ISWS CONTRACT REPORT 2019-04

Water Quality Trend Analysis for the Fox River Watershed: Stratton Dam to the Illinois River

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February 2019

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by

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Prepared for
Fox River Study Group

February 2019

Table of Contents

Page

List of Tables

List of Figures

Acknowledgments and Disclaimer

This technical report was prepared with funding from the Fox River Study Group, Inc., and its authors acknowledge the support and guidance of Cindy Skrukrud, Fox River Study Group Board Chair. This study was also supported by the regular duties and expertise of the authors at the Illinois State Water Survey, Prairie Research Institute, University of Illinois at Urbana-Champaign.

Dr. Michael Machesky was the original principal investigator for this study and we wish him the best in his retirement. The development of the Fox Database (FoxDB) was the brainchild of several Illinois State Water Survey researchers and staff. Since its inception, additional ISWS staff have updated and maintained the database. The authors gratefully acknowledge the following for their efforts: Karla Andrews, Sally McConkey, Alena Bartosova, Amy Russell, Jennifer Hill, William Gillespie, Jayanthi Gopal, and Dian Nurhayati.

Many agencies and organizations provided the data for the FoxDB that made this analysis possible (in alphabetical order): Deuchler Environmental, Inc., Fox Metro Water Reclamation District, Fox River Study Group, Fox River Water Reclamation District, Friends of the Fox, Huff & Huff, Illinois Environmental Protection Agency, Illinois State Water Survey, Max McGraw Wildlife Foundation, McHenry County Health Department, Metropolitan Water Reclamation District of Greater Chicago, Northeastern Illinois Planning Commission, U.S. Environmental Protection Agency, and U.S. Geological Survey.

Drs. Momcilo Markus and Zhenxing Zhang reviewed the report. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the Illinois State Water Survey, Prairie Research Institute, or the University of Illinois.

Executive Summary

This report presents a trend analysis conducted for nutrient-related water quality parameters collected at monitoring stations located on the Fox River main stem and tributaries and compiled and maintained in a database, FoxDB. An exploratory data analysis (EDA) was performed on a total of 141 water quality parameters across the 18 monitoring stations to summarize and extract the characteristics of the water quality data. Based on the EDA analysis, the Seasonal Kendall Test (SKT) for trends was selected as the core analysis method, and the EnvStats software R-package was used to perform the water quality trend analysis and EDA. A suite of procedures and workflows that use the EnvStats library of codes for the analysis were written using R programing language to extract selected water quality data from the FoxDB (i.e., the water quality database for the Fox River watershed) and perform the analysis. In addition to the nonparametric analysis using the SKT method, trend analyses of water quality concentration and fluxes (loads) were conducted for one Fox River main stem and two tributary monitoring stations that have not only long-term concentration data, but also the corresponding continuous daily discharge data. A total of 19 parametric models using concentration and flow data across the three stations were developed using the Weighted Regression on Discharge, Time, and Season (WRTDS) method for estimating trends in flow-normalized concentration and fluxes.

For all monitoring stations, the SKT trend analysis generally showed that most of the nutrient-related water quality parameters exhibited either a decreasing or no trend across all seasons. No upward annual trend was exhibited for organic nitrogen (Org-N), ammonia nitrogen, total suspended solids (TSS), or chlorophyll-A (CHL-A) at any of the monitoring stations. At the most downstream station on the main stem, the Fox River at Yorkville, no increasing trend was detected, with most of the water quality parameters showing a decreasing trend across all seasons. Most of the upward trend was detected for dissolved phosphorus (DP), particularly in spring and summer months. In comparison, total phosphorus (TP) showed an increasing annual trend only for Poplar Creek near the Mouth-Elgin station. For more than half of the stations, the pH showed a downward or no trend. In the case of pH, an upward or downward trend from the median, which is within the pH limits for freshwater, would indicate a declining water quality. All remaining water quality parameters exhibited decreasing longitudinal trends downstream of the Fox River at Algonquin, indicating improvement of the river's water quality, except for dissolved oxygen (DO), which rather implies a declining water quality trend.

The results of the trend analysis conducted using the WRTDS method generally indicate that flow-normalized concentration and fluxes (loads) of most water quality parameters decreased across all seasons from 2006 to 2016 for the Fox River at Montgomery, which is the only station in the main stem with the required concentration and flow data. A few exceptions were concentration and fluxes of total suspended solids (TSS) in spring and chlorophyll A (CHL-A) in summer, which showed increasing trends. If not in the percentage amount, the flux and concentration trends are largely similar for this station (i.e., they are in the same downward or upward direction). The only difference observed was between the spring ammonia nitrogen (NH3-N) concentration and its corresponding flux, which showed opposing trends, indicating that concentration trends are not necessarily informative of flux trends. Large decreases in summer DP, NH_3-N, and nitrate nitrogen (NO_3-N); winter TP, TSS, and CHL-A; and spring for DO, Org-N, and total kjeldahl nitrogen (TKN) concentrations were obtained for the Fox River at Montgomery station. A decreasing trend in concentration across all seasons, unlike for DO, is indicative of an improving water quality trend. In comparison with other water quality parameters, flow-normalized fluxes of TP and DP also appeared to have larger decreases across all seasons between 2006 and 2016. Similar downward trends of nitrate nitrogen (NO_3-N) fluxes were obtained in summer and fall seasons.

For the two tributaries, Blackberry Creek at Rt. 47 and Poplar Creek near Mouth-Elgin, most of the water quality concentration and fluxes showed larger upward trends with a few exceptions. The NH_3-N concentration exhibited the largest annual and seasonal increasing trends at both stations. Concentrations of TP, DP, and DO showed decreasing annual and seasonal trends for Blackberry Creek at Rt. 47, except in fall for DO and in summer for TP and DO concentrations. For Poplar Creek near Mouth-Elgin, the DP and DO concentrations showed improving water quality trends across all seasons. The flow-normalized DP and TKN fluxes exhibited decreasing annual and seasonal trends for Poplar Creek near Mouth-Elgin and Blackberry Creek at Rt. 47, respectively. The seasonal concentration trends largely conform to the annual trends for all three monitoring stations.

In addition to water quality trends, flow durations and trends of selected streamflow statistics including mean, 7-day minimum, and 1-day maximum flows are calculated to evaluate their changes through the years as they relate to water quality. The flow durations allow characterizing the ranges of flows in the river that are common or extreme during an entire year or season. The results indicate that the highest and lowest flow variability occurred in summer and spring seasons, respectively. The mean flow provides information about the central tendency of the multiyear hydrologic variability, whereas the minimum and maximum flow trends may explain part of the increase or decrease in constituent concentrations and fluxes. However, to explicitly attribute the change in water quality trends to some changes in hydrologic factors, the extent of other potential factors influencing water quality, such as conservation efforts, land use changes, etc., also need to be examined. Between 2006 and 2016, the mean and 7-day minimum flows exhibited an increasing trend with varying magnitudes across all seasons except for the spring 7-day minimum flow. Generally, the annual and seasonal 7-day minimum flows seem to show large increases during the period of analysis. The annual and seasonal 1-day maximum flows show increasing trends for Blackberry Creek at Rt. 47. For Poplar Creek near Mouth-Elgin, however, the 1-day maximum flow exhibited a decreasing trend in winter, spring, and fall seasons, whereas its annual and summer values had increased.

1. Introduction

This report presents a trend analysis of nutrient-related water quality data that have been collected throughout the Fox River watershed downstream of the Stratton Dam. A compilation of water quality data collected by the Fox River Study Group (FRSG), Illinois Environmental Protection Agency (IEPA), Fox Metro Water Reclamation District (Fox Metro), United States Geological Survey (USGS), Fox River Water Reclamation District (FRWRD), Illinois State Water Survey (ISWS), and Deuchler Environmental, Inc. (DEI) was stored in the environmental database, FoxDB, and used to construct the time series data for this analysis, spanning a period from 1997 to 2016. The FoxDB was created and is maintained by ISWS for compiling water chemistry and related data, such as sediment and flow in the Fox River watershed (McConkey et al., 2004).

The objectives of this analysis were to identify the presence or absence of trends in several nutrient-related water quality data collected in the Fox River watershed and to estimate rates of change if trends exist. Establishing the cause of a trend, if any, is beyond the scope of this study and requires a different study design that investigates the hydrologic processes, aquatic biogeochemistry, land uses, and anthropogenic activities in its entirety within the watershed. Streamflow histories were analyzed to provide insight into how flow variability, durations, and trends may have affected the water quality concentration and/or fluxes in the Fox River watershed. Long-term water quality data were required to conduct a trend analysis. In United States Environmental Protection Agency (USEPA) TechNotes 6 by Meals et al. (2011), monthly data of a five-year period has been suggested as the minimum for monotonic trend analysis. Most monitoring stations used in this study have five or more years of water quality data. Therefore, the core method of analysis used in this study is the Seasonal Kendall Test (SKT), which is a nonparametric test for monotonic trends (upward or downward trends). In cases where corresponding flow data are available in addition to long-term concentration data, a parametric test using the Weighted Regression on Time, Discharge, and Season (WRTDS) method has been implemented to evaluate trends in water quality concentrations and fluxes (loads), complementing the SKT analysis, which is used only for trends in water quality concentrations.

In the FoxDB, 18 monitoring stations in the Fox River and its tributaries were identified as meeting the minimum of at least five years of data for the trend analysis. The location of these monitoring stations, station ID, and descriptions are presented in Table 1 and in Figure 1, respectively. To be consistent, the same station ID numbers in the FoxDB are used in this report. The number of water quality parameters in each monitoring station varies from 2 to 10, and it includes total phosphorus (TP), dissolved phosphorus (DP), organic nitrogen (Org-N), ammonia nitrogen (NH_3-N), nitrate-nitrogen (NO_3-N), total kjeldahl nitrogen (TKN), dissolved oxygen (DO), pH, total suspended solids (TSS), and chlorophyll-A (CHL-A).

Exploratory data analysis (EDA) was performed on a total of 141 water quality parameters across the 18 monitoring stations to uncover the underlying data structure. EDA allows the thorough examination of data of interest to explore patterns, gaps, and trends. Summary statistics for each water quality parameter were computed to describe the information contained in the data in terms of its central tendency, spread, skewness, etc. The EDA analysis results for each water quality parameter can be used to evaluate the status of Fox River water quality in comparison with use-specific water quality standards. In Table 2, existing and additional water quality standards and criteria for the Illinois portion of the Fox River and its tributaries are provided. Some of the water quality standards in the table are extracted from Part 302 (water quality standards) of Title 35 of the Illinois Administrative Code, provided by the Illinois Pollution Control Board at https://pcb.illinois.gov/SLR/IPCBandIEPAEnvironmentalRegulationsTitle35.

Based on the results of the EDA analysis, the SKT method (Helsel and Hirsch, 2002) was selected as the primary process for conducting trend analyses on water quality concentration data. SKT is a distribution-free test, which is suitable for datasets that exhibit seasonality, autocorrelation, and missing values. The SKT analysis was performed for each of the 141 water quality parameters. The EnvStats R-package for environmental statistics (Millard, 2013) was used to perform the EDA and SKT analyses. EnvStats includes some of the major statistical methods and uses the R software environment, facilitating the programming of workflows and access to other features of R, such as plotting.

For three of the monitoring stations, the water quality concentration data have corresponding continuous flow data. Therefore, for those stations, trend analyses of both water quality concentration and fluxes (loads) were explored using the WRTDS method (Hirsch et al., 2010). The WRTDS method allows the estimation of long-term trends, not only of concentration, but also flux, and this procedure is part of the Exploration and Graphics for RivEr Trends (EGRET) software, which is an R-package developed by the USGS.

Table 1. Water Quality Parameters Analyzed by Monitoring Stations

Station ID	Station name	Water quality parameters by Station									
236	*Nippersink Cr at Spring Grove*	TP	DP	-	NH_3-N	-	TKN	DO	pH	TSS	-
1	*Nippersink Cr above Wonder Lake*	TP	DP	-	-	-	-	-	-	-	-
184	**Fox River at Johnsburg**	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	-	CHL-A
23	**Fox River at Rt 176**	TP	DP	-	NH_3-N	NO_3-N	TKN	DO	pH	TSS	-
258	**Fox River at Oakwood Hills**	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	-	CHL-A
4	*Flint Cr at Kelsey Rd-Lk Barrington*	TP	DP	-	NH_3-N	-	TKN	-	-	-	-
271	*Crystal Cr at Rt 31*	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	-	CHL-A
24	**Fox River at Algonquin**	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	TSS	CHL-A
268	*Tyler Cr at Rt. 31-Elgin*	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	-	CHL-A
25	*Poplar Cr near Mouth-Elgin*	TP	DP	-	NH_3-N	-	TKN	DO	pH	TSS	-
26	**Fox River at South Elgin**	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	TSS	CHL-A
14	*Ferson Cr at Rt 34*	TP	DP	-	NH_3-N	-	TKN	-	-	-	-
79	*Ferson Cr near Mouth-Elgin*	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	-	CHL-A
40	**Fox River at Geneva**	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	-	CHL-A
27	**Fox River at Montgomery**	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	TSS	CHL-A
34	**Fox River at Yorkville**	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	-	CHL-A
28	*Blackberry Cr at Rt 47*	TP	DP	-	NH_3-N	-	TKN	DO	pH	TSS	-
287	*Blackberry Cr near Mouth*	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	-	CHL-A

Note: Stations are in upstream-to-downstream order, and are in bold for Fox River main stem and in italics for tributaries.

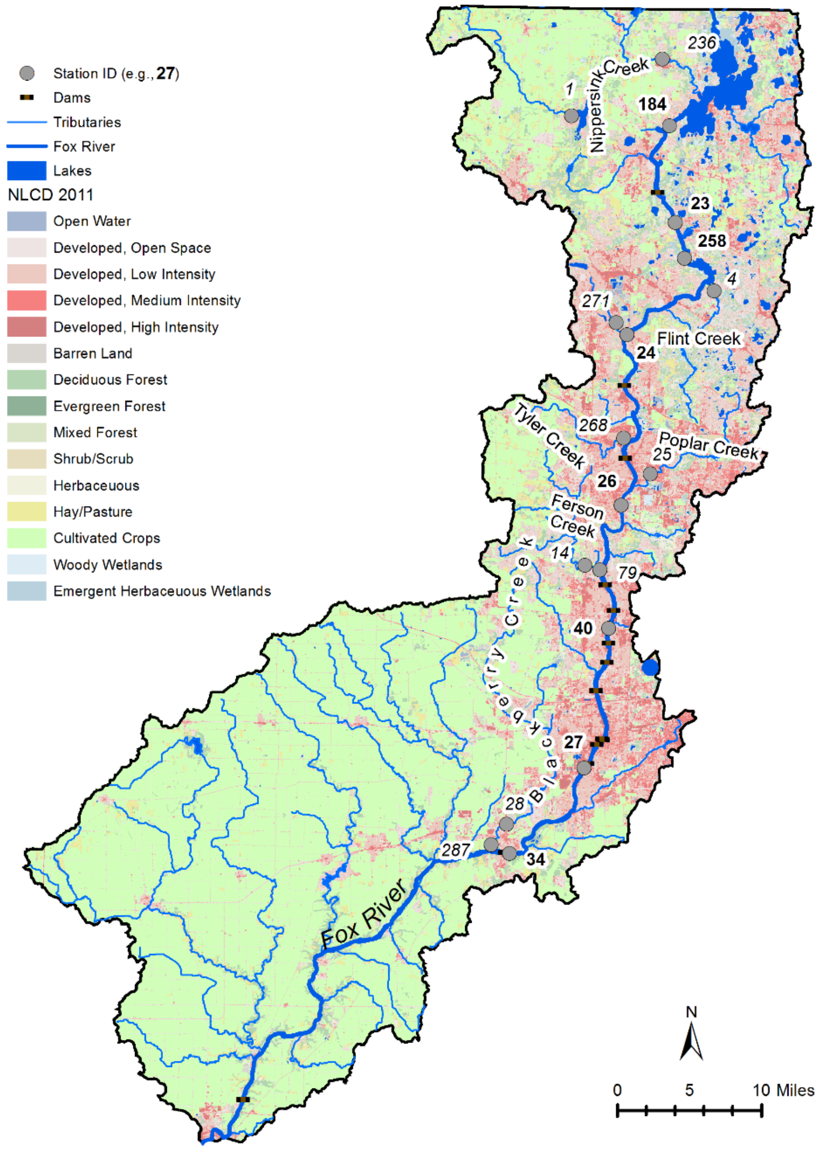

Figure 1. Fox River watershed – Stratton Dam to Illinois River

Table 2. Fox River Water Quality Standards

Water Quality Parameter	Existing Water Quality Standards for Fox River and its tributaries in Illinois	Other Water Quality Standards & Criteria
Total P (TP)	None	• Illinois lakes > 20 acres, including the Chain O'Lakes and other lakes within the Fox River watershed shall not exceed 0.05 mg/L (see Part 302.205) • The Wisconsin portion of the Fox River has a phosphorus standard of 0.1 mg/L. (available at https://dnr.wi.gov/topic/SurfaceWater/phosphorus.html) • Ecoregional criterium for Region VI Corn Belt and N Great Plains: 0.07625 mg/L. (https://www.epa.gov/nutrient-policy-data/ecoregional-criteria)
Dissolved P (DP)	None	
Organic-N (Org-N)	None	
Ammonia N (NH_3-N)	• Total NH3-N must in no case exceed 15 mg/L. • Acute standard is dependent on pH. Mean pH values in the Fox River range from 7.85 to 8.48. The acute standard at pH 8.2 is 5.73 mg/L. • Chronic standard differs for periods when Early Life Stage is present (March-October) and absent. It is dependent on temperature and pH. For pH 8.2, the Early Life Stage present value at 24C is 0.97 mg/L. For pH 8.2, the Early Life Stage absent value at 10C is 2.40 mg/L. The 30-day average concentration must not exceed the chronic standard except in those waters in which mixing is allowed.	• The most recent 2013 USEPA criterion document recognizes the sensitivity of freshwater mussels to ammonia levels. These new standards have not yet been adopted in Illinois. For pH 8.2 and 24C, the acute criterion is 1.9 mg/L (1-hour average). For pH 8.2 and 24C, the chronic criterion is 0.44 mg/L (30-day rolling average). Not to be exceeded more than 1 in 3 years on average. (https://www.epa.gov/wqc/aquatic-life-criteria-ammonia)
Nitrate N (NO_3-N)	• Public and food processing water supply standard. Waters of the State are generally designated for public and food processing use: 10 mg/L	
TKN	None	
Total N (= TKN+NO_3-N)	None	• USEPA recommends 2-6 mg/L of Total N. (https://www.epa.gov/sites/production/files/2015-09/documents/totalnitrogen.pdf) • Ecoregional criterium for Region VI Corn Belt and N Great Plains: 2.18 mg/L. (See https://www.epa.gov/nutrient-policy-data/ecoregional-criteria)
Dissolved Oxygen (DO)	• All waters except enhanced DO stretch below: Mar-July: not less than 5.0 mg/L at any time, 6.0 as daily mean avg'd over 7 days. Aug-Feb: not less than 3.5 mg/L at any time, 4.0 as daily minimum avg'd over 7 days, 5.5 as daily mean avg'd over 30 days. • Enhanced DO stretch (LAT/LONG): 41° 37' 3.7194"/-88° 33' 21.0162" to 41° 45' 59.5296"/-88° 18' 36.0858" Mar-July: not less than 5.0 mg/L at any time, 6.25 as daily mean avg'd over 7 days. Aug-Feb: not less than 4.0 mg/L at any time, 4.5 as daily minimum avg'd over 7 days, 6.0 as daily mean avg'd over 30 days.	
pH	6.5 to 9.0	
TSS	None	
Cholorophyll-A (CHL-A)	None	• Ecoregional criterium for Region VI Corn Belt and N Great Plains: 2.70 µg/L. (https://www.epa.gov/nutrient-policy-data/ecoregional-criteria)

2. Exploratory Data Analysis

Exploratory data analysis (EDA) is a graphical examination of the water quality data to detect any existing temporal patterns, such as seasonality, trends, step-changes, gaps, and outliers in the datasets. In this study, the EDA analysis was performed for all water quality parameters using the EnvStats R package and batches of R scripts. In addition, several other libraries of R-programs such as ROBDC (https://cran.r-project.org/web/packages/RODBC/index.html), which implements open database connectivity (ODBC), were used in conjunction with EnvStats. The ROBDC provides functions that allow direct access to a database file (in this particular case the FoxDB), eliminating the need to create intermediate data files with different formats and querying and manipulation of the required data for further analysis.

The availability of nutrient-related water quality parameters varies throughout the watershed. Only three stations have all ten of the water quality parameters: Fox River at Algonquin, Elgin, and Montgomery. Ten of the 18 stations have all the water quality parameters except TSS, which is available only for 7 stations. Phosphorus data are available for all monitoring stations, and NH_3-N and TKN are available for all but one station.

In Table 3, the period of record used in the EDA analysis for each water quality parameter is presented for each monitoring station, ranging from 5 to 20 years, excluding data gaps. It must be noted that the period of record for Blackberry near Mouth (station 287) includes data collected both before (2004–2011) and after the dam removal (2011–2016). The mean and median values of the water quality parameters are shown in Table 4; for DO, TSS, and all nutrient data, the unit is the concentration in milligrams per liter (mg/L). For CHL-A and pH data, the units are micrograms per liter (µg/L) and the standard unit, respectively. The mean and median values differ since the water quality data are generally skewed to the right, with the exception of pH, which tends to have similar means and medians. As shown in Table 4, the median values are typically less than that of the mean values because of the right-skewedness of the water quality data distribution. Summary statistics for 141 water quality parameters across the 18 monitoring stations are presented in Tables A.1 to A.10 in Appendix A.

Table 3. Periods of Records by Water Quality Parameter and Monitoring Station

Station ID	Station Name	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	TSS	CHL-A
236	*Nippersink Cr at Spring Grove*	1997-2016	1997-2016	-	1997-2016	-	1997-2016	1997-2015	1999-2015	2003-2016	-
1	*Nippersink Cr above Wonder Lak*	1997-2009	1997-2001	-	-	-	-	-	-	-	-
184	**Fox River at Johnsburg**	1997-2016	2002-2016	2002-2016	1997-2016	1997-2016	2002-2016	1997-2016	2002-2016	-	2002-2016
23	**Fox River at Rt 176**	1997-2016	1997-2016	-	1997-2016	1997-2011	1997-2016	1997-2015	1999-2015	2003-2016	-
258	**Fox River at Oakwood Hills**	1997-2016	2003-2016	2003-2016	1997-2016	1997-2016	2003-2016	1997-2016	2003-2016	-	2003-2016
4	*Flint Cr at Kelsey Rd-Lk Barringto*	2000-2011	2000-2011	-	2002-2011	-	2000-2011	-	-	-	-
271	*Crystal Cr at Rt 31*	2003-2016	2003-2016	2003-2016	2003-2016	2003-2016	2003-2016	2003-2016	2003-2016	-	2003-2016
24	**Fox River at Algonquin**	1997-2016	1997-2016	2002-2016	1997-2016	1997-2016	1997-2016	1997-2012	1999-2016	2003-2016	2002-2016
268	*Tyler Cr at Rt. 31-Elgin*	1997-2012	2003-2012	2002-2012	1997-2012	1998-2012	1998-2012	1997-2012	2003-2012	-	2003-2012
25	*Poplar Cr near Mouth-Elgin*	1997-2016	1997-2016	-	1997-2011	-	1997-2016	1997-2015	1999-2015	2003-2016	-
26	**Fox River at South Elgin**	1997-2016	1997-2016	1998-2016	1997-2016	1998-2016	1997-2016	1997-2016	1999-2016	2003-2016	2001-2016
14	*Ferson Cr at Rt 34*	2000-2012	2000-2012	-	2000-2011	-	2000-2012	-	-	-	-
79	*Ferson Cr near Mouth-Elgin*	2003-2016	2003-2016	2003-2016	2003-2016	2003-2016	2003-2016	2003-2016	2003-2016	-	2003-2016
40	**Fox River at Geneva**	2002-2016	2002-2016	2002-2016	2002-2016	2002-2016	2002-2016	2002-2016	2002-2016	-	2002-2016
27	**Fox River at Montgomery**	1997-2016	1997-2016	2002-2016	1997-2016	1997-2016	1997-2016	1997-2016	1997-2016	2003-2016	2002-2016
34	**Fox River at Yorkville**	2002-2016	2002-2016	2002-2016	1997-2016	2002-2016	2002-2016	1997-2016	1997-2016	-	2002-2016
28	*Blackberry Cr at Rt 47*	1997-2016	1997-2016	-	1997-2016	-	1997-2016	1997-2015	1999-2015	2003-2016	-
287	*Blackberry Cr near Mouth*	2004-2016	2004-2016	2004-2016	2004-2016	2004-2016	2004-2016	2004-2016	2004-2016	-	2004-2016

Note: Stations are in upstream-to-downstream order, and are in bold for Fox River main stem and in italics for tributaries.

Table 4. Mean and Median Values of the Water Quality Parameters

Station ID	Station Name	TP (mg/L)	DP (mg/L)	Org-N (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	TKN (mg/L)	DO (mg/L)	pH (su)	TSS (mg/L)	CHL-A (µg/L)
236	*Nippersink Cr at Spring Grove*	0.13/0.12	0.04/0.03	-	0.15/0.11	-	0.98/0.87	10.48/10.18	8.12/8.12	29.82/25	-
1	*Nippersink Cr above Wonder Lake*	0.17/0.09	0.05/0.03	-	-	-	-	-	-	-	-
184	**Fox River at Johnsburg**	0.16/0.14	0.05/0.04	1.69/1.53	0.08/0.06	1.04/0.76	1.75/1.61	10.84/10.5	8.48/8.5	-	81.63/70.2
23	**Fox River at Rt 176**	0.14/0.12	0.03/0.02	-	0.1/0.06	1.26/0.93	1.65/1.6	10.48/10.2	8.27/8.3	27.01/25	-
258	**Fox River at Oakwood Hills**	0.17/0.16	0.05/0.04	1.76/1.62	0.07/0.05	0.86/0.61	1.84/1.68	10/9.61	8.26/8.42	-	94.06/85.65
4	*Flint Cr at Kelsey Rd-Lk Barringto*	0.29/0.24	0.21/0.15	-	0.11/0.07	-	1.96/1.7	-	-	-	-
271	*Crystal Cr at Rt 31*	0.5/0.32	0.43/0.25	0.94/0.82	0.09/0.07	3.77/3.42	1/0.9	9.2/8.48	8.11/8.2	-	29.74/18.85
24	**Fox River at Algonquin**	0.18/0.16	0.06/0.04	1.72/1.68	0.1/0.06	1.29/1.01	1.67/1.6	10.05/9.93	8.17/8.23	32.88/30	92.56/86.2
268	*Tyler Cr at Rt. 31-Elgin*	0.14/0.11	0.06/0.05	0.79/0.68	0.07/0.06	2.39/1.78	0.83/0.77	11.49/11.15	8.2/8.2	-	9.69/8.6
25	*Poplar Cr near Mouth-Elgin*	0.09/0.07	0.03/0.02	-	0.08/0.04	-	1.1/1	10.83/10.36	7.85/7.85	12.18/8	-
26	**Fox River at South Elgin**	0.29/0.23	0.16/0.12	1.63/1.54	0.11/0.06	1.72/1.51	1.66/1.58	10.22/9.63	8.35/8.39	31.11/30	86.68/78.8
14	*Ferson Cr at Rt 34*	0.15/0.12	0.06/0.05	-	0.08/0.03	-	1.42/1.2	-	-	-	-
79	*Ferson Cr near Mouth-Elgin*	0.11/0.1	0.06/0.05	0.75/0.67	0.06/0.05	1.15/0.86	0.79/0.71	9.93/9.43	7.95/8.01	-	13.26/10.7
40	**Fox River at Geneva**	0.33/0.27	0.16/0.13	1.66/1.52	0.07/0.04	1.67/1.5	1.73/1.6	11.24/10.58	8.2/8.28	-	105.3/87.95
27	**Fox River at Montgomery**	0.32/0.27	0.16/0.13	1.59/1.46	0.08/0.04	1.67/1.46	1.6/1.52	9.45/9.29	8.34/8.33	34.12/33	99.88/80.05
34	**Fox River at Yorkville**	0.48/0.41	0.3/0.25	1.62/1.46	0.09/0.05	2.08/1.86	1.67/1.51	10.24/9.9	8.33/8.3	-	98.15/80
28	*Blackberry Cr at Rt 47*	0.12/0.09	0.04/0.03	-	0.1/0.05	-	1.01/0.83	10.03/9.74	7.92/7.97	28.23/20	-
287	*Blackberry Cr near Mouth*	0.12/0.11	0.05/0.05	0.75/0.69	0.07/0.05	1.28/1.01	0.8/0.75	10.72/10.24	7.99/7.98	-	12.84/10.55

Note: Stations are in upstream-to-downstream order, and are in bold for Fox River main stem and in italics for tributaries.

To further illustrate the EDA analysis, total phosphorus (TP) data for the Fox River at Montgomery (station ID 27) were used, as the station has long-term data that various agencies collected. In addition, station 27 has flow data, which allowed to conduct parametric trend test for water quality fluxes (loads) in addition to concentration. Figure 2 shows one-dimensional scatter plots of the TP concentration data collected by various agencies, including FRSG, IEPA, FRWRD, ISWS, and DEI from 1997 to 2016. As shown by the number of data points (n) in the figure, FRSG and IEPA collected the largest number of TP concentration samples for this station. The mean and standard deviation of TP concentration samples (mg/L) collected by the different agencies range from 0.2 to 0.4 and 0.1 to 0.2, respectively, representing varying data periods as illustrated in Figure 2.

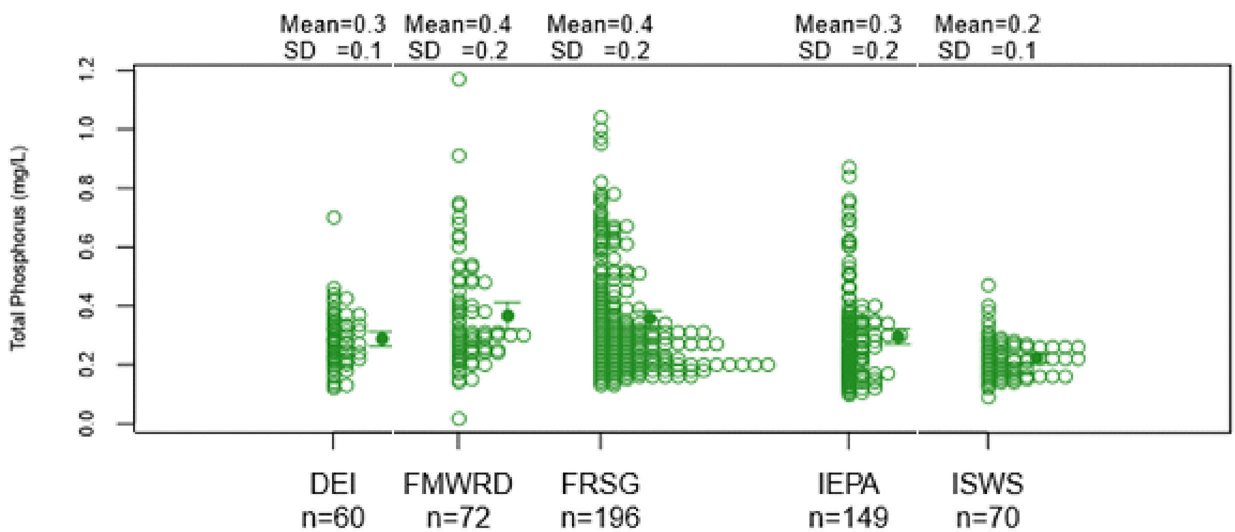

Figure 2. Strip plots of TP concentrations for Fox River at Montgomery

In Figure 3, the EDA results for TP concentrations at Fox River at Montgomery are presented and include (a) the combined time series of the samples collected by the different agencies; (b) yearly boxplots; (c) annual minimum, maximum, and mean values; and (d) monthly boxplot. The combined time series of the observation data and monthly time series data constructed using all the observations were used in the parametric and nonparametric trend analyses, respectively. The seasonality of the TP concentration data is clearly evident in the time series and monthly boxplots, which is true for nearly all water quality parameters analyzed in this study. This EDA analysis provided useful information for selecting an appropriate method of analysis for trends that account for the underlying data structure; for example, the seasonality exhibited in the TP concentration data. The yearly boxplot could provide preliminary insights into the existence of a trend or no trend. In the boxplots, the median concentration is shown by a line in the box that represents the interquartile range (IQR) between the first and the third quartile of the TP data in a month or year. Outliers are shown in circles and are defined as observations lying beyond 1.5 times the IQRs. The monthly boxplot shows that the median of the TP concentration is the highest in summer months, with the maximum occurring in August. The yearly boxplot generally indicates that the TP concentration exhibits a decreasing trend through the years since 2005. Low flows during the drought of 2012 may have caused the increase in TP concentration for that year.

For water quality stations with corresponding flow data, including Fox River at Montgomery, a parametric trend test was conducted which required that the water quality data or its log transformation be normally-distributed. As part of the EDA analysis, the Shapiro-Wilk Goodness-of-Fit test based on Chen and Balakrisnan (1995) was done for the TP concentration data, fitting it with a lognormal distribution. The result is presented in Figure 4. As shown in the figure, the histogram, plots of quantiles of TP versus quantiles of log-normal distribution (Q-Q), and the empirical cumulative density functions (CDFs) indicate that TP concentration observations could be assumed to have come from a lognormal distribution with at least a 99% confidence level.

