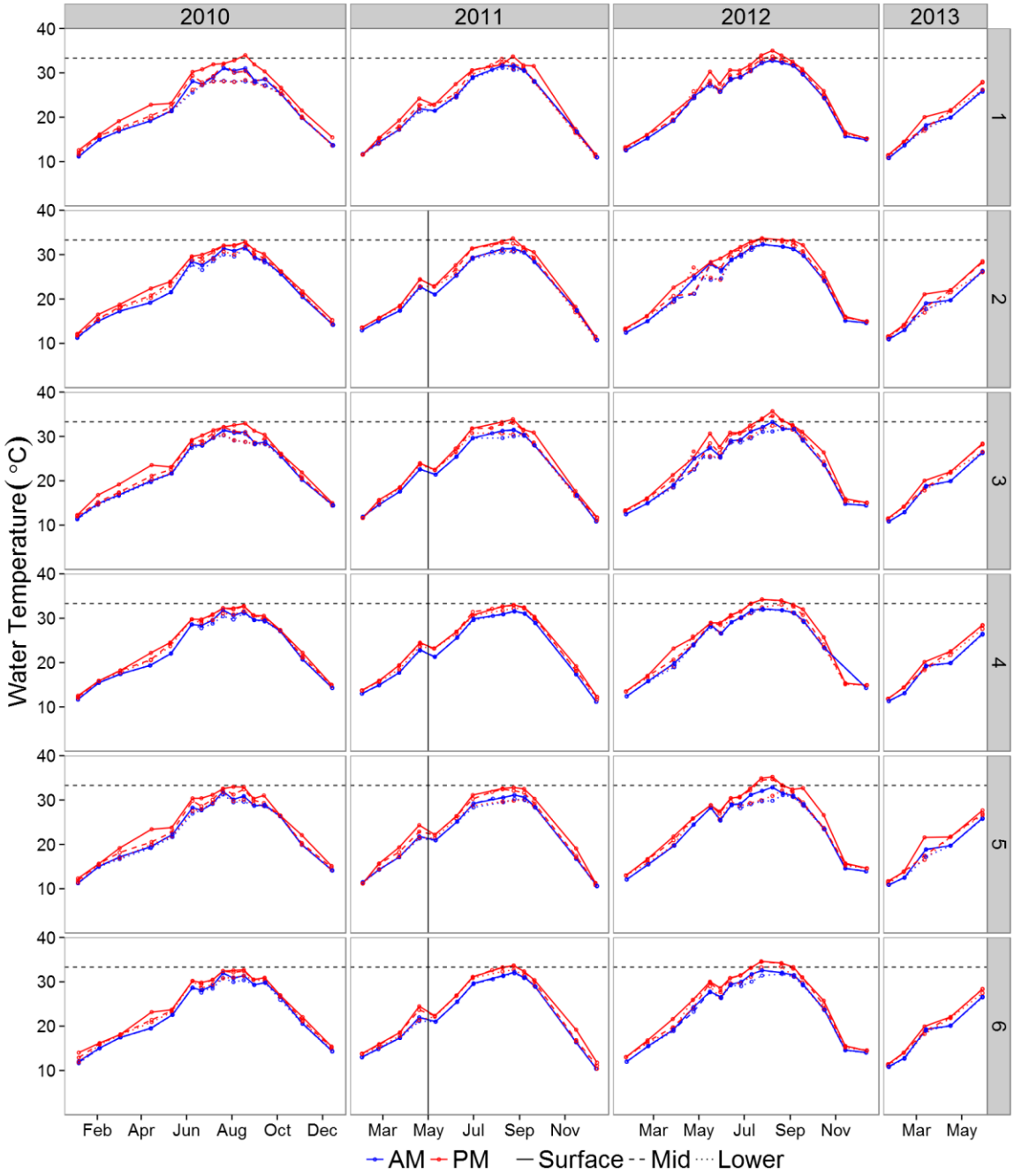

Figure 2.—Water temperature by time of day and depth category for each pond, 2010 – present.
Values are means over locations (inlet, outlet, and mid-pond). The time of day is represented by color, and the depth is represented by line type. A horizontal dashed line indicates the minimum standard for fish, and a vertical line indicates the date that water management stopped for Ponds 2 – 6.

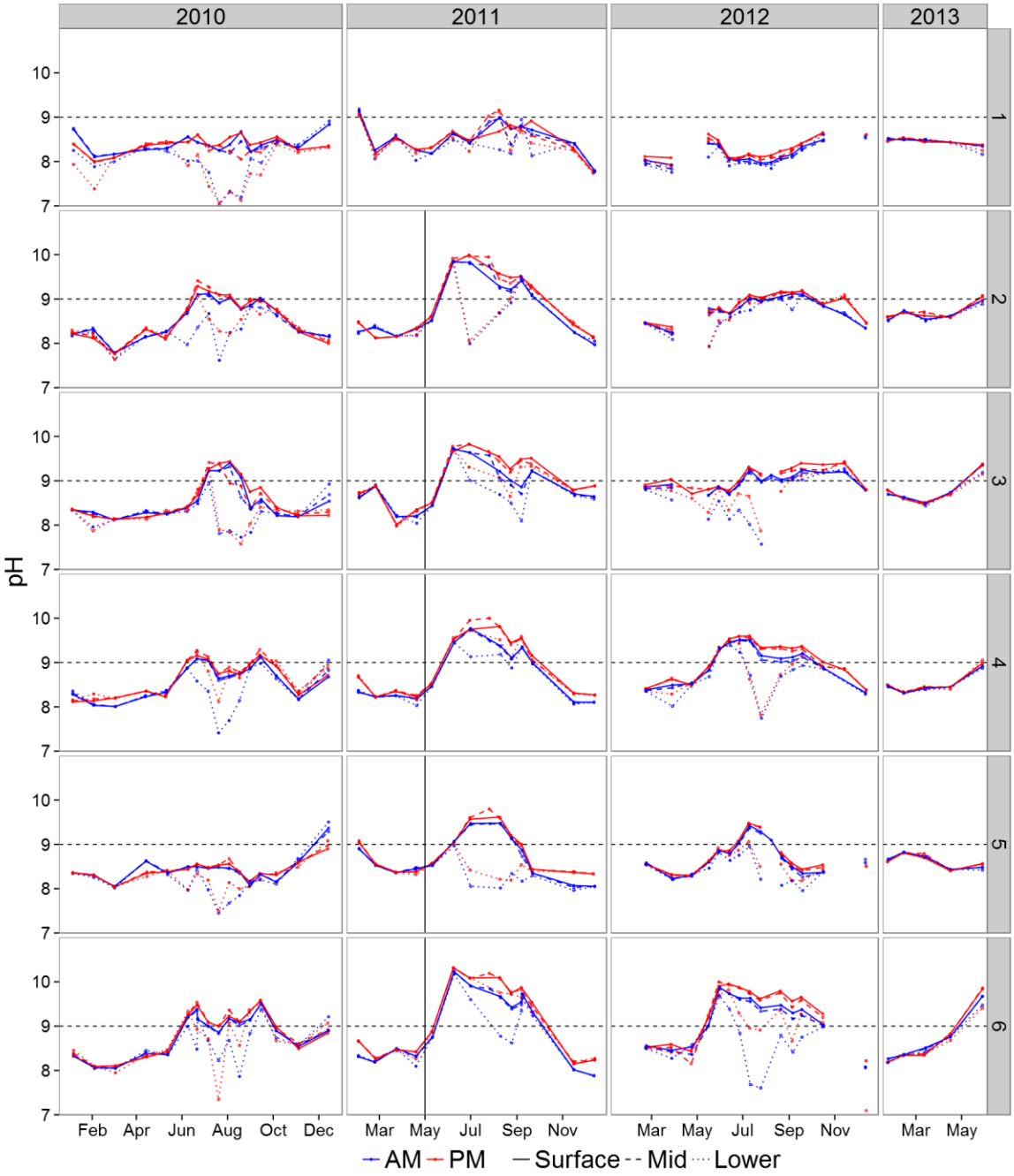

Figure 3.—Water pH by time of day and depth category for each pond, 2010 – present. Values are means over locations (inlet, outlet, and mid-pond). The time of day is represented by color, and the depth is represented by line type. A horizontal dashed line indicates the minimum standard for fish, and a vertical line indicates the date that water management stopped for Ponds 2 – 6.

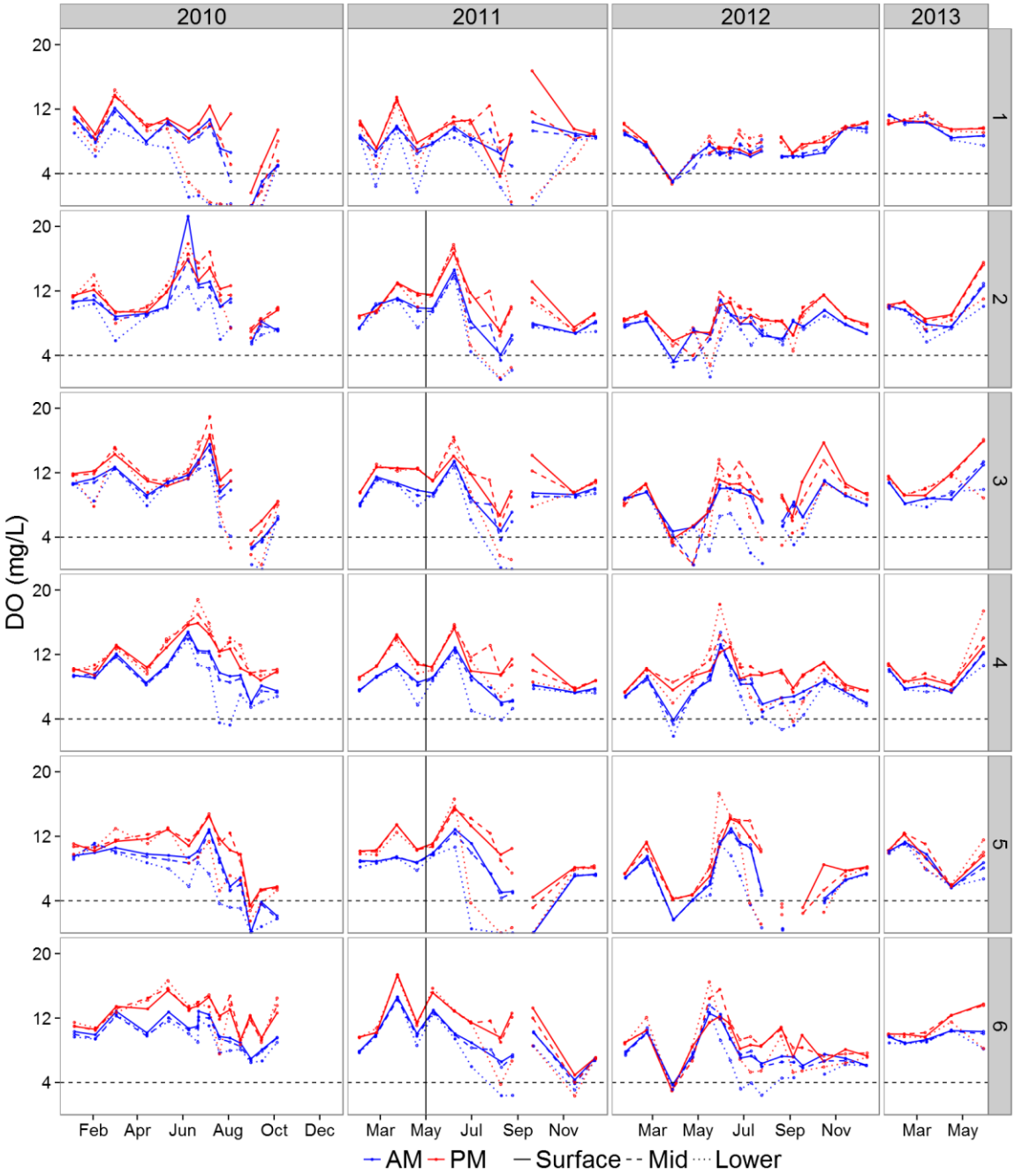

Figure 4.—Dissolved oxygen by time of day and depth category for each pond, 2010 – present.
Values are means over locations (inlet, outlet, and mid-pond). The time of day is represented by color, and the depth is represented by line type. A horizontal dashed line indicates the minimum standard for fish, and a vertical line indicates the date that water management stopped for Ponds 2 – 6.