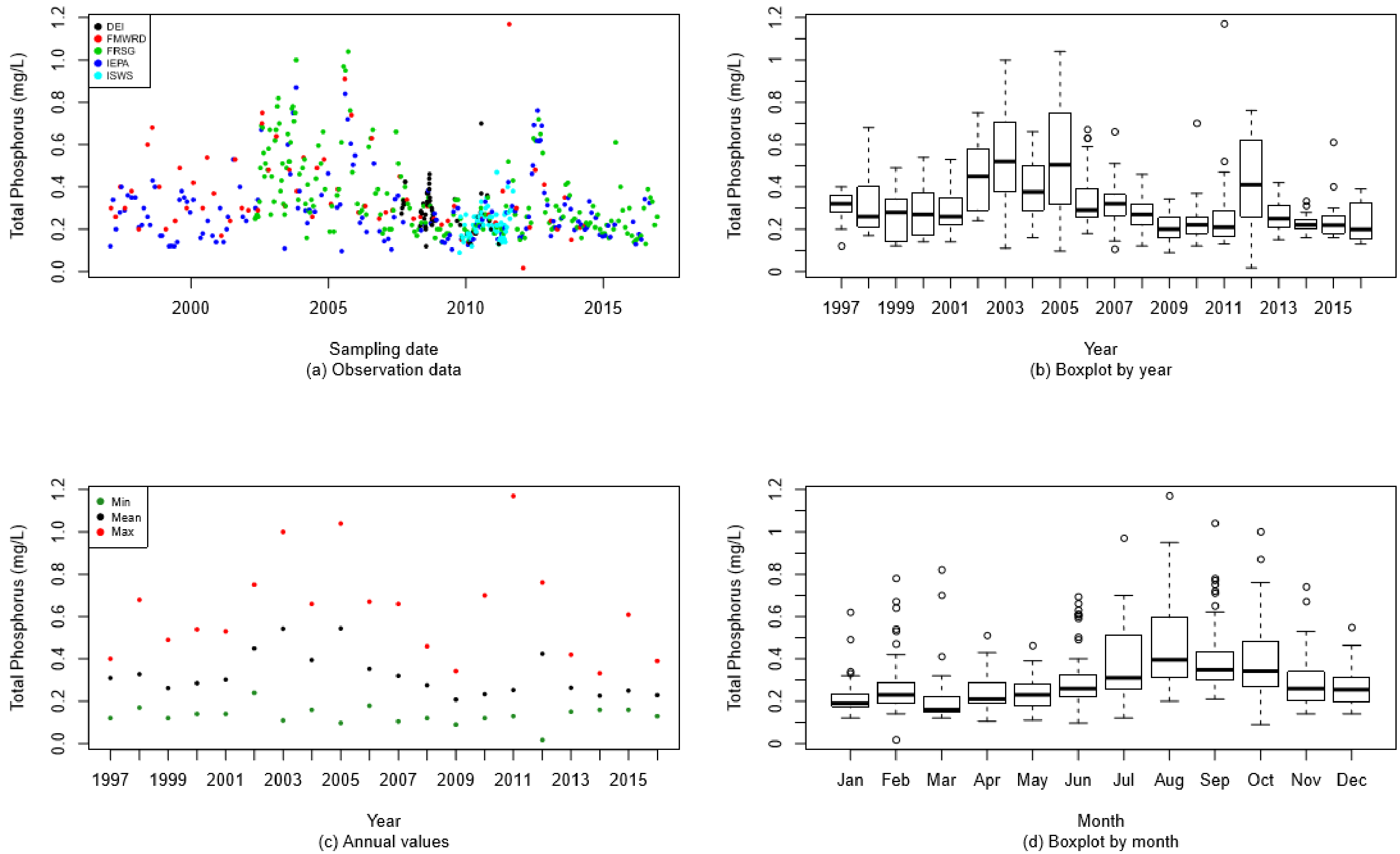

Figure 3. EDA results showing TP concentrations for Fox River at Montgomery

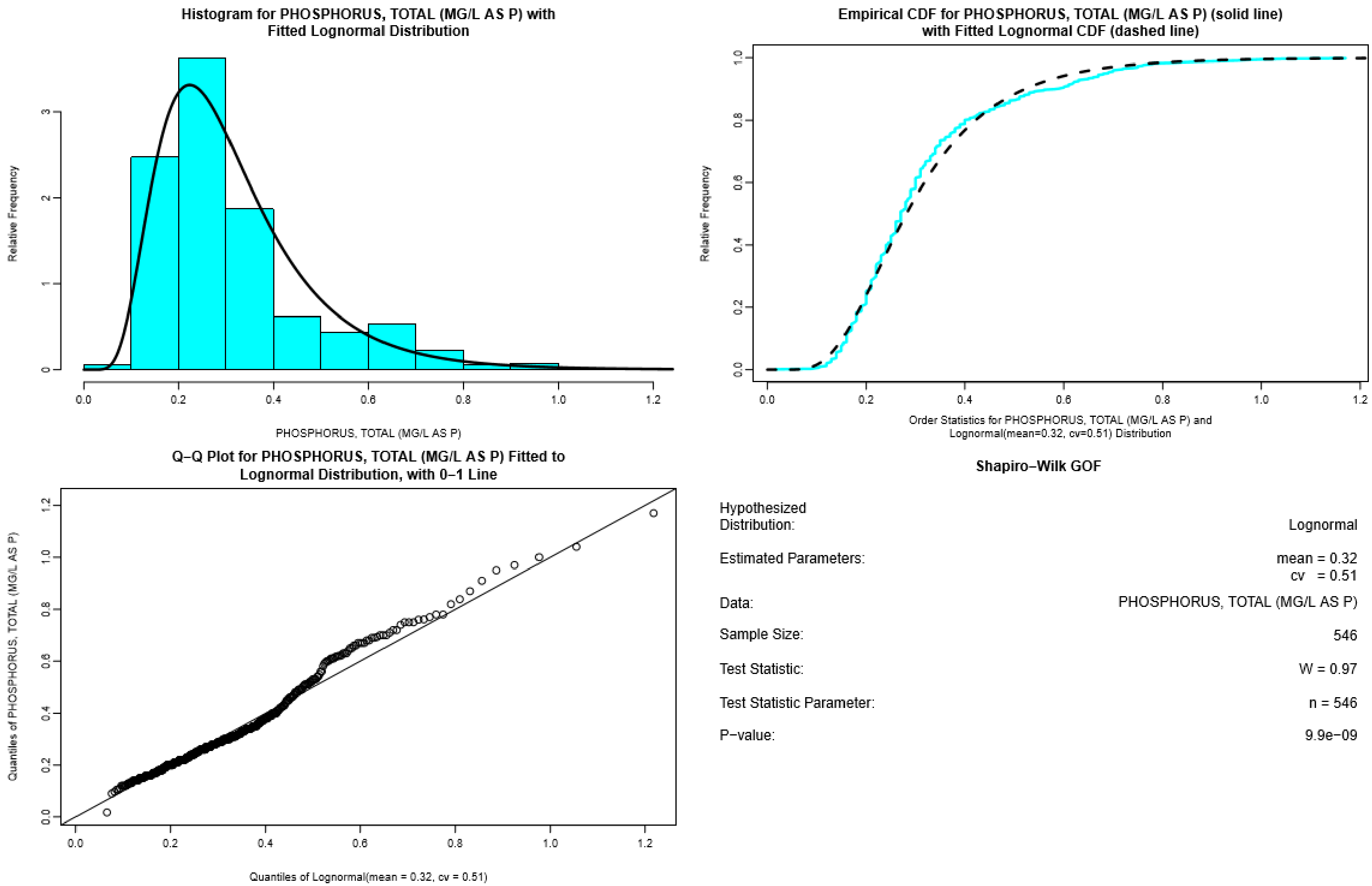

Figure 4. Goodness-of-Fit test results for TP at Fox River at Montgomery

3. Water Quality Trend Analysis

The objectives of this analysis was to identify the presence or absence of trends in nutrient-related water quality data collected in the Fox River watershed and to estimate rates of change if trends exist. Establishing the cause of a trend, if any, is beyond the scope of this study and requires a different study design, including analysis of the hydrologic processes, aquatic biogeochemistry, land uses, and anthropogenic activities within the watershed. Eighteen monitoring stations in the FoxDB met the minimum monthly data of a five-year period for monotonic trend analysis. Most stations have five or more years of water quality data. Therefore, the core method of analysis used in this study is the Seasonal Kendall Test (SKT) method, which is a nonparametric test for monotonic trends. In cases in which corresponding flow data are available, a parametric test using the Weighted Regression on Time, Discharge and Season (WRTDS) method is implemented to evaluate trends in water quality concentrations and fluxes, complementing the SKT analysis for trends in water quality concentrations. Brief descriptions of the two methods of analyses selected for trend tests are presented in the following sections.

3.1 Seasonal Kendall Test for Trend

The Seasonal Kendall Test (Hirsch and Slack, 1984) is a test for monotonic (upward or downward) trends in time series data that are expected to change in the same direction for one or more seasons. A season could be defined as a single month or a couple of months (e.g., June to August as summer months). A monotonic upward or downward trend indicates a consistently increasing or decreasing pattern in the variable of interest for a given season that may not necessarily be linear. The SKT, which is the generalized form of the Mann-Kendall test, is a nonparametric test for a trend that does not require the time series data to be distributed normally. It can be used in cases where there exist seasonality and serial correlation in the data. The method is also applicable if the time series includes missing data points and/or data with detection limits.

A brief description of the SKT method is given as follows. In a SKT test, the null hypothesis H_0 states that there is no trend (i.e., for each season, the time series data are randomly ordered over the years), whereas the alternative hypothesis H_a is that an upward or downward monotonic trend exists over the years for one or more seasons. To describe the SKT method, a season is assumed to be a month. Let $X = (X_1, X_2, \dots, X_i, \dots\ X_{12})$ be the time series data (X_i) collected over the years for i^{th} month and $X_1 = (x_{1,1}, x_{1,2}, \dots, x_{1,k}, \dots, x_{1,n1})$ to $X_{12} = (x_{12,1}, x_{12,2}, \dots, x_{12,k}, \dots, x_{12,n12})$ be a subset of January to December data over the years. Note that $n1$ and $n12$ are the number of data points over the years for the months of January and December, respectively, and different months can have a different number of data points. The SKT test begins by calculating the Kendall tau for each month. The following are steps involved in the analysis:

1. List the data collected for the i^{th} month in order of years of data collection and calculate the sign of all possible differences (i.e., a total of $ni(ni-1)/2$ pairs of $(x_{i,j} - x_{i,k})$ for $j > k$) between data points for the i^{th} month:

$$sgn(x_{i,j} - x_{i,k}) = 1\ if\ (x_{i,j} - x_{i,k}) > 0;$$

$$= 0\ \ if\ (x_{i,j} - x_{i,k}) = 0 \text{ or}$$

$if\ (x_{i,j} - x_{i,k})$ cannot be determined; or

$$= -1\ if\ (x_{i,j} - x_{i,k}) < 0$$

For example, $if\ (x_{i,j} - x_{i,k}) < 0,$ this would mean that the concentration value measured for the i^{th} month of j^{th} year is less than the value for the same month of k^{th} year.

2. Determine S_i , which is calculated as the number of positive differences minus the number of negative differences for the i^{th} month, and its variance, $Var(S_i)$. If $S_i > 0$, then the i^{th} month observations made in the later years are greater than those of earlier years for the same month, and vice-versa. S_i and $Var(S_i)$ are calculated as

$$S_i = \sum_{k=1}^{ni-1} \sum_{j=k+1}^{ni} sgn(x_{i,j} - x_{i,k})$$

$$Var(S_i) = \frac{1}{18}\left[ni(ni-1)(2ni+5) - \sum_{l=1}^{Li} t_{i,l}(t_{i,l}-1)(2t_{i,l}+5)\right]$$

where $sgn\ (\ )$ is defined as the sign function returning a value of 1, -1, or 0 for positive, negative, or zero value, respectively; L_i is the number of tied groups for the i^{th} month and $t_{i,l}$ is the number of data points in the l^{th}group for the i^{th} month. When ties exist because of equal data values or detection limits, the variance is adjusted for the ties. The Kendall tau (τ_i), which is the direction and magnitude of the trend and the Theil-Sen slope estimate (β_i) for i^{th} month can be expressed as

$$\tau_i = \frac{2S_i}{ni(ni-1)} \quad \text{and} \quad \beta_i = median\ \left(\frac{x_{i,j} - x_{i,k}}{j-k}\right)$$

Next, aggregate S_i and $Var(S_i)$ into $S'$and $Var(S')$, respectively, for m number of seasons (e.g., m=12 when the season is a month or m = 52 when the season is a week) as

$$S' = \sum_{i=1}^{m} S_i \quad \text{and} \quad Var(S') = \sum_{i=1}^{m} Var(S_i)$$

Overall τ' and β' are computed as weighted averages of the seasonal estimates and the median of all two-point slope estimates within each season, or month in this particular case.

3. Finally, compute the SKT statistic, Z_{skt} that indicates the tendency of the data to increase or decrease (a positive or negative Z_{skt}) , calculated as

$$Z_{skt} = \frac{S'-1}{\sqrt{Var(S')}} \quad if\ S' > 0$$

$$= 0 \;\; if\; S' = 0$$

$$= \frac{S' + 1}{\sqrt{Var(S')}} \;\; if\; S' < 0$$

To determine if a trend is statistically significant, a p-value (α) associated with Z_{skt} will be calculated, where α is the tolerable probability of rejecting the null hypothesis (i.e., no monotonic trend over time in this particular case). For this study, a p-value of $\alpha = 0.1$ is used, allowing a confidence level of 90% (i.e., $(100(1 - \alpha$) percentile) to accept the presence of a trend.

3.2 SKT Results and Discussion

As SKT is the core method of trend analysis chosen for this study, it is applied to all nutrient-related water quality data observed at the 18 monitoring stations in the Fox River watershed. The SKT analysis conducted is demonstrated here using monthly total phosphorus (TP) data for the Fox River at Montgomery, as shown in Figures 2 and 3. Below is the result of the SKT trend analysis for the TP concentration using EnvStats:

Null Hypothesis: All 12 values of **tau** ($\boldsymbol{\tau_i}$) = 0 (i.e., no monotonic trend).
Alternative Hypothesis: The seasonal taus are not all equal.
(Chi-Square Heterogeneity Test)
At least one seasonal tau is not equal to 0 and all non-zero taus have the same sign (Z_{skt}Trend Test)
Test Name: Seasonal Kendall Test for Trend
Estimated Parameter(s): **Overall tau ($\boldsymbol{\tau'}$) = -0.236431**
Overall slope ($\boldsymbol{\beta'}$) = -0.005576
Intercept = 12.675937500
Sample Sizes for each month (1 to 12): 18, 20, 17, 19, 19, 20, 19, 20, 18, 17, 20, 18
Total Sample Size: 225
Test Statistics: Chi-Square (Het) = 4.309498
$\mathbf{Z_{skt}}$ (Trend) = -4.838630
Test Statistic Parameter (degree of freedom): df = 11
P-values: **Chi-Square (Het) = 9.599737e-01**
$\mathbf{Z_{skt}}$ (Trend) = 1.307374e-06
Confidence Interval for Slope (CL > 90%): **LCL = -0.007500; UCL = -0.003518**

Kendall S-Statistic (S_i) and its variance $Var(S_i)$:
month: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
$\mathbf{S_i}$: -50, -59, -22, -33, -31, -7, -43, -31, -51, -38, -80, -28
$\mathbf{Var(S_i)}$: 696.0, 949.0, 589.3, 817.0, 817.0, 949.0, 817.0, 949.0, 697.0, 589.3, 950.0, 696.0

Seasonal (monthly) Estimates:

month	tau ($\boldsymbol{\tau_i}$)	slope (β_i)	intercept
1	-0.32679739	-0.006428571	13.110357
2	-0.31052632	-0.007316964	14.912489
3	-0.16176471	-0.004048611	8.318111
4	-0.19298246	-0.002500000	5.225000
5	-0.18128655	-0.003047619	6.351238
6	-0.03684211	-0.000665733	1.632627
7	-0.25146199	-0.007750000	15.903000
8	-0.16315789	-0.005892857	12.241518
9	-0.33333333	-0.005818182	12.036125
10	-0.27941176	-**0.013333333**	27.115833
11	-0.42105263	-0.007171429	14.656971
12	-0.18300654	-0.006800000	13.921000

The value of $\mathbf{Z_{skt}}$ **(Trend) = -4.838630** and its associated p-value of **1.307374e-06** indicate that the TP concentration exhibits a decreasing trend of **-0.005576 mg/L per year** (i.e., **overall slope**, $\boldsymbol{\beta'}$) with more than a 90% confidence level. The lower and upper confidence levels for the estimated rate of change lie between **LCL = -0.007500 and UCL = -0.003518**. The monthly estimates of tau ($\boldsymbol{\tau_i}$) and slope ($\boldsymbol{\beta_i}$) show decreasing trends for all months, with the maximum rate of change for the month of October, which is -**0.013333 mg/L per year**. The Chi-Square Heterogeneity Test was also performed to determine if the trend varies for different months and its p-value of **9.599737e-01** indicates no evidence of varying monthly trends.

Similarly, the SKT trend analysis was performed for all water quality parameters. The results are summarized in Tables 4–8, showing annual and seasonal trends in water quality concentrations and pH for all stations. For all water quality parameters, the SKT trend results are illustrated in Figures B.1 to B.10 in Appendix B.

Nutrients

Nutrient data used in the trend analysis include two forms of phosphorus and four forms of nitrogen. These are total phosphorus (TP), dissolved phosphorus (DP), organic nitrogen (Org-N), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), and total kjeldahl nitrogen (TKN). As shown in Table 2, nutrient concentration data were available for most of the 18 stations. The Org-N, NH_3-N, NO_3-N, and TKN data are available for more than 10 stations, and all of the 18 stations have TP and DP concentration data. The record length of the nutrient data generally varies from 5 to 20 years with a majority of the stations having 12 or more years of data and only one station with 3 years of NO_3-N data.

The TP and DP concentration data are available for all 18 stations used in the trend analysis. The mean TP concentration ranges from 0.026 mg/L Poplar Creek near Mouth-Elgin to 0.427 mg/L for Crystal Creek at Rt. 31 at Algonquin. The minimum TP concentration of 0.002 mg/L was observed at Poplar Creek near Mouth-Elgin, Fox River at Algonquin, and Fox River at Rt. 176, whereas the maximum TP concentration value of 3.59 mg/L was recorded at the Fox River at the South Elgin station. Across the stations in the Fox River watershed, the mean DP concentration ranges from 0.053 mg/L for Blackberry near Mouth to 0.499 mg/L for Crystal Creek at Rt. 31 at Algonquin. The minimum DP concentration of 0.009 mg/L was observed at

Blackberry near Mouth, whereas the maximum concentration value of 3.59 mg/L was recorded at Fox River at South Elgin. Currently, no water quality standard exists for TP and DP in the Fox River and its tributaries. There is, however, a TP standard of less than 0.05 mg/L for Illinois lakes with a total surface area of 20 acres, including Chain O'Lakes and others in the Fox River watershed.

The mean Org-N concentration varies from 0.748 mg/L at Ferson Creek near Mouth-Elgin to 1.76 mg/L at the Fox River at Oakwood Hills. The maximum Org-N concentration of 6.48 mg/L was observed at Crystal Creek at Rt. 31, whereas the minimum concentration of 0.03 mg/L was recorded at Fox River at Yorkville. There is no water quality standard for Org-N in the Fox River watershed.

All 18 stations except Nippersink Creek above Wonder Lake have NH_3-N concentration data, the majority of which have 20 years of record. The mean NH_3-N concentration ranges from 0.061 mg/L at Ferson Creek near Mouth-Elgin to 0.15 mg/L at Nippersink Creek at Spring Grove, both of which are monitoring stations in the Fox tributaries. The minimum and maximum NH_3-N concentrations of 0.005 and 1.58 mg/L were observed at the Fox River at Montgomery and Fox River at Algonquin, respectively. The maximum NH_3-N concentration for the analysis period is well below the acute standard of 5.73 mg/L for the Fox River and its tributaries.

The NO_3-N concentration data are available for 12 of the 18 stations, a majority of which have more than 10 years of record. The range of the mean NO_3-N concentration lies between 0.864 mg/L for Fox River at Oakwood Hills and 3.766 mg/L for Crystal Creek at Rt. 31 at Algonquin. The minimum and maximum NO_3-N concentrations of 0.01 mg/L and 14.3 mg/L were recorded at the Fox River at Montgomery and Fox River at Algonquin stations, respectively. The maximum NO_3-N concentration at the Fox River at Algonquin is above 10 mg/L, which is the water quality standard for public and food processing use.

The TKN concentration data are available for all but one station with the same period of record as that of the NH_3-N data. The mean TKN concentration ranges from 0.792 mg/L at Ferson Creek near Mouth-Elgin to 1.959 mg/L at Flint Creek at Kelsey Rd-Lk Barrington. The Fox River at Algonquin and Flint Creek at Kelsey Rd-Lk Barrington have the minimum and maximum TKN concentrations of all gaging stations used in the trend analysis (i.e., 0.01 mg/L and 27.8 mg/L), respectively. Although there is no TKN water quality standard, the USEPA recommends a water quality standard of 2 to 6 mg/L for the Total Nitrogen (TN) concentration, which is a summation of TKN and NO_3-N.

Annual, Seasonal, and Longitudinal Trends

Total Phosphorus

In Figures 5 and 6, the annual and seasonal TP concentration trends and estimated values of change in mg/L per year, respectively, are presented. The TP concentration showed decreasing, increasing, and no trends in five, one, and two of the monitoring stations on the Fox River main stem, respectively. For the decreasing trend, the decrease in TP concentration ranges from 1.4% per year (0.003 mg/L per year) at Fox River at South Elgin to 4.9% per year (0.02 mg/L per year) at Fox River at Yorkville, which is the most downstream station on the main stem. The percentage change per year is computed as a function of the median concentration. The increasing TP trend of 1.6% per year (0.002 mg/L per year) was estimated for Fox River at

Rt. 176, an upstream monitoring station. No trend was detected on seven of the ten Fox tributary stations. Decreasing trends of TP were estimated for Crystal Creek at Rt. 31 (21.9% per year or 0.07 mg/L per year) and Tyler Creek at Rt. 31-Elgin (3% per year or 0.003 mg/L per year).

The seasonal TP trend largely conforms to the annual trend. The winter, fall, spring, and summer months used in computing seasonal trends are December to February, March to May, June to August, and September to November, respectively. Only two stations on the Fox River main stem and two on its tributaries exhibited decreasing TP trends in summer. No summer TP trend was detected in the remaining 12 of the 18 stations. Crystal Creek at Rt. 31 showed decreasing trends for all seasons with the maximum TP reduction of 0.085 mg/L per year (26.6% per year) occurred in summer. Fox River at Rt. 176 and Poplar Creek near Mouth-Elgin experienced increasing TP trends in at least one or more seasons, with the maximum reduction of 0.004 mg/L per year (5.4%) in spring. Only two stations on the Fox River, namely Fox River at Yorkville and Fox River at Montgomery, showed decreasing trends in all seasons with a TP reduction ranging from 0.009 to 0.032 mg/L per year.

Downstream of Fox River at Rt. 176, there seems to be a decreasing annual or seasonal TP trend along the Fox River. For most stations, no longitudinal TP trend was detected in summer.

Dissolved Phosphorus

Decreasing and increasing annual trends for DP were detected in four and three stations, respectively. For the increasing TP trend, the reduction ranges from 2.1% per year for Fox River at Johnsburg to 4.4% per year for Fox River at Rt. 176, whereas the decreasing rate of change was estimated between 1 and 4.9% per year. No annual DP trend was detected for Fox River at Oakwood Hills. The DP concentration in the tributaries showed no annual trend in two of the ten stations but indicate either a decreasing or increasing trend in the remaining stations. The annual trend at Crystal Creek at Rt. 31 showed the maximum reduction of 25.5% per year (or 0.064 mg/L per year), whereas the maximum increasing trend of 4% per year (0.002 mg/L) was calculated for Ferson Creek near Mouth-Elgin.

The DP concentration exhibited variations of upward, downward, or no seasonal trend. For stations in the Fox River main steam, the fall DP trend showed a decreasing trend downstream of Algonquin but no trend upstream. The most downstream station exhibited a decreasing DP trend of 10.2% (0.026 mg/L per year) in the fall, which is the maximum rate of change for any of the seasonal trends along the Fox River. Upstream of Fox River at South Elgin, an increasing DP trend was detected in spring, summer, and winter for most of the stations on the Fox River, which also conforms to the annual DP trend. The DP concentration for Crystal Creek at Rt. 31 shows the largest decreasing trend in all seasons with the maximum reduction of 31.6% per year (0.079 mg/L) in the fall. The winter DP concentration on the tributaries showed either a decreasing or no trend.

Showing some longitudinal trends, all stations downstream of Fox River at Algonquin exhibited a decreasing annual trend with the maximum DP reduction occurring at Fox River at Yorkville, which is 0.012 mg/L per year (4.9% per year). The fall DP trend conforms to the annual trend along the Fox River main stem. In all seasons, either a decreasing or no DP trend was detected for stations downstream of the Fox River at Algonquin.

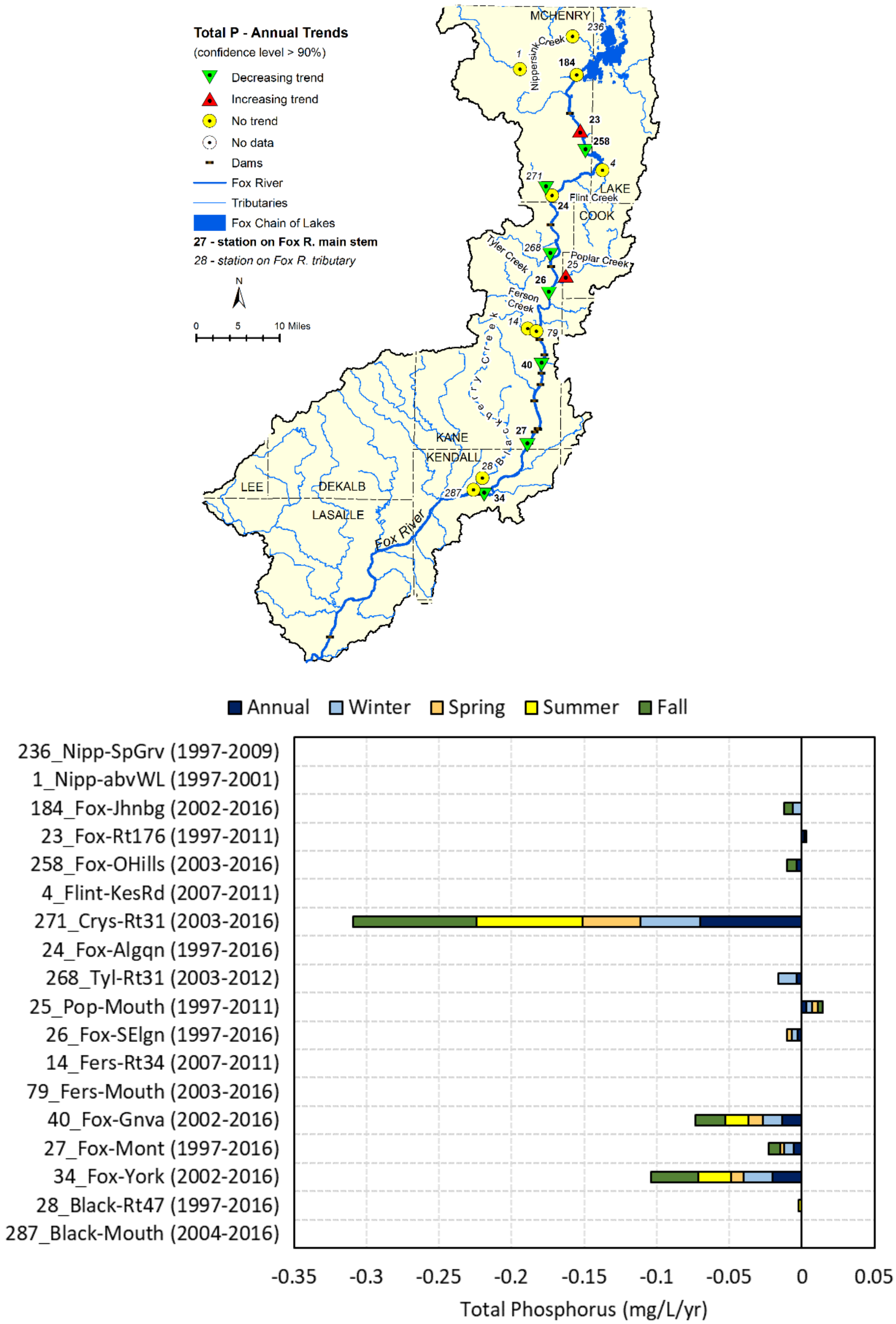

Figure 5. Annual trends of total phosphorus (TP) in the Fox River watershed

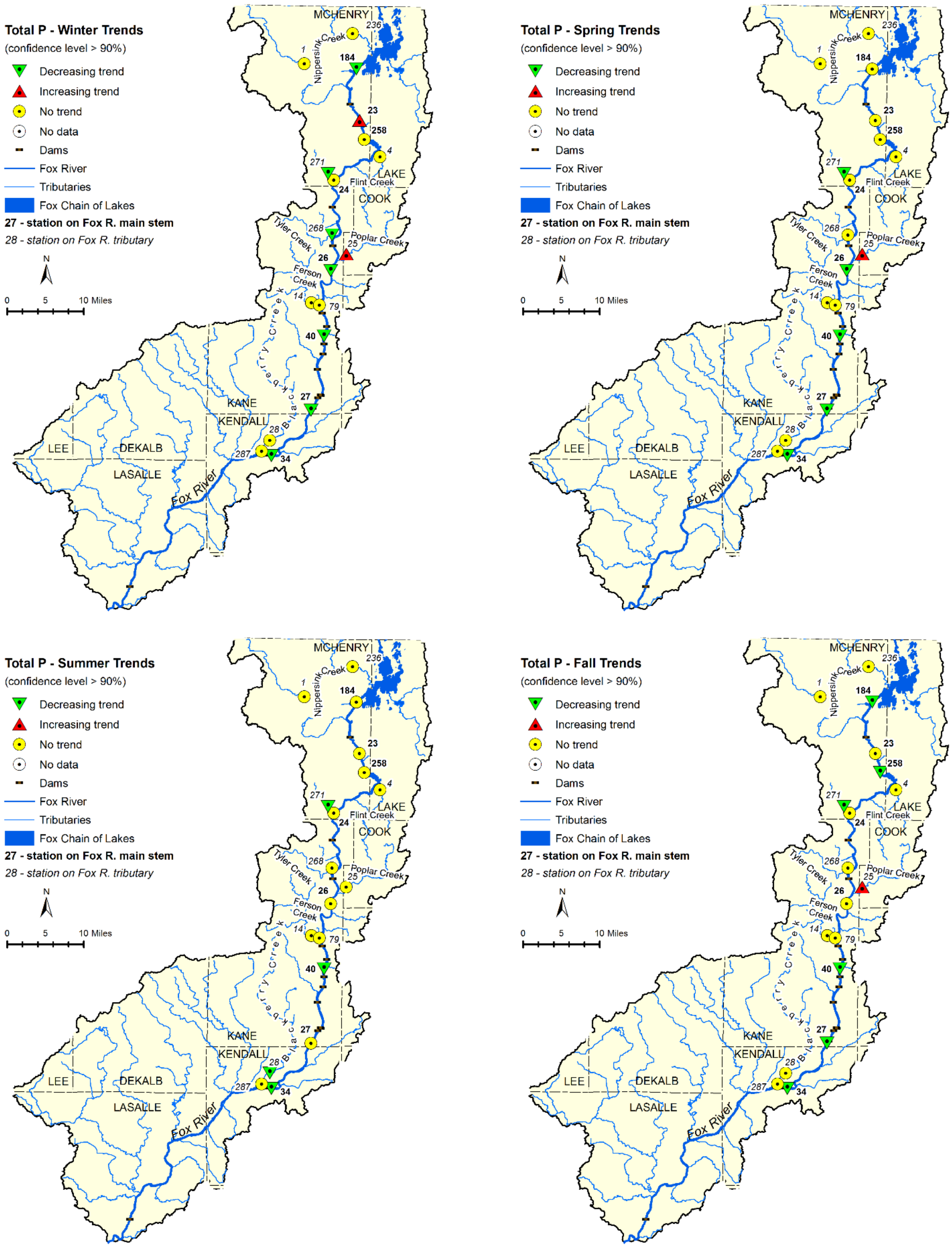

Figure 6. Seasonal trends of total phosphorus (TP) in the Fox River watershed

Organic Nitrogen

The Org-N concentration along the Fox River main stem shows a decreasing annual trend in five of the eight stations with a maximum reduction of 2% per year (0.03 mg/L per year) at the Fox River at Montgomery. In contrast, no trend is detected at the remaining two stations, namely Fox River at Algonquin and Fox River at Oakwood Hills. Similarly, none of the four stations in the Fox River tributaries with Org-N data shows any trend.

The Org-N concentration trends showed seasonal variations. For example, no winter trend was detected for Org-N, with the exception of Tyler Creek at Rt. 31-Elgin, which showed the maximum reduction of 12.5% per year (0.085 mg/L per year) of all seasons. In contrast, this same station exhibited the only increasing trend (i.e., 5.34% per year for the summer Org-N concentration). At Blackberry Creek at Rt. 47, the Org-N showed a decreasing summer trend of 9.8% per year (0.066 mg/L per year), but no annual or other seasonal trend was detected for the same station. For the remaining stations, the fall, spring, and summer trends conform to the annual trends.

Along the Fox River, the annual and seasonal Org-N concentration showed a decreasing trend, with the exception of Fox River at Johnsburg, which showed no spring, summer, or winter trends.

Ammonia Nitrogen

For only two of the eight stations in the Fox River, namely Fox River at Algonquin and Fox River at Rt. 176, no annual trend for the NH_3-N concentration was detected. All the remaining stations showed decreasing annual trends of NH_3-N concentration, with the largest decrease of 5.2% per year (0.002 mg/L) obtained for Fox River at Montgomery. In the tributaries, the NH_3-N concentration showed a decreasing annual trend at only three stations with the rest showing no trend. The largest decrease was 5.3% per year, which was for Blackberry Creek near Mouth. In contrast, no trend was detected for Blackberry Creek at Rt. 47, which is an upstream station on the same creek.

Despite exhibiting an annual trend for Fox River at Johnsburg, no seasonal NH_3-N trend was detected. In all other cases in which annual trends exist, there is at least one or more seasons with a similar trend. For the most part, fall and summer trends conform to annual trends with some exceptions. For example, the fall NH_3-N concentration showed an increasing trend of 4.3% per year for Tyler Creek at Rt. 31-Elgin, while no trend was detected annually or for any other season. The largest increasing trend of 11.8% per year was detected for the spring NH_3-N concentration at Blackberry Creek at Rt. 47. This station also exhibited one of the summer's largest decreasing trends (13.2% per year). In all of the monitoring stations upstream of Fox River at Montgomery, no spring trend was detected, with the exception of Nippersink Creek at Spring Grove, which showed a decreasing trend of 10.4% per year.

NH_3-N concentrations generally showed decreasing annual and seasonal trends along the Fox main stem for at least four of the eight stations. The winter NH_3-N concentration shows larger decreasing trends ranging from 8.3% per year for Fox River at South Elgin to 21% per year for Fox River at Yorkville.

Nitrate Nitrogen

The NO_3-N concentration showed a decreasing trend in six of the eight stations in the Fox River main stem with the maximum NO_3-N reduction of 4.6% (0.028 mg/L per year for Fox River at Oakwood Hills. An increasing or no trend was detected in two of the remaining stations; Fox River at Rt. 176 showed an increasing trend of 5.1% per year (0.047 mg/L of NO_3-N). Only four tributary stations have NO_3-N concentration data, and a decreasing trend of 9.6% per year (0.066 mg/L per year) was estimated for Blackberry Creek near Mouth, which was found to be the largest decrease in NO_3-N concentrations. An increasing trend was obtained for Crystal Creek at Rt. 31 and no trend was detected for the remaining two tributary stations.

Fox River at Rt. 176 showed an increasing NO_3-N trend in fall (6.2% per year), spring (9.2% per year), and winter (67.7% per year), but no trend in summer. Its winter increasing trend amounted to 0.63 mg/L per year. No seasonal trend was obtained for Crystal Creek at Rt. 31, which showed an increasing annual trend of 2.2% (0.075 mg/L per year). All of the remaining stations on the Fox River or its tributaries exhibited either a decreasing or no trend. The largest seasonal decrease of 37.4% per year (0.258 mg/L per year) was estimated for the winter NO_3-N concentration at Blackberry Creek near Mouth. There was no seasonal trend for the most downstream station on the Fox main stem (Fox River at Yorkville), in spite of detecting a decreasing annual trend.

All stations downstream and upstream of Fox River at Rt. 176 except one exhibited decreasing trends of NO_3-N concentrations, indicating that a decreasing longitudinal trend exists. Mostly, the fall and summer longitudinal trends follow the annual trend, whereas most of the spring and winter NO_3-N concentrations showed no trend.

Total Kjeldahl Nitrogen

All eight stations along the Fox River main stem did not show a statistically significant trend in TKN concentrations, whereas five of the nine tributary stations with TKN data exhibited a decreasing annual trend ranging from 0.4% (0.004 mg/L per year) at Nippersink Creek at Spring Grove to 12.6% per year (0.0.15 mg/L per year) at Ferson Creek at Rt. 34. In contrast, an increasing trend of TKN concentrations by 1.8% per year (0.017 mg/L per year) was estimated for Poplar Creek near Mouth-Elgin.

With few exceptions, no seasonal TKN trend was detected for most monitoring stations in the Fox River main stem, largely conforming to that of the annual trend. A decreasing spring trend of 0.82% per year (0.012 mg/L per year of TKN) was estimated for Fox River at Montgomery. In contrast, Fox River at Oakwood Hills showed an increasing winter trend of 2.1% per year (0.036 mg/L of TKN). In the tributaries, the seasonal TKN concentration showed an increasing trend in some stations and a decreasing or no trend in others. For example, Poplar Creek near Mouth-Elgin exhibited an increasing winter trend of TKN (3.8% per year or 0.038 mg/L per year), which is the largest increasing trend estimated for TKN concentrations in the tributaries or the Fox main stem. On the other hand, the largest decreasing trend of TKN concentrations was estimated in winter for Ferson Creek at Rt. 34 at 59.6% per year (0.715 mg/L per year). Fall TKN concentrations in the Fox main stem showed no trend. In contrast, results showed decreasing trends for Flint Creek at Kelsey Rd-Lk Barrington (15.7%) and Nippersink Creek at Spring Grove (0.6%); increasing trends for Blackberry Creek at Rt. 47 (0.7%), Ferson

Creek at Rt. 34 (0.8%), and Poplar Creek near Mouth-Elgin (3.1%); and no trends for the remaining four tributary stations.

In general, no annual or seasonal longitudinal trend was detected along the Fox River. A decreasing spring trend was detected for Fox River at Montgomery, despite no trends in all the stations upstream. An increasing winter trend at Fox River at Oakwood Hills did not translate into any trend downstream.

Dissolved Oxygen

Out of the 18 gaging stations used in the trend analysis, 13 stations have 13 to 20 years of DO concentration and pH data. These include all 8 stations on the Fox River main stem and 5 on the tributaries (see Table 3). The mean DO concentration on the Fox River and its tributaries ranges from 9.2 mg/L at Crystal Creek-Rt. 31 to 11.5 mg/L at Tyler Creek at Rt. 31-Elgin. The minimum and maximum DO levels of 0.82 and 27.6 mg/L were recorded at Nippersink Creek at Spring Grove and Fox River at Johnsburg, respectively. The Fox River and its tributaries have detailed water quality standards that vary by location, season, and number of consecutive days, as presented in Table 2. The DO water quality standards can be compared with the DO time series and monthly boxplots provided for each monitoring station in Appendix A.

Annual, Seasonal, and Longitudinal Trends

The DO concentrations exhibited a decreasing trend for most stations along the Fox River watershed, with the exception of station 258 (Fox River at Oakwood Hills). In contrast, no DO trend was detected for most of the gaging stations in the summer months. However, a decreasing trend was obtained at Tyler Creek-Rt. 31 at Elgin, Blackberry Creek near Mouth, Fox River at Yorkville, and the Algonquin stations.

The annual DO levels along the Fox River main stem showed a decreasing trend in six of the eight stations with the largest decrease of 1.7% per year (0.17 mg/L per year) at the most downstream station in the Fox main stem (Fox River at Yorkville). No trend in DO levels was exhibited at Fox River at Johnsburg, and an increasing trend of 0.7% per year (0.06 mg/L per year) was estimated at Fox River at Oakwood Hills. The annual DO levels in the Fox River tributaries indicate a decreasing trend in four out of seven stations analyzed, with the largest decrease of 1.6% per year (0.15 mg/L per year) at Blackberry Creek near Mouth. However, no statistically significant trend was detected at Blackberry Creek at Rt. 47, which is located a few miles upstream in the same creek.

The DO trends vary from season to season. In summer, the DO levels show a decreasing trend in only 4 out of the 13 stations, namely, Tyler Creek at Rt. 31-Elgin, Blackberry Creek near Mouth, Fox River at Yorkville, and Fox River at Algonquin. At Fox River at Geneva, the DO levels increased by 1.4% per year (0.145 mg/L per year) during the summer. In spring, most of the stations showed a decreasing trend in DO levels. Throughout the watershed, the largest seasonal decrease of 10.2% (0.98 mg/L per year) was calculated for Blackberry Creek near Mouth in winter, whereas the smallest decrease in DO levels was 0.6% (0.05mg/L per year) in the fall for the Fox River at South Elgin. Longitudinally along the Fox River, the annual and seasonal trend results consistently indicate that DO levels are generally declining at varying levels.

pH

All of the stations with DO data also have pH data. The mean and median pH values ranged from 7.8 to 8.5 on both the Fox main stem and tributaries, which is within the pH limit for freshwater (6.5 to 9.0). The minimum and maximum pH values of 6.0 and 13.4 were observed at Fox River at Oakwood Hills and Blackberry Creek near Mouth, respectively. All but two stations showed some violations of the pH limit. These two stations are Fox River at Oakwood Hills and Fox River at Montgomery, both located on the Fox River main stem.

Annual, Seasonal, and Longitudinal Trends

For all monitoring stations, the central tendencies of all pH values, as expressed in their mean and median values, are within the pH limits for freshwater; thus a decreasing or increasing pH trend would indicate a declining water quality. The majority of the stations on the Fox River main stem do not show any trend in pH values, as the values were stable. Decreasing pH trends were seen only at Fox River at Montgomery and Fox River at Yorkville, whereas an increasing pH trend was exhibited at Fox River at Johnsburg. Decreasing pH trends were detected at Crystal Creek-Rt. 31, Blackberry Creek near Mouth, and Blackberry Creek at Rt. 47. In contrast, increasing pH trends were seen at Tyler Creek at Rt. 31-Elgin and Ferson Creek near Mouth-Elgin.

The majority of the stations showed no seasonal trend in pH values, which also indicates stable pH values in all seasons. For the most part, the spring pH trends are in line with the annual decreasing trends. The fall pH values showed no trend for most stations, but the increasing trend in two stations (Ferson Creek near Mouth-Elgin and Fox River at Johnsburg) conforms to the annual pH trends. In summer, there was a decreasing pH trend at Fox River at Yorkville, Poplar Creek near Mouth-Elgin, and Blackberry Creek near Mouth. The winter pH values showed an increasing trend at Ferson Creek near Mouth-Elgin, whereas these values showed decreasing trends at Fox River at Montgomery and Fox River at Yorkville. For either decreasing or increasing pH trends detected, the maximum change per year was less than1%. The pH values showed a decreasing trend downstream of the Fox River at Geneva Park-Fabyan.

Total Suspended Solids

The TSS concentration data are available for only seven stations, of which four are on the Fox main stem and three are on its tributaries. The mean TSS concentrations across these stations vary from 12.2 mg/L for Poplar Creek near Mouth-Elgin to 34.1 mg/L for Fox River at Montgomery. The minimum and maximum TSS concentrations are 1.0 and 203 mg/L, with both recorded at Blackberry Creek at Rt. 47. No water quality standard is currently available for TSS.

Annual, Seasonal, and Longitudinal Trends

Out of the four stations on the Fox River main stem with TSS data, two showed no annual TSS trend, and the remaining two downstream stations exhibited a decreasing TSS trend with a maximum reduction of 0.65 mg/L per year (2% per year) at the Fox River at Montgomery. No annual trend was seen in any of the three stations on Fox tributaries with TSS data.

No TSS trend was detected in the Fox River main stem or tributaries for fall or spring except for Fox River at Montgomery, which showed a decreasing fall trend of 2.67 mg/L per year (8.1% per year). Increasing winter trends were detected for Fox River at Rt. 176 and Poplar Creek near Mouth-Elgin, which were 2.0 and 3.3 mg/L per year, respectively, but neither station showed an annual TSS trend. Poplar Creek near Mouth-Elgin also exhibited a decreasing summer TSS trend of 1.2 mg/L per year. An increasing trend for summer TSS concentrations was detected at Blackberry Creek at Rt. 47, but all remaining stations show no trend for the summer months.

A longitudinal TSS trend seems to appear along the Fox River because both stations downstream of Algonquin showed a reduction in TSS concentrations. The fall TSS trend conforms to the annual trend along the Fox River. No distinct longitudinal trend was observed for other seasons.

Chlorophyll-A

Only 11 out of the 18 stations have CHL-A concentration data, the majority of which are located in the Fox main stem (i.e., seven stations). The mean CHL-A concentration across these stations has a range of 95.6 µg/l with higher and lower concentrations on the Fox main stem and tributaries, respectively. The mean concentration on the main stem ranges from 81.6 µg/l at Fox River at Johnsburg to 105.3 µg/l at Fox River at Geneva. In contrast, the mean CHL-A concentration in the tributaries varies from 9.7 µg/l at Tyler Creek at Rt. 31-Elgin to 29.7 µg/l at Crystal Creek at Rt. 31. The range of CHL-A concentration on the Fox main stem and tributary stations is 478.8 µg/l, with the lowest concentration of 0.63 µg/l observed at Ferson Creek near Mouth-Elgin and Blackberry Creek near Mouth. The maximum CHL-A concentration in the tributaries is 244.4 µg/l for Crystal Creek at Rt. 31. Currently, there is no CHL-A standard for Fox River and its tributaries.

Annual, Seasonal, and Longitudinal Trends

The CHL-A concentration showed a decreasing annual trend in all seven stations with observed data in the Fox River main stem, ranging from 1.37 µg/l per year (1.7% per year) for Fox River at South Elgin to 2.87 µg/l (3.4% per year) for Fox River at Oakwood Hills. In contrast, no annual trend was detected for all four tributary stations with CHL-A records.

No trend was detected for summer CHL-A concentrations. Fall and spring trends conform to annual trends with the maximum decreasing fall trend of 4.8 µg/l per year (6% per year) for Fox River at Yorkville. Despite having no annual CHL-A trend for Ferson Creek near Mouth-Elgin, an increasing winter trend of 5.2% (0.56 µg/l) was detected. Along the Fox River, CHL-A concentrations clearly showed decreasing annual, fall, and spring trends.

Summaries of the annual, winter, spring, summer, and fall trends are presented in Tables 5 through 9, showing increasing, decreasing, no trend, or '-' for no data. Furthermore, insufficient data for conducting the annual or seasonal trend analysis falls under the no data category. Improving, stable, and declining trends are shown in green, yellow, and red colors. In the tables, the stations are listed in upstream (Nippersink Creek at Spring Grove) to downstream (Blackberry Creek near Mouth) order and tributaries (in italics) appear in the order of their confluence with the Fox River (in bold).

Table 5. Annual Water Quality Trends

Station ID	Station Name	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	TSS	CHL-A
236	*Nippersink Cr at Spring Grove*	No Trend	Decreasing	-	Decreasing	-	No Trend	No Trend	No Trend	No Trend	-
1	*Nippersink Cr above Wonder Lake*	No Trend	No Trend	-	-	-	-	-	-	-	-
184	**Fox River at Johnsburg**	No Trend	Increasing	Decreasing	Decreasing	Decreasing	Decreasing	No Trend	Increasing	-	Decreasing
23	**Fox River at Rt 176**	Increasing	Increasing	-	No Trend	Increasing	No Trend	Decreasing	No Trend	No Trend	-
258	**Fox River at Oakwood Hills**	Decreasing	No Trend	No Trend	Decreasing	Decreasing	No Trend	Increasing	No Trend	-	Decreasing
4	*Flint Cr at Kelsey Rd-Lk Barrington*	No Trend	No Trend	-	No Trend	-	No Trend	-	-	-	-
271	*Crystal Cr at Rt 31*	Decreasing	Decreasing	No Trend	No Trend	Increasing	No Trend	Decreasing	Decreasing	-	No Trend
24	**Fox River at Algonquin**	No Trend	Increasing	No Trend	No Trend	Decreasing	No Trend	Decreasing	No Trend	No Trend	Decreasing
268	*Tyler Cr at Rt. 31-Elgin*	Decreasing	Decreasing	No Trend	No Trend	No Trend	No Trend	Decreasing	Increasing	-	No Trend
25	*Poplar Cr near Mouth-Elgin*	Increasing	Increasing	-	No Trend	-	Increasing	No Trend	No Trend	No Trend	-
26	**Fox River at South Elgin**	Decreasing	Decreasing	Decreasing	Decreasing	No Trend	Decreasing	Decreasing	No Trend	Decreasing	Decreasing
14	*Ferson Cr at Rt 34*	No Trend	No Trend	-	No Trend	-	No Trend	-	-	-	-
79	*Ferson Cr near Mouth-Elgin*	No Trend	Increasing	No Trend	Decreasing	Decreasing	No Trend	Decreasing	Increasing	-	No Trend
40	**Fox River at Geneva**	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	No Trend	-	Decreasing
27	**Fox River at Montgomery**	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing
34	**Fox River at Yorkville**	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	-	Decreasing
28	*Blackberry Cr at Rt 47*	No Trend	Decreasing	-	No Trend	-	No Trend	No Trend	Decreasing	No Trend	-
287	*Blackberry Cr near Mouth*	No Trend	No Trend	No Trend	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing	-	No Trend

Note: Color code – "red" declining trend; "green" improving trend; "yellow" stable; "-" no data.

Table 6. Winter Water Quality Trends

Station ID	Station Name	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	TSS	CHL-A
236	*Nippersink Cr at Spring Grove*	No Trend	No Trend	-	No Trend	-	No Trend	No Trend	No Trend	No Trend	-
1	*Nippersink Cr above Wonder Lake*	No Trend	Decreasing	-	-	-	-	-	-	-	-
184	**Fox River at Johnsburg**	Decreasing	No Trend	No Trend	No Trend	No Trend	No Trend	-	No Trend	-	No Trend
23	**Fox River at Rt 176**	Increasing	Increasing	-	No Trend	Increasing	No Trend	No Trend	No Trend	-	-
258	**Fox River at Oakwood Hills**	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	-	-	-	No Trend
4	*Flint Cr at Kelsey Rd-Lk Barrington*	No Trend	No Trend	-	No Trend	-	No Trend	-	-	-	-
271	*Crystal Cr at Rt 31*	Decreasing	Decreasing	No Trend	No Trend	No Trend	No Trend	No Trend	-	-	No Trend
24	**Fox River at Algonquin**	No Trend	Increasing	No Trend	No Trend	No Trend	No Trend	Decreasing	No Trend	No Trend	Decreasing
268	*Tyler Cr at Rt. 31-Elgin*	Decreasing	Decreasing	Decreasing	No Trend	Decreasing	No Trend	No Trend	-	-	No Trend
25	*Poplar Cr near Mouth-Elgin*	Increasing	No Trend	-	No Trend	-	Increasing	No Trend	No Trend	Increasing	-
26	**Fox River at South Elgin**	Decreasing	Decreasing	No Trend	Decreasing	No Trend	Decreasing	Decreasing	No Trend	No Trend	Decreasing
14	*Ferson Cr at Rt 34*	No Trend	No Trend	-	No Trend	-	No Trend	-	-	-	-
79	*Ferson Cr near Mouth-Elgin*	No Trend	No Trend	No Trend	No Trend	Decreasing	No Trend	Decreasing	Increasing	-	Increasing
40	**Fox River at Geneva**	Decreasing	No Trend	No Trend	Decreasing	No Trend	No Trend	Decreasing	No Trend	-	No Trend
27	**Fox River at Montgomery**	Decreasing	No Trend	No Trend	Decreasing	No Trend	Decreasing	No Trend	Decreasing	No Trend	No Trend
34	**Fox River at Yorkville**	Decreasing	Decreasing	No Trend	Decreasing	No Trend	No Trend	Decreasing	Decreasing	-	Decreasing
28	*Blackberry Cr at Rt 47*	No Trend	Decreasing	-	No Trend	-	No Trend	No Trend	No Trend	No Trend	-
287	*Blackberry Cr near Mouth*	No Trend	No Trend	No Trend	Decreasing	Decreasing	No Trend	Decreasing	-	-	No Trend

Note: Color code – "red" declining trend; "green" improving trend; "yellow" stable; "-" no data.

Table 7. Spring Water Quality Trends

Station ID	Station Name	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	TSS	CHL-A
236	*Nippersink Cr at Spring Grove*	No Trend	Decreasing	-	Decreasing	-	No Trend	No Trend	No Trend	No Trend	-
1	*Nippersink Cr above Wonder Lake*	No Trend	No Trend	-	-	-	-	-	-	-	-
184	**Fox River at Johnsburg**	No Trend	Increasing	No Trend	No Trend	No Trend	Decreasing	No Trend	No Trend	-	Decreasing
23	**Fox River at Rt 176**	No Trend	Increasing	-	No Trend	Increasing	No Trend	No Trend	No Trend	No Trend	-
258	**Fox River at Oakwood Hills**	No Trend	Increasing	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	-	Decreasing
4	*Flint Cr at Kelsey Rd-Lk Barrington*	No Trend	No Trend	-	No Trend	-	No Trend	-	-	-	-
271	*Crystal Cr at Rt 31*	Decreasing	Decreasing	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	-	No Trend
24	**Fox River at Algonquin**	No Trend	Increasing	No Trend	No Trend	No Trend	No Trend	Decreasing	No Trend	No Trend	Decreasing
268	*Tyler Cr at Rt. 31-Elgin*	No Trend	No Trend	No Trend	No Trend	Decreasing	No Trend	Decreasing	No Trend	-	No Trend
25	*Poplar Cr near Mouth-Elgin*	Increasing	Increasing	-	No Trend	-	No Trend	No Trend	No Trend	No Trend	-
26	**Fox River at South Elgin**	Decreasing	No Trend	Decreasing	No Trend	No Trend	Decreasing	Decreasing	No Trend	No Trend	Decreasing
14	*Ferson Cr at Rt 34*	No Trend	No Trend	-	No Trend	-	No Trend	-	-	-	-
79	*Ferson Cr near Mouth-Elgin*	No Trend	Increasing	No Trend	No Trend	Decreasing	No Trend	Decreasing	No Trend	-	No Trend
40	**Fox River at Geneva**	Decreasing	Decreasing	Decreasing	No Trend	No Trend	Decreasing	Decreasing	No Trend	-	Decreasing
27	**Fox River at Montgomery**	Decreasing	No Trend	Decreasing	Decreasing	No Trend	No Trend	Decreasing	Decreasing	No Trend	Decreasing
34	**Fox River at Yorkville**	Decreasing	Decreasing	Decreasing	Decreasing	No Trend	Decreasing	Decreasing	Decreasing	-	Decreasing
28	*Blackberry Cr at Rt 47*	No Trend	No Trend	-	Increasing	-	No Trend	No Trend	Decreasing	No Trend	-
287	*Blackberry Cr near Mouth*	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	Decreasing	Decreasing	-	No Trend

Note: Color code – “red” declining trend; “green” improving trend; “yellow” stable; “-” no data.

Table 8. Summer Water Quality Trends

Station ID	Station Name	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	TSS	CHL-A
236	*Nippersink Cr at Spring Grove*	No Trend	No Trend	-	No Trend	-	No Trend	No Trend	No Trend	No Trend	-
1	*Nippersink Cr above Wonder Lake*	No Trend	No Trend	-	-	-	-	-	-	-	-
184	**Fox River at Johnsburg**	No Trend	Increasing	No Trend	No Trend	Decreasing	No Trend	No Trend	No Trend	-	No Trend
23	**Fox River at Rt 176**	No Trend	Increasing	-	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	-
258	**Fox River at Oakwood Hills**	No Trend	No Trend	No Trend	No Trend	Decreasing	No Trend	No Trend	No Trend	-	No Trend
4	*Flint Cr at Kelsey Rd-Lk Barrington*	No Trend	No Trend	-	No Trend	-	No Trend	-	-	-	-
271	*Crystal Cr at Rt 31*	Decreasing	Decreasing	No Trend	No Trend	No Trend	No Trend	No Trend	No Trend	-	No Trend
24	**Fox River at Algonquin**	No Trend	Increasing	No Trend	No Trend	Decreasing	No Trend	Decreasing	No Trend	No Trend	No Trend
268	*Tyler Cr at Rt. 31-Elgin*	No Trend	No Trend	Increasing	No Trend	No Trend	Increasing	Decreasing	No Trend	-	No Trend
25	*Poplar Cr near Mouth-Elgin*	No Trend	Increasing	-	No Trend	-	No Trend	No Trend	Decreasing	Decreasing	-
26	**Fox River at South Elgin**	No Trend	No Trend	Decreasing	No Trend	No Trend	Decreasing	No Trend	No Trend	No Trend	No Trend
14	*Ferson Cr at Rt 34*	No Trend	-	-	No Trend	-	No Trend	-	-	-	-
79	*Ferson Cr near Mouth-Elgin*	No Trend	Increasing	No Trend	Decreasing	Decreasing	No Trend	No Trend	No Trend	-	No Trend
40	**Fox River at Geneva**	Decreasing	Decreasing	Decreasing	Decreasing	No Trend	Decreasing	Increasing	No Trend	-	No Trend
27	**Fox River at Montgomery**	No Trend	No Trend	Decreasing	Decreasing	Decreasing	No Trend	No Trend	No Trend	No Trend	No Trend
34	**Fox River at Yorkville**	Decreasing	Decreasing	Decreasing	Decreasing	No Trend	Decreasing	Decreasing	Decreasing	-	No Trend
28	*Blackberry Cr at Rt 47*	Decreasing	No Trend	-	Decreasing	-	No Trend	No Trend	No Trend	Increasing	-
287	*Blackberry Cr near Mouth*	No Trend	No Trend	Decreasing	Decreasing	Increasing	Decreasing	No Trend	No Trend	-	No Trend

Note: Color code – “red” declining trend; “green” improving trend; “yellow” stable; “-” no data.

Table 9. Fall Water Quality Trends

Station ID	Station Name	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	TSS	CHL-A
236	*Nippersink Cr at Spring Grove*	No Trend	No Trend	-	No Trend	-	No Trend	No Trend	No Trend	No Trend	-
1	*Nippersink Cr above Wonder Lake*	No Trend	No Trend	-	-	-	-	-	-	-	-
184	**Fox River at Johnsburg**	Decreasing	No Trend	Decreasing	No Trend	No Trend	Decreasing	No Trend	Increasing	-	Decreasing
23	**Fox River at Rt 176**	No Trend	No Trend	-	No Trend	Increasing	No Trend	No Trend	No Trend	No Trend	-
258	**Fox River at Oakwood Hills**	Decreasing	No Trend	No Trend	Decreasing	Decreasing	No Trend	No Trend	No Trend	-	No Trend
4	*Flint Cr at Kelsey Rd-Lk Barrington*	No Trend	No Trend	-	No Trend	-	No Trend	-	-	-	-
271	*Crystal Cr at Rt 31*	Decreasing	Decreasing	No Trend	No Trend	No Trend	No Trend	Decreasing	No Trend	-	No Trend
24	**Fox River at Algonquin**	No Trend	No Trend	No Trend	Decreasing	Decreasing	No Trend	No Trend	No Trend	No Trend	Decreasing
268	*Tyler Cr at Rt. 31-Elgin*	No Trend	No Trend	No Trend	Increasing	No Trend	No Trend	No Trend	No Trend	-	No Trend
25	*Poplar Cr near Mouth-Elgin*	Increasing	No Trend	-	No Trend	-	Increasing	No Trend	No Trend	No Trend	-
26	**Fox River at South Elgin**	No Trend	Decreasing	Decreasing	Decreasing	No Trend	Decreasing	Decreasing	No Trend	No Trend	No Trend
14	*Ferson Cr at Rt 34*	No Trend	No Trend	-	No Trend	-	No Trend	-	-	-	-
79	*Ferson Cr near Mouth-Elgin*	No Trend	Increasing	No Trend	Decreasing	Decreasing	No Trend	No Trend	Increasing	-	No Trend
40	**Fox River at Geneva**	Decreasing	Decreasing	Decreasing	Decreasing	No Trend	Decreasing	Decreasing	No Trend	-	Decreasing
27	**Fox River at Montgomery**	Decreasing	No Trend	Decreasing	Decreasing	Decreasing	No Trend	No Trend	No Trend	Decreasing	Decreasing
34	**Fox River at Yorkville**	Decreasing	Decreasing	Decreasing	Decreasing	No Trend	Decreasing	Decreasing	Decreasing	-	Decreasing
28	*Blackberry Cr at Rt 47*	No Trend	No Trend	-	No Trend	-	No Trend	No Trend	No Trend	No Trend	-
287	*Blackberry Cr near Mouth*	No Trend	No Trend	No Trend	Decreasing	Decreasing	No Trend	Decreasing	No Trend	-	No Trend

Note: Color code – "red" declining trend; "green" improving trend; "yellow" stable; "-" no data.

3.3 Weighted Regression on Time, Discharge, and Season

The Weighted Regression on Time, Discharge, and Season (WRTDS) is a relatively new emerging method developed to provide a more accurate representation of long-term trends, and seasonal and discharge-related components of long-term water quality datasets. The WRTDS method is designed to provide estimates of actual and flow-normalized water quality concentrations and fluxes (loads). Estimating the actual history of concentrations and fluxes fosters the understanding of changes occurring in the stream or river water quality and related impacts on the aquatic ecosystem. The flow-normalized concentration and flux estimates are obtained by eliminating the influences of streamflow variability on the water quality parameter of interest, and thus the flux estimates are good indicators of water quality trends, measuring progress made toward load reduction affected by management practices implemented in the watershed.

The WRTDS model considers concentration to be a product of four components, including trend, seasonal, discharge, and random components. Therefore, the model divides the water quality datasets into these four components. The trend component is essentially a moving average of the time series data, indicating the gradual change in water quality condition through the years. The seasonal component depicts the annual cycle of water quality variation that is generally consistent but can gradually change from year to year in the WRTDS. The discharge and random components take into account the flow influences on water quality and the unexplained variation in concentration, respectively. Accounting for these components, the WRTDS equation (Hirsch et al., 2010) can be expressed as

$$\ln(c) = \beta_0 + \beta_1 t + \beta_2 \ln(Q) + \beta_3 \sin(2\pi t) + \beta_4 \cos(2\pi t) + \varepsilon$$

where c is the concentration, Q is discharge, t is the time in years, ε is the unexplained variation, and $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4$ are fitted coefficients that vary through the record. Unlike common approaches, this method calibrates the parameters of the equation for every combination of Q and t where estimates are required. It must be noted that the weighted regression estimation system that calculates the expected value of the concentration (c) for a given Q and t is the integral part of the WRTDS method. The relevance of each observation to an estimation point determines its weight in the regression and is defined by a distance between the observation and the estimation point in terms of discharge and time data points. This distance between an observation and estimation point has three dimensions: time distance as measured by the difference in years; seasonal distance as measured by the difference in times of year; and discharge distance as measured by the difference in the natural log of the discharges. Using these distances, corresponding weights are calculated using a Tricube weight function, and the product will be the overall weight for each data point to be used in the weighted regression. The longer the distance of an observation from an estimation point in either time, season, or discharge, the smaller the chance of that observation being a part of the regression or the lesser its importance. Hirsch et al. (2010, 2015) provides a detailed description of the WRTDS method, which is also part of the USGS's R-package, known as Exploration and Graphics for RivEr Trends (EGRET) software. In addition to implementing the WRTDS method, EGRET provides a useful tool for analyzing long-term changes in water quality and streamflow, including a data-retrieval package that is designed to accept USGS data, EPA STORET, and user-specified text files.

3.4 WRTDS Results and Discussion

Although the SKT trend analysis presented earlier provides concentration trends and estimate changes in magnitude, year-to-year variations in hydrologic conditions may have impacted trends in water quality concentrations. Actual concentration and flux histories may suggest a worsening water quality for a pollutant concentration that increases with flow for a year or two near the end of the period of record, making it hard to detect if trends exist. The WRTDS method allows computing flow-normalized concentration and fluxes where flow-driven variability is eliminated, and thus existing trends, if any, can be identified. In addition, it provides histories of both actual and flow-normalized concentrations and fluxes.

Only four stations fulfill the requirement for conducting parametric trend analysis using the WRTDS method. Three of these stations (Fox River at Montgomery, Blackberry Creek at Rt. 47, and Poplar Creek near Mouth-Elgin) have concentration data along with the corresponding flow data that extend to the year 2016. All remaining stations have either no flow data, insufficient observations (<100 samples), or missing (discontinuous) discharge data, which are required to develop a WRTDS model. For nine of the ten nutrient-related water quality parameters, except pH, WRTDS models were developed. Fox River at Montgomery has all nine water quality parameters, whereas Blackberry Creek at Rt. 47 and Polar Creek at Elgin have only five of the nine parameters, excluding Org-N, NO_3-N, TSS, and CHL-A. In total, 19 WRTDS models were developed that account for the highly variable nature of water quality concentrations as a function of time, discharge, and season. The models were used to evaluate both flow-normalized concentrations and flux histories for the 19 water quality parameters obtained across the three stations.

In a WRTDS model, a flow-normalized concentration on a specific day is calculated as an integral part of the fitted estimates of concentration (i.e., a function of discharge and time) multiplied by the probability density function (pdf) of the discharge for that day of the year. When there are long-term data, the historical discharge sample data could be used in place of the pdf, as was the case in this study. For example, Fox River at Montgomery has 20 years of TP concentration data from 1997 to 2016 but has discharge data for only 14 of the 20 years from water year 2003 to 2016. To estimate a flow-normalized TP concentration and flux for any given date, say for January 1, 2003, all 14 of the January 1 discharge values in the dataset are assumed to have likely occurred on the estimation date (January 1, 2003). The WRTDS model then estimates 14 values of TP concentration for January 1, 2003, using each of the 14 January 1 discharge values, but with the time variable set to the estimation date. The mean of these 14 estimated TP concentration values will be the flow-normalized TP concentration. Similarly, the flow-normalized flux is computed as the product of the flow-normalized TP concentration and mean daily flow for the estimation date. Consequently, trends in concentration may not necessarily imply trends in flux because days of high discharges could strongly affect flux trends, but they have little influence on concentration trends. For percentage changes in concentration and flux to be the same, the changes in concentration across all ranges of discharge and for all seasons need to be identical. In WRTDS, trends are not restricted as being linear or monotonic, and thus the trends could be different across seasons and flows.

The 19 WRTDS models developed using concentration-discharge relationships were examined using graphical comparisons and computations of model biases, exploring the performance of the fitted model. For the Fox River at Montgomery, the output of the WRTDS model for TP is presented using eight panel graphics in Figure 7, showing the quality of the fitted

WRTDS model. The first four panels show WRTDS residuals (i.e., observed minus estimated values of concentration in natural log units, $\ln(c)$) as a function of estimated concentrations in natural log units, discharge, date, and months, respectively. For a good quality model, the WRTDS residuals need to be approximately symmetrical around the zero value line; in the case of the boxplot, the zero line is expected to pass through the middle of the boxes. In addition, these residuals should not show any substantial curvature in the first three panels, which would indicate either an over-prediction or under-prediction if the residuals are negative or positive, respectively. In this case, the TP WRTDS model residuals seem to be symmetrical around the value of zero with no apparent curvature. If there were single or multiple events that profoundly affected the TP concentration during the period of analysis, the third panel, which shows residuals versus time, would have shown these events. The fourth panel showing residuals versus the boxplot of concentration by month indicates that the model is accounting for seasonal differences in the TP concentration at Fox River at Montgomery because the boxes are symmetrical around the value of zero for nearly all months. The fifth panel, which shows a figure consisting of three boxplots of concentration based on sample day values, sample day estimates, and all day estimates, indicates a good performing model with nearly identical median and interquartile ranges of concentrations and similar distribution. It must be noted that the width of the boxplots is proportional to the square root of the sample size and thus, a wider boxplot for all of the day estimates is to be expected. The scatter plot of observed versus estimated concentration shown in panel six is clustered and symmetrical around the 1:1 line with no substantial departures from that line, indicating the model's good performance. The seventh panel shows boxplots of discharge values during sampled days and all days, providing insight into the distribution of discharges in the sampled days. In this case, the two boxplots being equivalent indicates that the TP sampling appears to cover ranges of discharges, which is particularly important in the estimation of fluxes and flux trends. The last and eighth panel is a scatter plot of observed versus estimated TP fluxes on all sampled days. Since the dots appear to be symmetrical around the 1:1 line, there is a close match between observed and estimated TP fluxes.

A flux bias statistic, which is defined as the difference between the sums of estimated and observed fluxes on all sampled days divided by the sum of estimated fluxes, is computed for TP at Fox River at Montgomery to be 0.0193 (an average error of 1.93% in flux estimates). The absolute flux bias statistic for all remaining water quality parameters, including DP, Org-N, NH_3-N, NO_3-N, TKN, and TSS at Fox River at Montgomery, is below 0.065, except for CHL-A, which is calculated to be 0.166. For Blackberry Creek at Rt. 47 and Poplar Creek near Mouth-Elgin, the absolute flux bias for TP and TKN was found to be below 0.085, whereas it ranges between 0.2 to 0.4 for DP and NH_3-N fluxes. A significant amount of the DP and NH_3-N concentration data (20 to 35% of the sample data) for these two stations is below the detection limit and thus is incorporated as censored data in the model. As a result, larger biases were obtained and this poor model performance needs to be taken into account when examining DP and NH_3-N concentration and flux estimates and trends in these two stations. Next, the WRTDS analysis results are presented for each monitoring station.

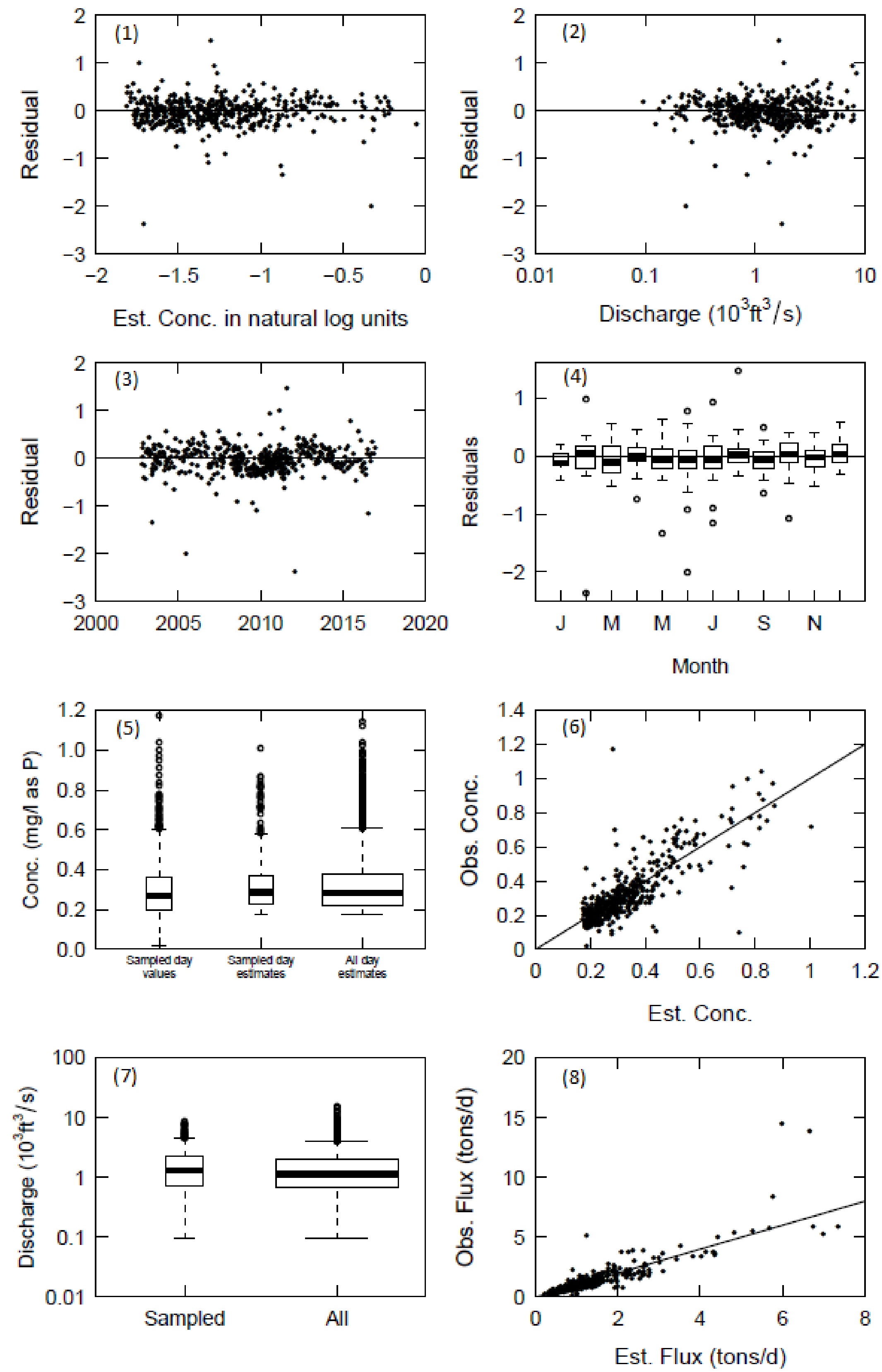

Figure 7. WRTDS model output for total phosphorus (TP) at Fox River at Montgomery

Trends in Flow-normalized Concentration

Annual and seasonal trends in flow-normalized concentration are estimated for Fox River at Montgomery, Blackberry Creek at Rt. 47, and Poplar Creek near Mouth-Elgin between 2006 and 2016. Changes in flow-normalized concentrations in milligrams per liter (mg/L) and percent (%) are presented in Tables 10 and 11, respectively. The annual values are based on a water year, which starts in October and ends in September of the following year, and the four seasons are winter (December to February), spring (March to May), summer (June to August), and fall (September to November).

The result of concentration trend analysis using the WRTDS method indicates that the flow-normalized concentrations of almost all water quality parameters analyzed showed decreasing trends across all seasons from 2006 to 2016 for Fox River at Montgomery, with the exception of spring TSS and summer CHL-A concentrations. Large concentration decreases at this station were obtained in summer for DP, NH_3-N, and NO_3-N; in winter for TP, TSS, and CHL-A; and in spring for DO, Org-N, and TKN. Unlike other water quality parameters, a decreasing DO concentration at Fox River at Montgomery across all seasons is indicative of a declining water quality trend. The changes in annual TP and DP concentrations between 2006 and 2016 are 27% and 28%, respectively, showing the largest decreases as compared to the remaining water quality parameters. In contrast, the decrease in the annual TKN, DO, and TSS concentrations was less than 10%.

For the two tributary monitoring stations (Blackberry Creek at Rt. 47 and Poplar Creek near Mouth-Elgin), NH_3-N concentrations exhibited the largest annual and seasonal increasing trends. TP, DP, and DO concentrations for Blackberry Creek at Rt. 47 showed decreasing annual and seasonal trends, except in fall for DO and in summer for TP and DO. Across all seasons, the TKN concentration at this station increased from 1.7% in winter to 38% in summer with an average annual decrease of 23% between 2006 and 2016. For Poplar Creek near Mouth-Elgin, the DP and DO concentrations show improving water quality trends across all seasons. For all three monitoring stations, the seasonal concentration trends largely conform to the annual trends.

Figure 8 illustrates the annual phosphorus and nitrogen trend results for Fox River at Montgomery, showing average annual and seasonal flow-normalized concentrations. Note that the dots in the figure represent the actual values of annual mean concentration, whereas the flow-normalized concentration is represented by a line. In this figure, although all concentrations show decreasing trends, there are differences between them. For example, the decrease in NO_3-N for the Fox River at Montgomery is more pronounced after 2010, as evidenced by a steeper slope in flow-normalized concentration, and the reverse is true for NH_3-N.

All annual and seasonal trend results for the remaining water quality parameters and the two tributary stations are included in Appendix D.