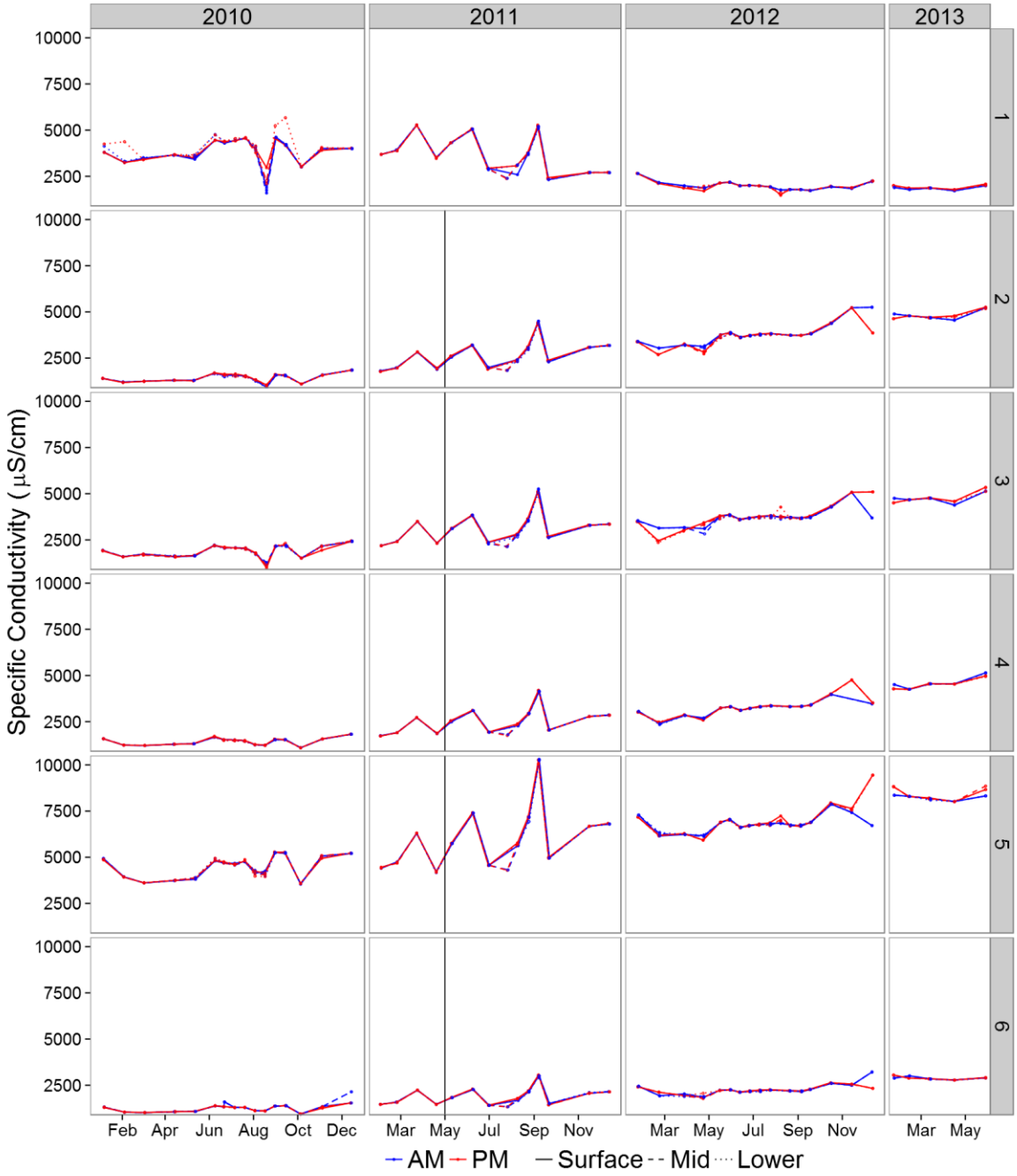

Figure 5.—Specific conductivity by time of day and depth category for each pond, 2010 – present.

Values are means over locations (inlet, outlet, and mid-pond). The time of day is represented by color, and the depth is represented by line type. A horizontal dashed line indicates the minimum standard for fish, and a vertical line indicates the date that water management stopped for Ponds 2 – 6.

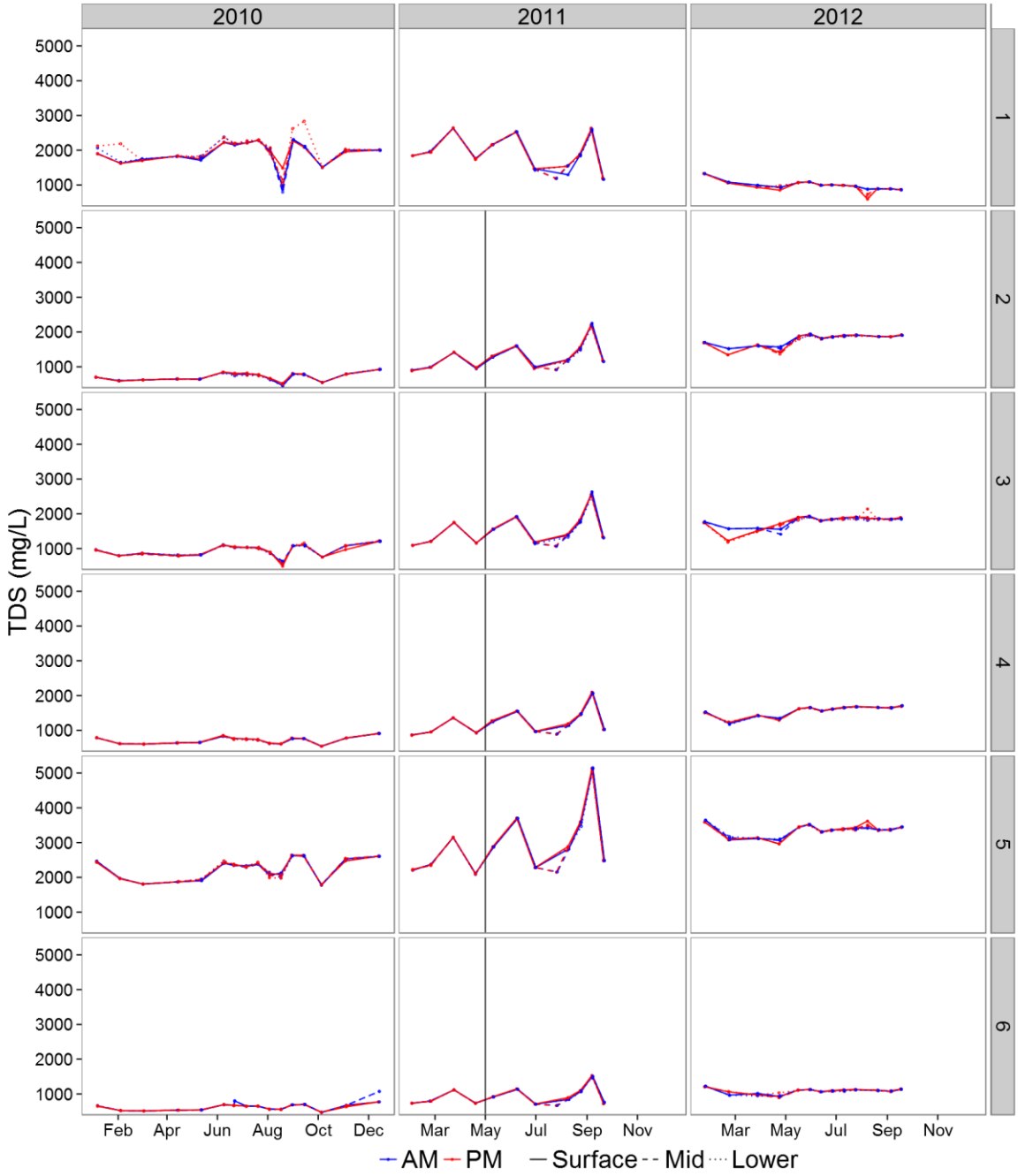

Figure 6.—Total dissolved solids by time of day and depth category for each pond, 2010 – present.
Values are means over locations (inlet, outlet, and mid-pond). The time of day is represented by color, and the depth is represented by line type. A horizontal dashed line indicates the minimum standard for fish, and a vertical line indicates the date that water management stopped for Ponds 2 – 6.

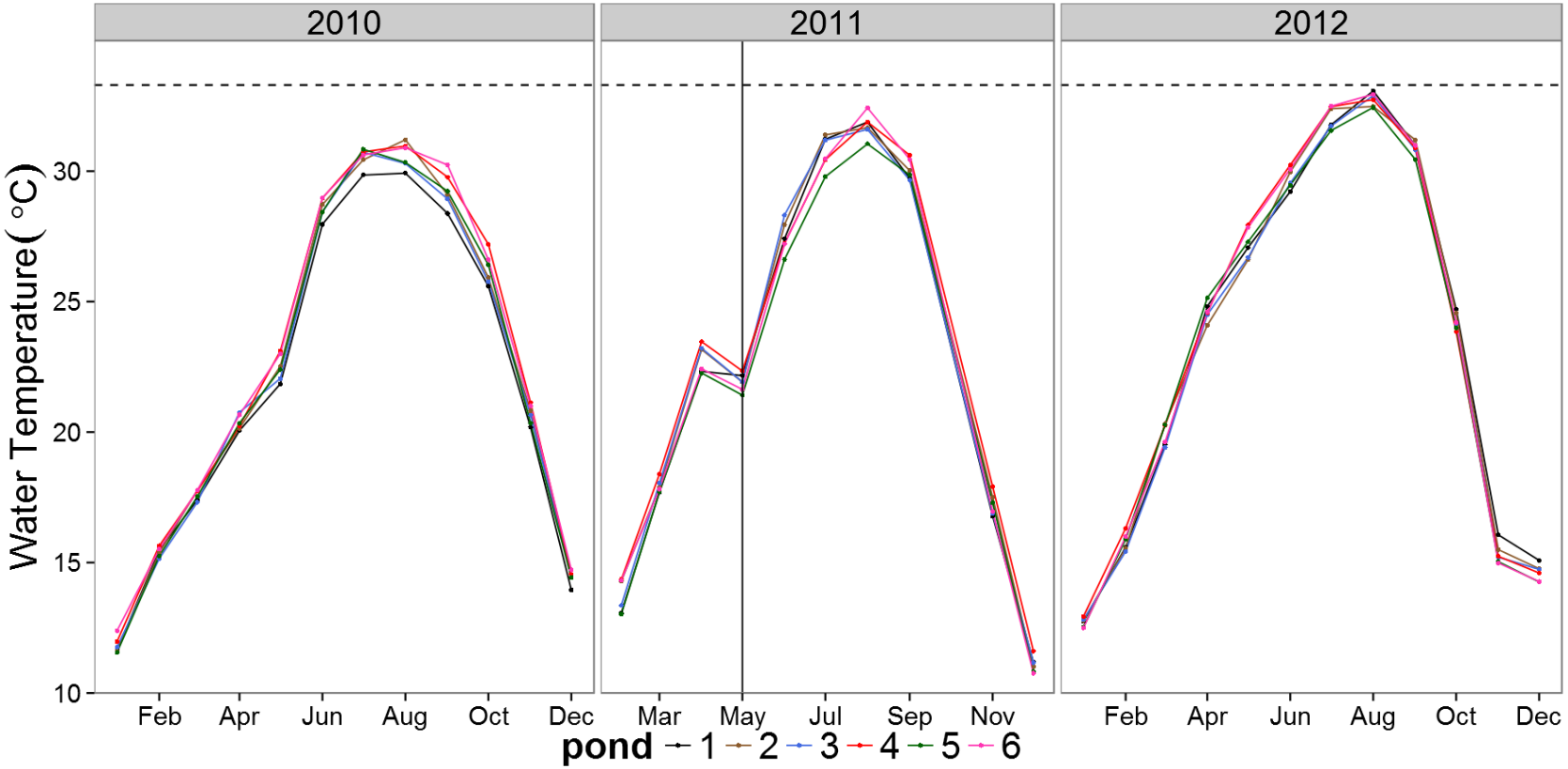

Figure 7.—Monthly mean water temperature for each pond, 2010 – 2012.
Values are means over time of day, depth, and location (inlet, outlet, and mid-pond). A horizontal dashed line indicates the maximum standard for fish (33.3 °C), and a vertical line indicates the date that water management stopped for Ponds 2 – 6.

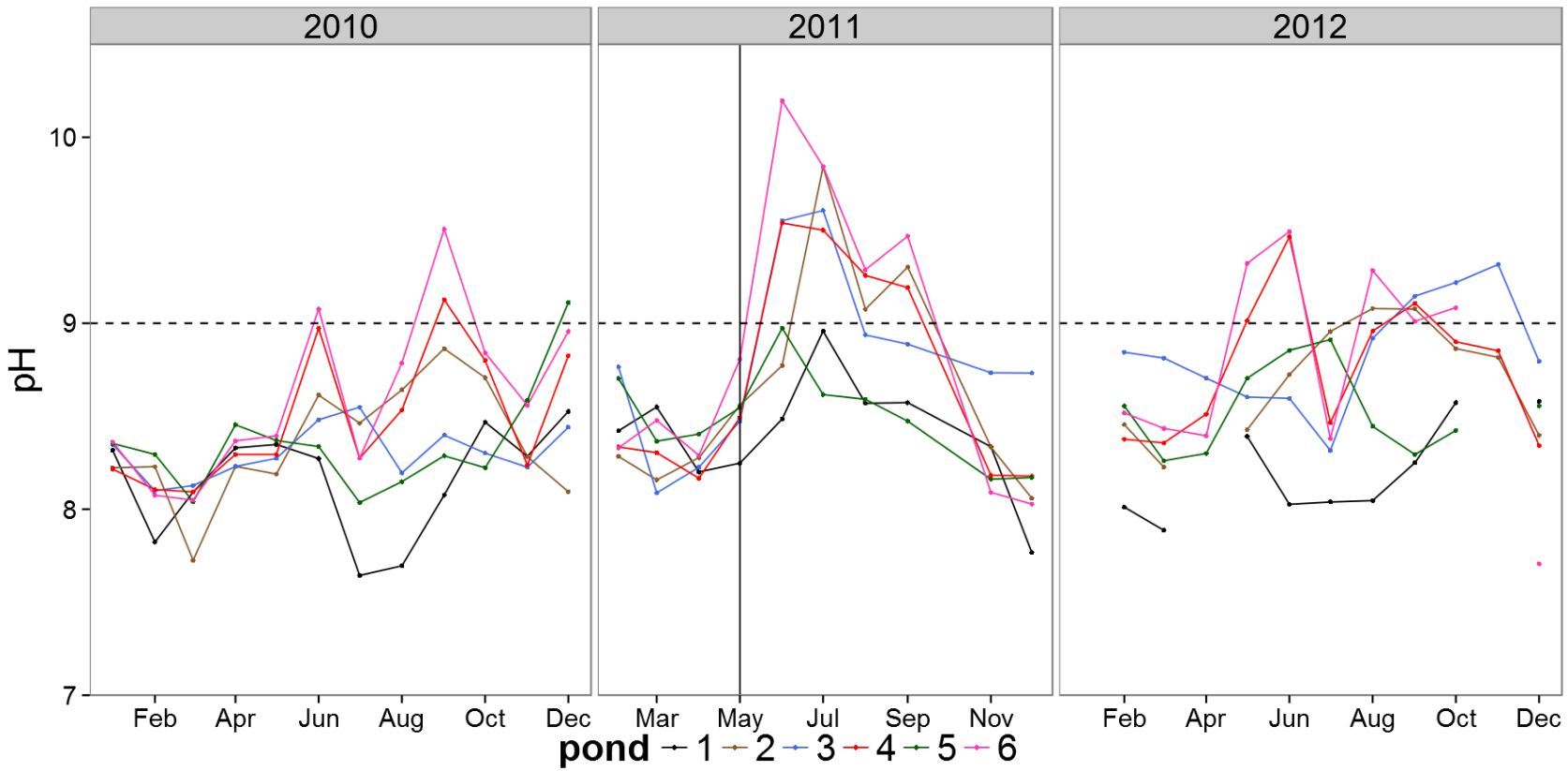

Figure 8.—Monthly mean pH for each pond, 2010 – 2012.
Values are means over time of day, depth, and location (inlet, outlet, and mid-pond). A horizontal dashed line indicates the maximum standard for fish, and a vertical line indicates the date that water management stopped for Ponds 2 – 6.

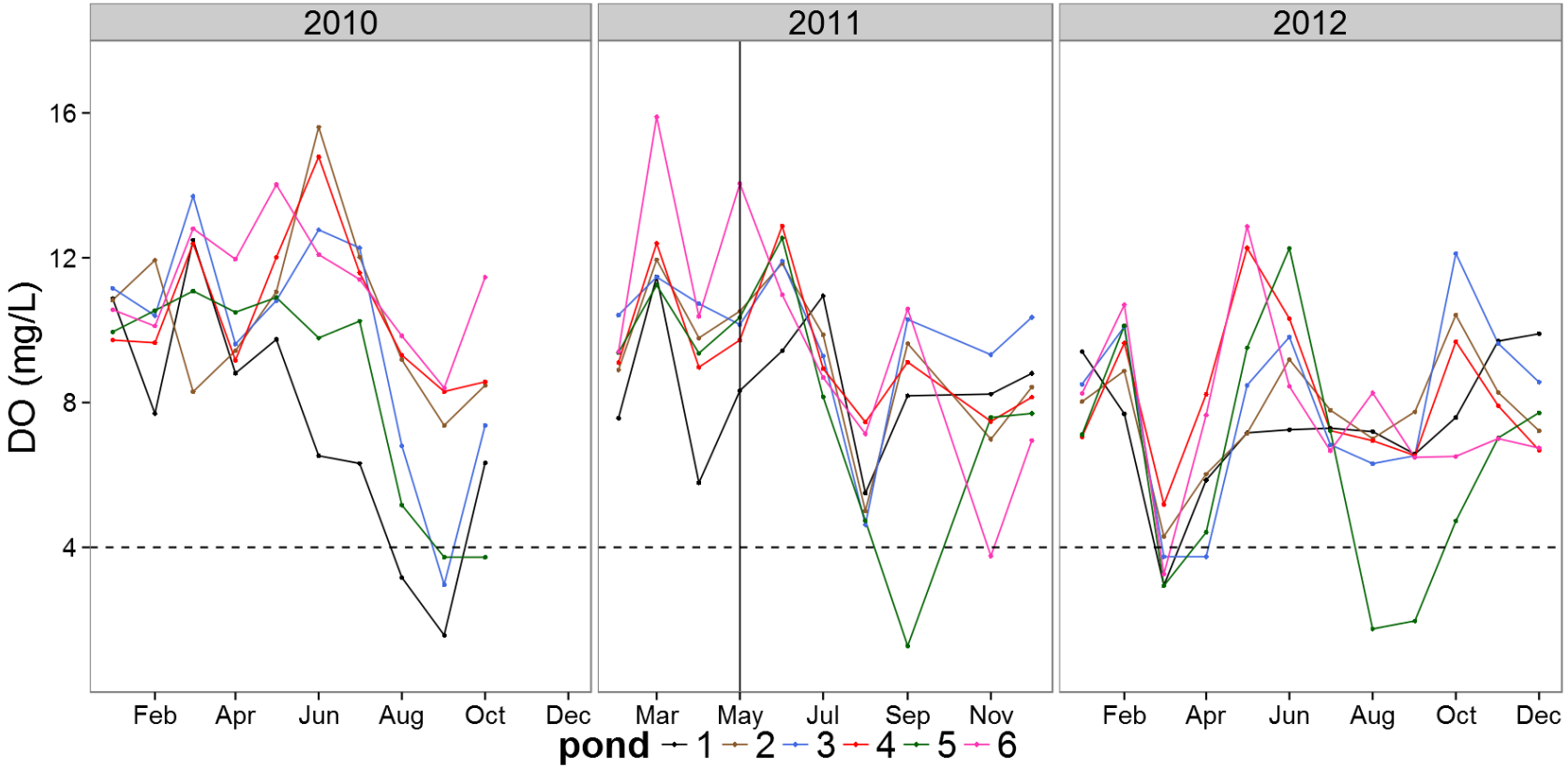

Figure 9.—Monthly means of dissolved oxygen for each pond, 2010 – 2012.
Values are means over time of day, depth, and location (inlet, outlet, and mid-pond). A horizontal dashed line indicates the maximum standard for fish, and a vertical line indicates the date that water management stopped for Ponds 2 – 6.

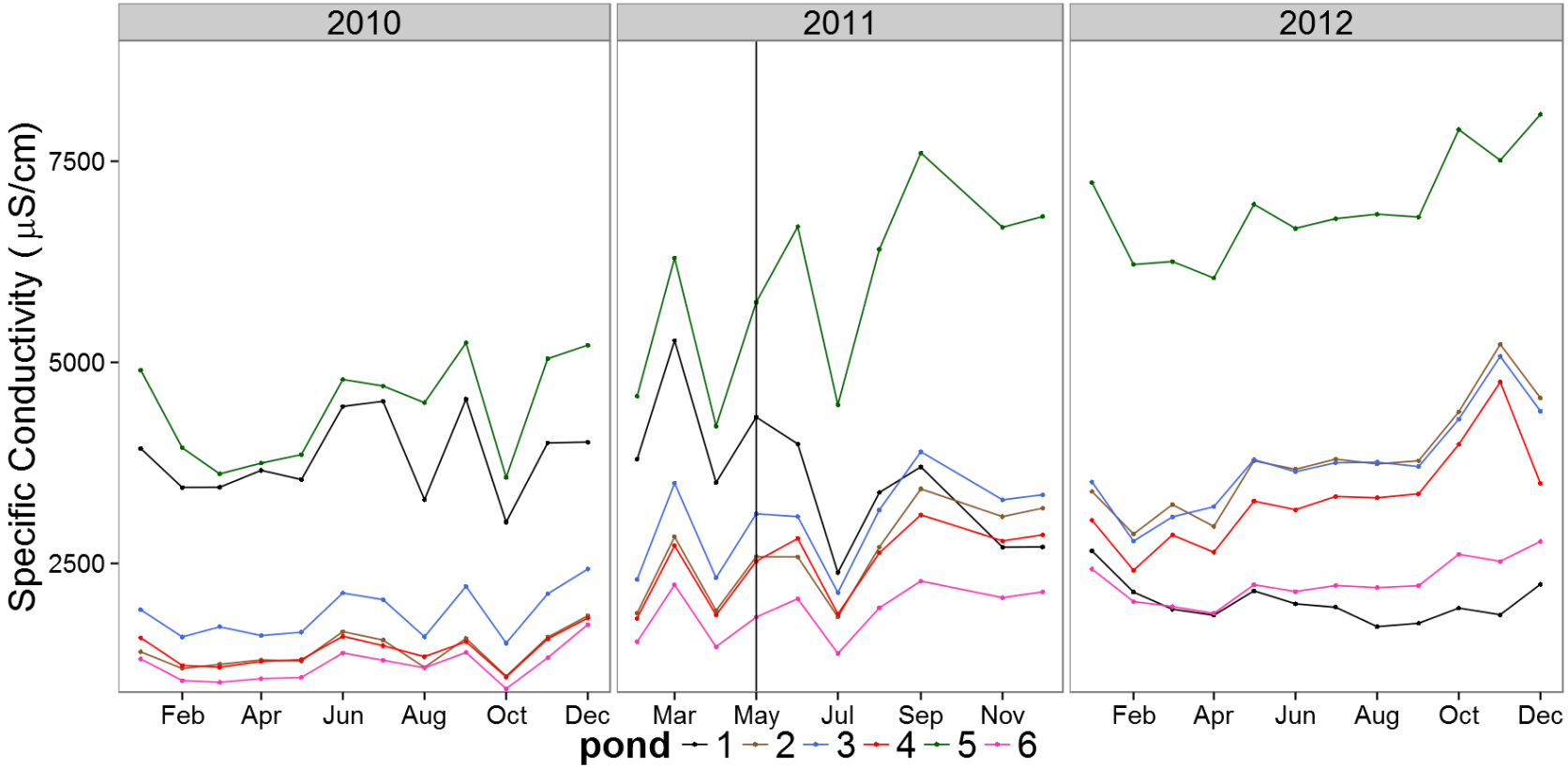

Figure 10.—Monthly mean specific conductivity for each pond, 2010 – 2012.
Values are means over time of day, depth, and location (inlet, outlet, and mid-pond). A vertical line indicates the date that water management stopped for Ponds 2 – 6.