Table 10. Changes in Flow-normalized Concentrations (mg/L) between 2006 and 2016

Station ID	Station Name		TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	TSS	CHL-A
25	*Poplar Cr near Mouth-Elgin* :	Annual	1.900	-0.650	-	0.081	-	19.000	12.000	-	-
		Winter	0.091	-0.009	-	0.084	-	38.000	0.570	-	-
		Spring	0.019	-0.008	-	0.051	-	11.000	0.800	-	-
		Summer	-0.005	-0.013	-	0.140	-	-0.007	0.570	-	-
		Fall	0.063	-0.018	-	0.055	-	0.810	0.620	-	-
27	**Fox River at Montgomery**:	Annual	-0.099	-0.054	-0.180	-0.019	-0.390	-0.130	-1.000	-3.500	-0.011
		Winter	-0.110	-0.048	-0.110	-0.041	-0.400	-0.190	-1.900	-2.600	-0.012
		Spring	-0.059	-0.024	-0.260	-0.003	-0.290	-0.140	-1.100	1.100	-0.023
		Summer	-0.093	-0.069	-0.210	-0.008	-0.340	-0.050	-0.300	-1.400	0.008
		Fall	-0.120	-0.076	-0.070	-0.023	-0.570	-0.110	-0.820	-9.400	-0.011
28	*Blackberry Cr at Rt 47:*	Annual	0.011	0.017	-	0.280	-	-0.200	-0.088	-	-
		Winter	0.027	0.040	-	0.410	-	-0.010	-0.260	-	-
		Spring	0.024	0.019	-	0.400	-	-0.390	-0.880	-	-
		Summer	-0.012	0.002	-	0.230	-	-0.410	0.014	-	-
		Fall	0.004	0.009	-	0.100	-	-0.010	0.840	-	-

Note: "red" declining trend; "green" improving trend; "-" no data

Table 11. Percent Changes in Flow-normalized Concentrations between 2006 and 2016

Station ID	Station Name		TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	TSS	CHL-A
25	*Poplar Cr near Mouth-Elgin* :	Annual	51	-35	-	109	-	52	3.8	-	-
		Winter	168	-60	-	59	-	110	4.1	-	-
		Spring	28	-35	-	99	-	22	7.2	-	-
		Summer	-5.3	-24	-	293	-	-0.73	7.2	-	-
		Fall	82	-65	-	99	-	92	6.3	-	-
27	**Fox River at Montgomery**:	Annual	-27	-28	-11	-23	-20	-7.7	-8.7	-9.6	-10
		Winter	-34	-23	-11	-31	-13	-16	-12	-15	-35
		Spring	-21	-22	-18	-4.3	-14	-9.2	-9.4	3	-28
		Summer	-22	-32	-9.2	-15	-38	-2.2	-3.4	-2.6	4.2
		Fall	-29	-31	-4	-31	-32	-5.9	-7.4	-25	-8.7
28	*Blackberry Cr at Rt 47:*	Annual	12	43	-	405	-	-23	-0.85	-	-
		Winter	42	161	-	382	-	-1.7	-1.9	-	-
		Spring	27	73	-	502	-	-34	-8.1	-	-
		Summer	-9.3	2.1	-	531	-	-38	0.18	-	-
		Fall	5.7	25	-	222	-	-1.6	8.8	-	-

Note: "red" declining trend; "green" improving trend; "-" no data

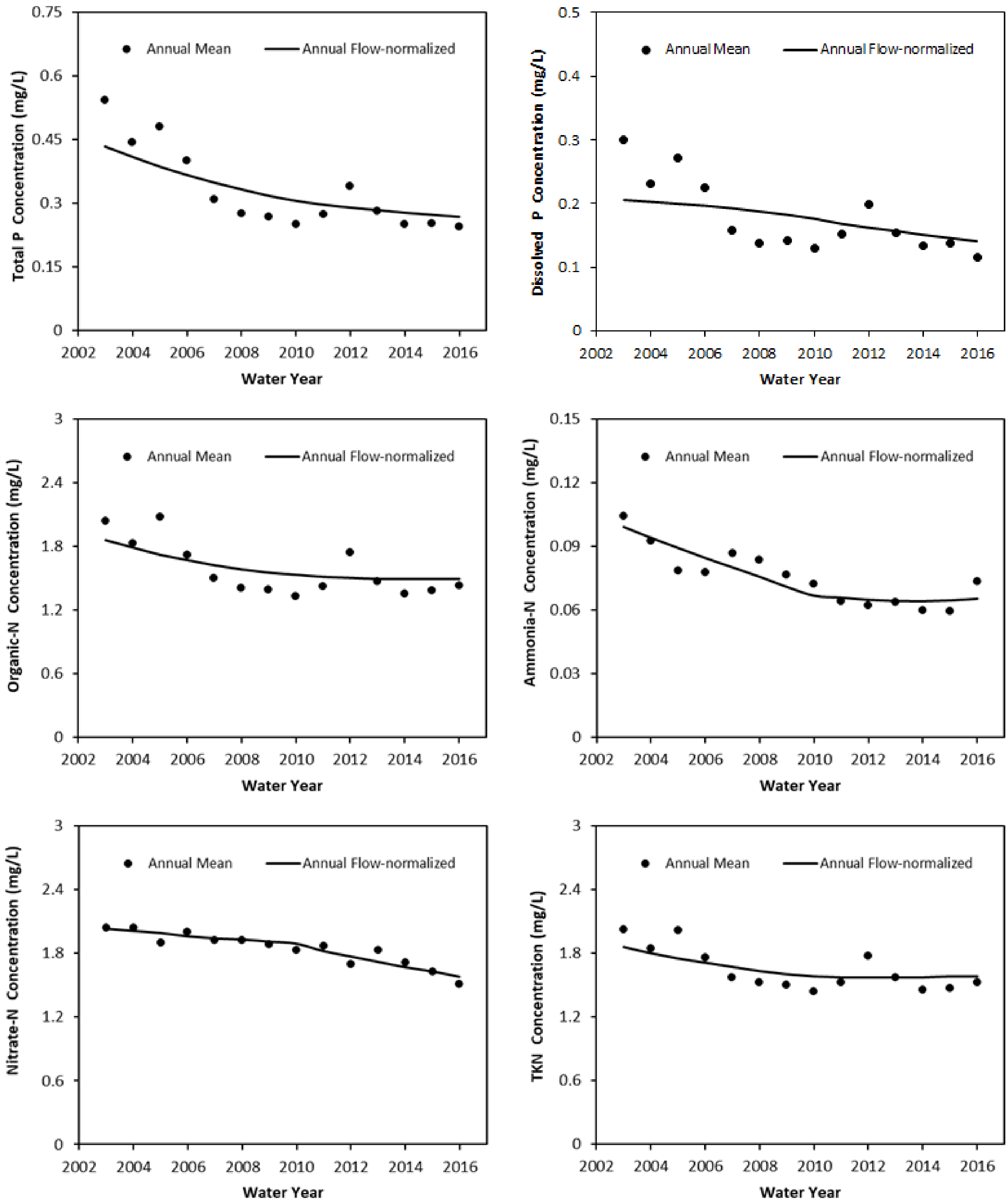

Figure 8. Actual and flow-normalized phosphorus and nitrogen concentrations for Fox River at Montgomery

Trends in Flow-normalized Flux

For the same water quality parameters, with the exception of DO, annual and seasonal trends in flow-normalized fluxes are also estimated for the three monitoring stations between 2006 and 2016. Changes in flow-normalized fluxes in pounds per year (lbs/yr) and percent (%) are presented in Tables 12 and 13, respectively.

Flow-normalized fluxes (loads) of most water quality parameters decreased across all seasons from 2006 to 2016 for the Fox River at Montgomery. An upward trend occurring around 2009-2010 was obtained only for spring fluxes of ammonia nitrogen (NH_3-N) and TSS and summer fluxes of CHL-A during the same period. In comparison with other water quality parameters, flow-normalized fluxes of TP and DP show a larger decrease across all seasons between 2006 and 2016. A similar downward trend of nitrate nitrogen (NO_3-N) fluxes were obtained for Fox River at Montgomery in the summer and fall months. For Fox River at Montgomery, the flow-normalized fluxes show a decreasing annual trend ranging from 6.3% for TSS (a difference of 8.49×10^6 lbs/yr between the 2006 and 2016 fluxes) to 25% (108×10^3 lbs/yr) for DP. From 2006 to 2016, the downward annual trends for TKN, CHL-A, and TSS fluxes were found to be less than 10%. The DP fluxes decreased by 20% to 31% across all seasons and similarly, the TP fluxes consistently reduced across all seasons by 16% to 30% with an average annual decrease of 20% (200.6×10^3 lbs/yr). All nutrient fluxes showed decreasing annual and seasonal trends, with the exception of the NH_3-N flux in spring that seemed to exhibit a slightly increasing trend (0.1% or 400 lbs/yr). A maximum upward trend of 6.7% (24.3×10^3 lbs/yr) from 2006 to 2016 was detected for the CHL-A flux in the summer. The TSS flux also increased by 4.2% (8.2×10^6 lbs/yr) in the spring. The maximum percentage change in flow-normalized fluxes was obtained for NO_3-N in the fall, which was 32% (1.13×10^6 lbs/yr). The 2016 summer NO_3-N flux also showed a large decrease in 2016 of 28% from that of 2006.

Trend analysis results showing actual and flow-normalized phosphorus and nitrogen fluxes for Fox River at Montgomery are illustrated in Figure 9. All annual and seasonal trend results for the remaining water quality parameters and the two tributary stations are included in Appendix D. Although the seasonal trends conform to annual trends in most cases, there are differences in seasonal and annual trends for some of the water quality parameters. For example, the spring NH_3-N flux showed a downward trend until 2009, followed by an upward trend thereafter. However, it exhibited a decreasing trend in summer, fall, and winter seasons that stabilized in the later years, conforming to the annual trend. Similarly, the TSS flux showed a downward trend, followed by an upward trend in spring. Although there is a difference in percentage changes, the flux and concentration trends are largely similar for this station (i.e., they are in the same downward or upward direction). The only difference observed was between spring NH_3-N concentration and flux, which showed opposing trends. The NH_3-N concentration decreased by 4.3% between 2006 and 2016, whereas its fluxes increased by 0.1% during the same time, showing that concentration trends do not necessarily translate into flux trends.

For Blackberry Creek at Rt. 47 and Poplar Creek near Mouth-Elgin, the WRTDS models were developed for five nutrient-related water quality parameters, namely NH_3-N, TKN, TP, and DP. All flow-normalized fluxes with few exceptions show larger upward trends for these two stations. The DP and TKN fluxes exhibited decreasing annual and seasonal trends for Poplar Creek near Mouth-Elgin and Blackberry Creek at Rt. 47, respectively. The NH_3-N, TKN, and TP fluxes for Poplar Creek near Mouth-Elgin showed increasing trends across all seasons from 2006 to 2016, ranging from 11% for summer TKN to 118% for fall TP fluxes. For this same station, large increases of 51% to 118% were obtained for TKN and TP fluxes that are similar across all seasons. For this station, only DP fluxes showed a downward trend across all seasons ranging from 29% in winter to 41% in spring with an annual downward trend of 35% (1.43×10^3 lbs/yr). In contrast, for Blackberry Creek at Rt. 47, flow-normalized fluxes for NH_3-N, TP, and DP showed an upward trend across all seasons from 2006 to 2016. The maximum annual increase of 163% (24.3×10^3 lbs/yr) was obtained for the NH_3-N flux, which is over a 100% increase across all seasons. Unlike Poplar Creek near Mouth-Elgin, both TP and DP showed a similar upward trend across all seasons ranging from 4.8% to 92% for TP and from 13% to 68% for DP fluxes. For this station, decreasing trends of TKN fluxes ranging from 0.04% in winter to 26% in summer were detected, with the exception of fall months that exhibited an upward trend of 2.7% in the TKN flux from 2006 to 2016.

Table 12. Changes in Flow-normalized Fluxes (×10^3 lbs/yr) between 2006 and 2016

Station ID	Station Name		TP	DP	Org-N	NH_3-N	NO_3-N	TKN	TSS	CHL-A
25	*Poplar Cr near Mouth-Elgin* :	Annual	4.2	-1.4	-	1.5	-	41.9	-	-
		Winter	6.6	-1.0	-	2.9	-	83.8	-	-
		Spring	1.4	-1.8	-	1.1	-	24.3	-	-
		Summer	1.4	-2.1	-	1.4	-	8.6	-	-
		Fall	8.2	-0.9	-	0.6	-	63.9	-	-
27	**Fox River at Montgomery**:	Annual	-200.6	-108.0	-533.5	-39.7	-1009.7	-381.4	-8492.2	-22.0
		Winter	-229.3	-99.2	-231.5	-81.6	-1097.9	-463.0	-7149.6	-18.3
		Spring	-202.8	-88.2	-1051.6	0.4	-1155.2	-463.0	8218.8	-70.5
		Summer	-165.3	-132.3	-619.5	-22.0	-751.8	-229.3	-9352.0	24.3
		Fall	-176.4	-110.2	-103.6	-55.8	-1128.8	-280.0	-21550.2	-16.5
28	*Blackberry Cr at Rt 47:*	Annual	6.6	4.9	-	24.3	-	-19.2	-	-
		Winter	13.4	11.9	-	26.5	-	-0.04	-	-
		Spring	9.3	4.6	-	46.3	-	-44.1	-	-
		Summer	0.8	1.4	-	16.5	-	-35.3	-	-
		Fall	3.3	1.9	-	5.1	-	1.4	-	-

Note: "red" declining trend; "green" improving trend; "-" no data

Table 13. Percent Changes in Flow-normalized Fluxes between 2006 and 2016

Station ID	Station Name		TP	DP	Org-N	NH_3-N	NO_3-N	TKN	TSS	CHL-A
25	*Poplar Cr near Mouth-Elgin* :	Annual	51.0	-35.0	-	21.0	-	52.0	-	-
		Winter	105.0	-29.0	-	22.0	-	110.0	-	-
		Spring	13.0	-41.0	-	12.0	-	22.0	-	-
		Summer	16.0	-36.0	-	46.0	-	11.0	-	-
		Fall	118.0	-30.0	-	19.0	-	99.0	-	-
27	**Fox River at Montgomery**:	Annual	-21.0	-25.0	-11.0	-14.0	-16.0	-7.8	-6.3	-8.8
		Winter	-30.0	-21.0	-8.2	-22.0	-13.0	-14.0	-13.0	-21.0
		Spring	-16.0	-20.0	-15.0	0.1	-11.0	-6.4	4.2	-20.0
		Summer	-16.0	-31.0	-11.0	-12.0	-28.0	-4.0	-4.7	6.7
		Fall	-25.0	-29.0	-3.5	-2.9	-32.0	-8.7	-26.0	-8.7
28	*Blackberry Cr at Rt 47:*	Annual	43.0	46.0	-	163.0	-	-15.0	-	-
		Winter	92.0	68.0	-	108.0	-	-0.04	-	-
		Spring	48.0	57.0	-	190.0	-	-20.0	-	-
		Summer	4.8	13.0	-	277.0	-	-26.0	-	-
		Fall	37.0	32.0	-	198.0	-	2.7	-	-

Note: “red” declining trend; “green” improving trend; “-” no data

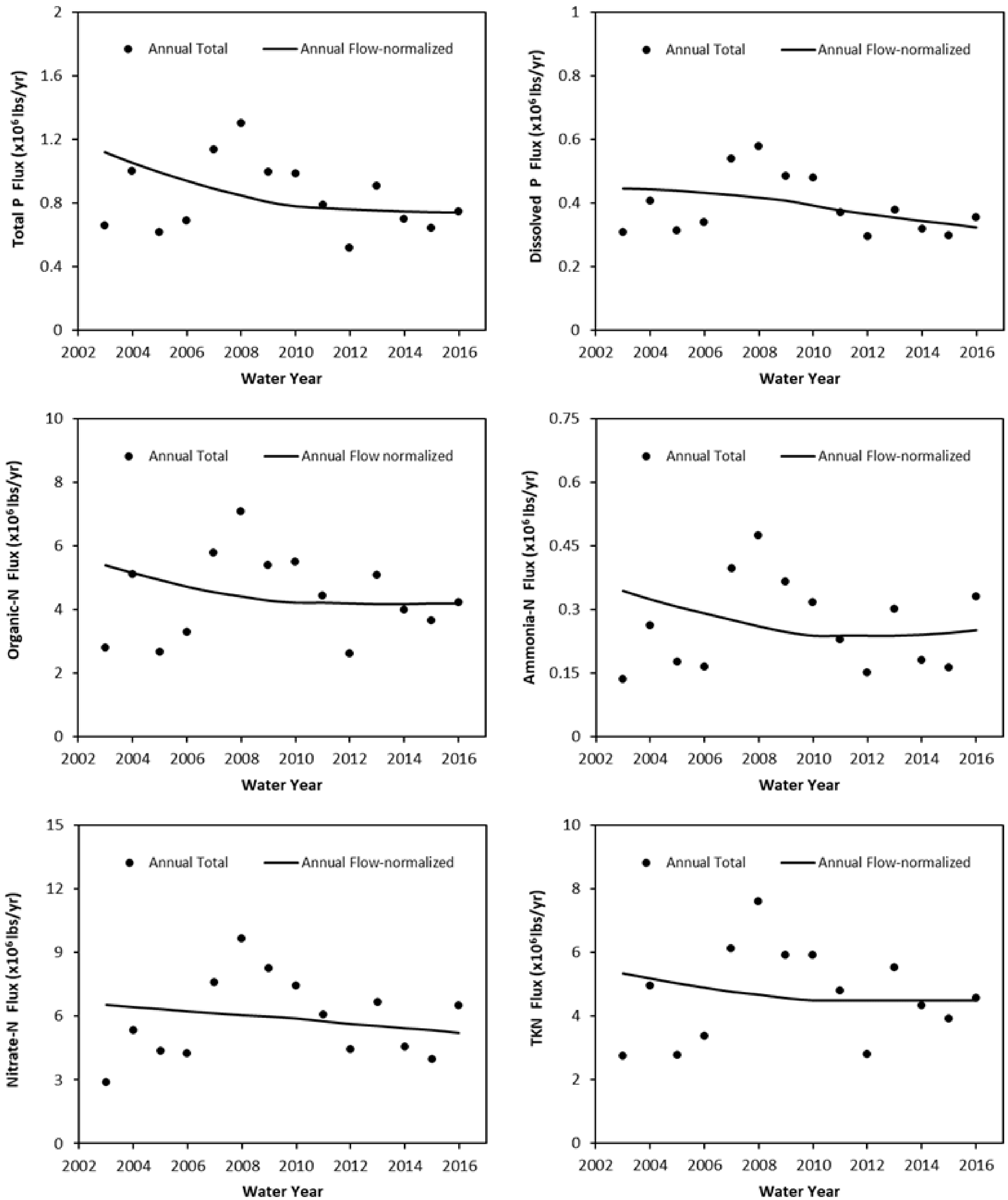

Figure 9. Actual and flow-normalized phosphorus and nitrogen fluxes for Fox River at Montgomery

3.5 Streamflow Durations and Trends

In addition to the water quality trends, selected streamflow statistics were evaluated for the periods of water quality data in an effort to characterize the annual and seasonal flow histories for the three monitoring stations. Figure 10 illustrates the annual and seasonal discharges in cubic feet per second (cfs) for Fox River at Montgomery, Poplar Creek near Mouth-Elgin, and Blackberry Creek at Rt. 47. The mean discharge for Fox River at Montgomery during the 2003-2016 period is 44.61 cfs with the minimum and maximum annual discharges occurring in 2003 and 2008, respectively. For Poplar Creek near Mouth-Elgin and Blackberry Creek at Rt. 47, the mean discharges for the period from 1997 to 2016 were 0.98 and 1.62 cfs, respectively. For both stations, the maximum annual discharges occurred in 2009, whereas the minimum annual discharges were obtained in 2006 for Poplar Creek near Mouth-Elgin and in 2003 for Blackberry Creek at Rt. 47. In all three stations, spring discharges were higher, whereas fall discharges were lower with few exceptions (e.g., 2008 fall discharges in the tributaries shown in green color).

Flow durations and trends (e.g., changes in mean, 7-day minimum, and 1-day maximum flows) were examined using continuous flow records available for periods of analysis. These streamflow statistics help provide insight into multi-year hydrologic variability and its potential influence on increasing or decreasing constituent concentrations and/or fluxes. However, to explicitly attribute the change in water quality trends to changes in hydrologic factors, the extent of other potential factors that affect water quality, such as conservation efforts, land use changes, and so forth, should also be examined.

Annual and seasonal flow durations were calculated as percentiles of flow exceedance for five periods of analysis, which include annual (October to September), fall (September to October), winter (December to February), spring (March to May), and summer (June to August). The 50th percentile flow represents the median flow value for the period of analysis (e.g., summer median flow), and it is the flow value that is exceeded 50% of the time over the period of analysis. Similarly, the 25th and 75th percentile flows are flow values that are less than or equal to the 25% and 75% of flows for each of the five periods of analysis, respectively. The range between the 25th and 75th percentiles, which is also called as interquartile range (IQR), represents 50% of the flow duration and provides insight into the distribution of the flow records, characterizing variations in flow values during the period of analysis. The smaller or larger the IQR is, the smaller or larger the variation in streamflow will be. To compare the IQRs for different periods of analysis, a coefficient of variation (COV) is calculated as a measure of the dispersion in flow values of interest.

Table 14 provides the annual and seasonal streamflow duration and the IQR and COV results for one station in the Fox main stem and two in the tributaries. The annual median flows for Poplar Creek near Mouth-Elgin, Fox River at Montgomery, and Blackberry Creek at Rt. 47 are 15.1, 1150, and 32.7 cfs, respectively. For all three stations, the largest median flow occurred in the spring season, whereas the smallest values were calculated for summer, except for Blackberry Creek at Rt. 47. The IQR is the highest in spring for all stations, indicating the flow variability in that season. However, in comparison to annual and other seasonal values, the spring season shows the smallest flow variations, as indicated in the lowest COV values. The largest flow variation occurred in the summer season for all stations, as evidenced by the largest COV values for each station.

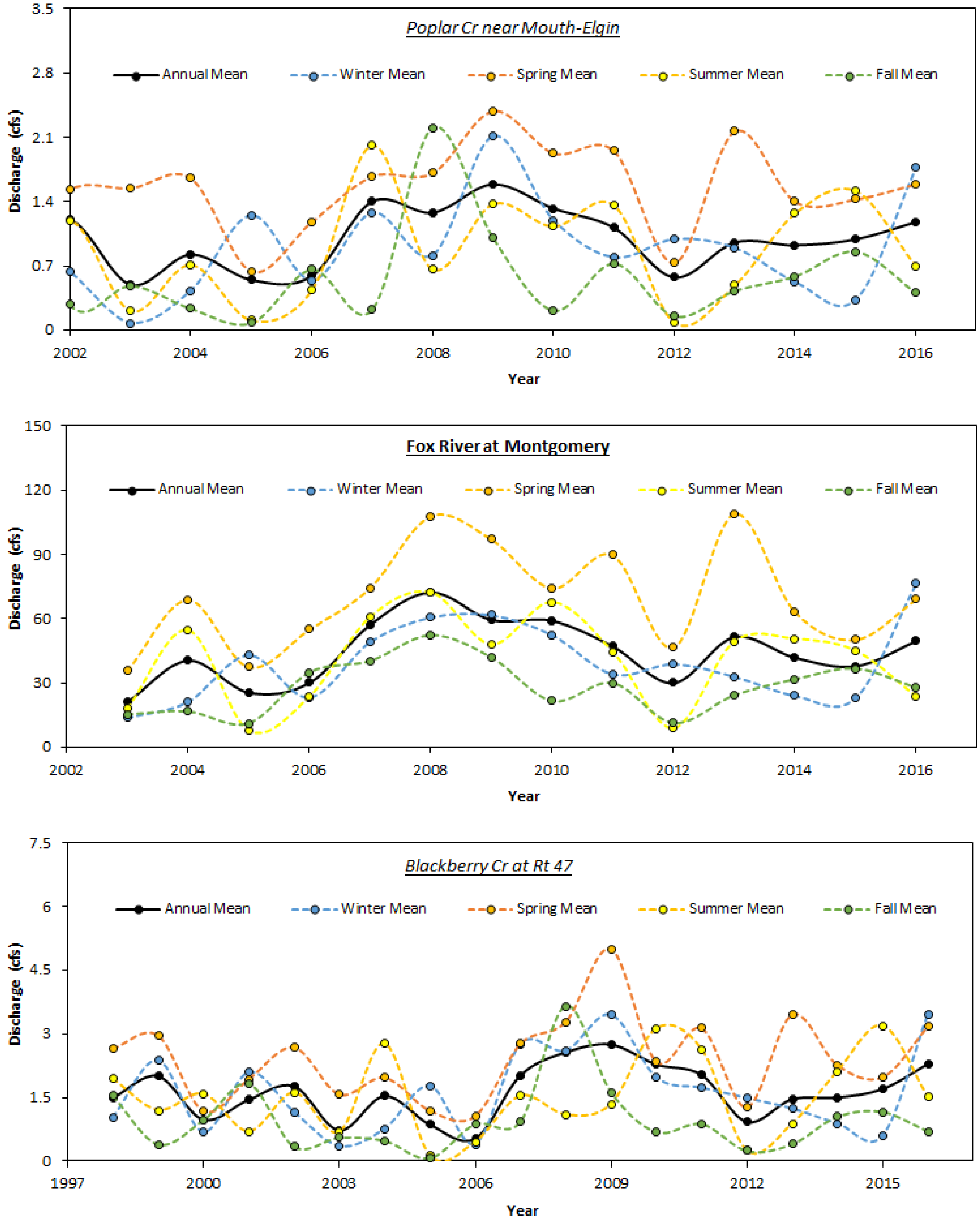

Figure 10. Annual, winter, spring, summer, and fall mean discharges for the three monitoring stations

Annual and seasonal trends of selected streamflow statistics, including mean, 7-day minimum, and 1-day maximum flows, are calculated to evaluate their changes through the years as they relate to water quality. It must be noted that the annual 1-day maximum flow is not identical to the annual peak discharge, which represents the instantaneous maximum discharge value for the year. The difference between the 1-day maximum and annual peak discharges is larger for smaller streams since the discharge could change from a very low to an annual maximum value in a given day. The mean provides the central tendency of the multi-year hydrologic variability. The minimum and maximum flow trends may help explain part of the increase or decrease in constituent concentration and fluxes.

Table 14. Annual and Seasonal Flow Durations (cubic-feet per second, cfs)

Station ID	Station Name	min	5%	10%	25%	50%	75%	90%	95%	max	IQR	COV
25	*Poplar Cr near Mouth-Elgin:*	Period of analysis (1997-2016)										
	Annual	0.51	1.63	2.6	5.99	15.1	33.1	78.1	134	1400	27.11	1.8
	Winter	0.58	2.4	3.46	7.2	14.7	31.6	74	127	928	24.4	1.7
	Spring	0.7	7.4	11.7	19	29.9	55.1	123	176	1050	36.1	1.2
	Summer	0.56	1.29	1.79	3.88	9.31	24.4	60.5	111	1020	20.52	2.2
	Fall	0.51	1.3	1.85	3.64	8.07	18.5	39.6	78.6	1400	14.86	1.8
27	**Fox River at Montgomery:**	Period of analysis (2002-2016)										
	Annual	95.8	258	430	666	1150	2040	3280	4120	15500	1374	1.2
	Winter	243	440	500	707	1100	1770	2760	3310	8940	1063	1.0
	Spring	248	704	908	1430	2190	3210	4260	5260	14600	1780	0.8
	Summer	95.8	209	287	544	917	1850	3310	4550	13200	1306	1.4
	Fall	99.6	209	245	538	800	1230	1760	2170	15500	692	0.9
28	*Blackberry Cr at Rt 47:*	Period of analysis (1997-2016)										
	Annual	0.32	5.8	9.3	16.8	32.7	64.1	118	178	1970	47.3	1.4
	Winter	3.23	10.2	12	17.4	31.5	60.2	127	202	1600	42.8	1.4
	Spring	8.18	17.3	23.8	39	60.7	96.9	157	225	1530	57.9	1.0
	Summer	0.73	4.4	7.01	14.1	28	57	109	161	1030	42.9	1.5
	Fall	0.32	3.23	5.43	10.8	19.5	33.8	58.8	88.2	1970	23	1.2

For all five periods of analysis, changes in mean, 7-day minimum, and 1-day maximum flows between 2006 and 2016 in percent and cubic-feet per day are presented in Tables 15 and 16, respectively. The results presented in the figures and tables indicate that the mean and 7-day minimum flows exhibit an increasing trend with varying magnitudes across all seasons except for the spring 7-day minimum flow, which showed a 1.5% decrease between 2006 and 2016. Generally, the annual and seasonal 7-day minimum flows seem to show larger changes during the period of analysis, ranging from 32% for Blackberry Creek at Rt. 47 in winter to at least 108% for the Fox River at Montgomery and Poplar Creek near Mouth-Elgin in a climate year. The annual and seasonal 1-day maximum flows show increasing trends for Blackberry Creek at Rt. 47. In contrast, for Poplar Creek near Mouth-Elgin, the 1-day maximum flow exhibits a decreasing trend in winter, spring, and fall seasons, whereas its annual and summer values have increased.

Table 15. Changes in Selected Streamflow Statistics (cfs) between 2006 and 2016

Station ID	Station Name		7-day minimum	Mean	1-day Maximum
25	*Poplar Cr near Mouth-Elgin* :	Annual	0.0015	0.005	0.035
		Winter	0.0032	0.0059	-0.012
		Spring	0.0015	0.0054	-0.0097
		Summer	0.0018	0.0078	0.071
		Fall	0.002	0.00094	-0.0076
27	**Fox River at Montgomery**:	Annual	0.25	0.47	1.1
		Winter	0.4	0.5	0.43
		Spring	0.56	0.59	0.54
		Summer	0.22	0.34	1.6
		Fall	0.27	0.29	-0.045
28	*Blackberry Cr at Rt 47:*	Annual	0.0032	0.012	0.22
		Winter	0.0049	0.011	0.022
		Spring	-0.00039	0.014	0.096
		Summer	0.0049	0.013	0.034
		Fall	0.0056	0.0045	0.011

Note: “blue” increasing flow trend; “orange” decreasing flow trend

Table 16. Percent Changes in Selected Streamflow Statistics between 2006 and 2016

Station ID	Station Name		7-day minimum	Mean	1-day Maximum
25	*Poplar Cr near Mouth-Elgin* :	Annual	109	16	6.5
		Winter	87	23	-6.2
		Spring	18	11	-3
		Summer	84	37	39
		Fall	86	5.9	-5.8
27	**Fox River at Montgomery**:	Annual	108	35	16
		Winter	79	45	15
		Spring	80	28	11
		Summer	65	32	49
		Fall	98	37	-1.7
28	*Blackberry Cr at Rt 47:*	Annual	53	24	39
		Winter	32	25	9.5
		Spring	-1.5	18	25
		Summer	52	34	16
		Fall	75	19	10

Note: “blue” increasing flow trend; “orange” decreasing flow trend

In Figures 11, 12, and 13, the streamflow statistics including 7-day minimum, mean, and 1-day maximum flow are plotted for Poplar Creek near Mouth-Elgin, Fox River at Montgomery, and Blackberry Creek at Rt. 47, respectively. The streamflow statistics are calculated as water depths over the drainage area of the monitoring stations and are expressed in units of millimeters per day (mm/d) for plotting purposes. This value can be converted to inches per day by dividing the values by 25.4 (1 inch = 25.4 mm). The circles and lines in the figures represent the streamflow statistics and their smoothed version (i.e., the locally weighted streamflow statistics). The smoothed version provides insight into streamflow trends by focusing on multi-year variability and changes in its central tendencies of these three streamflow statistics. It must be noted that the annual 7-day minimum is computed for a climate year (April to March), whereas the mean and 1-day maximum flow statistics are calculated for a water year (October to September). Using a climate year for low flow statistics avoids counting individual drought events twice in consecutive water years since a water year is bounded by typically low-flow months. The drainage areas of the monitoring stations in square miles are 1,732 for Fox River at Montgomery, 35.2 for Poplar Creek near Mouth-Elgin, and 70.2 for Blackberry Creek at Rt. 47.

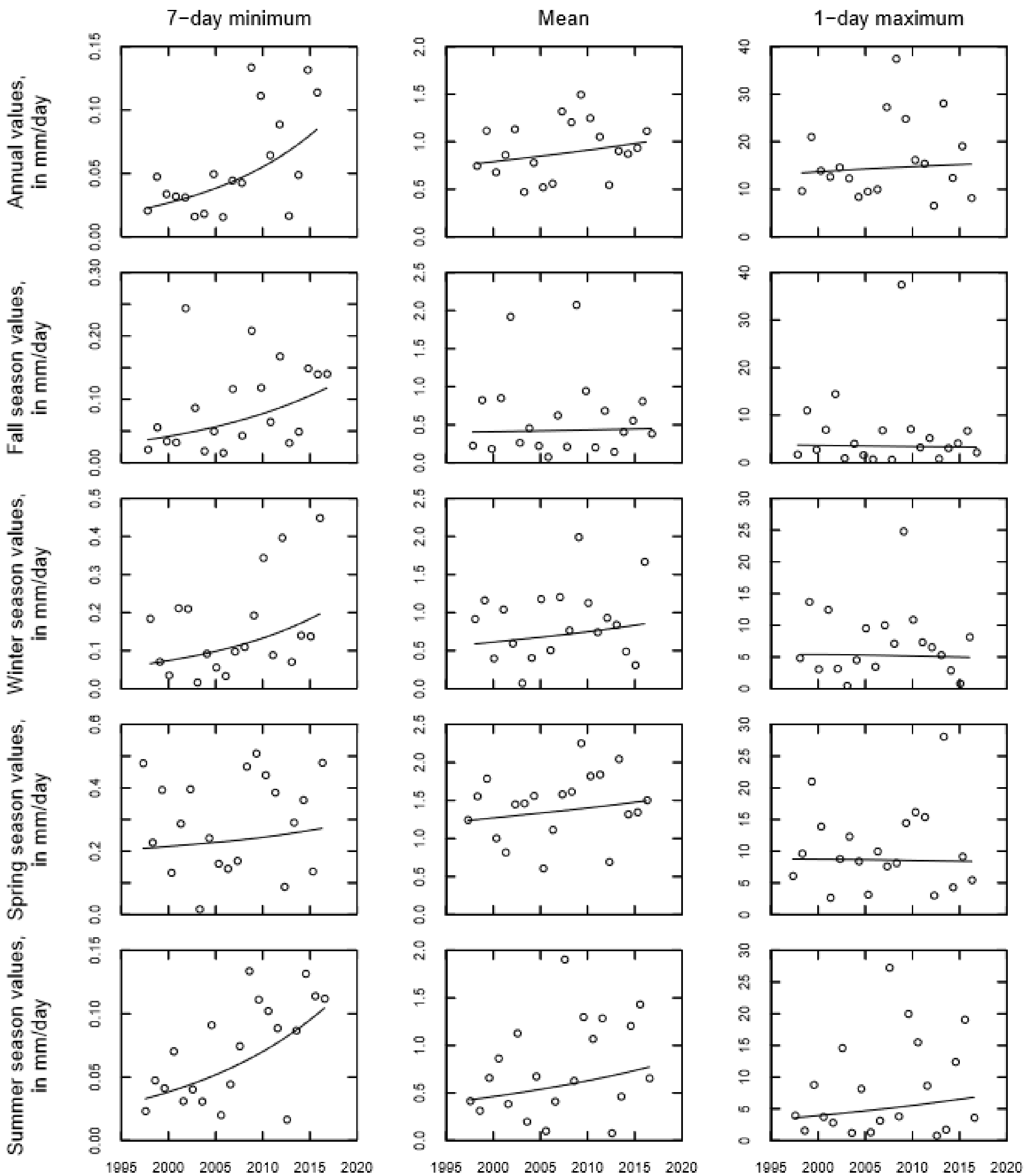

Figure 11. Annual and seasonal flow statistics for Poplar Creek near Mouth-Elgin

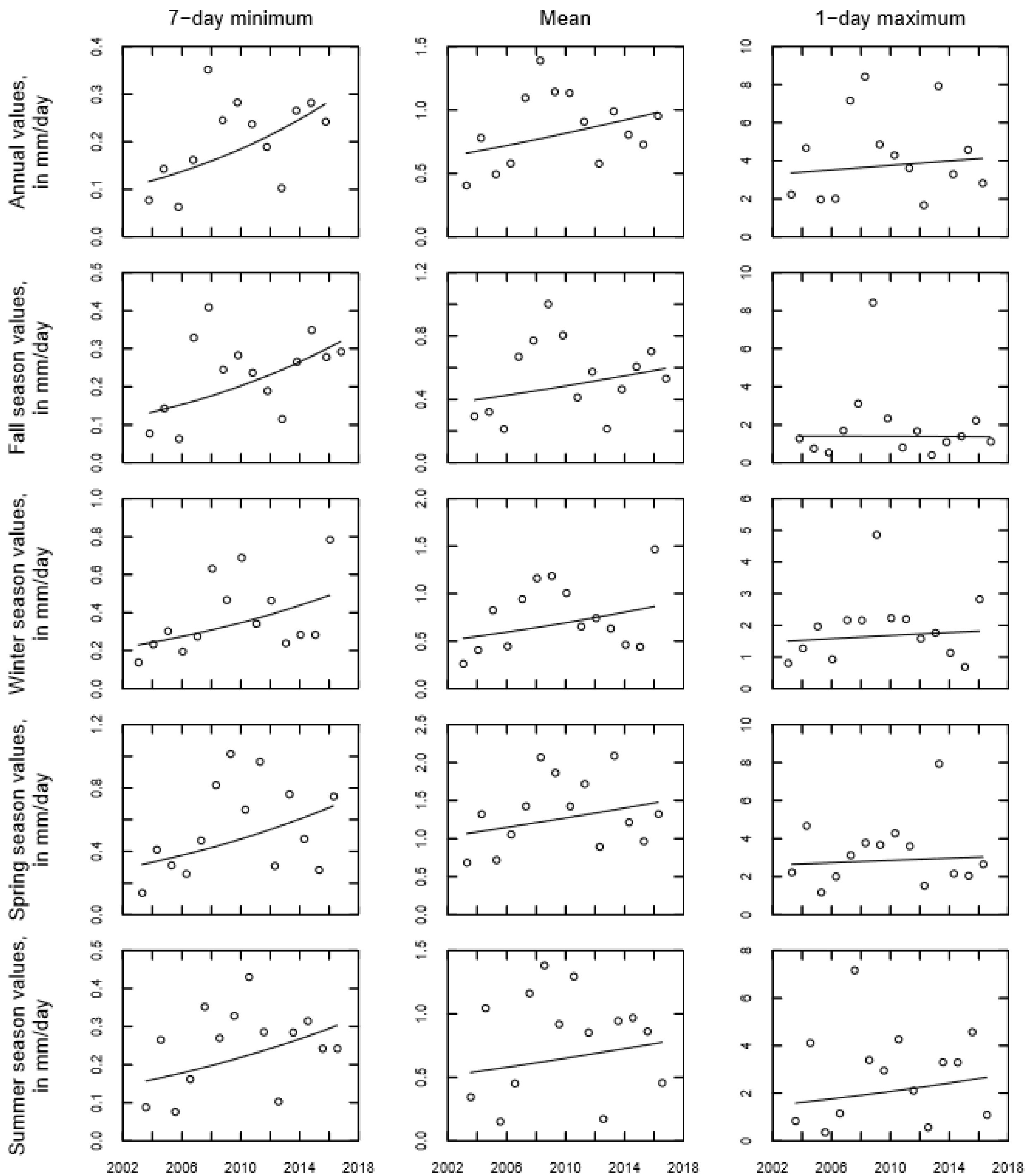

Figure 12. Annual and seasonal flow statistics for Fox River at Montgomery

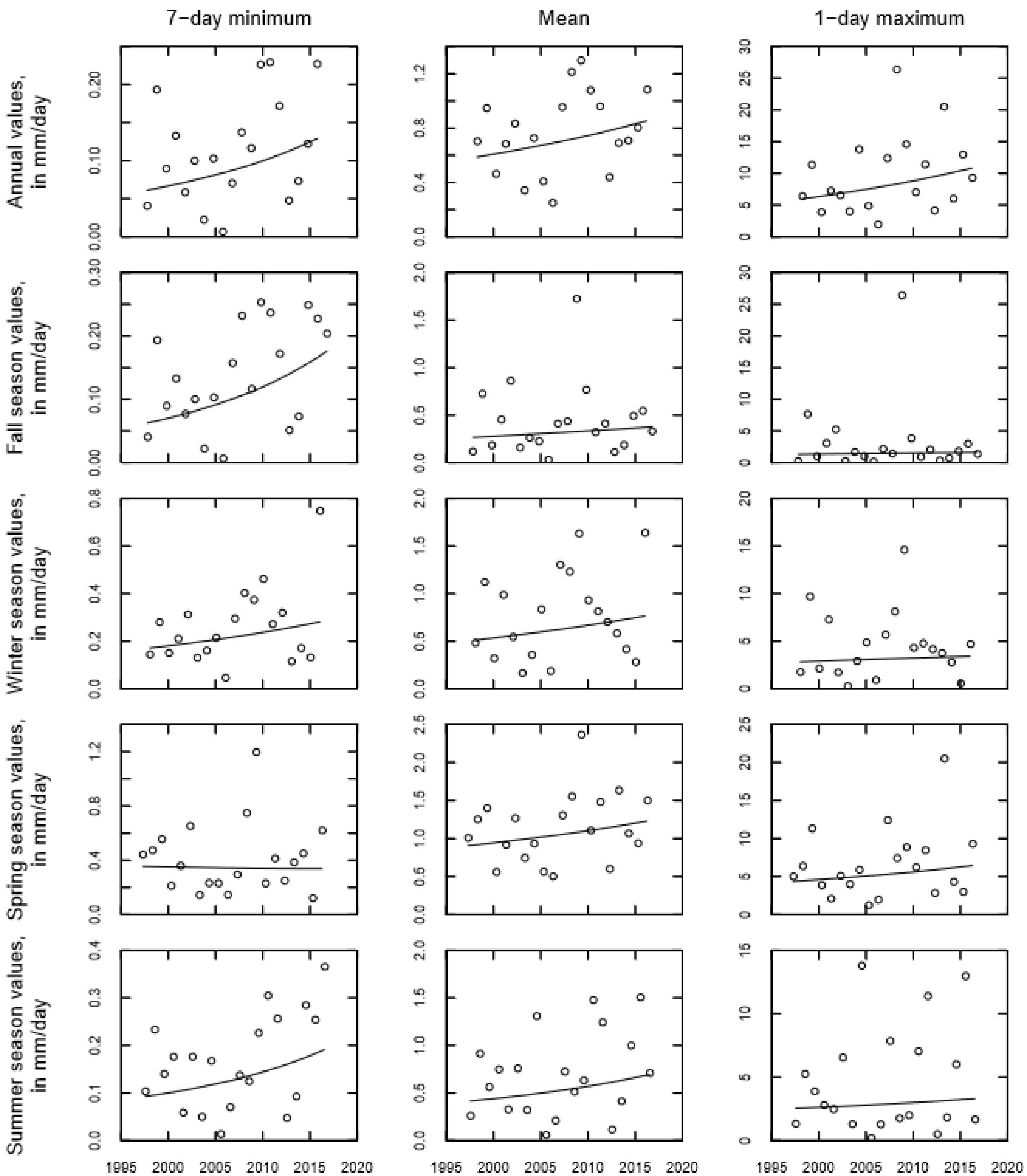

Figure 13. Annual and seasonal flow statistics for Blackberry Creek at Rt. 47

4. Summary

In this study, a trend analysis was conducted for nutrient-related water quality parameters obtained from 18 monitoring stations located in the Fox River main stem and tributaries. Exploratory data analysis (EDA) was performed for a total of 141 water quality parameters across the 18 monitoring stations to better understand the underlying characteristics of the water quality data. Based on the EDA analysis, the core method of analysis selected was the Seasonal Kendall Test (SKT) for trends. The EnvStats software R-package, which includes the SKT method as one of its algorithms, was used to perform the trend analysis based on data of water quality concentrations at each of the monitoring stations. A trend analysis for pH was also conducted. The trend analysis involved preparing computer codes using the R program with the EnvStats library of codes. Using the codes, selected water quality data were directly extracted from the FoxDB, which is the database containing all water quality and related data obtained from various agencies. In addition to the trend analysis for concentrations and pH using the SKT method, a trend analysis of water quality concentrations and fluxes (loads) using a parametric model was conducted for three stations (one Fox River main stem and two tributary stations), which have not only the long-term concentration data, but also the corresponding continuous daily discharge data. The analysis was performed using the Weighted Regression on Time, Discharge, and Season (WRTDS) method, and a total of 19 WRTDS models were developed using concentration and flow data across the three stations.

For all monitoring stations, the SKT trend analysis generally showed that most of the nutrient-related water quality parameters exhibit either a decreasing or no trend across all seasons. No upward annual trend was exhibited for organic nitrogen (Org-N), ammonia nitrogen, total suspended solids (TSS), or chlorophyll-A (CHL-A) at any of the monitoring stations. At the most downstream station on the main stem (Fox River at Yorkville), no increasing trend was detected, with most of the water quality parameters showing a decreasing trend across all seasons. Most of the upward trend was detected for dissolved phosphorus (DP), particularly in spring and summer months. In contrast, total phosphorus (TP) showed an increasing annual trend only for the Poplar Creek near Mouth-Elgin station. For more than half of the stations, the pH showed an upward or no trend. All water quality parameters exhibited a decreasing longitudinal trend downstream of the Fox River at Algonquin.

The results of the trend analysis conducted using the WRTDS method generally indicate that flow-normalized concentration and fluxes (loads) of most water quality parameters decreased across all seasons from 2006 to 2016 for the Fox River at Montgomery. A few exceptions were the concentration and fluxes of TSS in spring and CHL-A in summer, which showed increasing trends. Although there is a difference in the percentage changes, the flux and concentration trends are largely similar for this station (i.e., they are in the same downward or upward direction). The only difference observed was between the spring NH3-N concentration and its corresponding flux, which showed opposing trends, indicating that concentration trends are not necessarily informative of flux trends. Large decreases in summer DP, NH3-N, and NO3-N; winter TP, TSS, and CHL-A; and spring for DO, Org-N, and TKN concentrations were obtained for the Fox River at Montgomery station. A decreasing trend in concentration across all seasons, unlike for DO, is indicative of an improving water quality trend. In comparison with other water quality parameters, flow-normalized fluxes of TP and DP also showed larger decreases across all seasons between 2006 and 2016. A similar downward trend of nitrate nitrogen (NO3-N) fluxes were obtained in the summer and fall.

For the two tributaries (Blackberry Creek at Rt. 47 and Poplar Creek near Mouth-Elgin) most of the water quality concentrations and fluxes showed larger upward trends with a few exceptions. NH3-N concentrations exhibited the largest annual and seasonal increasing trends at both stations. Concentrations of TP, DP, and DO showed decreasing annual and seasonal trends for Blackberry Creek at Rt. 47, except in fall for DO and in summer for TP and DO concentrations. For Poplar Creek near Mouth-Elgin, the DP and DO concentrations showed improving water quality trends across all seasons. The flow-normalized DP and TKN fluxes exhibited decreasing annual and seasonal trends for Poplar Creek near Mouth-Elgin and Blackberry Creek at Rt. 47, respectively. The seasonal concentration trends largely conform to the annual trends for all three monitoring stations.

In addition to water quality trends, flow durations and trends of selected streamflow statistics, including mean, 7-day minimum, and 1-day maximum flows, were calculated to evaluate their changes through the years as they relate to water quality. The flow durations allow characterizing the ranges of flows in the river that are common or extreme during an entire year or season. The results indicate that the highest and lowest flow variability occurred in summer and spring, respectively. The mean flow provides information about the central tendency of the multi-year hydrologic variability, whereas the minimum and maximum flow trends may explain part of the increase or decrease in constituent concentration and fluxes. However, to explicitly attribute the change in water quality trends to some changes in hydrologic factors, the extent of other potential factors influencing water quality, such as conservation efforts, land use changes, etc., also need to be examined. For all three stations, low flow appears to be increasing. Between 2006 and 2016, the mean and 7-day minimum flows exhibited an increasing trend with varying magnitudes across all seasons except for the spring 7-day minimum flow. Generally, the annual and seasonal 7-day minimum flows seemed to show large increases during the period of analysis. The annual and seasonal 1-day maximum flows showed increasing trends for Blackberry Creek at Rt. 47. In contrast, for Poplar Creek near Mouth-Elgin, the 1-day maximum flow exhibited a decreasing trend in winter, spring, and fall seasons, whereas its annual and summer values had increased.

5. Recommendations for Future Work

The majority of the water quality monitoring stations do not have corresponding flow data and, as a result, WRTDS models based on concentration and discharge relationships were developed only for water quality parameters in the three stations. However, flow estimates for most of these stations can be generated using the current Fox River watershed modeling efforts using (Hydrologic Simulation Program – Fortran (HSPF). A similar watershed model was previously developed by ISWS for the entire Fox River watershed including the Wisconsin portion. The hydrologic model was developed using Soil and Water Assessment Tool (SWAT), which is a physically-based, basin-scale model, to assess the impacts of potential climate change on water supply availability in the Fox River watershed (Bekele (Getahun) and Knapp, 2010; Bekele (Getahun) and Knapp, 2009). With additional modeling efforts, the SWAT-based Fox River watershed model can also be used to generate flow estimates for the water quality monitoring stations. A comparison between flow estimates of HSPF and SWAT could help in understanding the uncertainties in the estimates, thereby selecting the best flow estimates for use in WRTDS model development. The development of WRTDS models for those stations with longer water quality data allows estimating flow-normalized concentration and flux trends, complementing the current trend analysis. The additional modeling efforts for the SWAT-based Fox River watershed model can be further leveraged to include water quality components that would allow an evaluation of best management practices (e.g., scenarios proposed in the Illinois Nutrient Loss Reduction Strategy) in reducing nonpoint source pollution. Finally, by updating the FoxDB at least every three years, a meaningful trend analysis can be conducted that will provide insight into the water quality status of the Fox River and its tributaries.

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Appendices

This report includes four appendices that are compiled as a separate document. The appendices are:

Appendix A – Selected Outputs of Exploratory Data Analysis

Appendix B – Summary Statistics of the Water Quality Parameters

Appendix C – Water Quality Trend Maps

Appendix D – Annual and Seasonal Trends of Flow-normalized Concentration and Fluxes

Appendix A - Selected Outputs of the Exploratory Data Analysis

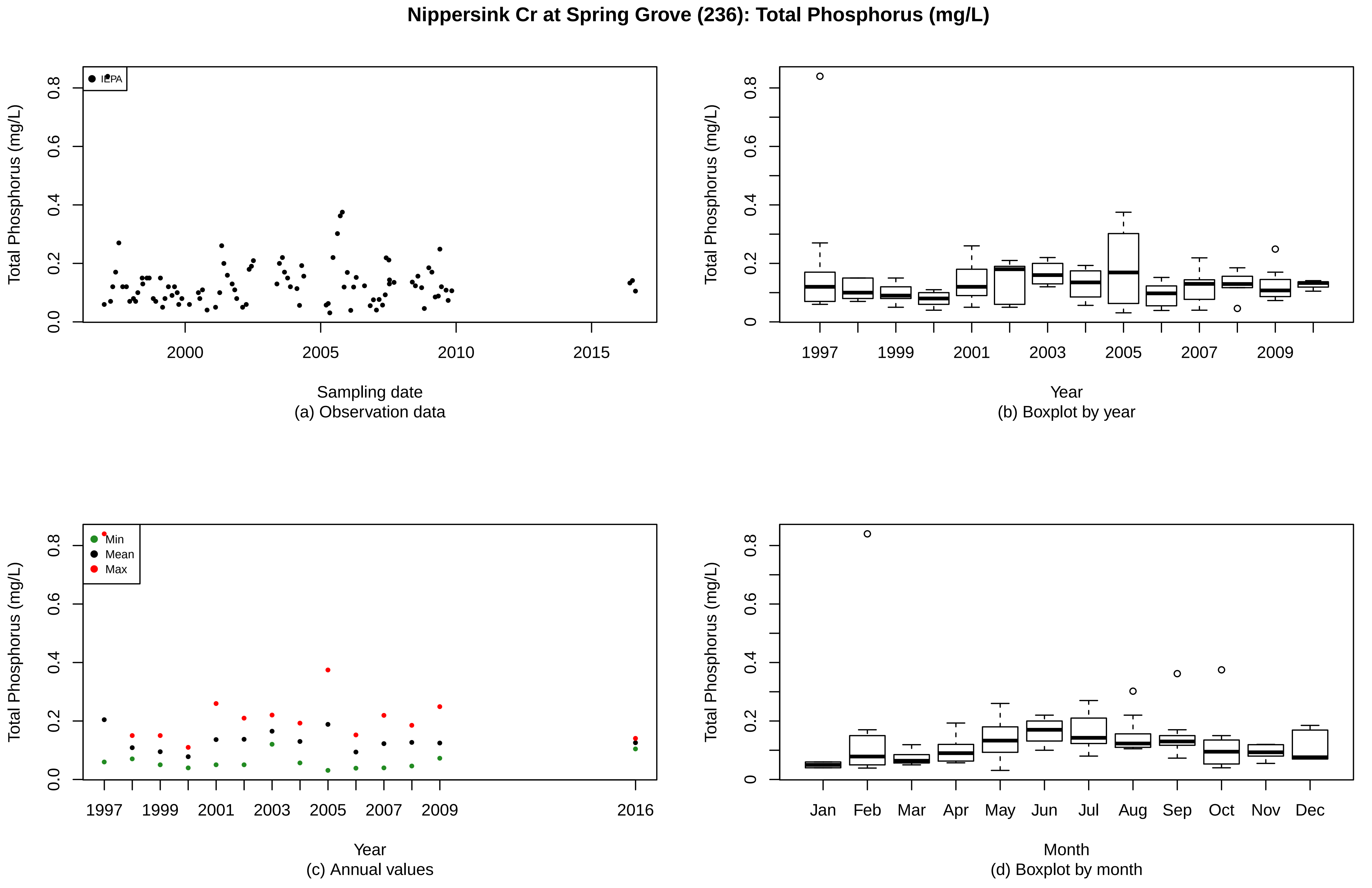
Table A.1 Water Quality Parameters Analyzed by Monitoring Stations

Station ID	Station name	Water quality parameters by Station									
236	*Nippersink Cr at Spring Grove*	TP	DP	-	NH_3-N	-	TKN	DO	pH	TSS	-
1	*Nippersink Cr above Wonder Lake*	TP	DP	-	-	-	-	-	-	-	-
184	**Fox River at Johnsburg**	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	-	CHL-A
23	**Fox River at Rt 176**	TP	DP	-	NH_3-N	NO_3-N	TKN	DO	pH	TSS	-
258	**Fox River at Oakwood Hills**	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	-	CHL-A
4	*Flint Cr at Kelsey Rd-Lk Barrington*	TP	DP	-	NH_3-N	-	TKN	-	-	-	-
271	*Crystal Cr at Rt 31*	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	-	CHL-A
24	**Fox River at Algonquin**	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	TSS	CHL-A
268	*Tyler Cr at Rt. 31-Elgin*	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	-	CHL-A
25	*Poplar Cr near Mouth-Elgin*	TP	DP	-	NH_3-N	-	TKN	DO	pH	TSS	-
26	**Fox River at South Elgin**	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	TSS	CHL-A
14	*Ferson Cr at Rt 34*	TP	DP	-	NH_3-N	-	TKN	-	-	-	-
79	*Ferson Cr near Mouth-Elgin*	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	-	CHL-A
40	**Fox River at Geneva**	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	-	CHL-A
27	**Fox River at Montgomery**	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	TSS	CHL-A
34	**Fox River at Yorkville**	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	-	CHL-A
28	*Blackberry Cr at Rt 47*	TP	DP	-	NH_3-N	-	TKN	DO	pH	TSS	-
287	*Blackberry Cr near Mouth*	TP	DP	Org-N	NH_3-N	NO_3-N	TKN	DO	pH	-	CHL-A

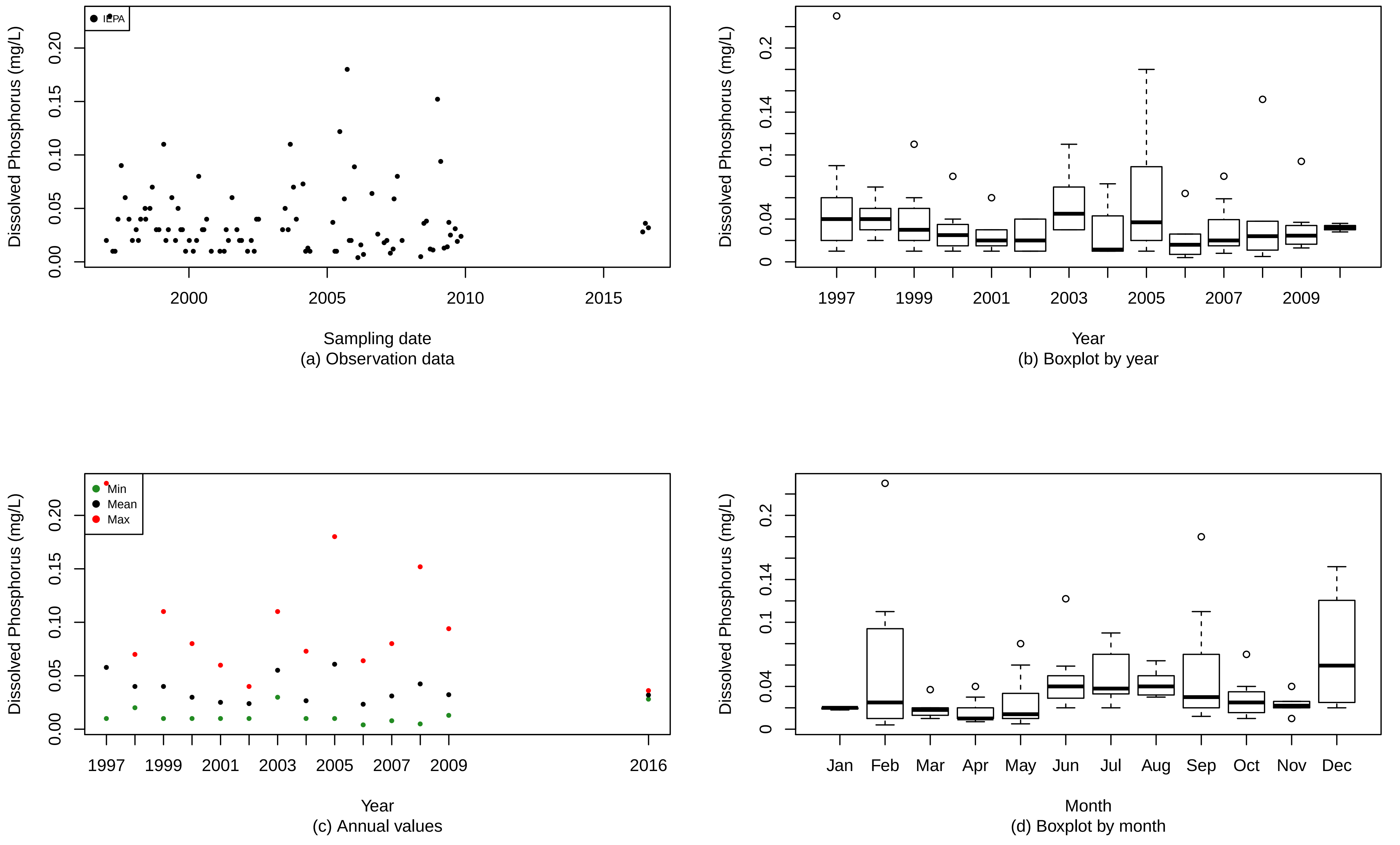
Note: Stations are in upstream-to-downstream order, and are in bold for Fox River main stem and in italics for tributaries.

Table A.2 Fox River Water Quality Standards

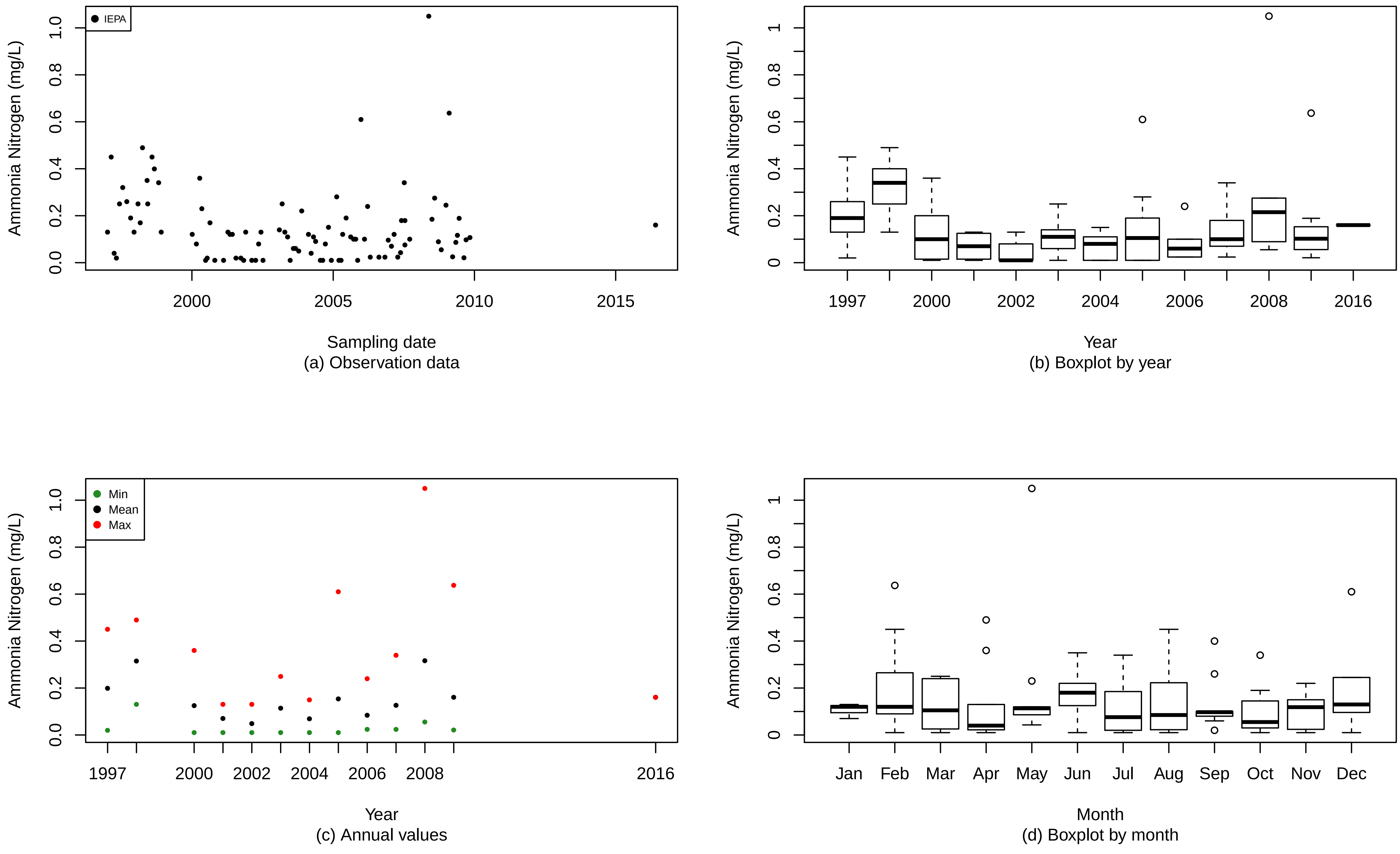
Water Quality Parameter	Existing Water Quality Standards for Fox River and its tributaries in Illinois	Other Water Quality Standards & Criteria
Total P (TP)	None	• Illinois lakes > 20 acres, including the Chain O'Lakes and other lakes within the Fox River watershed shall not exceed 0.05 mg/L (see Part 302.205) • The Wisconsin portion of the Fox River has a phosphorus standard of 0.1 mg/L. (available at https://dnr.wi.gov/topic/SurfaceWater/phosphorus.html) • Ecoregional criterium for Region VI Corn Belt and N Great Plains: 0.07625 mg/L. (https://www.epa.gov/nutrient-policy-data/ecoregional-criteria)
Dissolved P (DP)	None	
Organic-N (Org-N)	None	
Ammonia N (NH_3-N)	• Total NH3-N must in no case exceed 15 mg/L. • Acute standard is dependent on pH. Mean pH values in the Fox River range from 7.85 to 8.48. The acute standard at pH 8.2 is 5.73 mg/L. • Chronic standard differs for periods when Early Life Stage is present (March-October) and absent. It is dependent on temperature and pH. For pH 8.2, the Early Life Stage present value at 24C is 0.97 mg/L. For pH 8.2, the Early Life Stage absent value at 10C is 2.40 mg/L. The 30-day average concentration must not exceed the chronic standard except in those waters in which mixing is allowed.	• The most recent 2013 USEPA criterion document recognizes the sensitivity of freshwater mussels to ammonia levels. These new standards have not yet been adopted in Illinois. For pH 8.2 and 24C, the acute criterion is 1.9 mg/L (1-hour average). For pH 8.2 and 24C, the chronic criterion is 0.44 mg/L (30-day rolling average). Not to be exceeded more than 1 in 3 years on average. (https://www.epa.gov/wqc/aquatic-life-criteria-ammonia)
Nitrate N (NO_3-N)	• Public and food processing water supply standard. Waters of the State are generally designated for public and food processing use: 10 mg/L	
TKN	None	
Total N (= TKN+NO_3-N)	None	• USEPA recommends 2-6 mg/L of Total N. (https://www.epa.gov/sites/production/files/2015-09/documents/totalnitrogen.pdf) • Ecoregional criterium for Region VI Corn Belt and N Great Plains: 2.18 mg/L. (See https://www.epa.gov/nutrient-policy-data/ecoregional-criteria)
Dissolved Oxygen (DO)	• All waters except enhanced DO stretch below: Mar-July: not less than 5.0 mg/L at any time, 6.0 as daily mean avg'd over 7 days. Aug-Feb: not less than 3.5 mg/L at any time, 4.0 as daily minimum avg'd over 7 days, 5.5 as daily mean avg'd over 30 days. • Enhanced DO stretch (LAT/LONG): 41° 37' 3.7194"/-88° 33' 21.0162" to 41° 45' 59.5296"/-88° 18' 36.0858" Mar-July: not less than 5.0 mg/L at any time, 6.25 as daily mean avg'd over 7 days. Aug-Feb: not less than 4.0 mg/L at any time, 4.5 as daily minimum avg'd over 7 days, 6.0 as daily mean avg'd over 30 days.	
pH	6.5 to 9.0	
TSS	None	
Cholorophyll-A (CHL-A)	None	• Ecoregional criterium for Region VI Corn Belt and N Great Plains: 2.70 µg/L. (https://www.epa.gov/nutrient-policy-data/ecoregional-criteria)


Nippersink Cr at Spring Grove (236): Total Phosphorus (mg/L)
IEPA
Total Phosphorus (mg/L)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Month
(d) Boxplot by month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

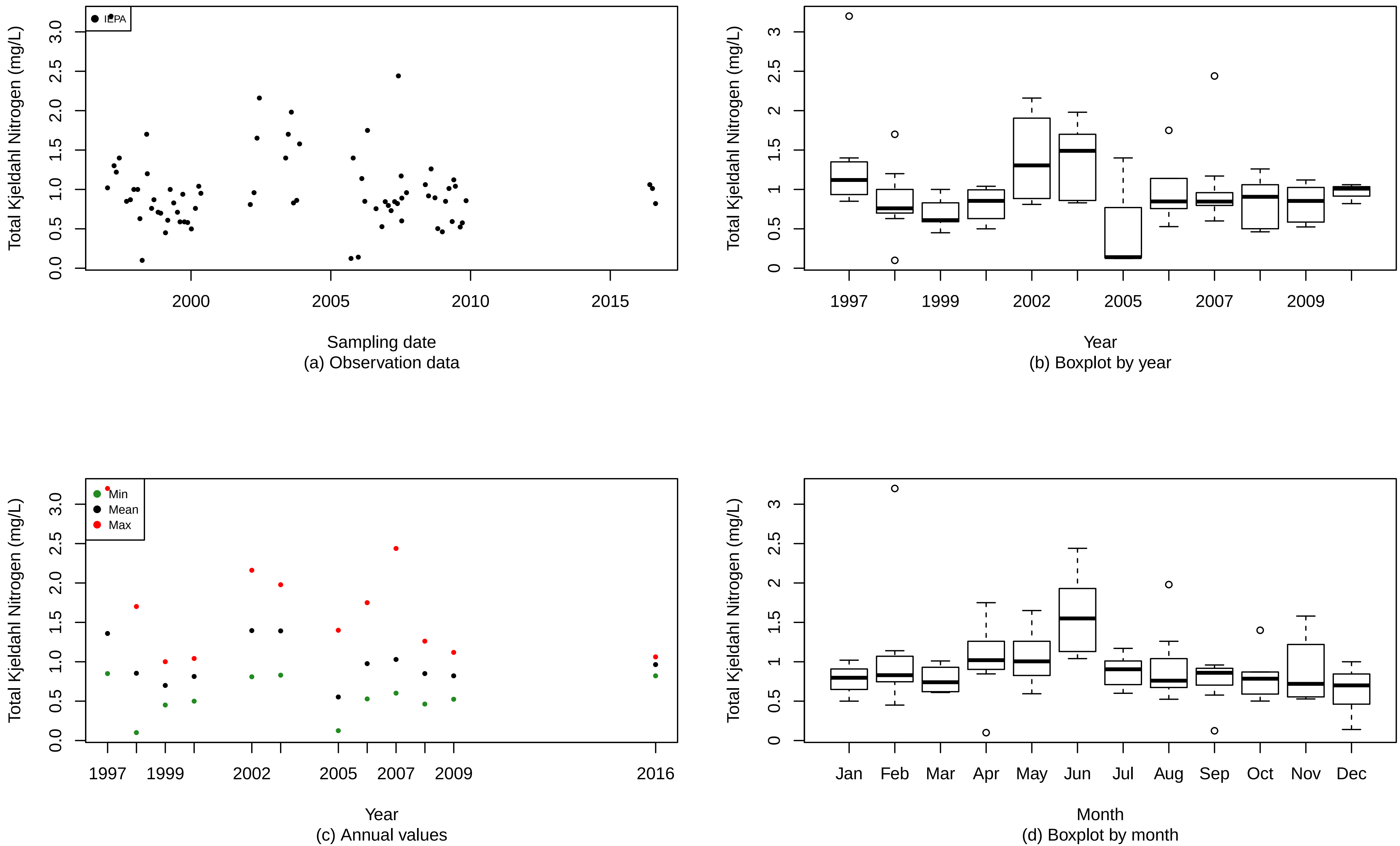
Nippersink Cr at Spring Grove (236): Dissolved Phosphorus (mg/L)



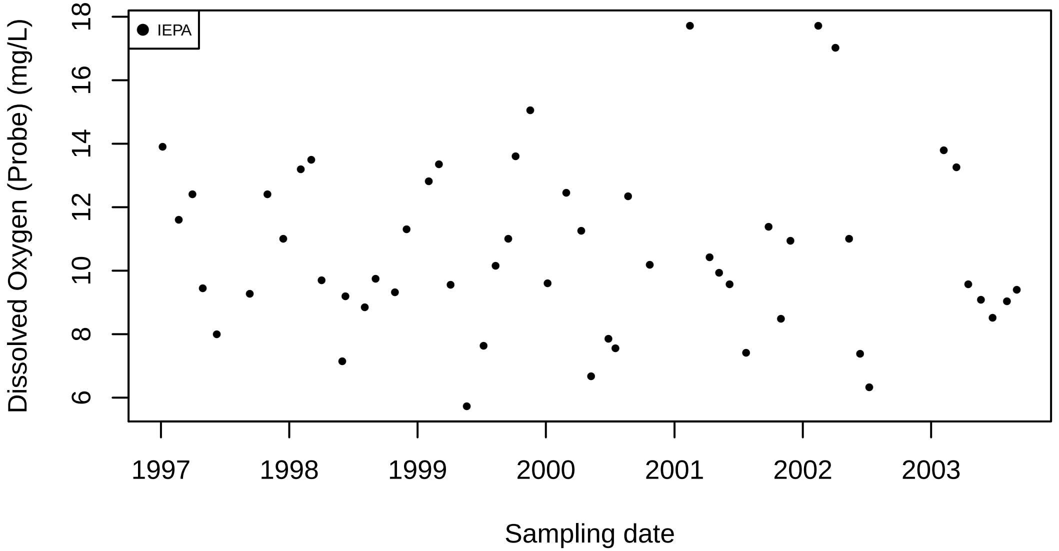
Nippersink Cr at Spring Grove (236): Ammonia Nitrogen (mg/L)



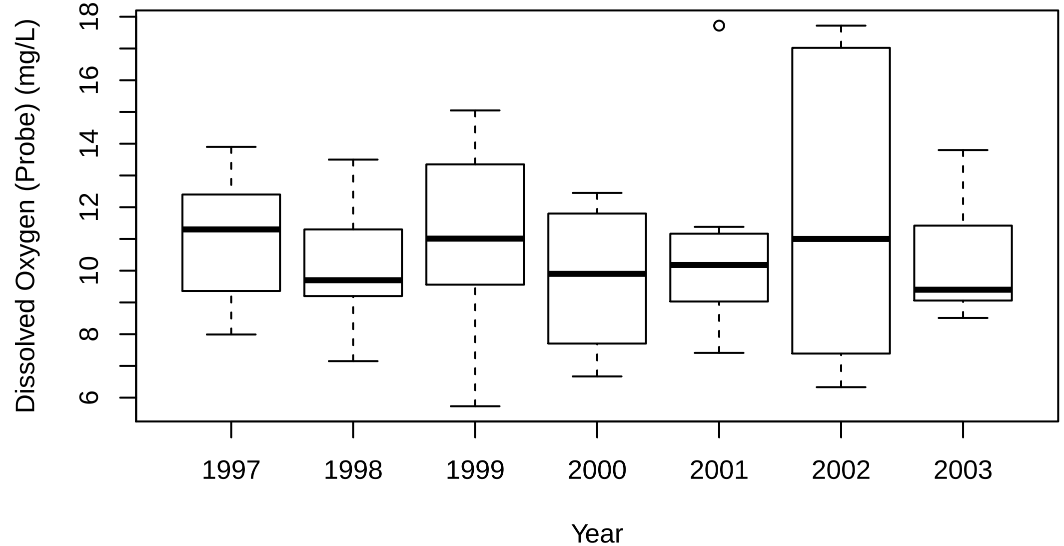
Nippersink Cr at Spring Grove (236): Total Kjeldahl Nitrogen (mg/L)



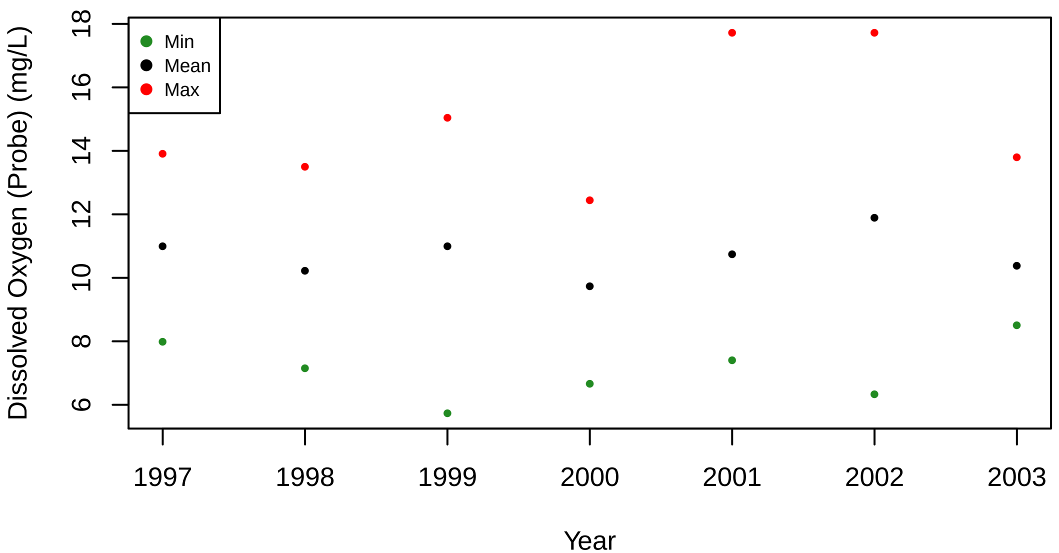
Nippersink Cr at Spring Grove (236): Dissolved Oxygen (Probe) (mg/L)