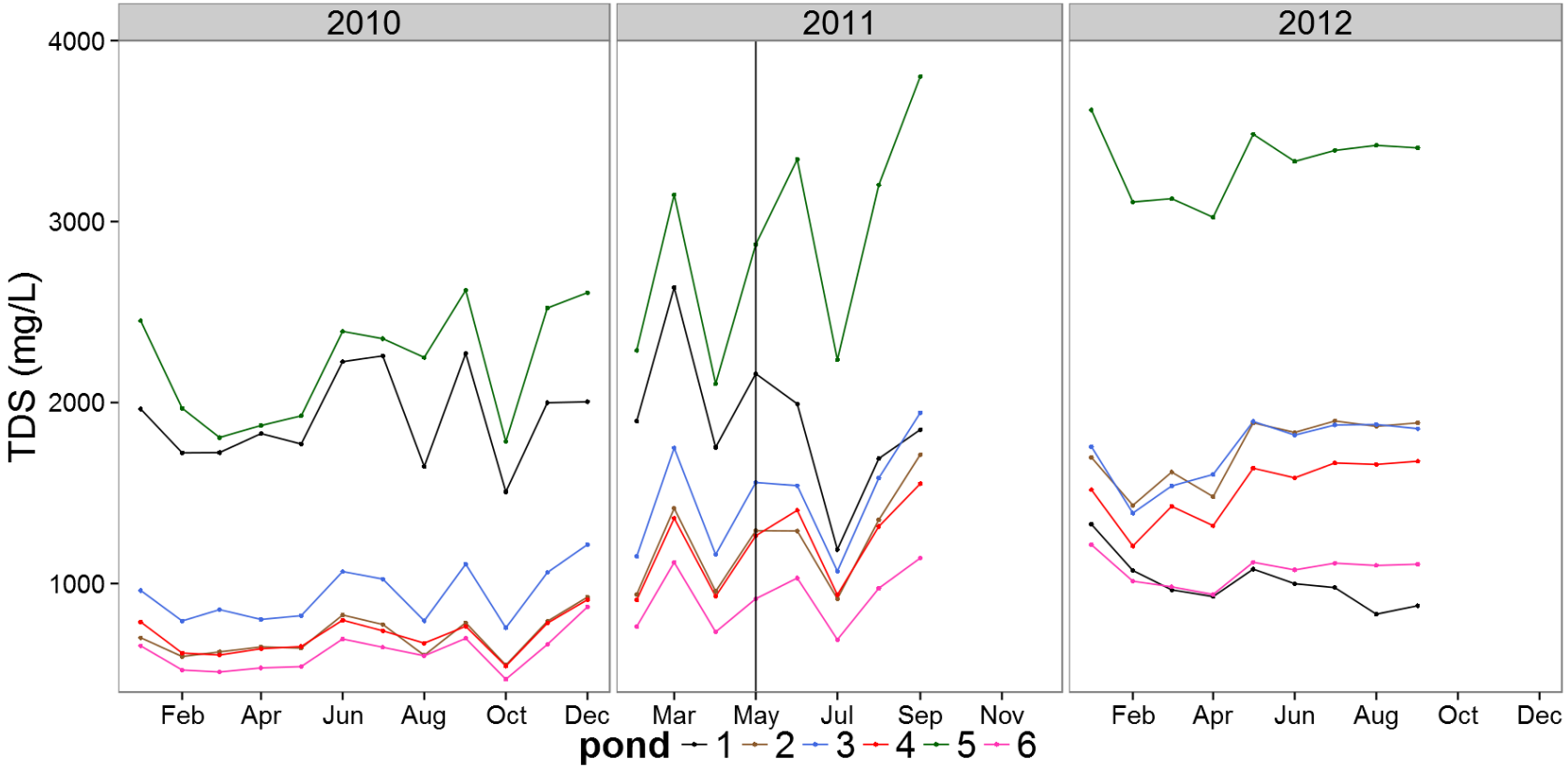

Figure 11.—Monthly mean total dissolved solids for each pond, 2010 – 2012.
Values are means over time of day, depth, and location (inlet, outlet, and mid-pond). A vertical line indicates the date that water management stopped for Ponds 2 – 6.

magnitude of change in all water quality parameters, except water temperature, were consistent with what we would expect after changes in water management for Ponds 2 – 6 (table 1). From 2010 to 2011 – 2012, water temperature increased by a small amount in all ponds, with a somewhat larger increase in Pond 1. The temperature increased more in 2012 in all ponds.

A statistically significant increase in DO was observed in Pond 1 (mean ± 95% confidence interval [CI], 2.3 ± 0.65), but statistical declines in all other ponds (range of mean change, -1.0 to -2.5). Declines were larger in 2012, but the increase in Pond 1 was larger in 2011. The pH increased in all ponds, with the mean change in Ponds 2 – 6 slightly greater than that observed in Pond 1. The largest increase was in 2011 for all ponds. Specific conductivity and TDS both increased by substantial amounts in Ponds 2 – 6 while declining in Pond 1, and all increases were greater in 2012 than in 2011.

While changes in temperature, DO, and pH were statistically significant, they were relatively small. The means for 2011 – 2012 were usually not substandard (i.e., CIs remained below maximum standards or above minimum standards).

Water Chemistry

Lab EC and pH concentrations were reported from the physico-chemical data; the results were similar, and they will not be reported for water chemistry. TDS exceeded the ADEQ standards, 723 – 747 mg/L, in all ponds during all months (table 2). Trace elements of arsenic were detected in low concentration: ADEQ and EPA levels were 49 to 2,206 times greater than those reported at the Imperial Ponds (figure 12, table 2). Se often exceeded chronic toxicity levels, 2.0 µg/L and 5.0µg/L, as set by the ADEQ and EPA, and the majority of reported concentrations were bound by detection limits (figure 13).

Concentrations for NH_3-N levels were greatest in Pond 5 compared to that of the other ponds. On April 20, 2012, Pond 5 had the highest levels observed at the Imperial Ponds, 1.29 mg/L. Both Ponds 4 and 5 had a similar spike in NH_3-N concentration in January 2012; however, no concentrations were near the standards set by the EPA (figure 14 and table 3). Total -N values often exceeded those set by the ADEQ, 1.6 – 1.8 mg/L, and the EPA, 0.4 mg/L (figure 15). Total -P minimum and maximum concentrations per pond are as follows: Pond 1, 0.206 – 2.12; Pond 2, 0.393 – 1.85; Pond 3, 0.309; Pond 4, 0.391 – 5.099; Pond 5, 1.23 – 3.21; and Pond 6, 0.307 – 1.196 mg/L. With the exception of Pond 6 on

Table 1.—Comparing water quality parameters before and after changes in water management for May – September, 2010 – 2012

(Data for 2011 – 2012 were compared with 2010 for all ponds. Differences were calculated as average (2011 – 2012) and average (2010). Values are estimated means and standard errors for 2010 and 2011 – 2012, mean change (after – before water addition stopped) with 95% CI, standard error, and p-value for t-test on null hypothesis of no change. Mean changes to 2011 and 2012 are also provided with p-values from t-tests. Estimates are from mixed model repeated measures ANOVA on monthly mean values for inlet, outlet, and mid-pond. The best-fit covariance structure is noted for each parameter.)

Parameter		2010		2011-12		(2011-12) vs. 2010				2011 vs. 2010		2012 vs. 2010		
(Covariance)	Pond	Mean	SE*	Mean	SE*	Mean	± 95% CI*	SE*	Pr > |t|	Mean	Pr > |t|	Mean	Pr > |t|	Description of Results
Temperature	1	27.6	0.122	29.5	0.11	1.9	0.34	0.163	<.0001	0.9	<.0001	2.8	<.0001	Small increase in temperature in all
(ANTE)	2	28.4		29.6		1.2			<.0001	0.2	0.2030	2.1	<.0001	ponds, largest in Pond 1. Largest change
	3	28.1		29.4		1.3			<.0001	0.4	0.0072	2.2	<.0001	in 2012.
	4	28.7		29.7		1.0			<.0001	-0.2	0.1877	2.1	<.0001	
	5	28.2		29.0		0.7			0.0001	-0.5	0.0026	2.0	<.0001	
	6	28.7		29.7		0.9			<.0001	-0.3	0.0501	2.1	<.0001	
DO	1	5.5	0.23	7.8	0.24	2.3	0.65	0.328	<.0001	3.0	<.0001	1.6	<.0001	Increase in Pond 1, decrease in all other
(ARH)	2	11.0		8.6		-2.5			<.0001	-1.7	0.0006	-3.3	<.0001	ponds. Largest change in 2012 except
	3	9.1		8.4		-0.7			0.0267	0.05	0.9122	-1.5	<.0001	Pond 1
	4	11.2		9.1		-2.1			<.0001	-1.6	0.0012	-2.5	<.0001	
	5	8.0		7.0		-1.0			0.0041	-0.6	0.2303	-1.4	0.0001	
	6	11.2		9.4		-1.7			<.0001	-0.9	0.0598	-2.6	<.0001	
pH	1	8.02	0.092	8.36	0.063	0.34	0.23	0.112	0.0037	0.55	0.0002	0.13	0.2658	Larger increase in Ponds 2-6. Largest
(ARH)	2	8.59		9.01		0.43			0.0004	0.58	0.0001	0.27	0.0264	change in 2011.
	3	8.47		8.97		0.50			<.0001	0.69	<.0001	0.31	0.0119	
	4	8.65		9.16		0.51			<.0001	0.58	0.0001	0.44	0.0006	
	5	8.26		8.67		0.40			0.0008	0.42	0.0036	0.38	0.0025	
	6	8.88		9.31		0.43			0.0004	0.66	<.0001	0.21	0.0922	
SpC	1	4069	35.6	2735	11.7	-1334	79.8	37.42	<.0001	-515	<.0001	-2153	<.0001	Decrease in Pond 1, increase in all other
(ANTE)	2	1452		3189		1736			<.0001	1174	<.0001	2299	<.0001	ponds. Largest change in 2012.
	3	1926		3404		1478			<.0001	1153	<.0001	1803	<.0001	
	4	1449		2940		1492			<.0001	1140	<.0001	1842	<.0001	
	5	4617		6498		1881			<.0001	1566	<.0001	2196	<.0001	
	6	1272		2054		782			<.0001	628	<.0001	935	<.0001	
TDS	1	2034	17.8	1364	5.9	-670	39.9	18.71	<.0001	-258	<.0001	-1082	<.0001	Decrease in Pond 1, increase in all other
(ANTE)	2	726		868		868			<.0001	587	<.0001	1150	<.0001	ponds. Largest change in 2012.
	3	963		1702		739			<.0001	576	<.0001	902	<.0001	
	4	725		1470		745			<.0001	570	<.0001	920	<.0001	
	5	2309		3249		941			<.0001	783	<.0001	1099	<.0001	
	6	636		1026		390			<.0001	314	<.0001	467	<.0001	

*SE and CI estimated from ANOVA are the same for all ponds.

Table 2.—Modified summary on numeric water quality standards by the Arizona Department of Environmental Quality and the United States Environmental Protection Agency (created by Jeanette Haegele)
(— = no data)

Water quality parameters	Arizona Department of Environmental Quality[1]	United States Environmental Protection Agency[2]
Nutrients		
Ammonia-nitrogen (mg/L)	See table 3	See table 3
Total nitrogen (mg/L)	1.6 – 1.8	0.4
Total phosphorus (mg/L)	0.115 – 0.140	0.017
Trace Elements		
Selenium (µg/L)[3] Chronic toxicity	2	5
Other parameters		
pH	6.5 – 9.0	6.5 – 9.0
Total dissolved solids (mg/L)	723 – 747	—

[1] The standards recommended by the ADEQ are specific to warm water lakes and reservoirs designated for aquatic and wildlife use. Ranges apply to peak season (April to October for warm water lakes). All criteria were obtained from ADEQ (2009). The threshold range for TDS is specific to the Colorado River below Hoover Dam (723 mg/L) and below Parker Dam (747 mg/L).

[2] The standards recommended by the EPA in this table are specific to aquatic life in freshwater systems. The standards for trace elements and pH were obtained from the EPA's online national recommended water quality criteria (EPA 2009a). The nutrient standards for lakes and reservoirs were obtained from a summary of nutrient criteria (EPA 2009b): all the Native Fish Sanctuaries are in Aggregate Ecoregion III ("Xeric West").

[3] The EPA is reviewing selenium standards, and only chronic criteria are available on their online compilation (EPA 2009a). In a draft report, the EPA (2004) recommends acute criteria should be based on the relative proportion of selenite and selenate, and chronic criteria should be based on Se concentrations within fish tissue.

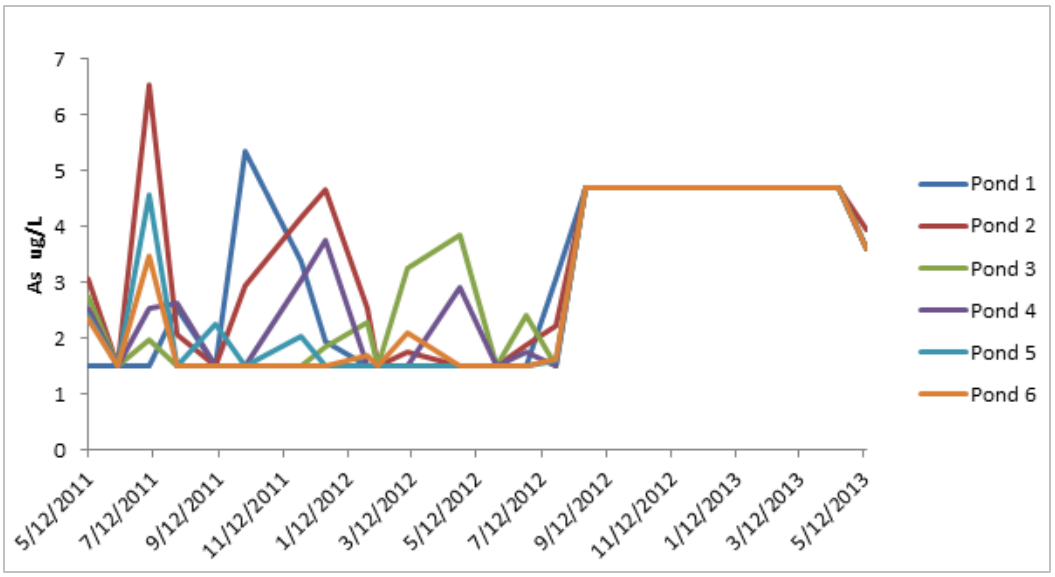

Figure 12.—Arsenic concentrations (µg/L) in Ponds 1 – 6.

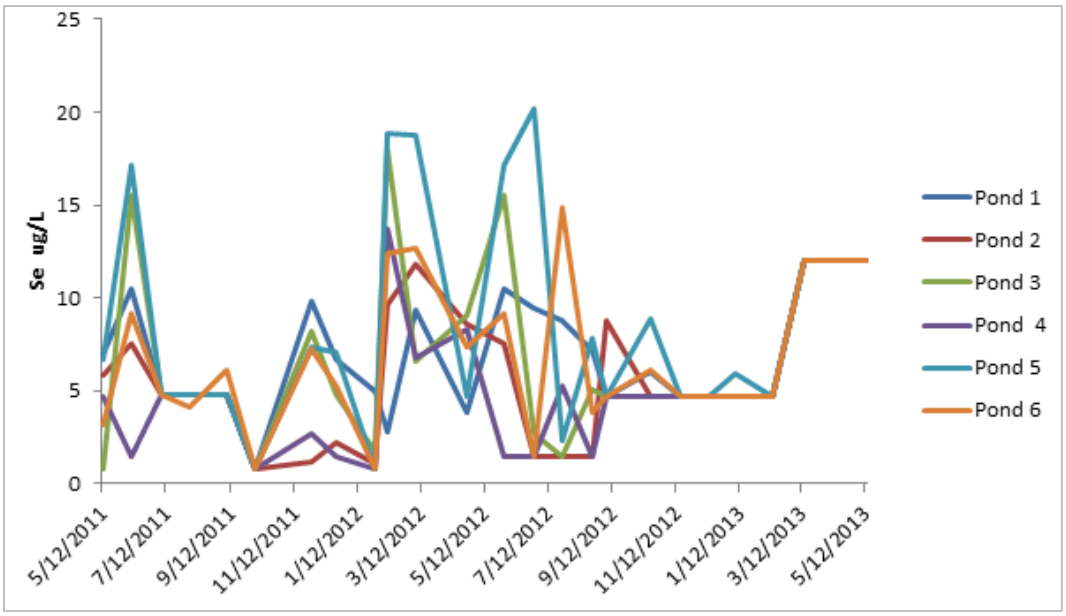

Figure 13.—Selenium concentrations (µg/L) in Ponds 1 – 6.

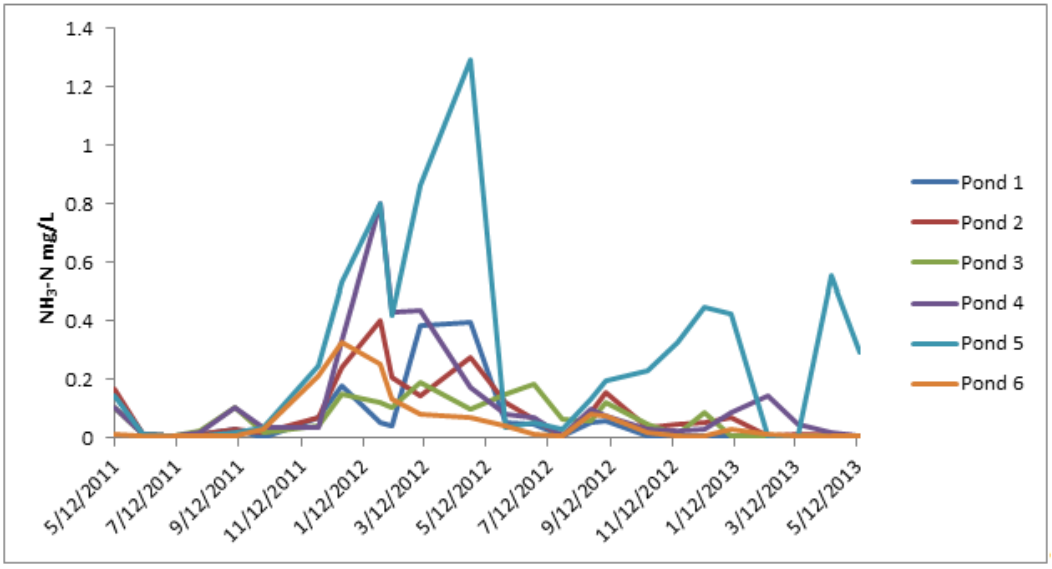

Figure 14.—Ammonia nitrogen concentrations (mg/L) in Ponds 1 – 6.

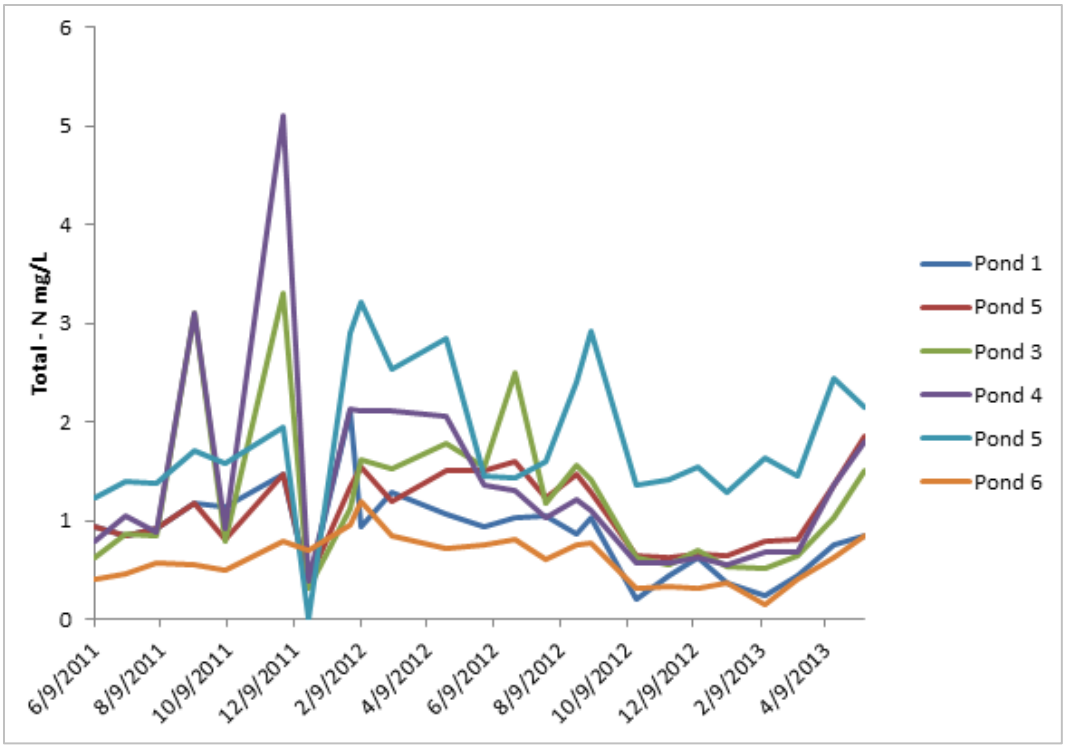

Figure 15.—Total nitrogen concentrations (mg/L) in Ponds 1 – 6.

Table 3.—Acute criteria for ammonia-nitrogen (NH_3-N) in freshwater designated for aquatic and wildlife use when salmonids are absent

(For pH from 6.6 to 9.0, NH3-N values were obtained from the EPA (1999). For pH exceeding 9.0, NH3-N values were calculated using the formula shown below.)

Table provided by Jeanette Haegele and modified to include pH 9.5 – 9.7

(pH in standard units: mg/L)

pH	NH3-N	pH	NH3-N
7.2	29.5	8.5	3.2
7.3	26.2	8.6	2.65
7.4	23	8.7	2.2
7.5	19.9	8.8	1.84
7.6	17	8.9	1.56
7.7	14.4	9	1.32
7.8	12.1	9.1	1.14
7.9	10.1	9.2	0.99
8	8.4	9.3	0.87
8.1	6.95	9.4	0.77
8.2	5.72	9.5	0.7
8.3	4.71	9.6	0.64
8.4	3.88	9.7	0.6

For pH exceeding 9.0, criteria for acute toxicity of NH_3-N (mg/L) when salmonids are not present were determined by the following formula (EPA 1999):

$$\frac{0.411}{1+10^{7.204-pH}}+\frac{58.4}{1+10^{pH-7.204}}$$

multiple occasions and Pond 1 in April 2012, all ponds were between the standards set by the ADEQ, 0.115 – 0.140. However, all ponds exceeded 0.017 mg/L, the standard set by the EPA, on multiple occasions (figure 16).

The ADEQ and EPA have not set criteria for NO3+NO_2-N or Ortho-P. NO3+NO_2-N had similar concentration between ponds over the 2-year study period. During November 2011, Ponds 2, 5, and 6 had a NO3+NO_2-N 9 to 29 times greater than in Ponds 3 and 4. In August 2013, Pond 5 had a NO3+NO_2-N concentration of approximately 38 times greater than that of the other ponds (figure 17). Ortho -P concentrations were highest in Ponds 3 and 4 in November 2011, approximately 15 times higher than the other ponds. All ponds had increased levels in April 2012 (figure 18).

Water Elevation

The ponds show similar elevation trends to that of the river, with the exception of Pond 1, which had water added on a frequent basis. Pond 1 exceeded the maximum level on the staff gage on several occasions and was frequently reported at the maximum elevation 187.0. As the river increased over time, December 19, 2011 – April 16, 2012, the water elevation of Ponds 2 – 6 also increased. Pond 4 and 6 maintained a stable water elevation throughout most of 2012 and only decreased when the river experienced an approximately 2-foot drop in elevation. Ponds 2, 3, and 5 appeared to follow similar fluctuations in water elevation as that of the river (figure 19).

Phytoplankton and Zooplankton

Phytoplankton were reported by division, cyanobacteria, bacillariophyta, chlorophyta, cryptophyta, and pyrrohyta and reported as cell densities (cells per liter). Cyanobacteria, bacillariophyta, chlorophyta, and cryptophyta were found in all six ponds on multiple occasions over the 2-year study (figures 20 – 23). Pyrrohyta was detected within all six ponds over the study; only Pond 3 had reportable densities in January 2012, and Pond 2 in April 2012. Pond 1 only had reportable densities in July 2012 (figure 24). Phytoplankton diversity was between 12 – 26 genera among sites.

Zooplankton data were log 10 transformed because of the limited numbers and species occurring at the Imperial Ponds (figures 25 – 30). Zooplankton was reported as order cladocera, subclass copepod, class ostracoda, and phylum rotifera.

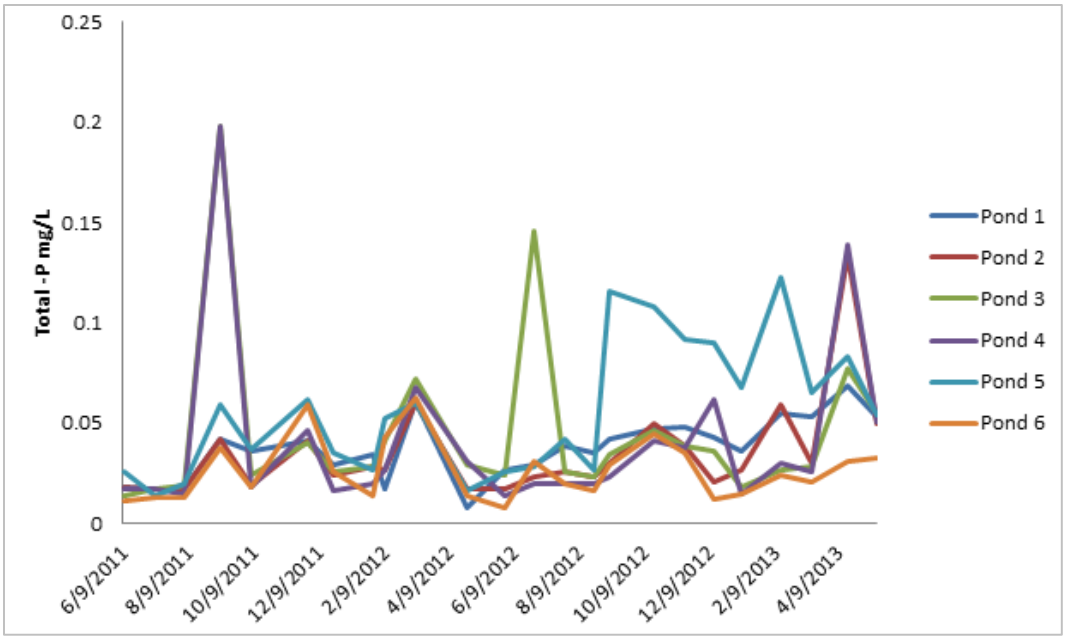

Figure 16.—Total phosphorus concentrations (mg/L) in Ponds 1 – 6.