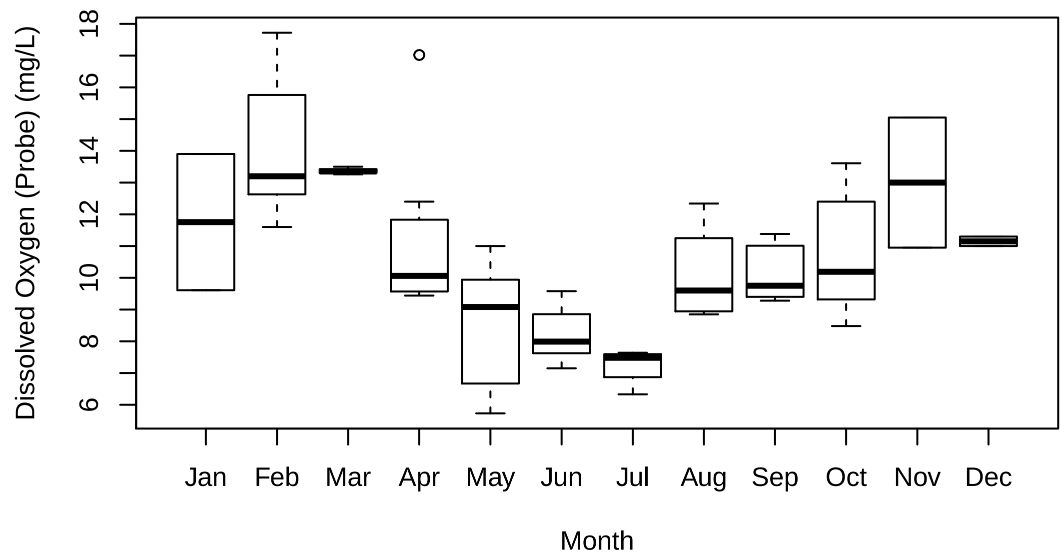
(a) Observation data



(b) Boxplot by year

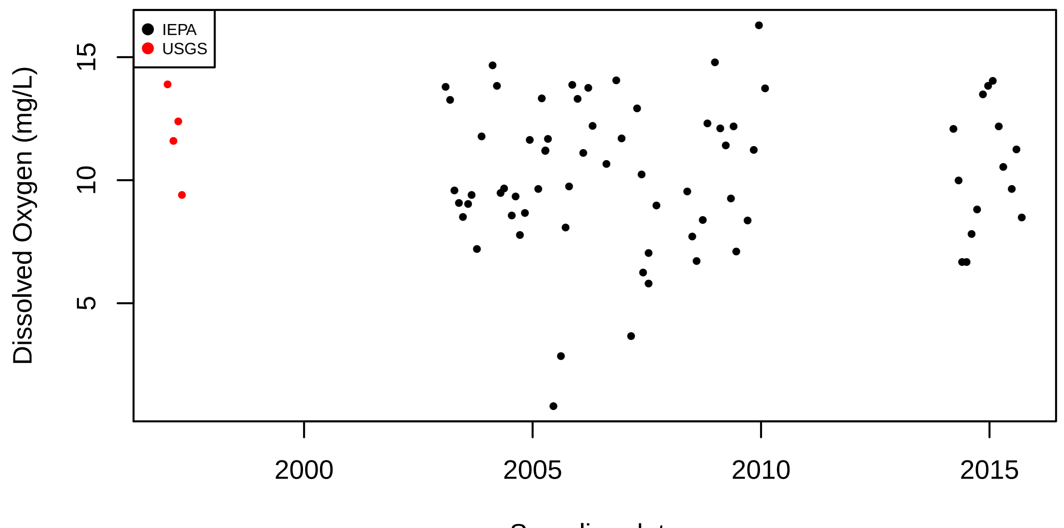


(c) Annual values

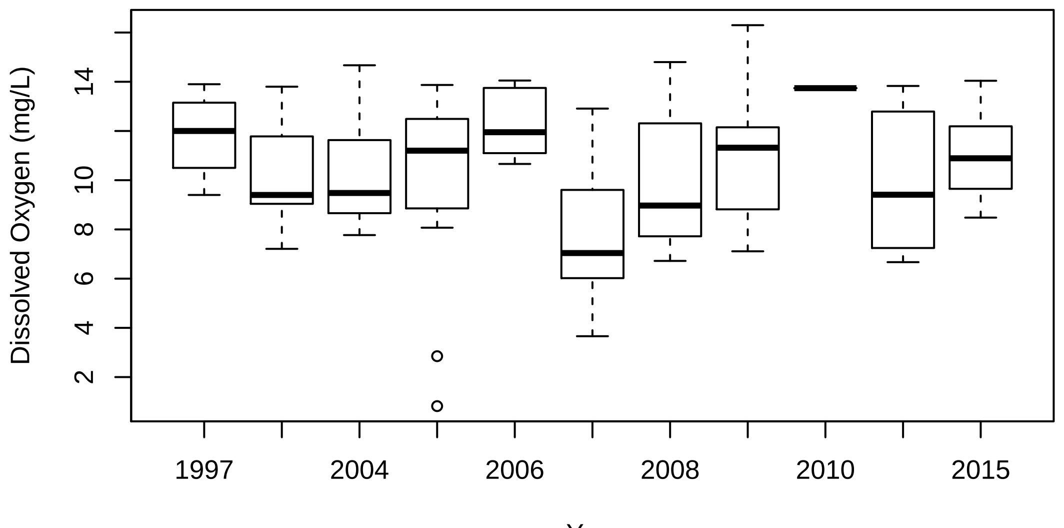


(d) Boxplot by month

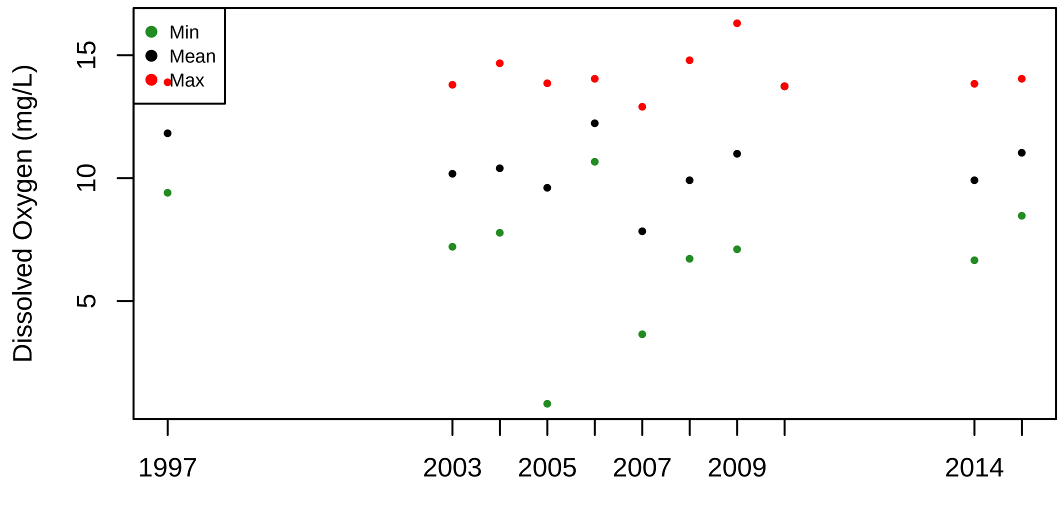
Nippersink Cr at Spring Grove (236): Dissolved Oxygen (mg/L)



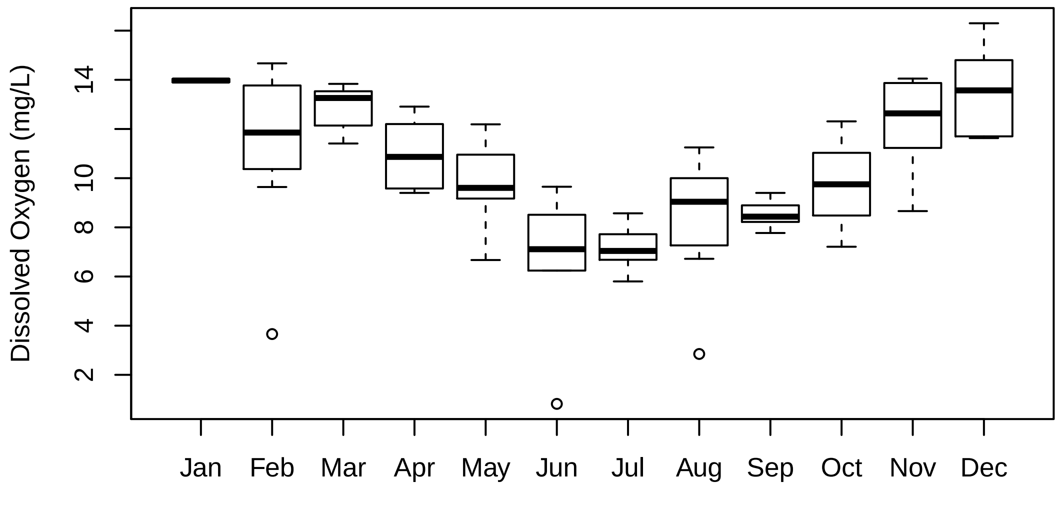
(a) Observation data



(b) Boxplot by year

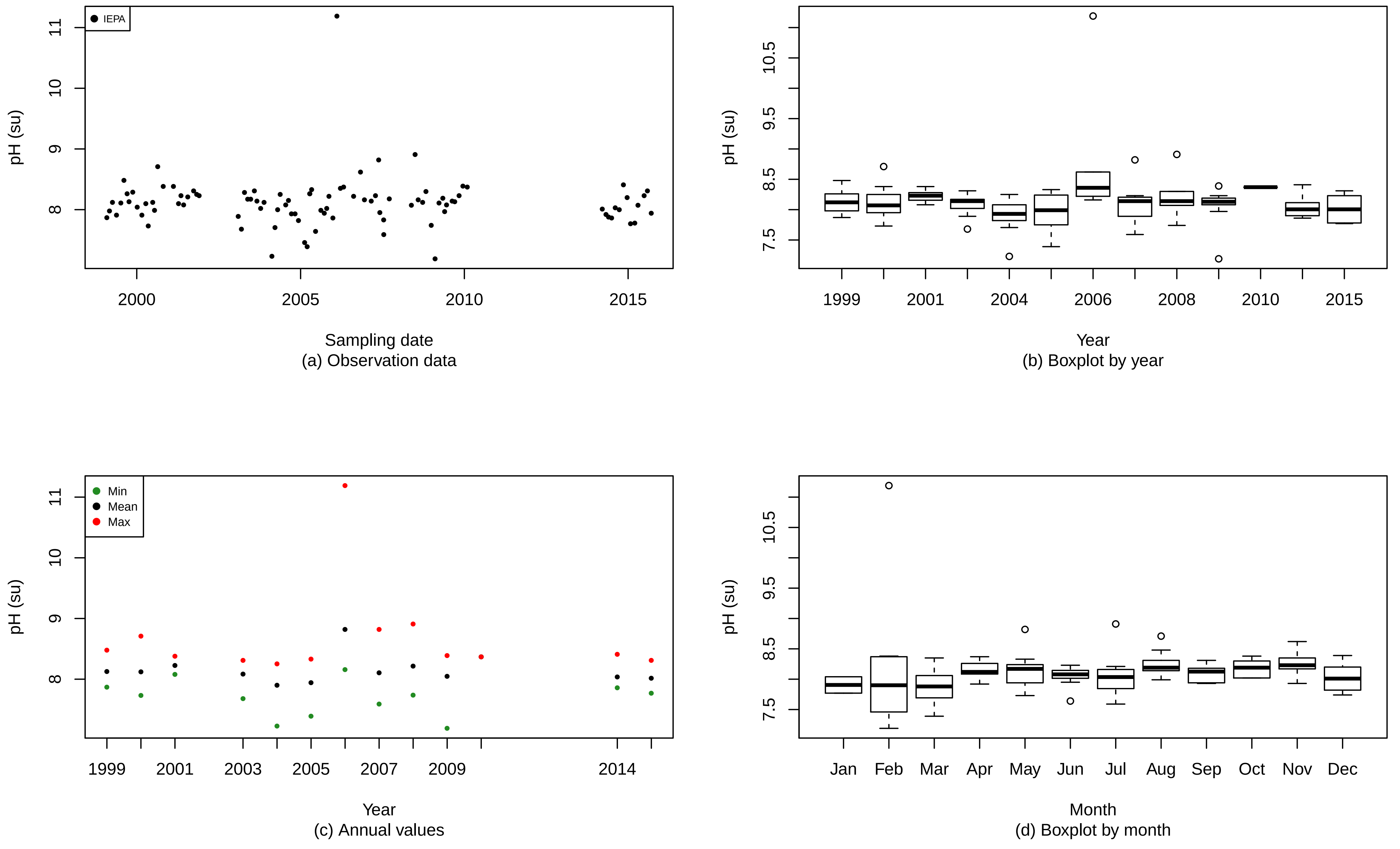


(c) Annual values

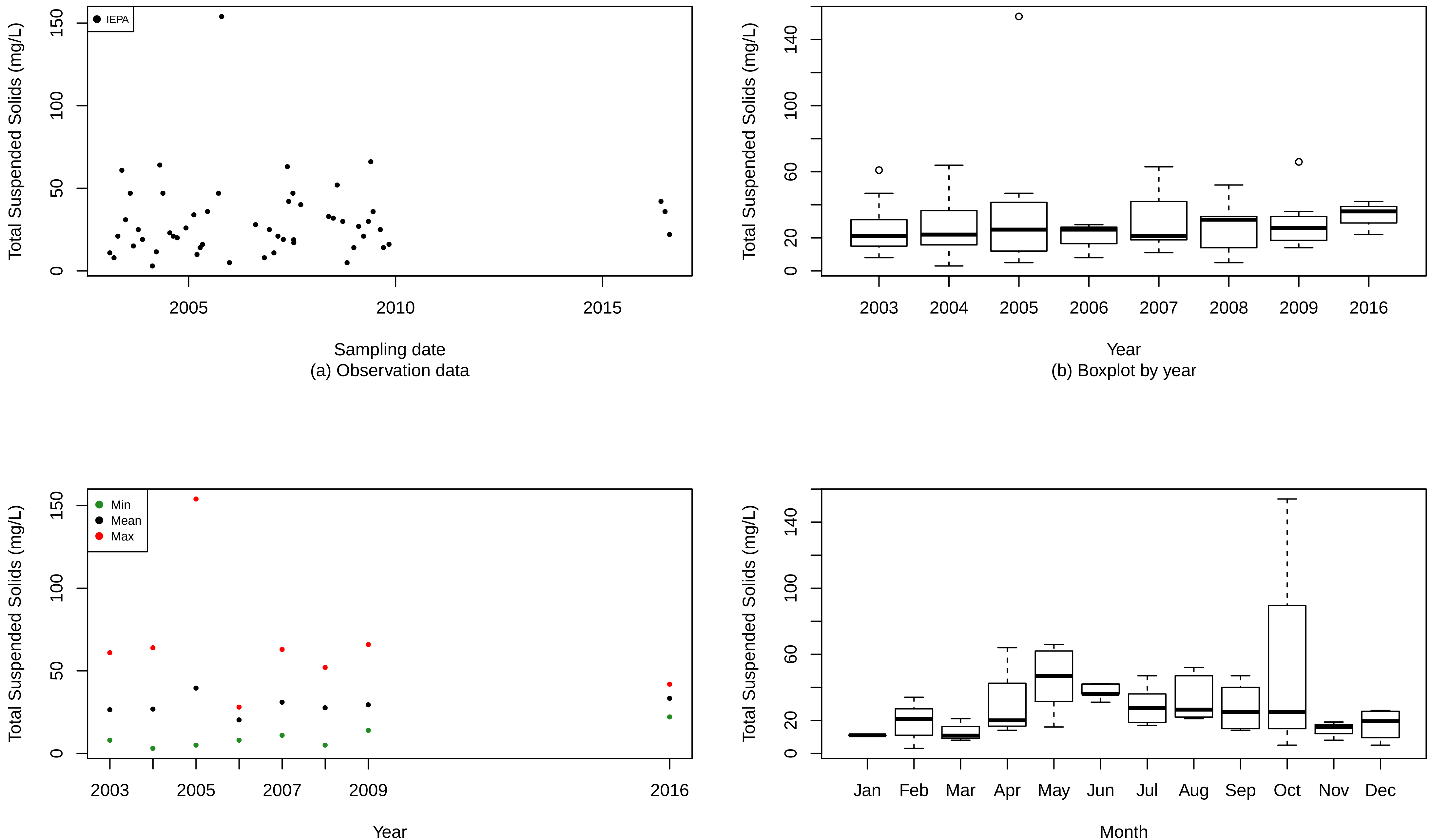


(d) Boxplot by month

Nippersink Cr at Spring Grove (236): pH (su)



Nippersink Cr at Spring Grove (236): Total Suspended Solids (mg/L)



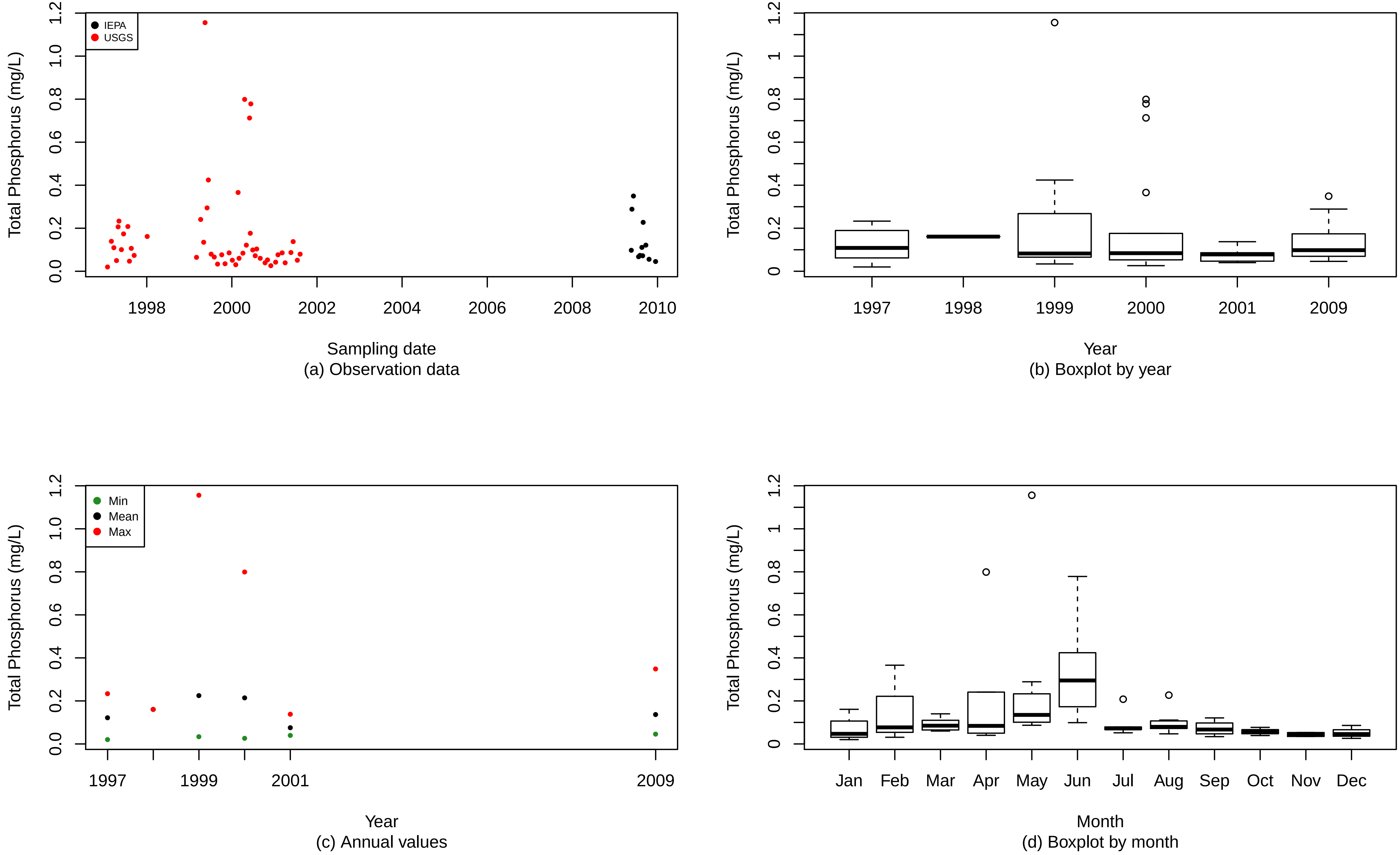
(a) Observation data

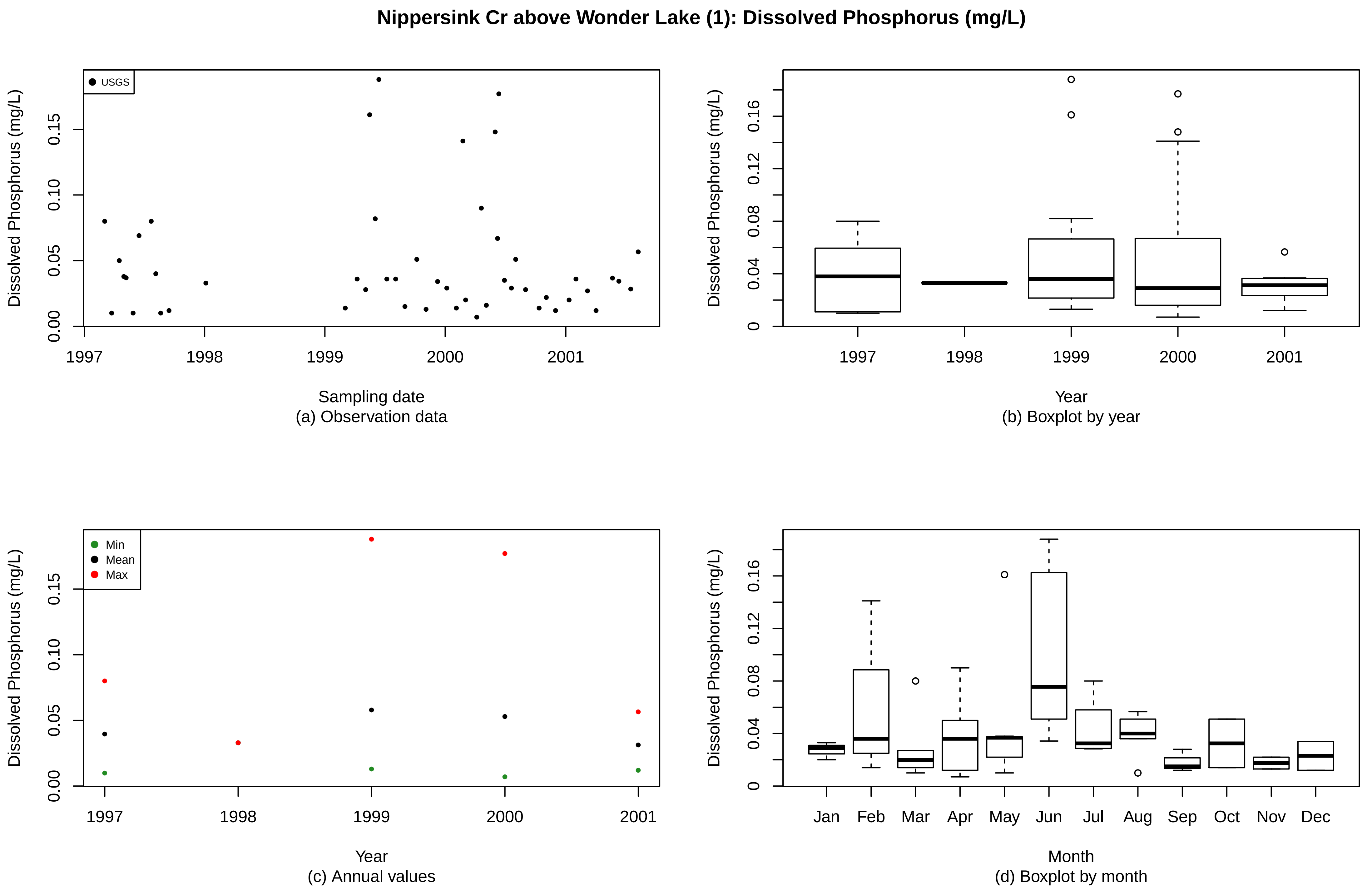
(b) Boxplot by year

(c) Annual values

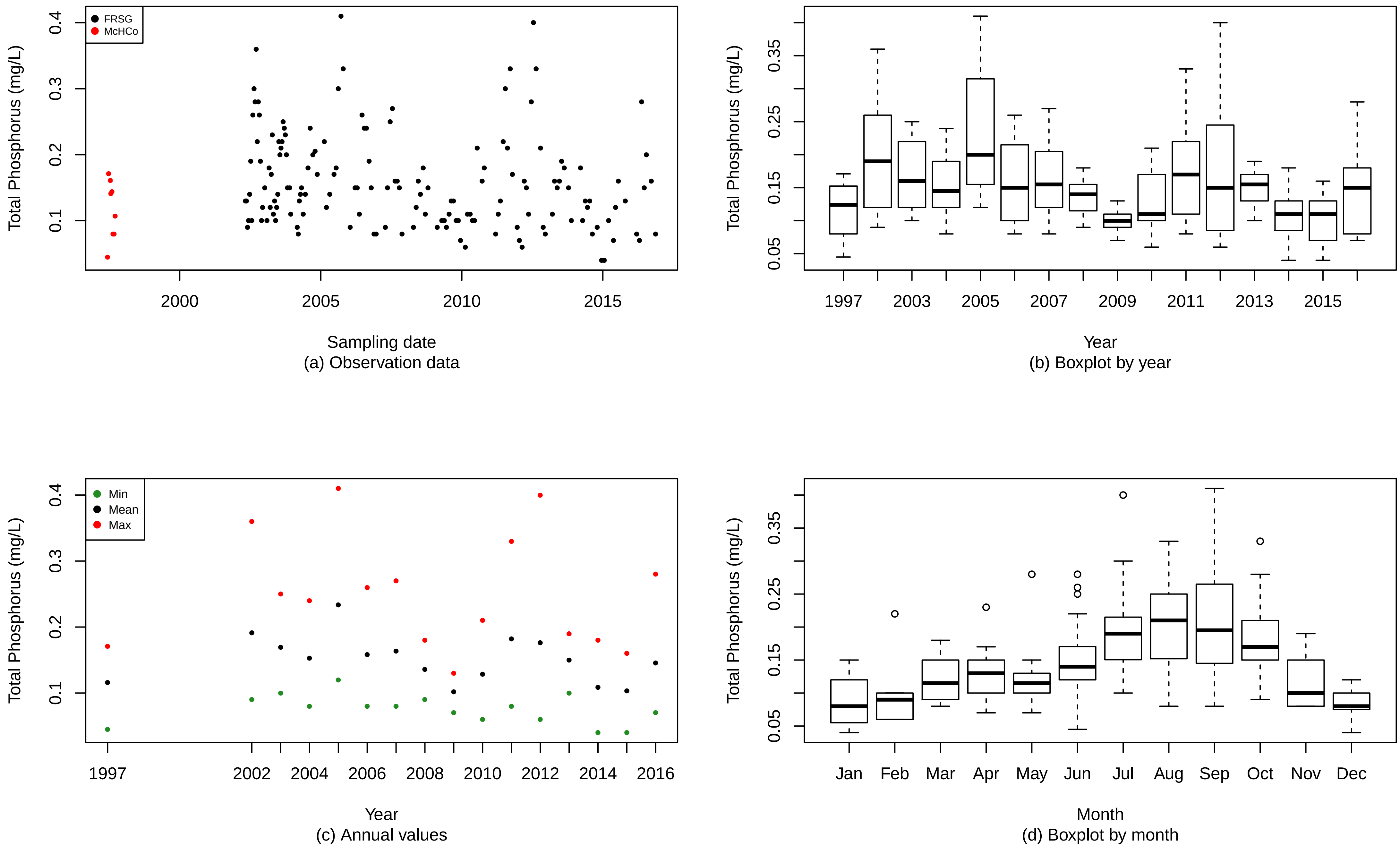
(d) Boxplot by month

Nippersink Cr above Wonder Lake (1): Total Phosphorus (mg/L)

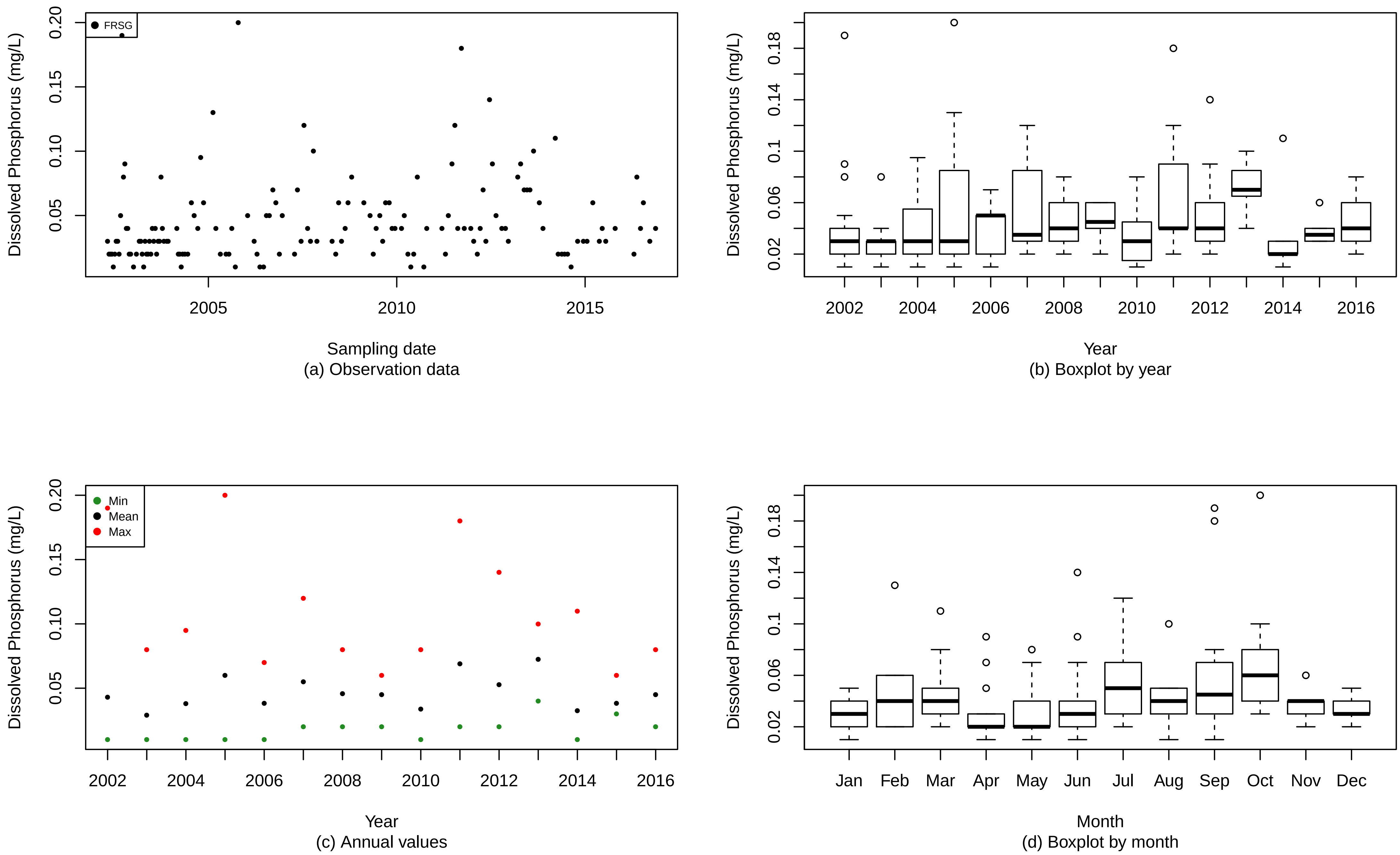



Nippersink Cr above Wonder Lake (1): Dissolved Phosphorus (mg/L)
USGS
Dissolved Phosphorus (mg/L)
0.00
0.05
0.10
0.15
1997
1998
1999
2000
2001
Sampling date
(a) Observation data
0
0.04
0.08
0.12
0.16
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
(d) Boxplot by month

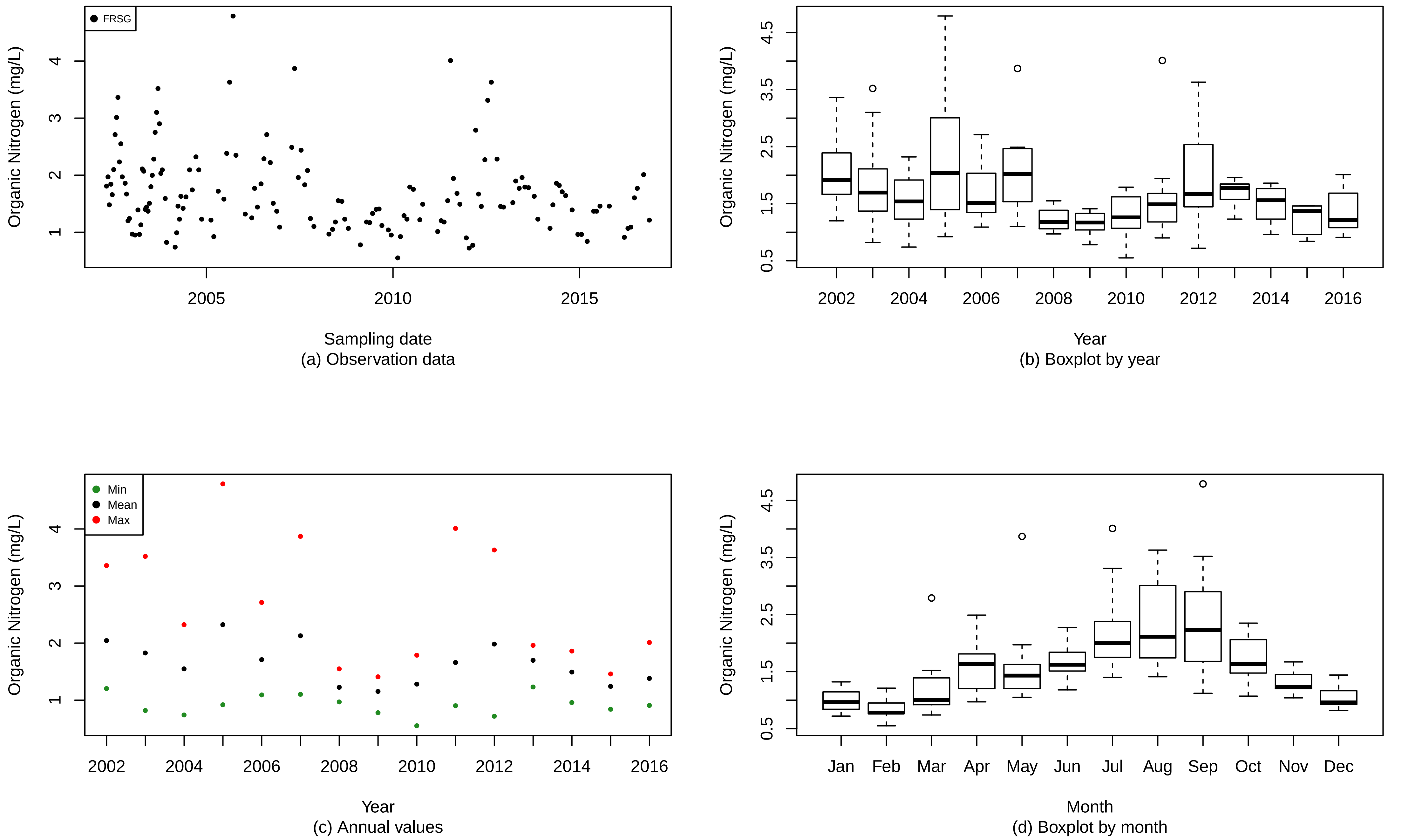
Fox River at Johnsburg (184): Total Phosphorus (mg/L)



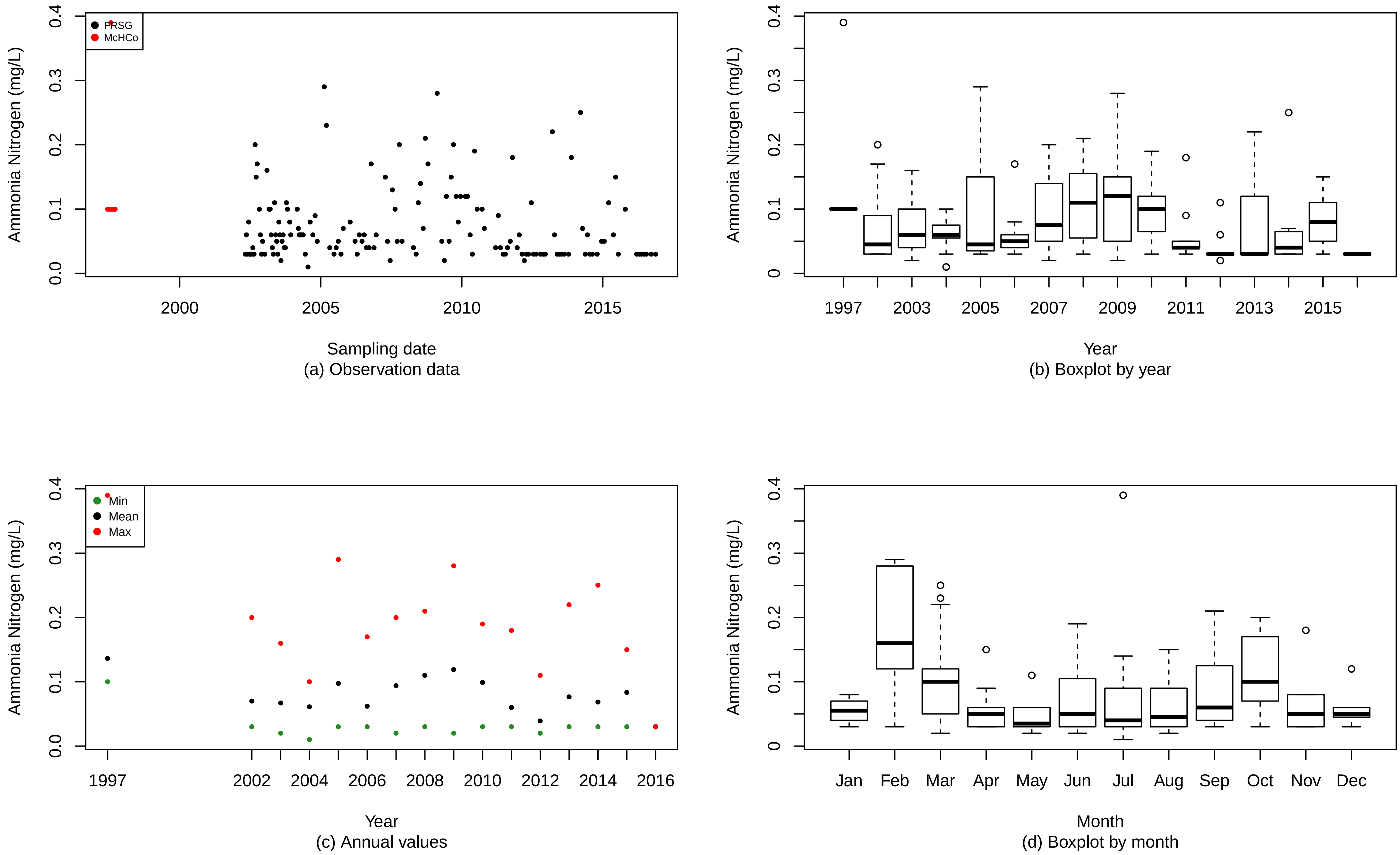
Fox River at Johnsburg (184): Dissolved Phosphorus (mg/L)

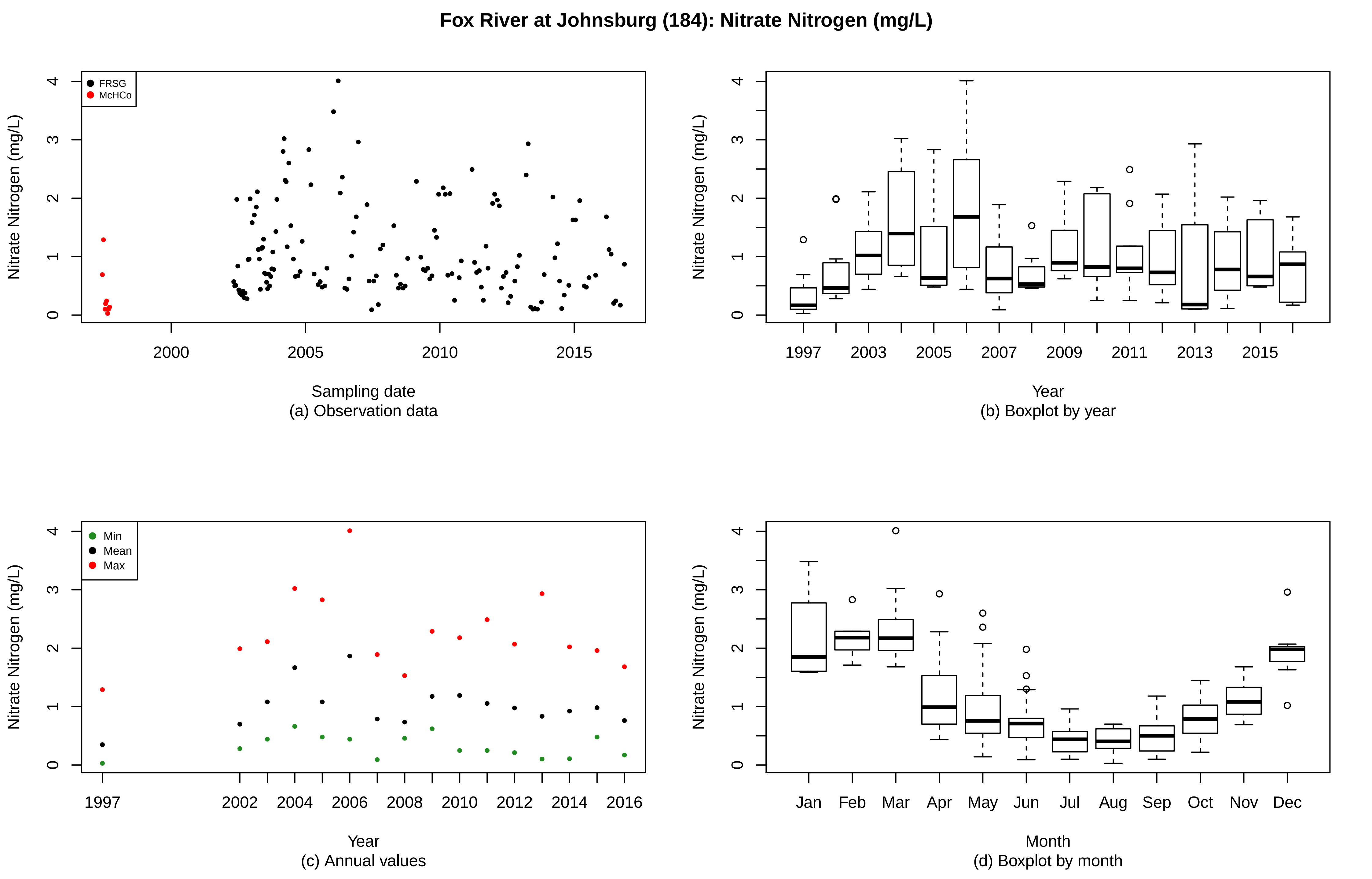


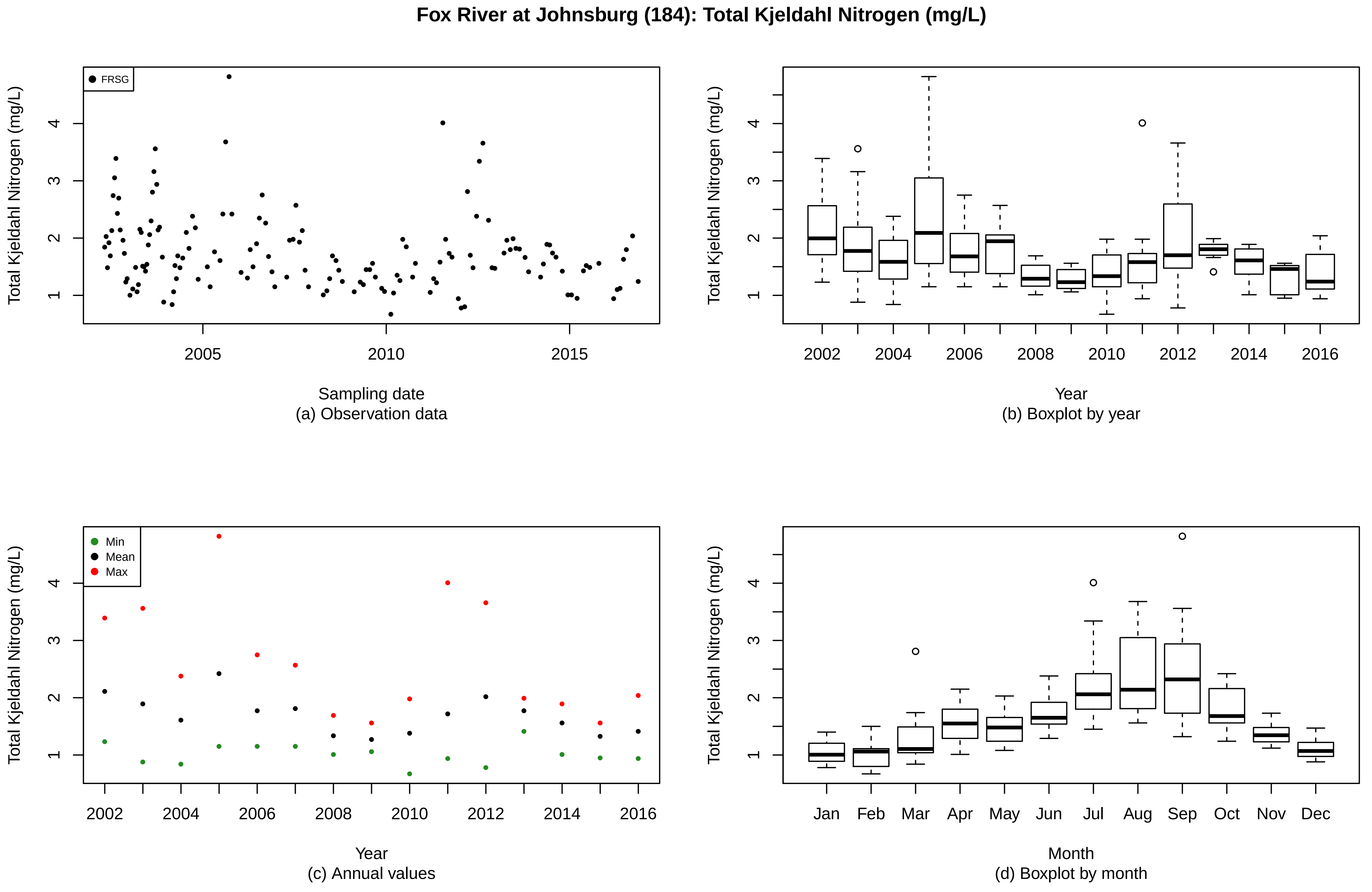
Fox River at Johnsburg (184): Organic Nitrogen (mg/L)



Fox River at Johnsburg (184): Ammonia Nitrogen (mg/L)

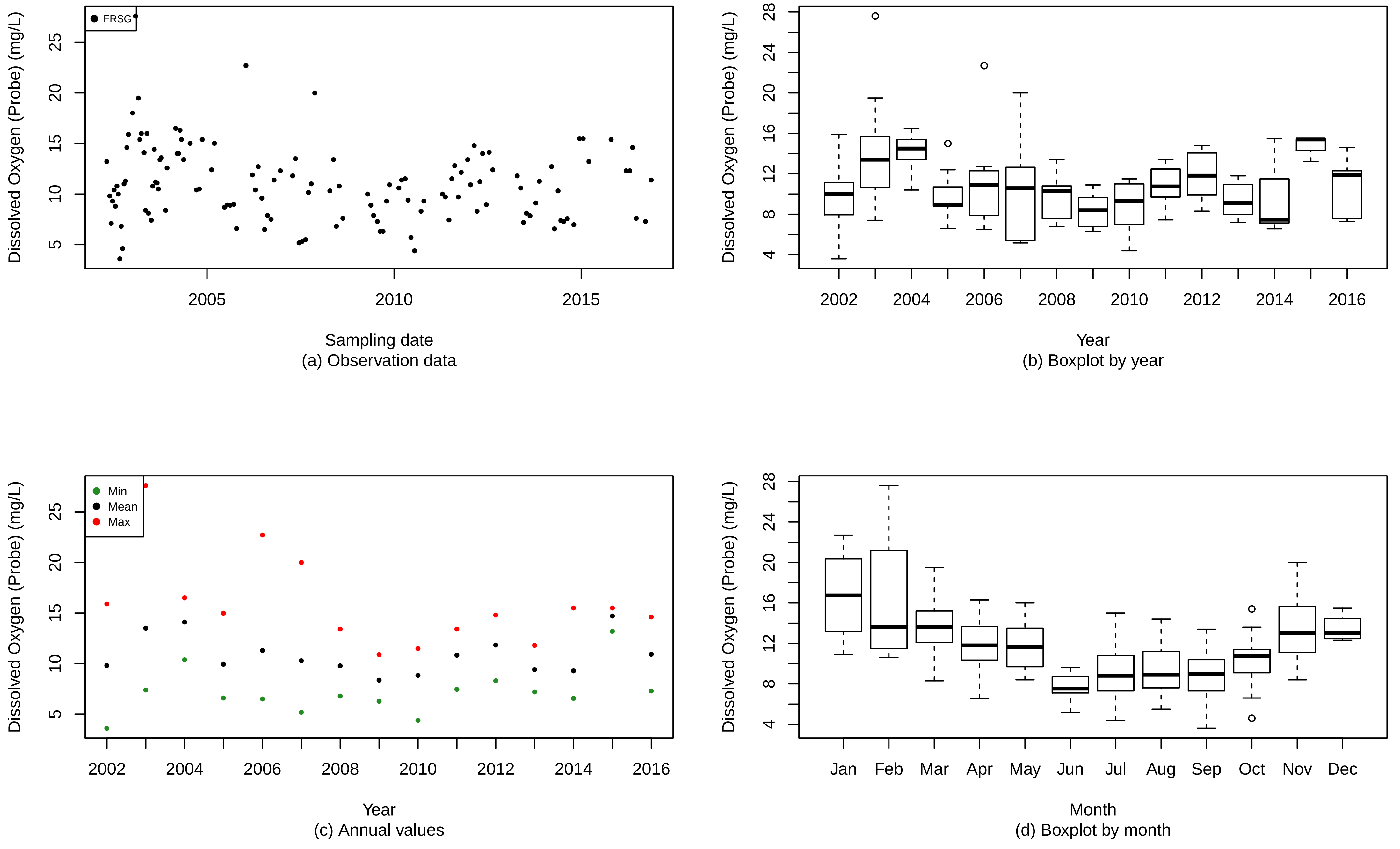



Fox River at Johnsburg (184): Nitrate Nitrogen (mg/L)
Nitrate Nitrogen (mg/L)
0
1
2
3
4
FRSG
McHCo
2000
2005
2010
2015
Sampling date
(a) Observation data
1997
2003
2005
2007
2009
2011
2013
2015
Year
(b) Boxplot by year
Min
Mean
Max
1997
2002
2004
2006
2008
2010
2012
2014
2016
Year
(c) Annual values
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
(d) Boxplot by month

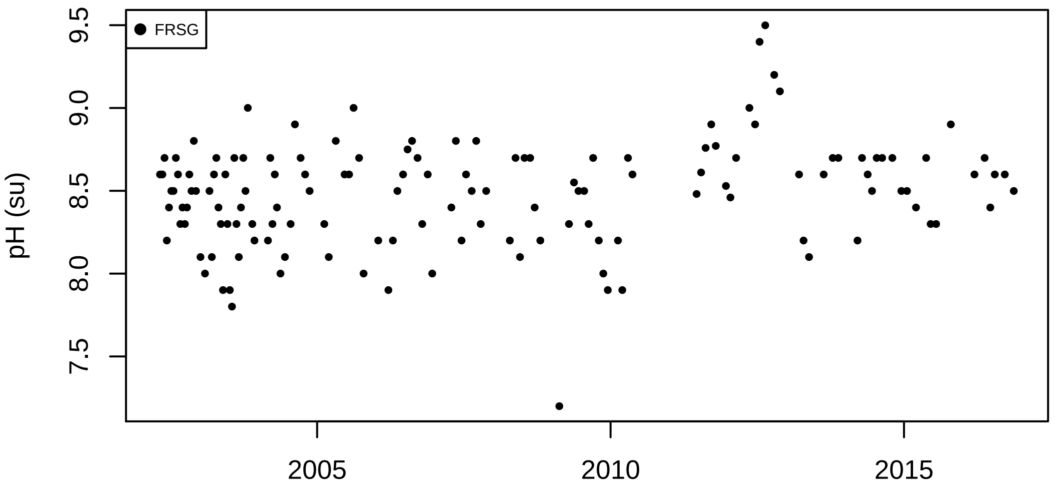


Fox River at Johnsburg (184): Total Kjeldahl Nitrogen (mg/L)
FRSG
Total Kjeldahl Nitrogen (mg/L)
1
2
3
4
2005
2010
2015
Sampling date
(a) Observation data
2002
2004
2006
2008
2010
2012
2014
2016
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
(d) Boxplot by month

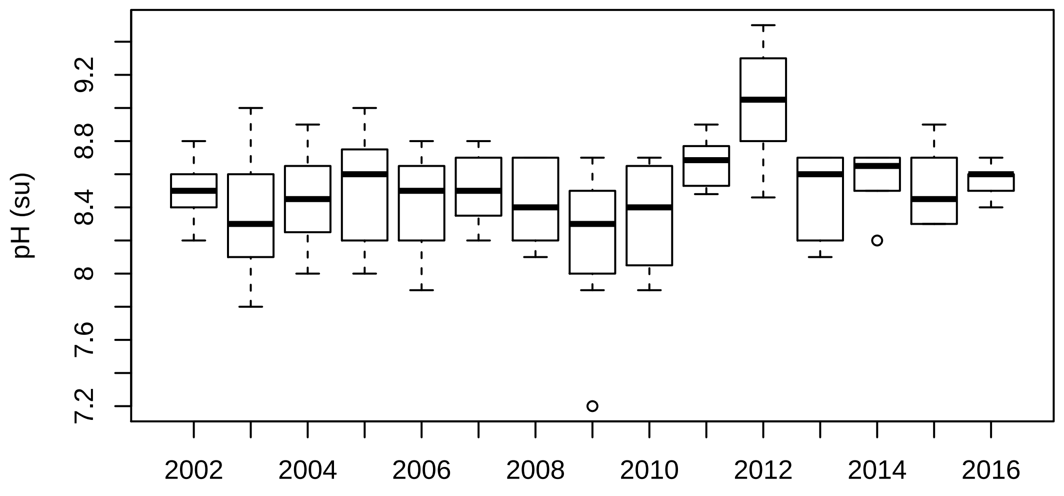
Fox River at Johnsburg (184): Dissolved Oxygen (Probe) (mg/L)



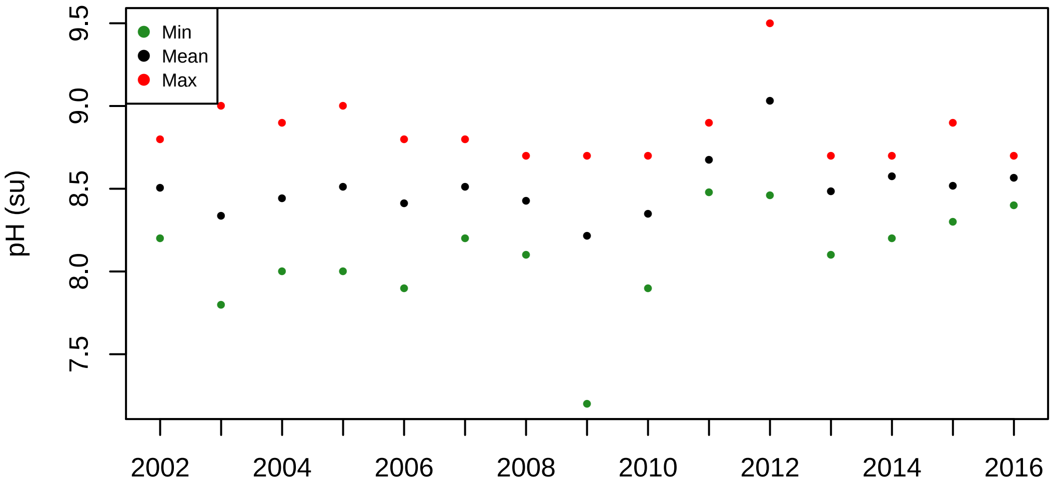
Fox River at Johnsburg (184): pH (su)



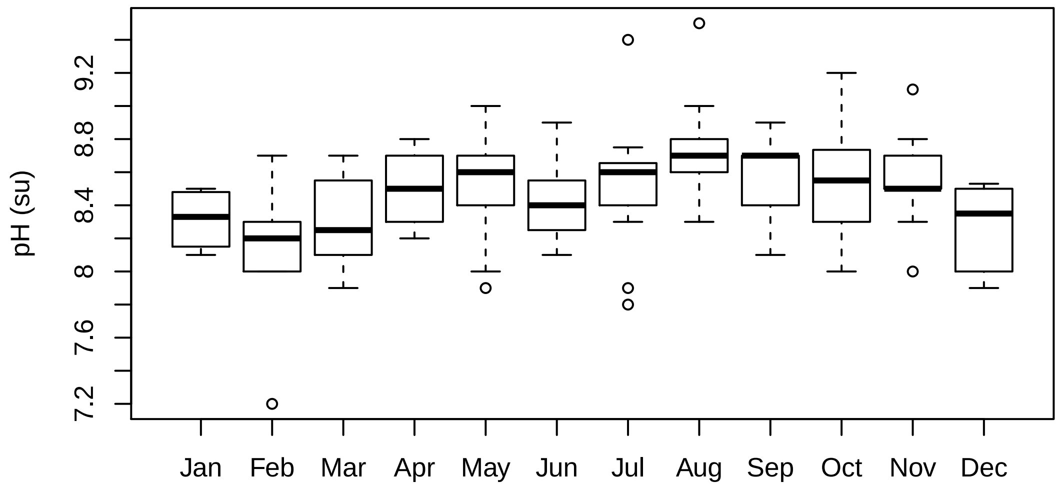
Sampling date
(a) Observation data



Year
(b) Boxplot by year

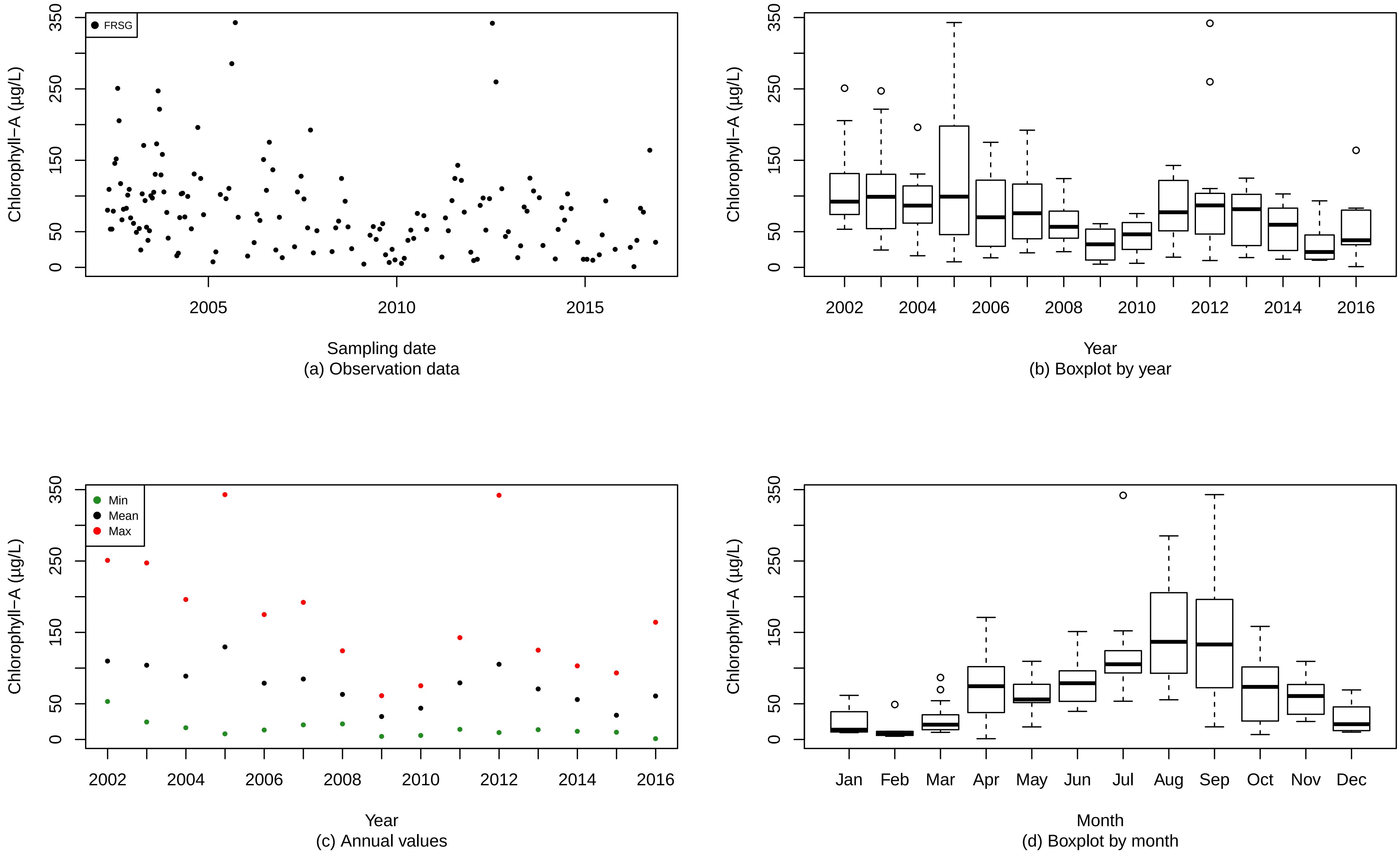


Year
(c) Annual values

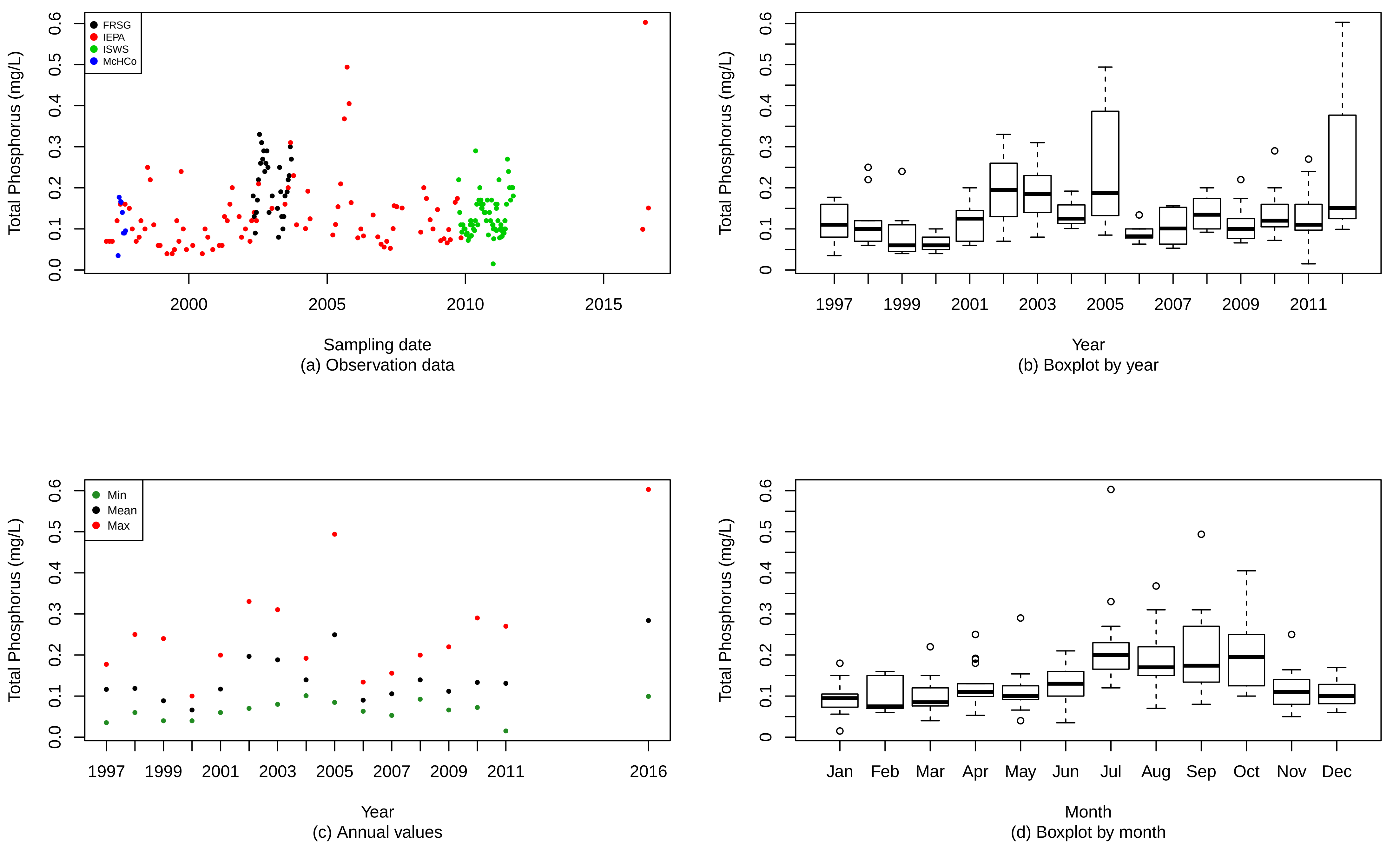


Month
(d) Boxplot by month

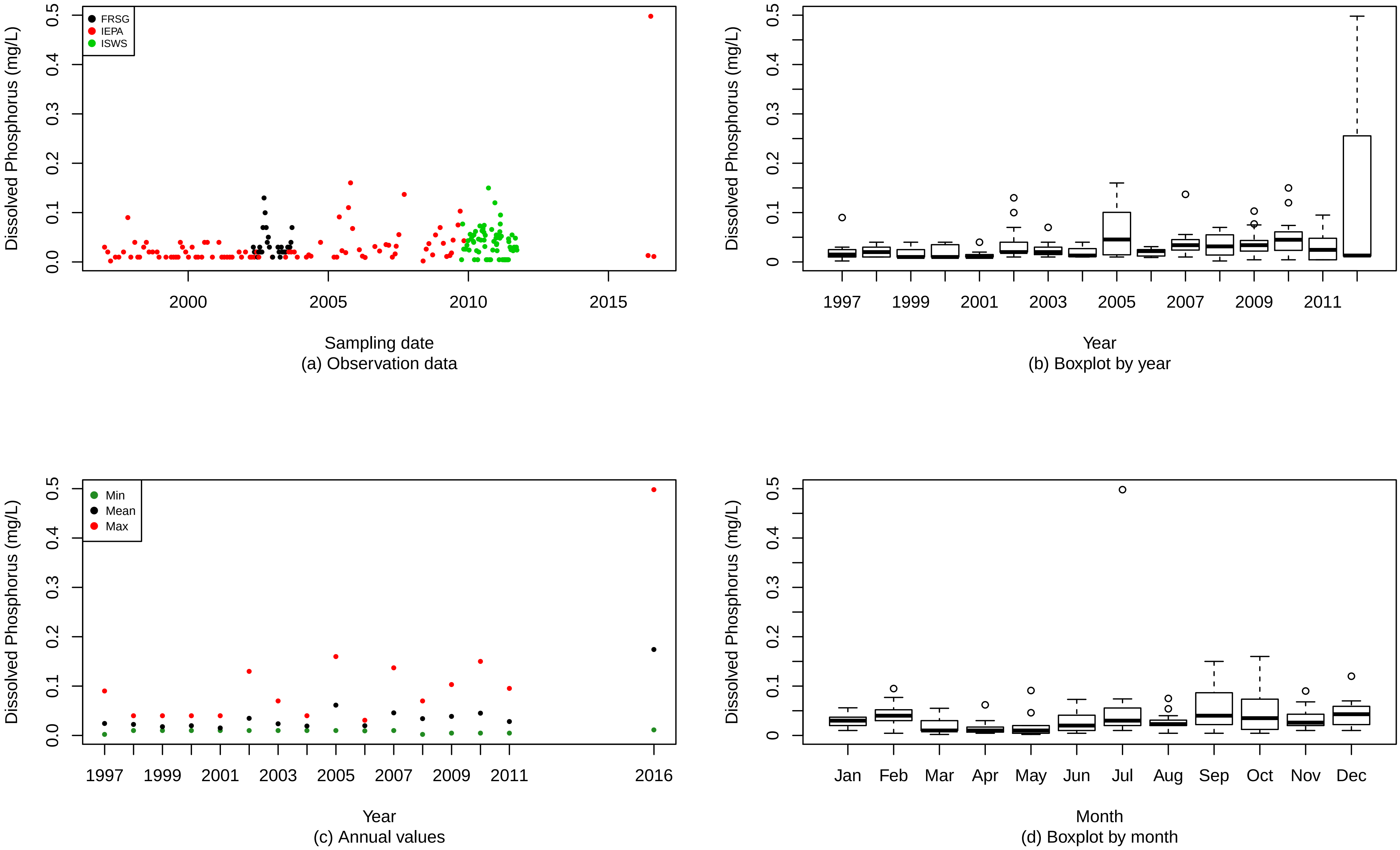
Fox River at Johnsburg (184): Chlorophyll−A (µg/L)



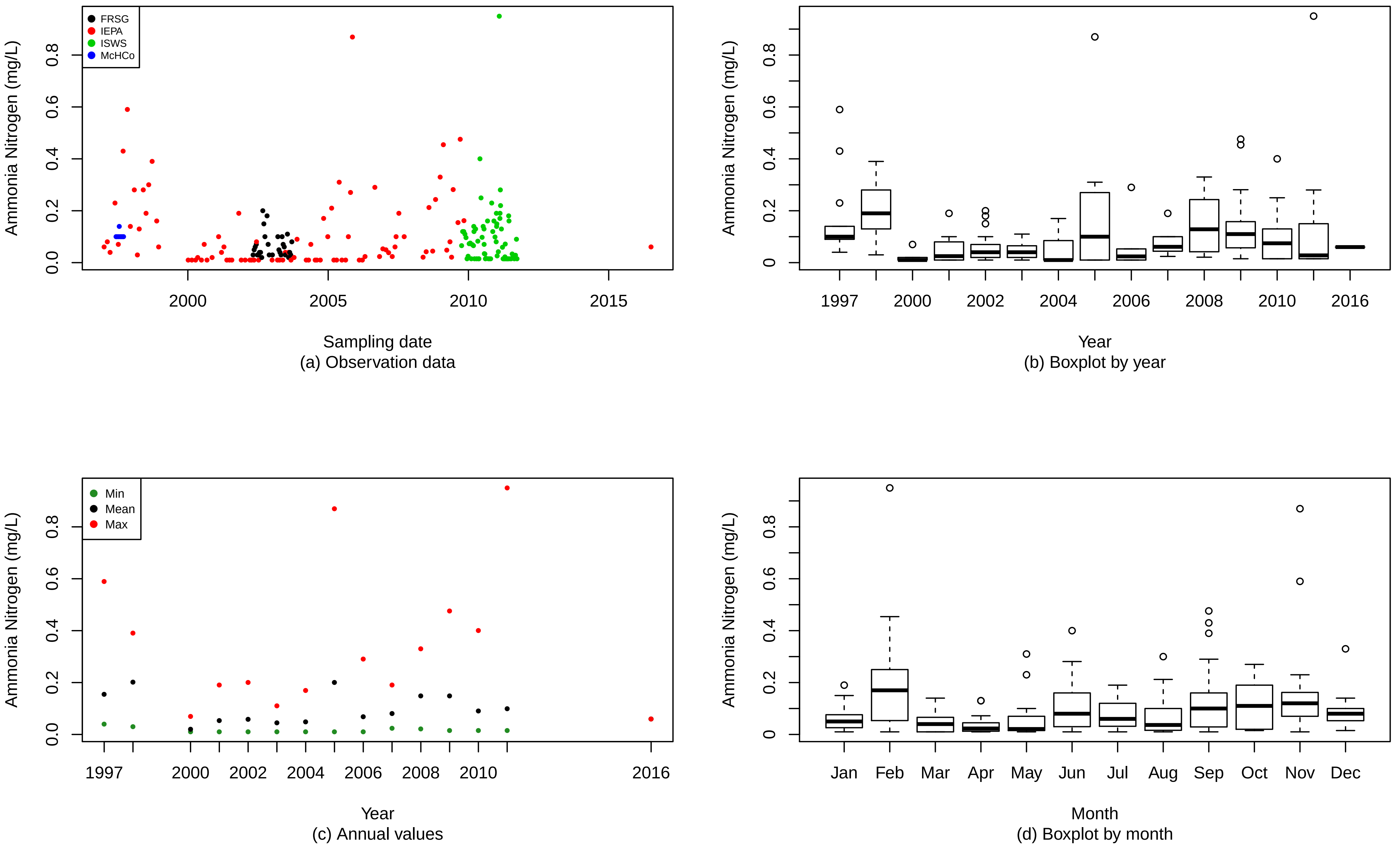
Fox River at Rt 176 (23): Total Phosphorus (mg/L)