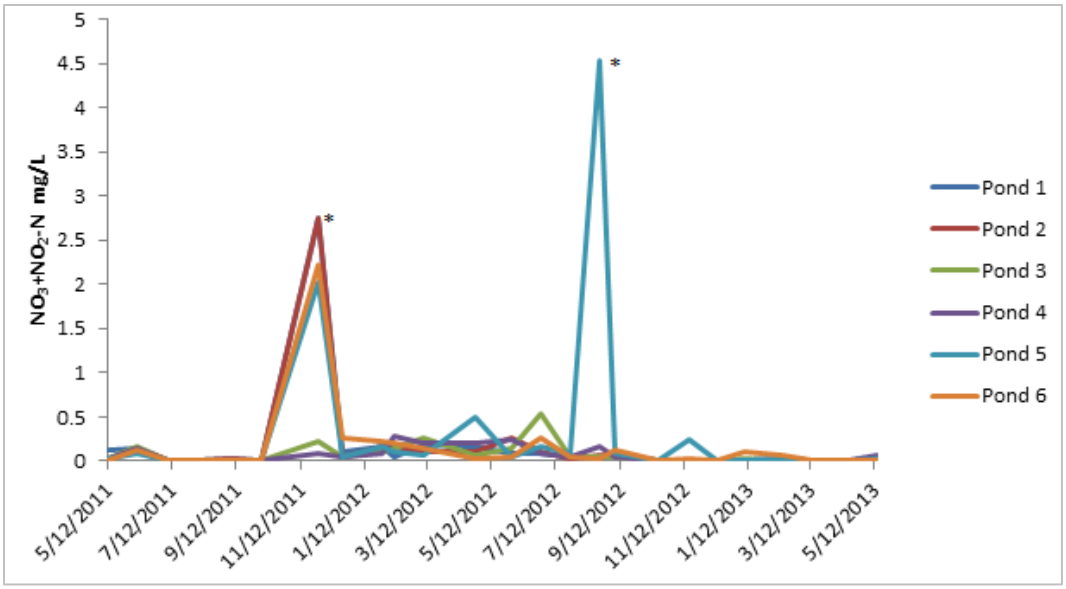

Figure 17.—Nitrate-nitrite concentrations (mg/L) in Pods 1 – 6.
* Samples assumed to be preserved with nitric acid in place of sulfuric acid, resulting in much higher concentrations.

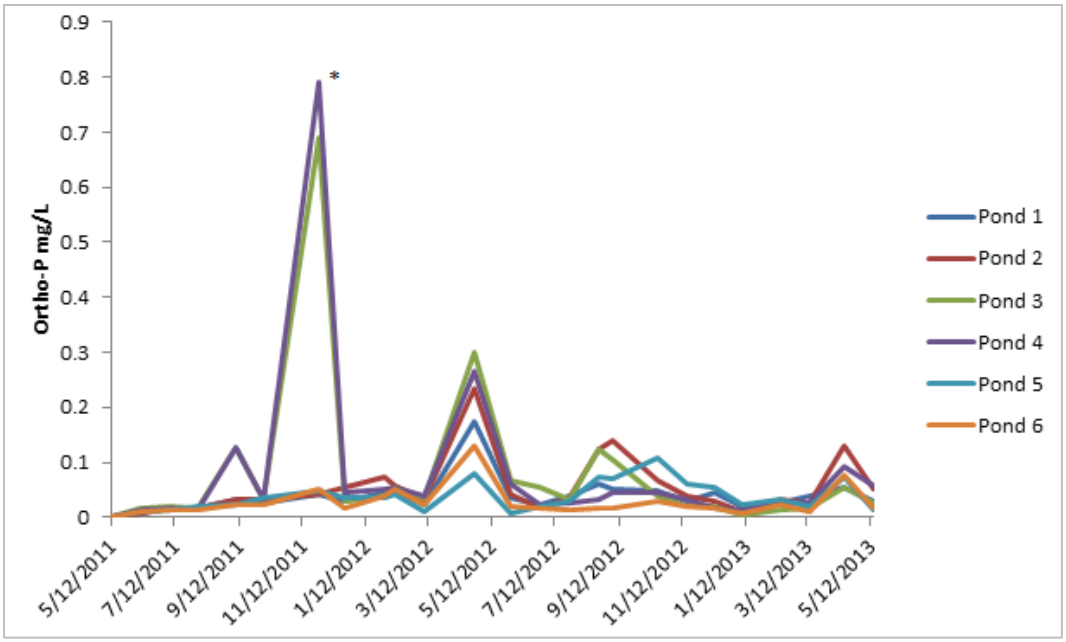

Figure 18.—Orthophosphorous concentrations (mg/L) in Ponds 1 – 6.
* Holding times were exceeded upon receipt of samples.

DISCUSSION

A trend analysis from the physico-chemical profiles indicates that the temperature is increasing over time in all six of the ponds; however, it appears to be increasing at a slightly higher rate in Pond 1. Previous results had credited the well water with maintaining the temperature under the set standard of 33.3 °C at the Imperial Ponds (Kesner et al. 2010b, 2012). These results suggest that the water source may not be the only influence on temperature control within the ponds.

The pH also appeared to have increasing values over time, with differences being observed between ponds. The pH commonly exceeded 9.0 in Ponds 2 – 6 in both summer 2011 and 2012, with the highest pH values observed in 2011. The highest pH level was recorded in Pond 2, with a pH of 9.92 in June 2011. The pH levels were lowest in Pond 1, likely a result of well water (with lower pH, well pH was recorded from November 2011 – present; minimum pH recorded was 7.4, maximum pH was 8.0, and the average pH was 7.8) being supplied to the pond. The pH appeared to peak during the warmest months of the year and remained below the threshold during cooler months. The pH levels may be able to be maintained with minimal pumping during certain times throughout the year.

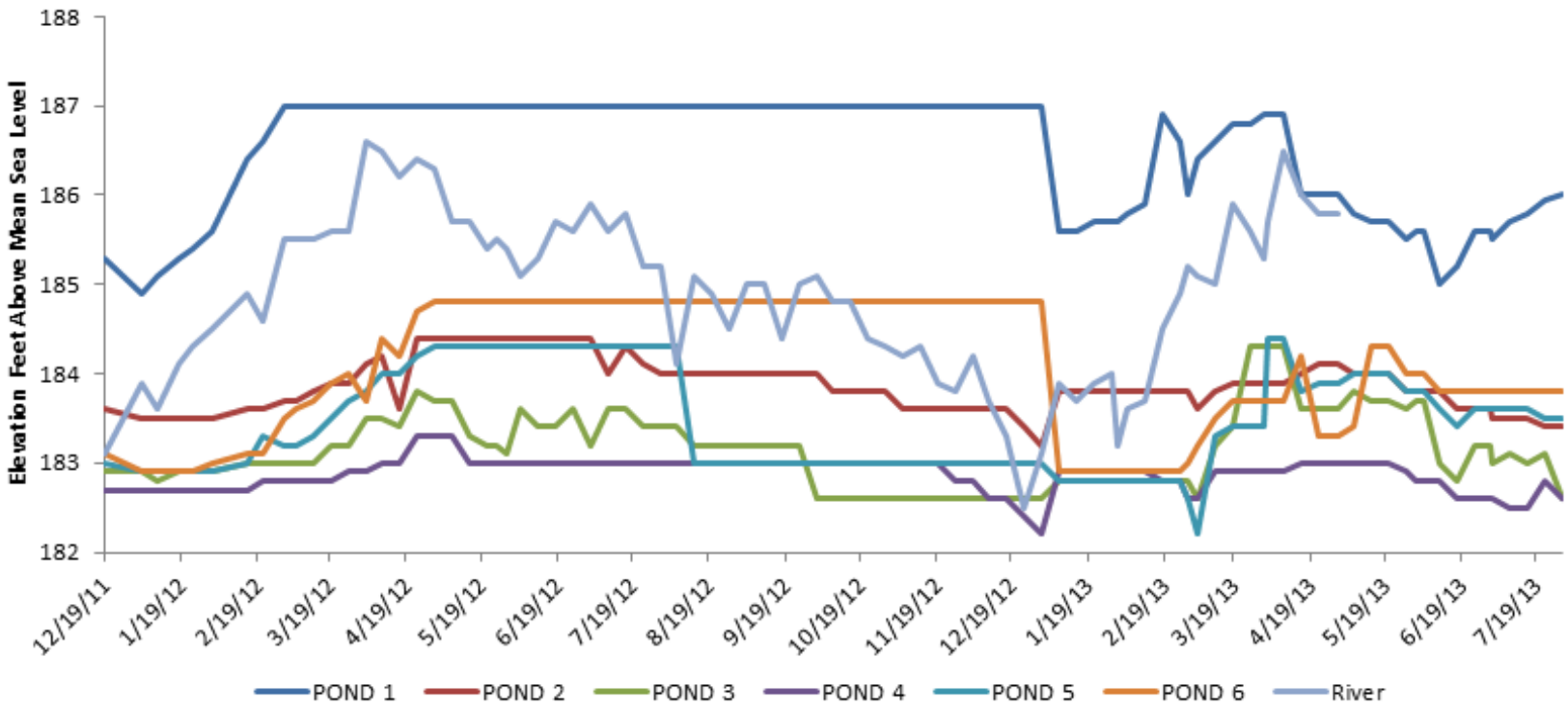

Figure 19.—Surface water elevations of the Colorado River and Ponds 1 – 6.
Elevations are in feet above mean sea level.

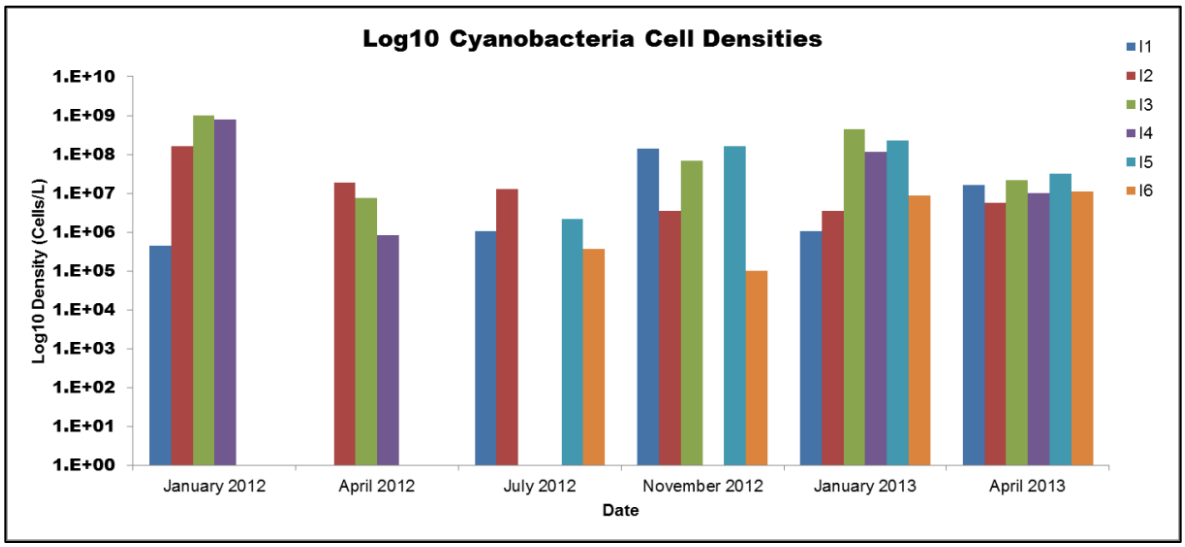

Figure 20.—Log10 cyanobacteria cell densities (cells per liter).

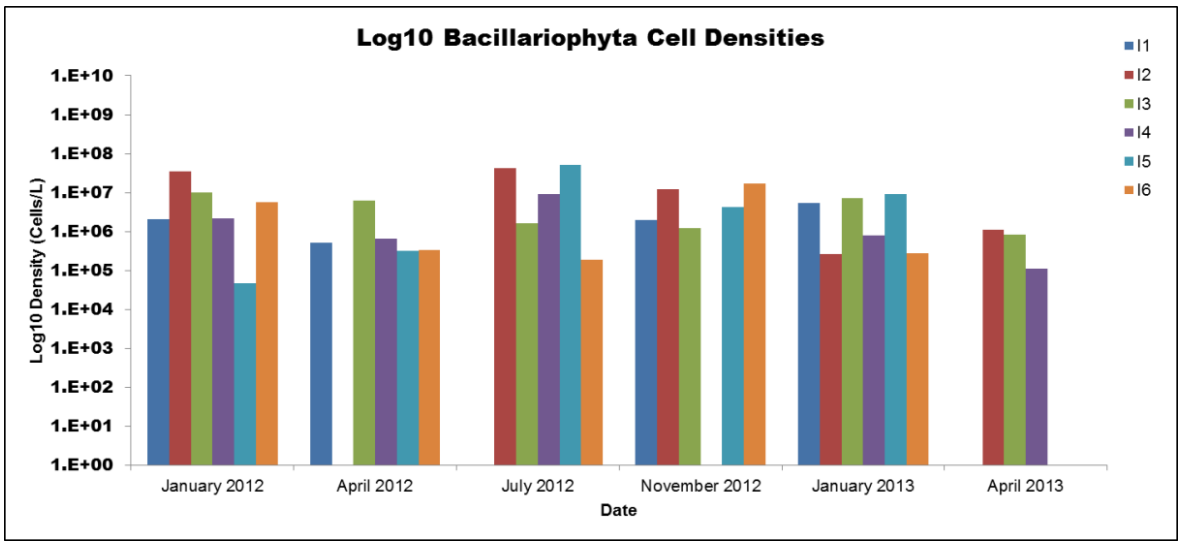

Figure 21.—Log10 bacillariphyta cell densities (cells per liter).

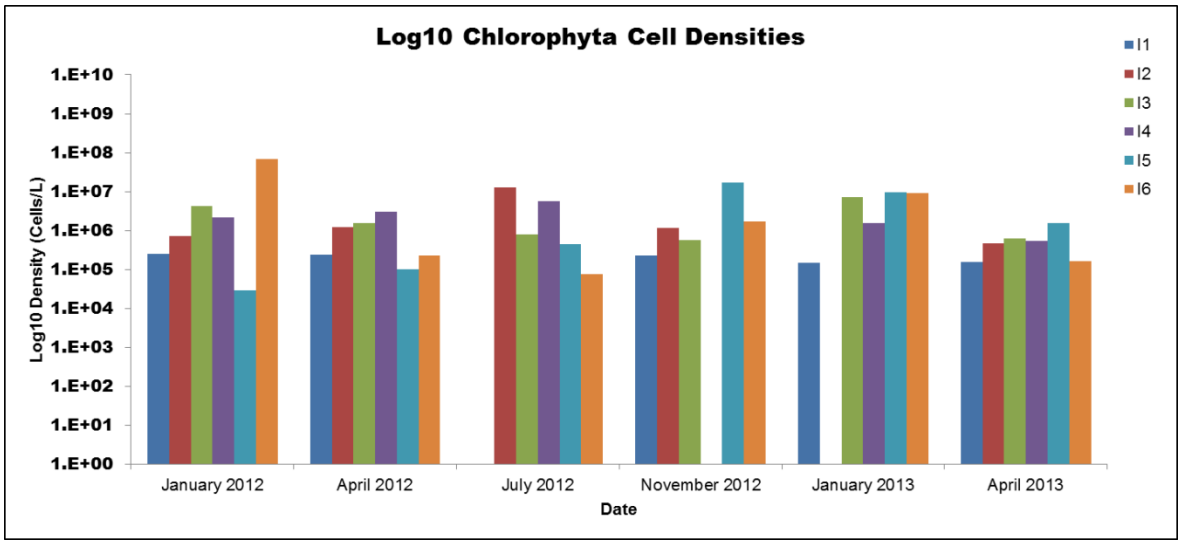

Figure 22.—Log10 chlorophyta cell densities (cells per liter).

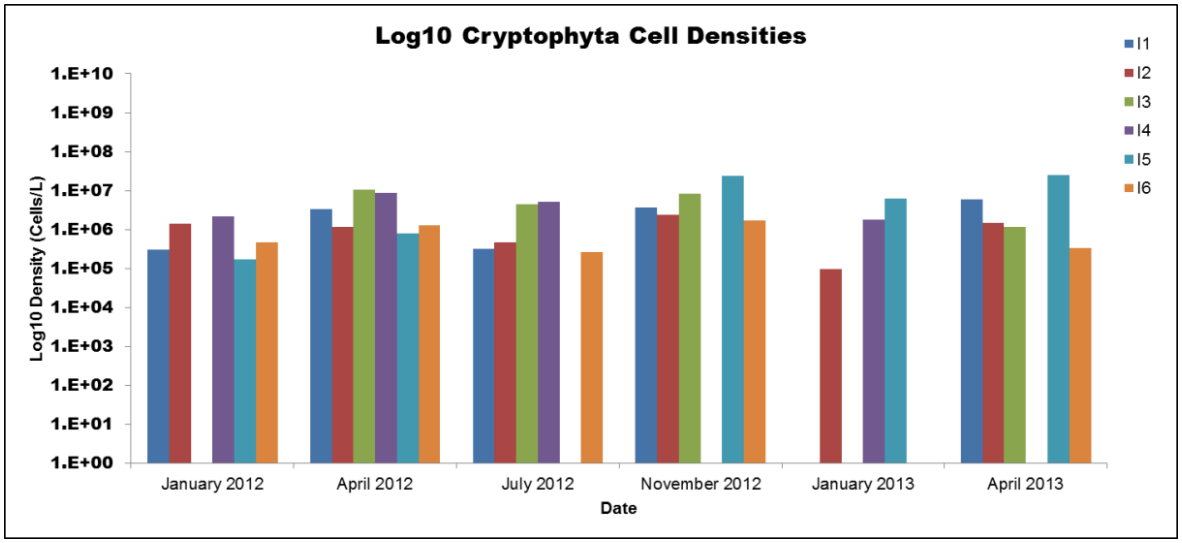

Figure 23.—Log10 cryptophyta cell densities (cells per liter).

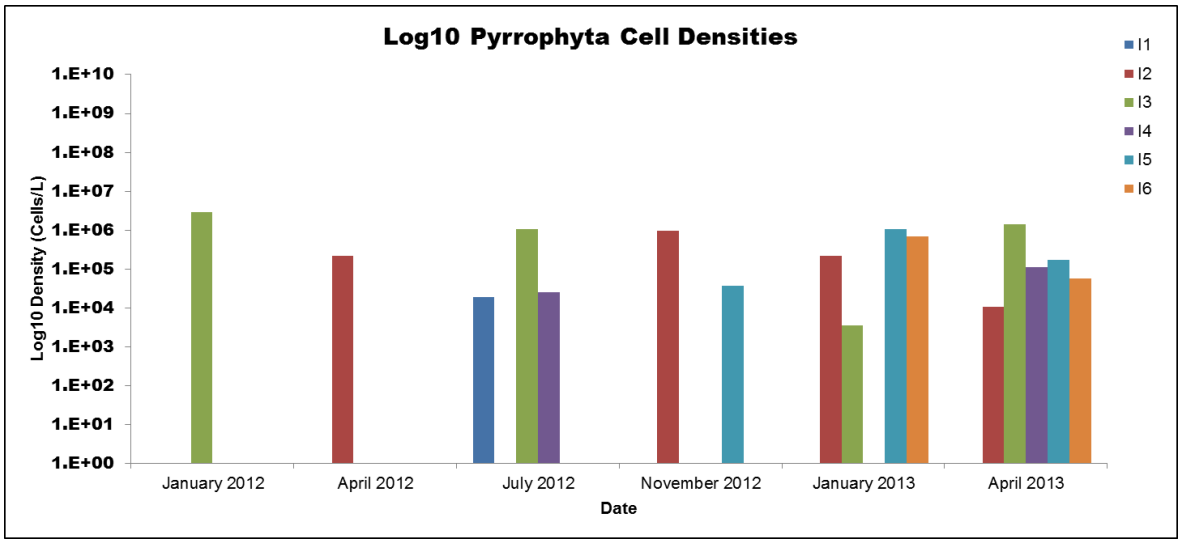

Figure 24.—Log10 pyrrophyta cell densities (cells per liter).

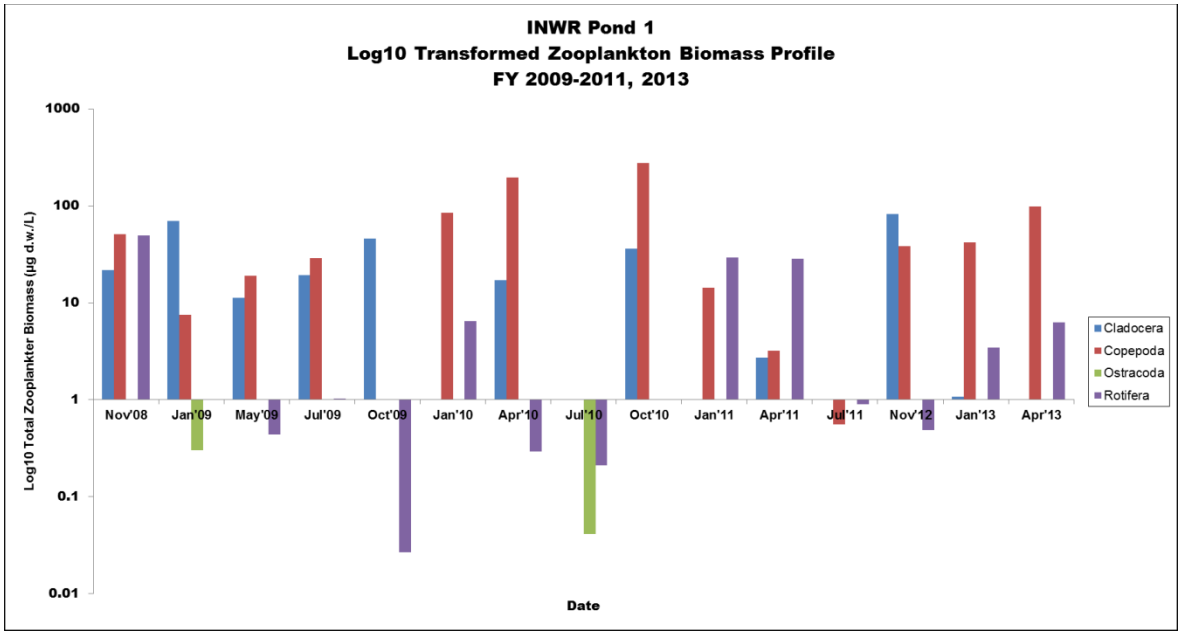

Figure 25.—Total biomass profile for Pond 1 (micrograms dry weight per liter).
Data was log10 transformed because samples were depauperate of most zooplankters over time. The transformations were used for presentation purposes and maintain the integrity of overall trends.

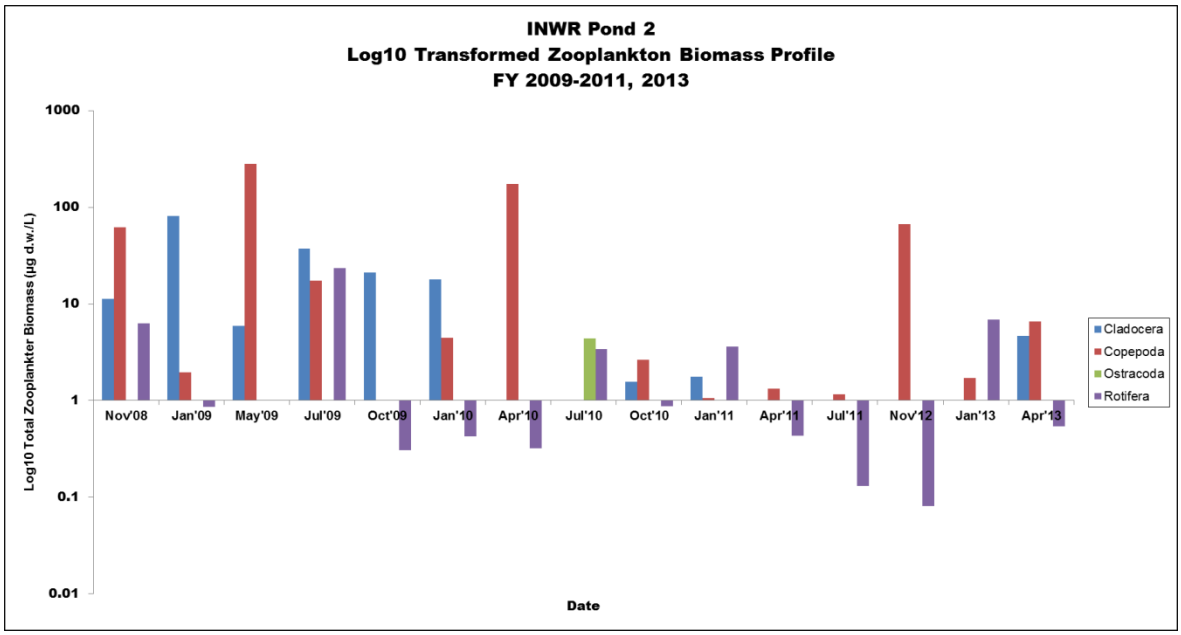

Figure 26.—Total biomass profile for Pond 2 (micrograms dry weight per liter).
Data was log10 transformed because samples were depauperate of most zooplankters over time. The transformations were used for presentation purposes and maintain the integrity of overall trends.

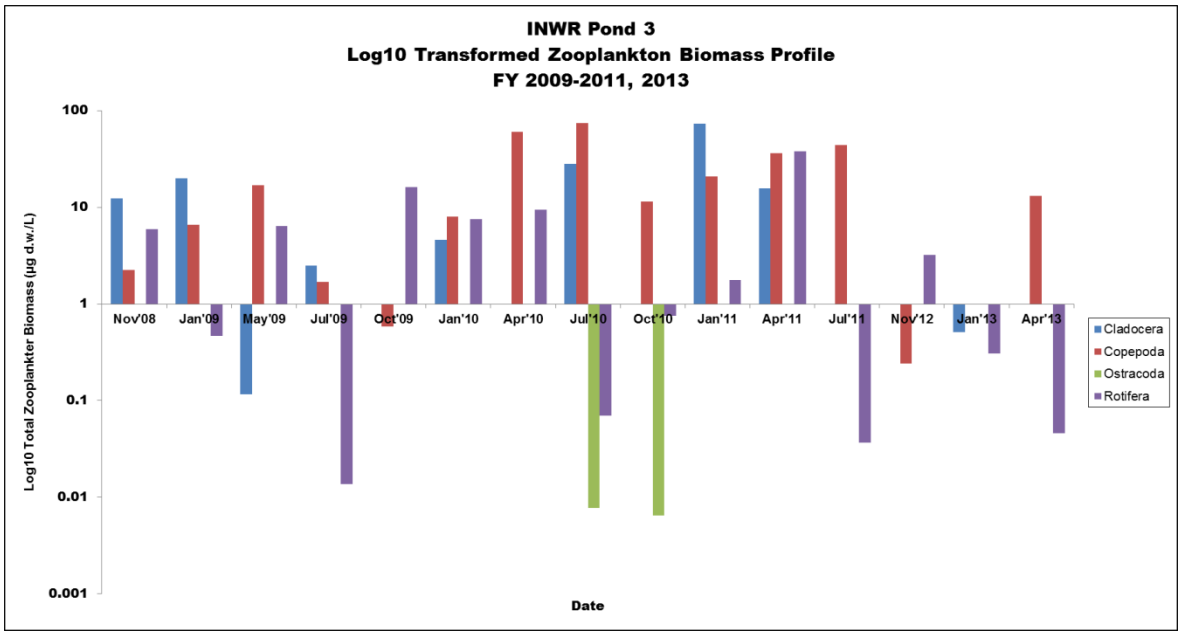

Figure 27.—Total biomass profile for Pond 3 (micrograms dry weight per liter).
Data was log10 transformed because samples were depauperate of most zooplankters over time. The transformations were used for presentation purposes and maintain the integrity of overall trends. Total zooplankter biomass for Pond 3 is on a smaller scale than the other five ponds because of lower biomass over time.

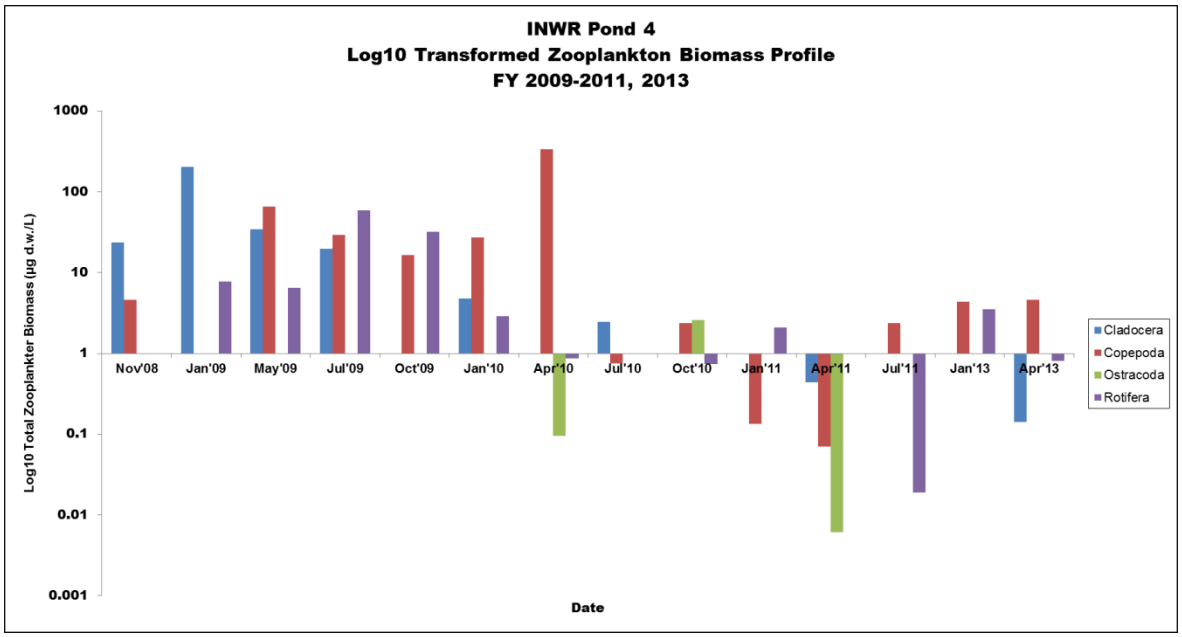

Figure 28.—Total biomass profile for Pond 4 (micrograms dry weight per liter).
Data was log10 transformed because samples were depauperate of most zooplankters over time. The transformations were used for presentation purposes and maintain the integrity of overall trends.

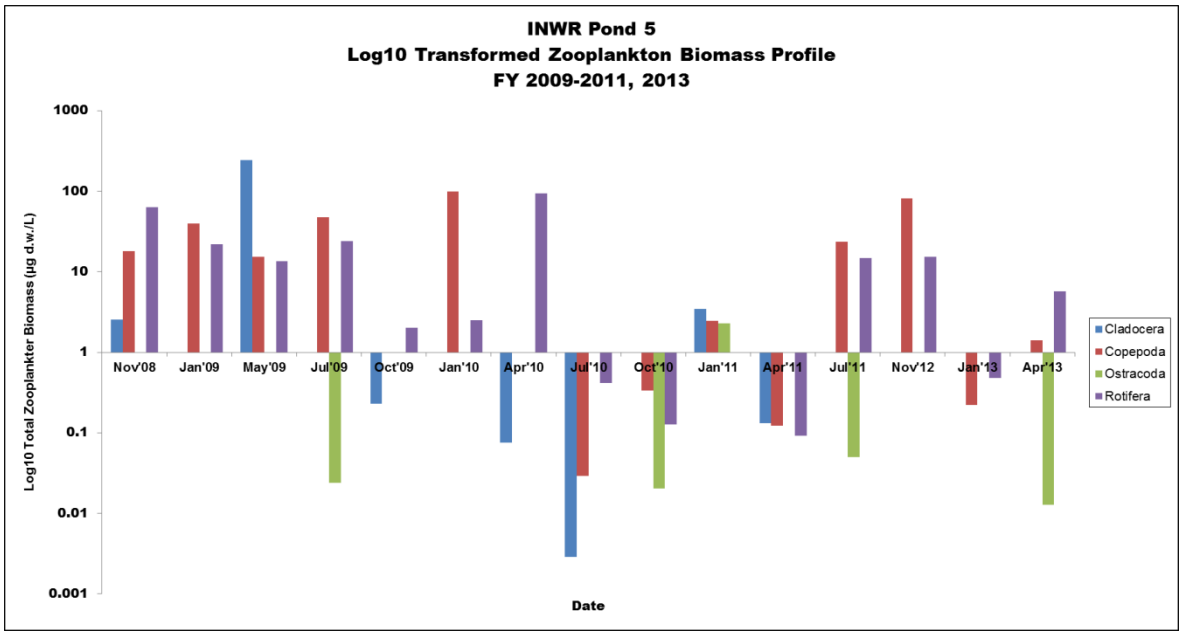

Figure 29.—Total biomass profile for Pond 5 (micrograms dry weight per liter).
Data was log10 transformed because samples were depauperate of most zooplankters over time. The transformations were used for presentation purposes and maintain the integrity of overall trends.

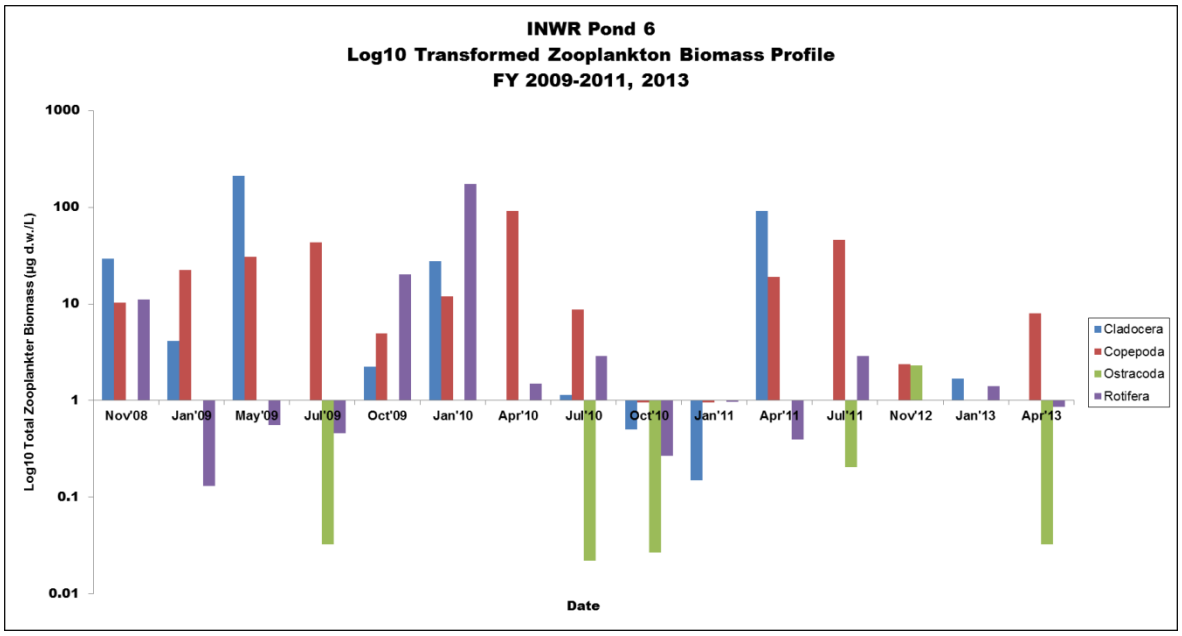

Figure 30.—Total biomass profile for Pond 6 (micrograms dry weight per liter).
Data was log10 transformed because samples were depauperate of most zooplankters over time. The transformations were used for presentation purposes and maintain the integrity of overall trends.

DO levels fell below 4 mg/L at the lowest depth measurement, but remained within acceptable levels at other sample points within the ponds. However, the mid and lower depths often had higher DO levels than surface measurement, which may reflect supersaturation in samples near aquatic vegetation. DO levels within the ponds do not appear to be a major cause for concern at this time.

Specific conductivity levels show a gradual increase over time in all ponds. Pond 5 has the highest specific conductivity levels of all the ponds, with the highest recorded concentration at 10,450 µS/cm in September 2011. The maximum specific conductivity in Ponds 1, 2, 3, 4 and 6 was 5,105 µS/cm; higher levels of specific conductivity (5,950 µS/cm) have been observed at Davis Cove, Lake Mohave, Arizona/Nevada, a backwater that is currently sustaining a population of BONY and RASU (Jeanette Haegele 2013, personal communication). Fertilization studies show that RASU egg hatch is most successful at 1,000 and 3,000 µS/cm, but hatch and development were documented between 1,000 and 12,000 µS/cm (Stolberg 2012). Specific conductivity levels may be similar to those of Davis Cove and within egg development and hatch for RASU. However, ways to mitigate specific conductivity levels should be evaluated, as the data show an increase in levels over time.

TDS was well above the standards set by both the ADEQ and EPA. However, these standards may not best suit the standards for BONY and RASU. Juvenile

bonytail were found to select TDS levels of 4,100 – 4,700 mg/L (Pimentael and Bulkley 1983). These TDS values have not been recorded in Ponds 1 – 4 or Pond 6. Limited data were found for TDS standards for BONY and RASU, which may merit additional research at various life stages for both fishes. Continuously measured (automated) data for physico-chemical parameters would allow a more accurate estimate of how frequently standards are exceeded.

Se concentrations were above the chronic toxicity levels set by the ADEQ and EPA; however, many of the reported concentrations were bound by detection limits. These data should be considered cursory information regarding Se in the ponds, especially as it relates to Se toxicity. We looked at a single measurement of Se to effectively assess Se bioaccumulation; multiple elements, including water concentration, soils, and biota, should be evaluated (Lemly 2002). Future monitoring of Se concentrations will be adjusted as soon as appropriate protocols become developed. This protocol development will be based on guidance from LCR MSCP Conservation Measure MRM5:

> "Conduct monitoring of selenium levels in sediment, water, and/or biota present in LCR MSCP created backwater…increased levels of selenium in created backwater and marshes or in covered species that use them, the LCR MSCP will undertake research to develop feasible methods to manage the conservation areas in a manner that will eliminate or compensate for the effects on increase selenium levels. If feasible management methods are identified they will be implemented…" (Reclamation 2004)

LCR MSCP Work Task C59: Selenium Monitoring in Created Backwater and Marsh Habitat has been created to develop a long-term Se monitoring plan to address Conservation Measure MRM5 (Reclamation 2013). Phytoplankton had not been collected prior to this study. These data should serve only as a reference to what is in the ponds and should not be used for trend analyses as a result of inconsistent sampling techniques. Zooplankton analyses were not consistent between Aquatic Consulting & Testing, Inc., and BSA Environmental Services, Inc. Data analyzed by Aquatic Consulting & Testing, Inc., was excluded from our dataset because biomass data were not available for those samples. Total biomass (dry weight µg/L) is considered the most relevant depiction of zooplankton as a food resource for fish (John Beaver, personal communication). From the present biomass datasets, there appear to be no apparent trends.

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