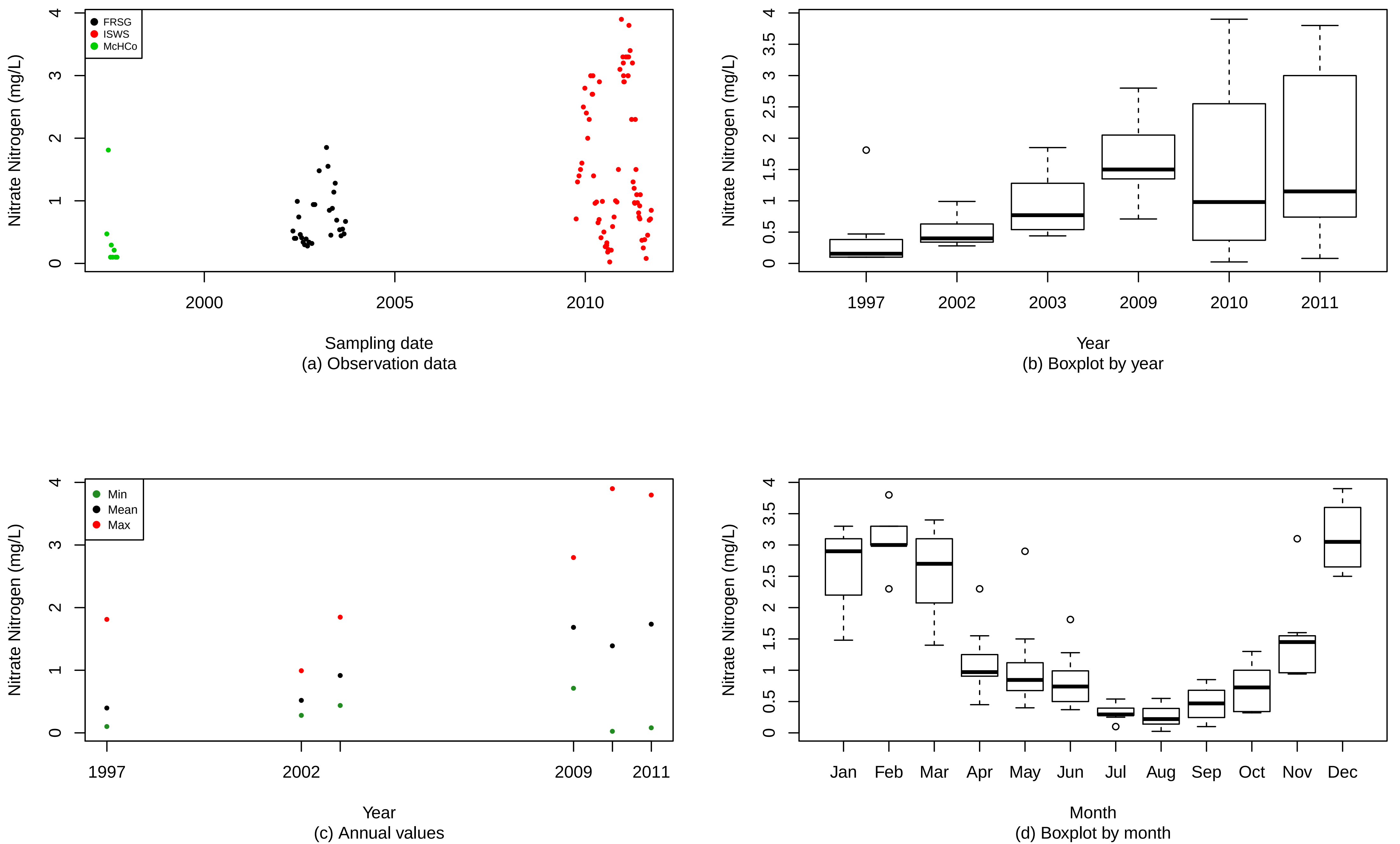
Fox River at Rt 176 (23): Dissolved Phosphorus (mg/L)



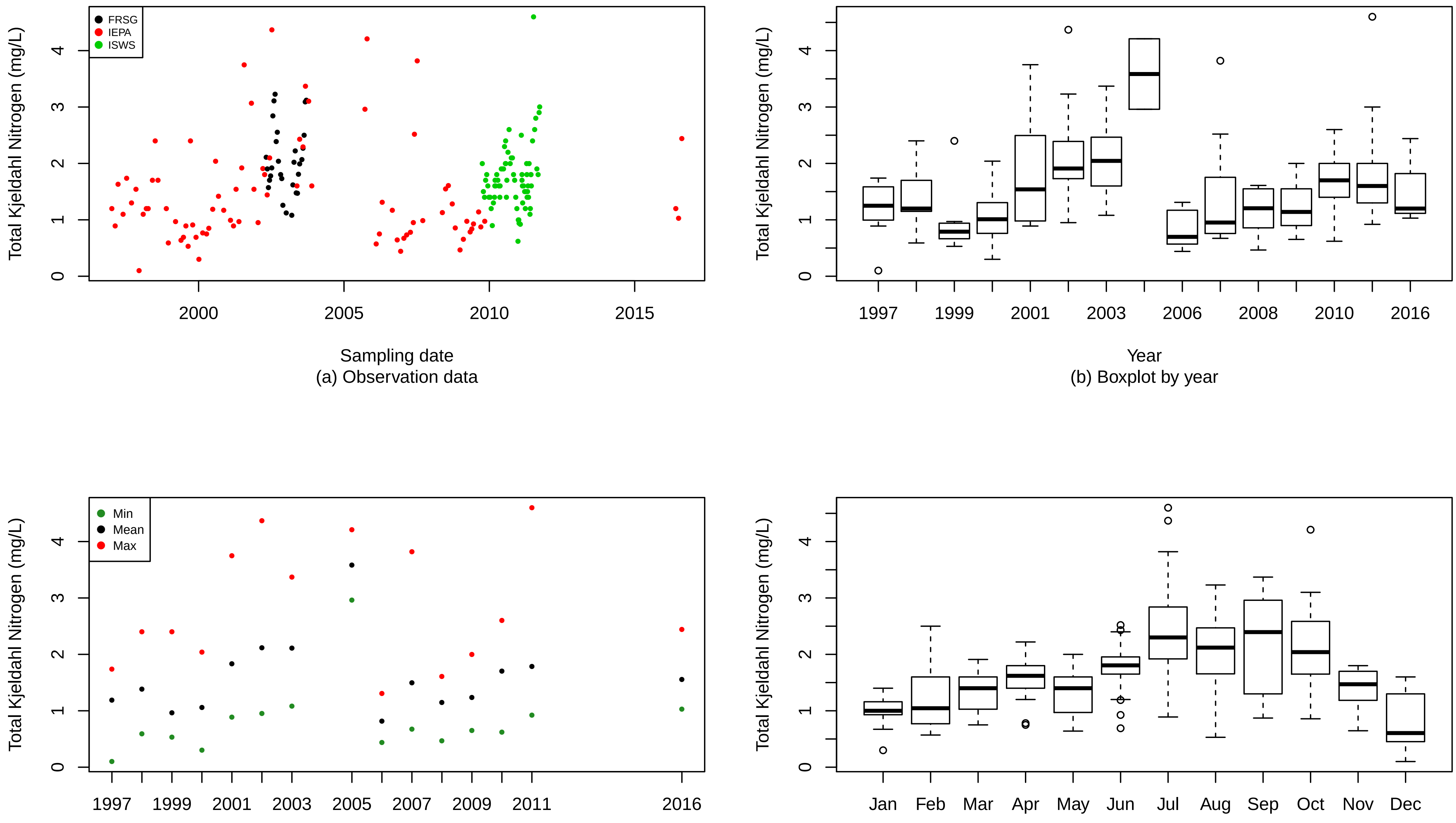
Fox River at Rt 176 (23): Ammonia Nitrogen (mg/L)



Fox River at Rt 176 (23): Nitrate Nitrogen (mg/L)



Fox River at Rt 176 (23): Total Kjeldahl Nitrogen (mg/L)

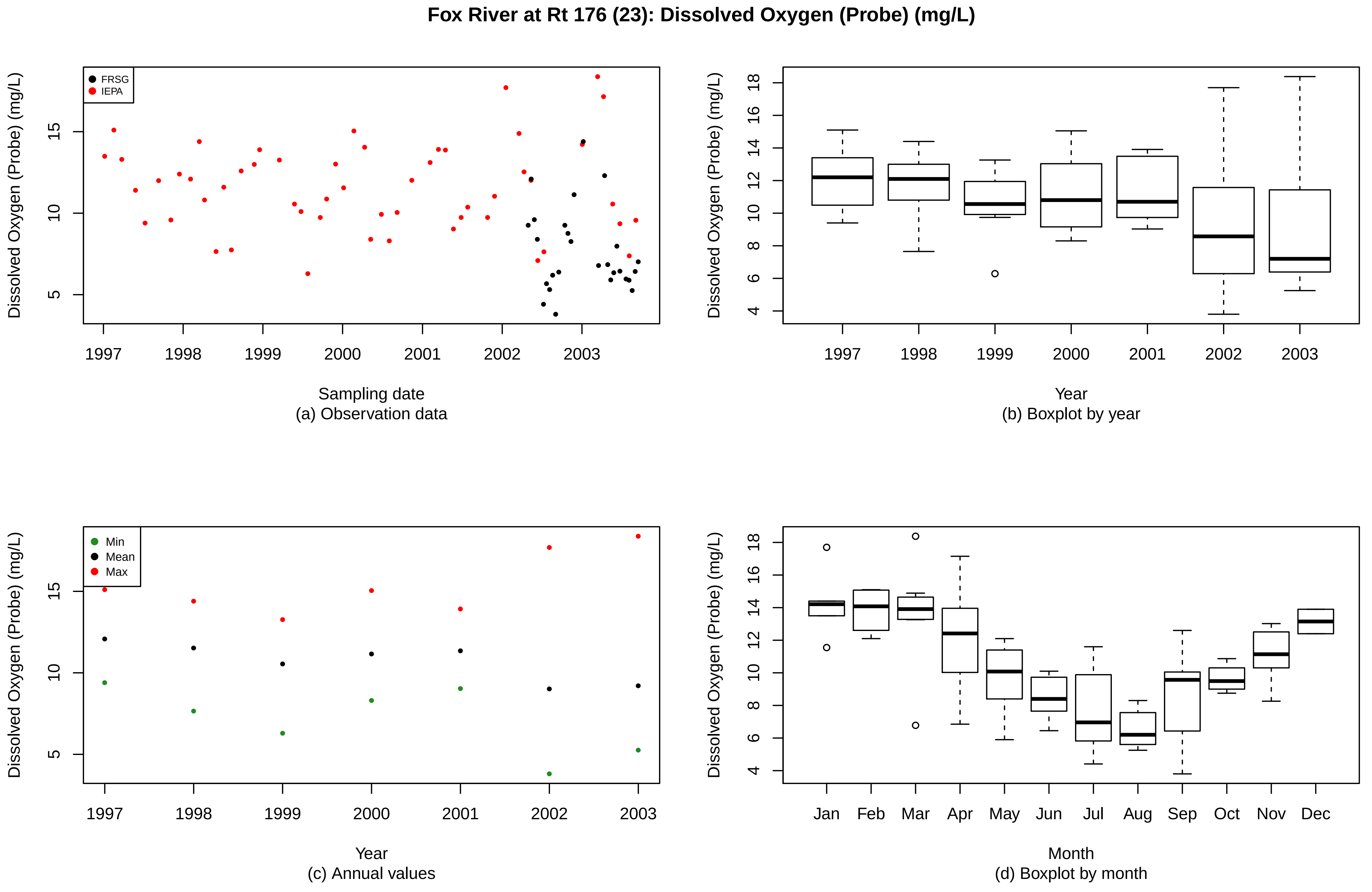


(a) Observation data

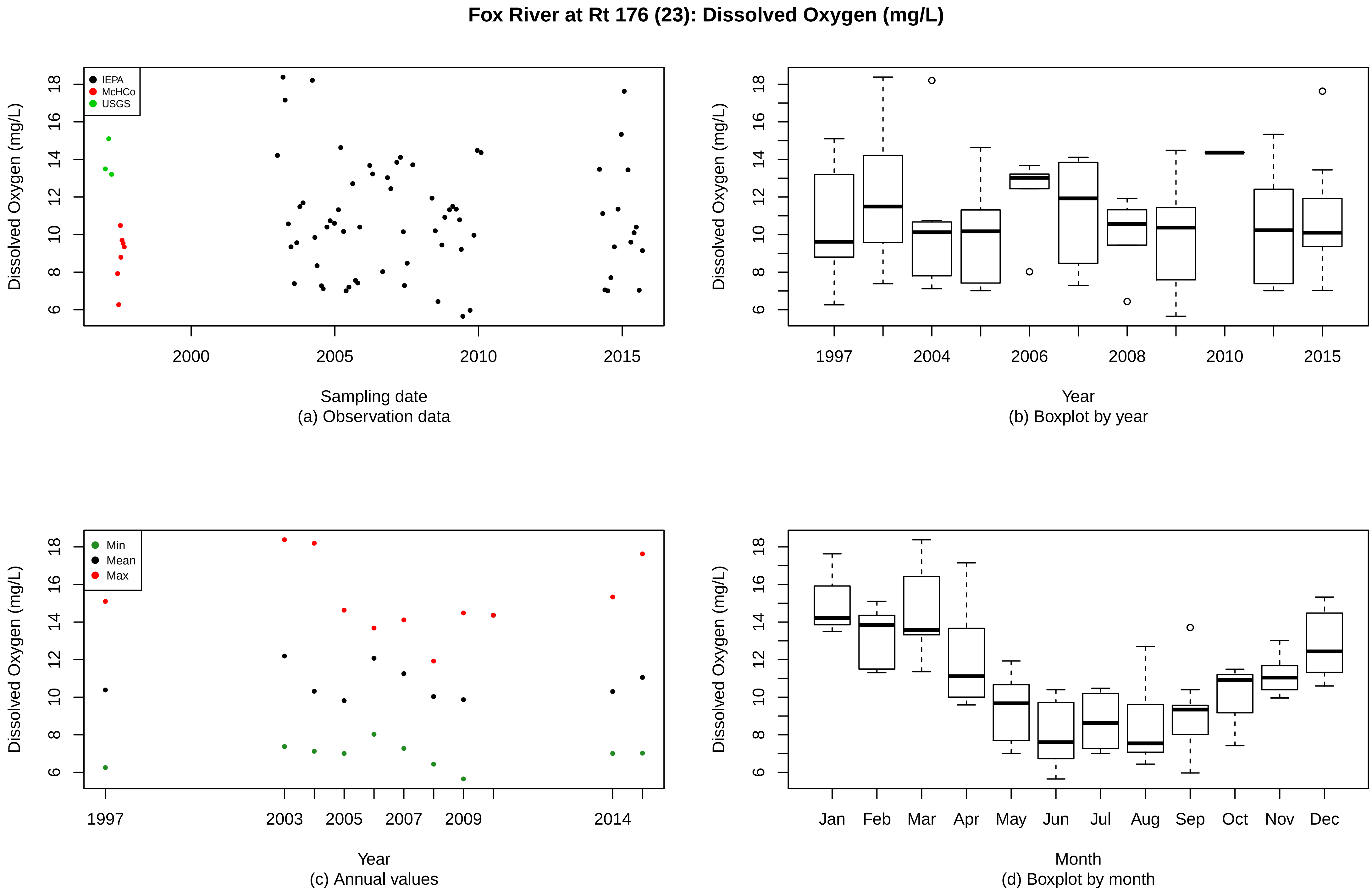
(b) Boxplot by year

(c) Annual values

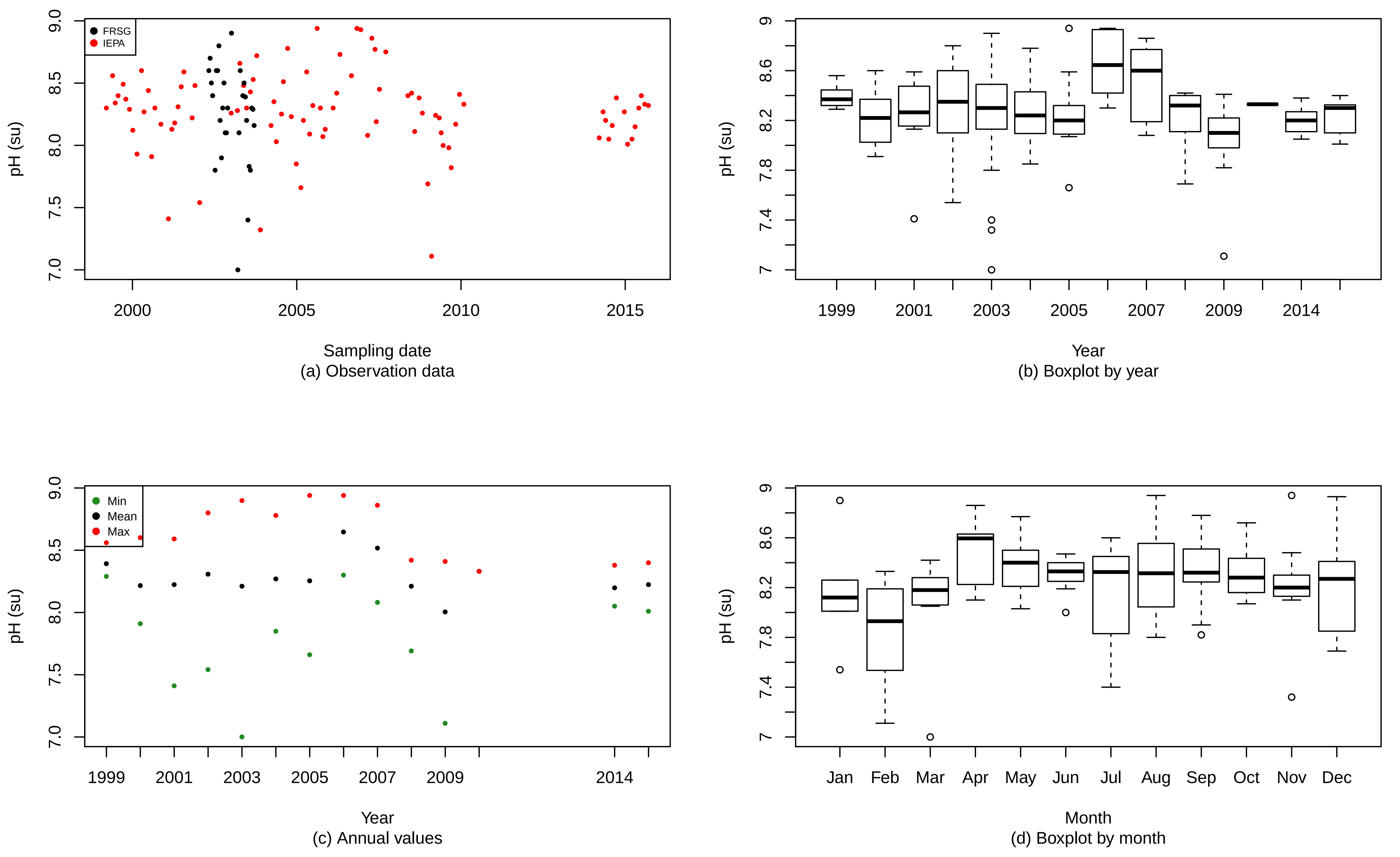
(d) Boxplot by month

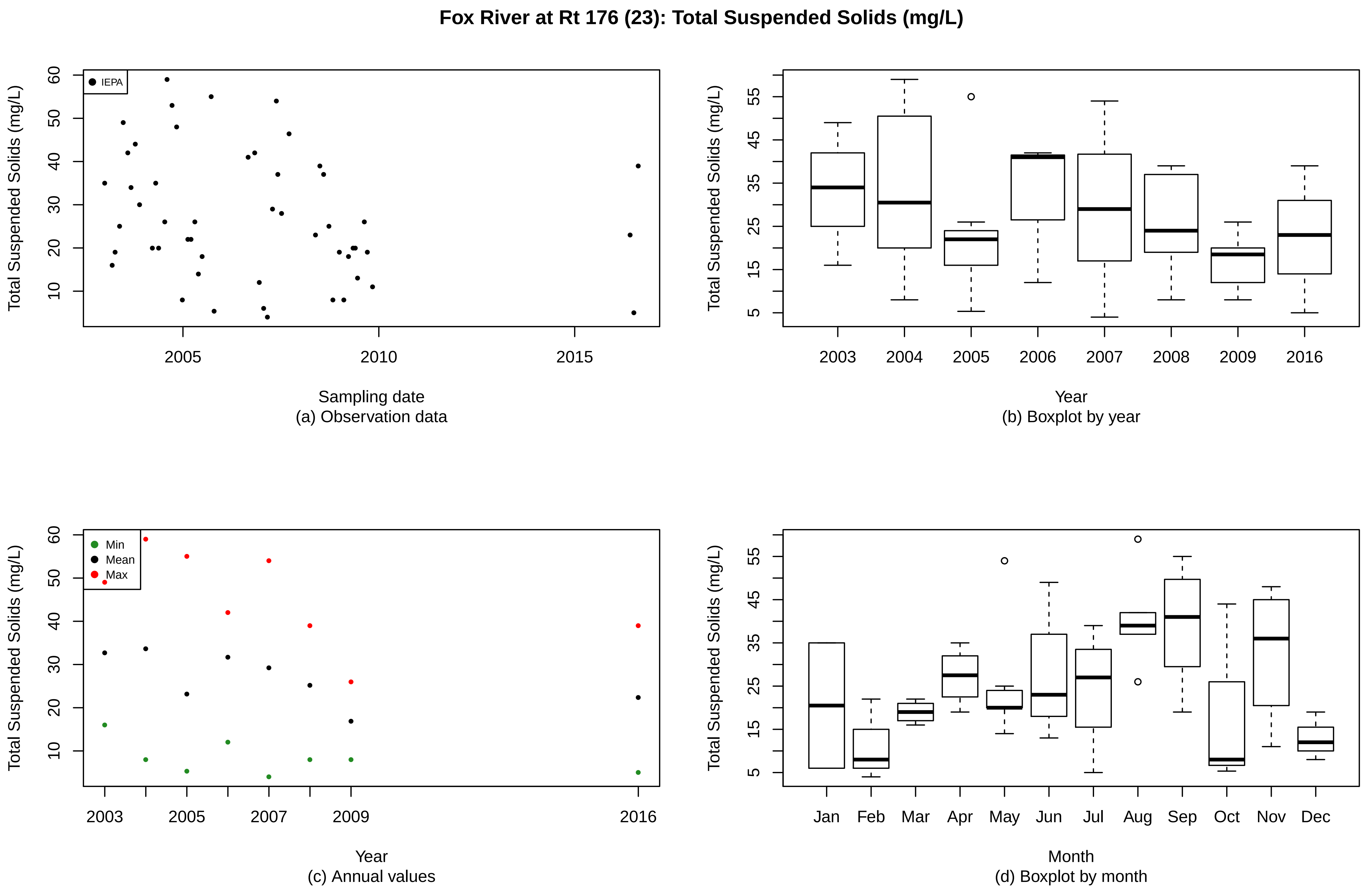


Fox River at Rt 176 (23): Dissolved Oxygen (Probe) (mg/L)
FRSG
IEPA
Dissolved Oxygen (Probe) (mg/L)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Month
(d) Boxplot by month
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Fox River at Rt 176 (23): Dissolved Oxygen (mg/L)
IEPA
McHCo
USGS
Dissolved Oxygen (mg/L)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Month
(d) Boxplot by month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

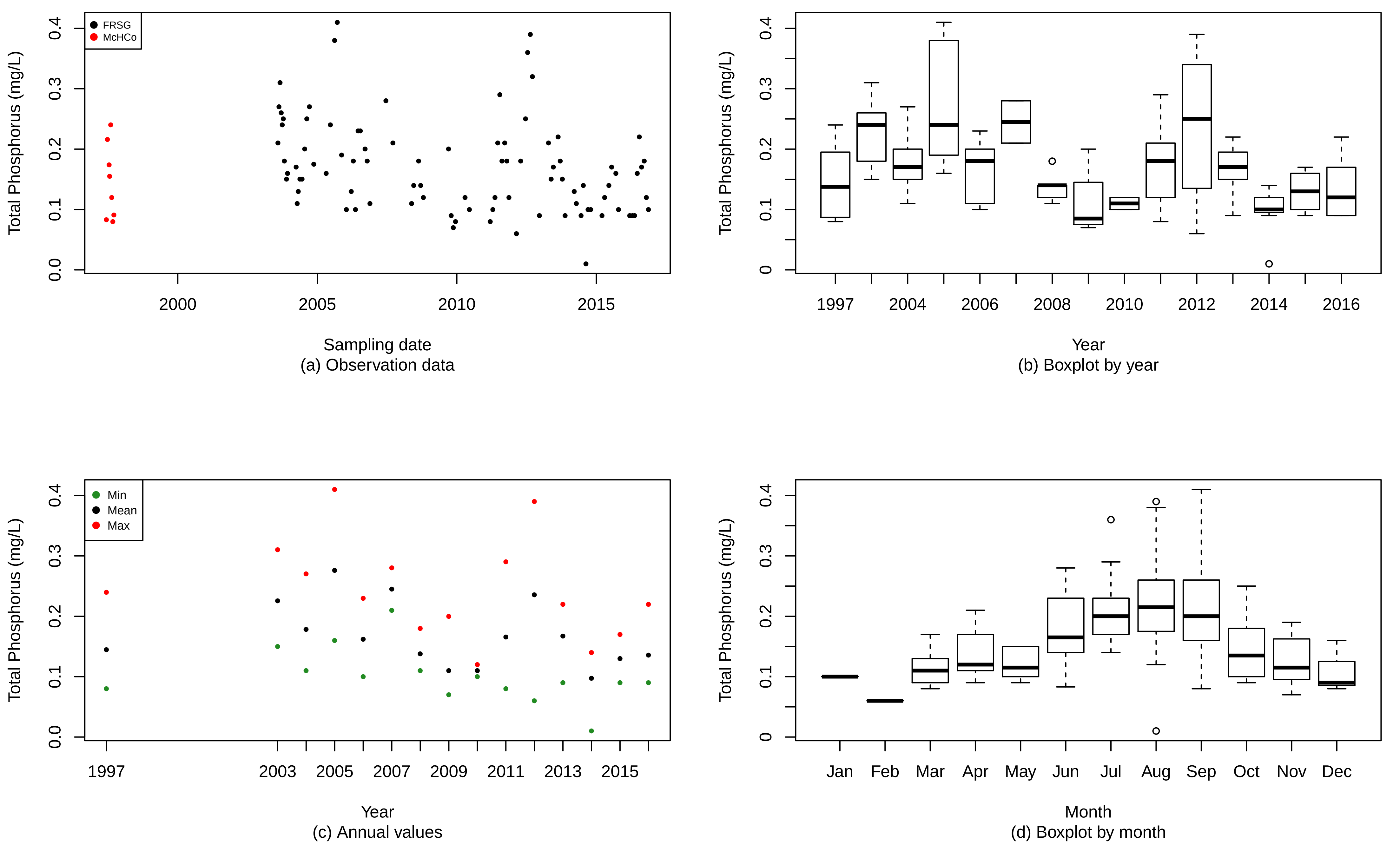
Fox River at Rt 176 (23): pH (su)



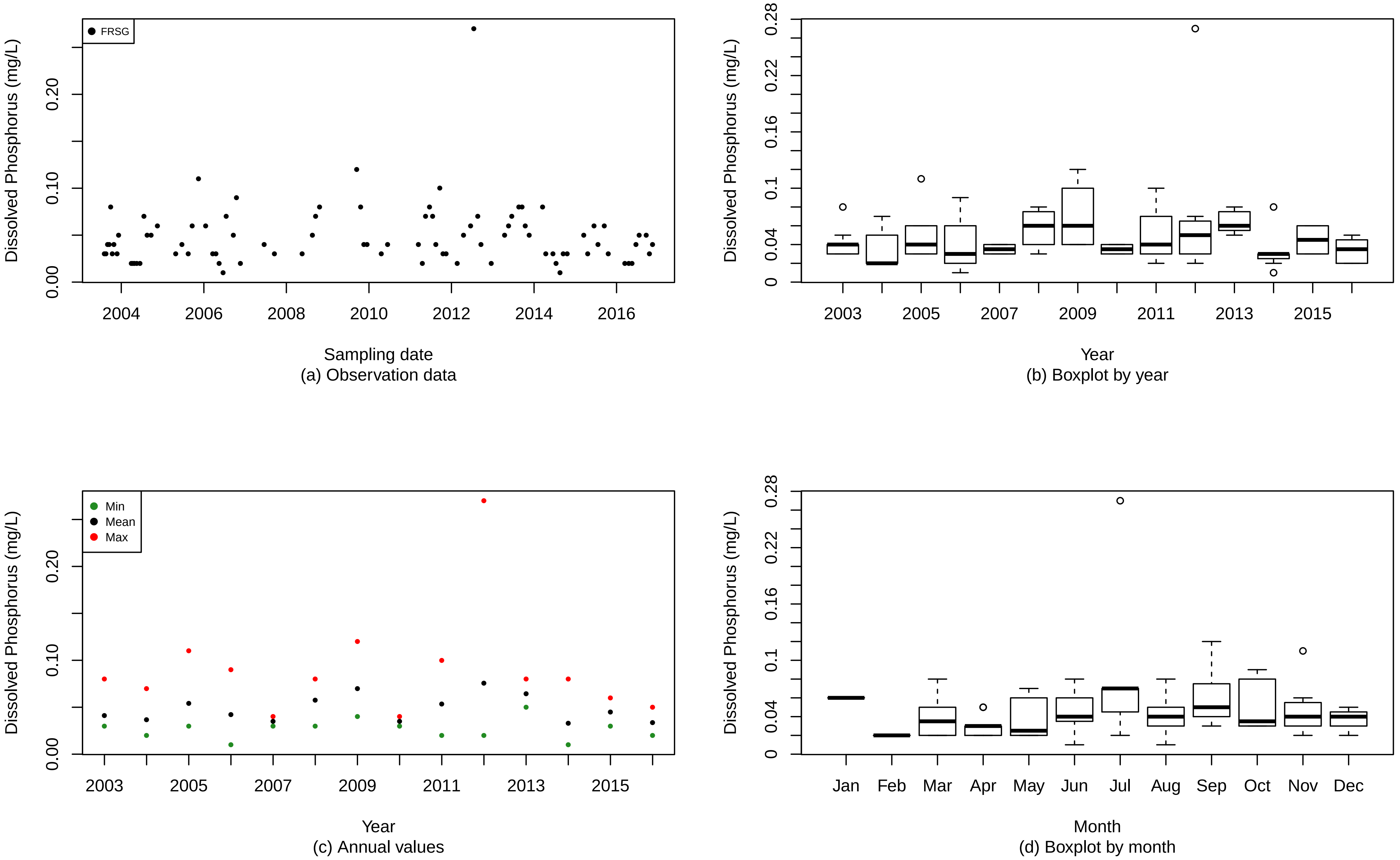


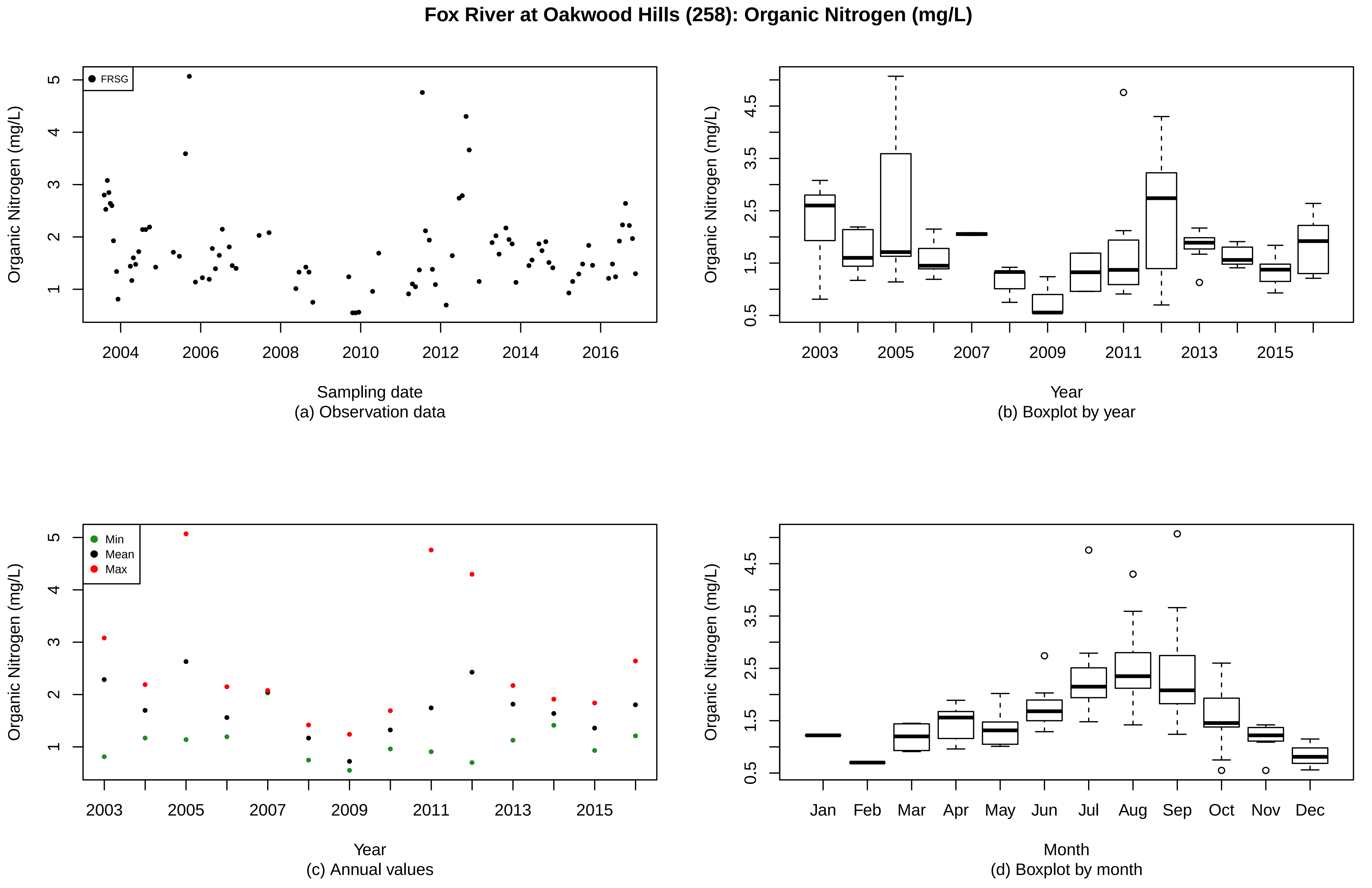
Fox River at Rt 176 (23): Total Suspended Solids (mg/L)
IEPA
Total Suspended Solids (mg/L)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Month
(d) Boxplot by month

Fox River at Oakwood Hills (258): Total Phosphorus (mg/L)

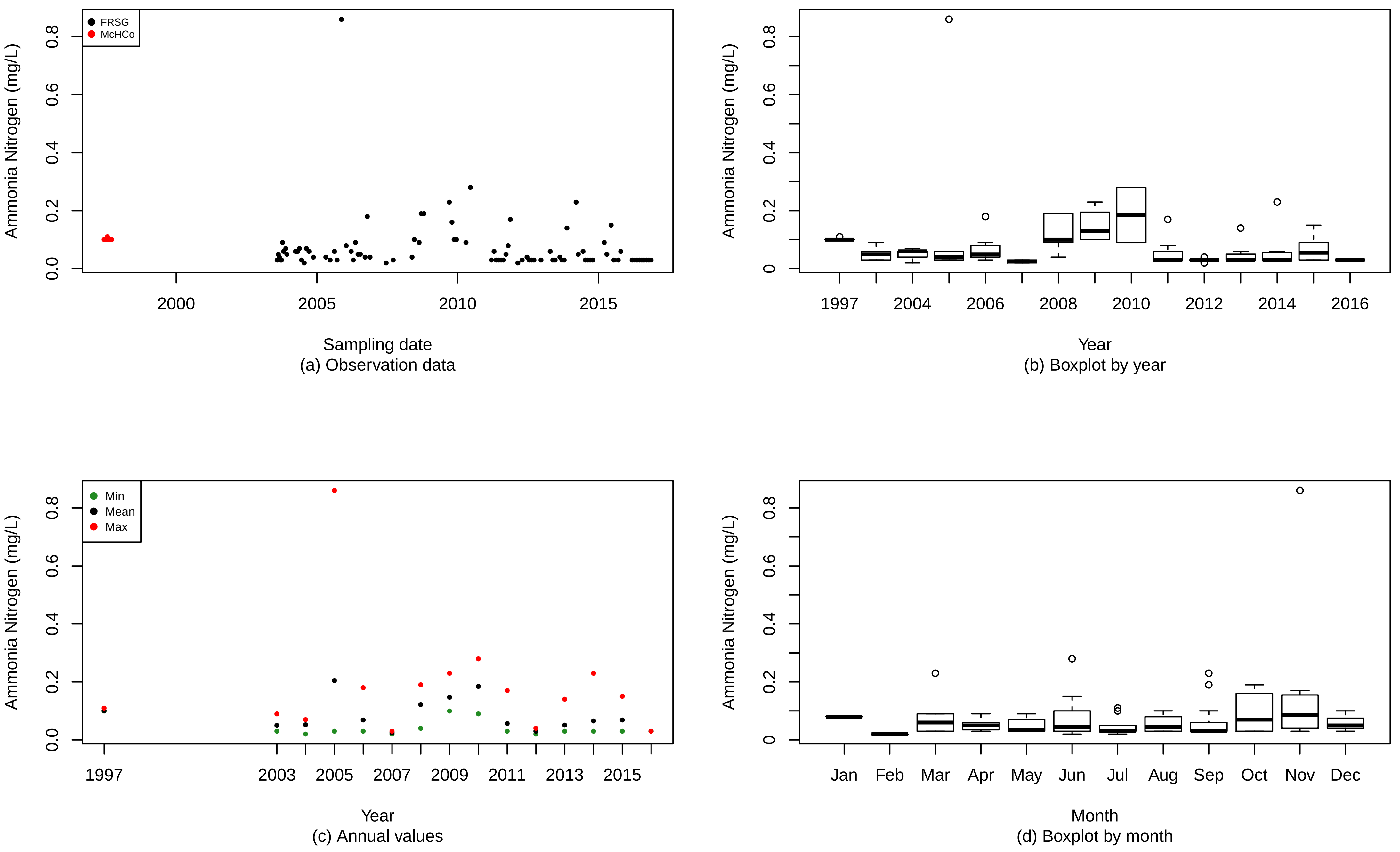


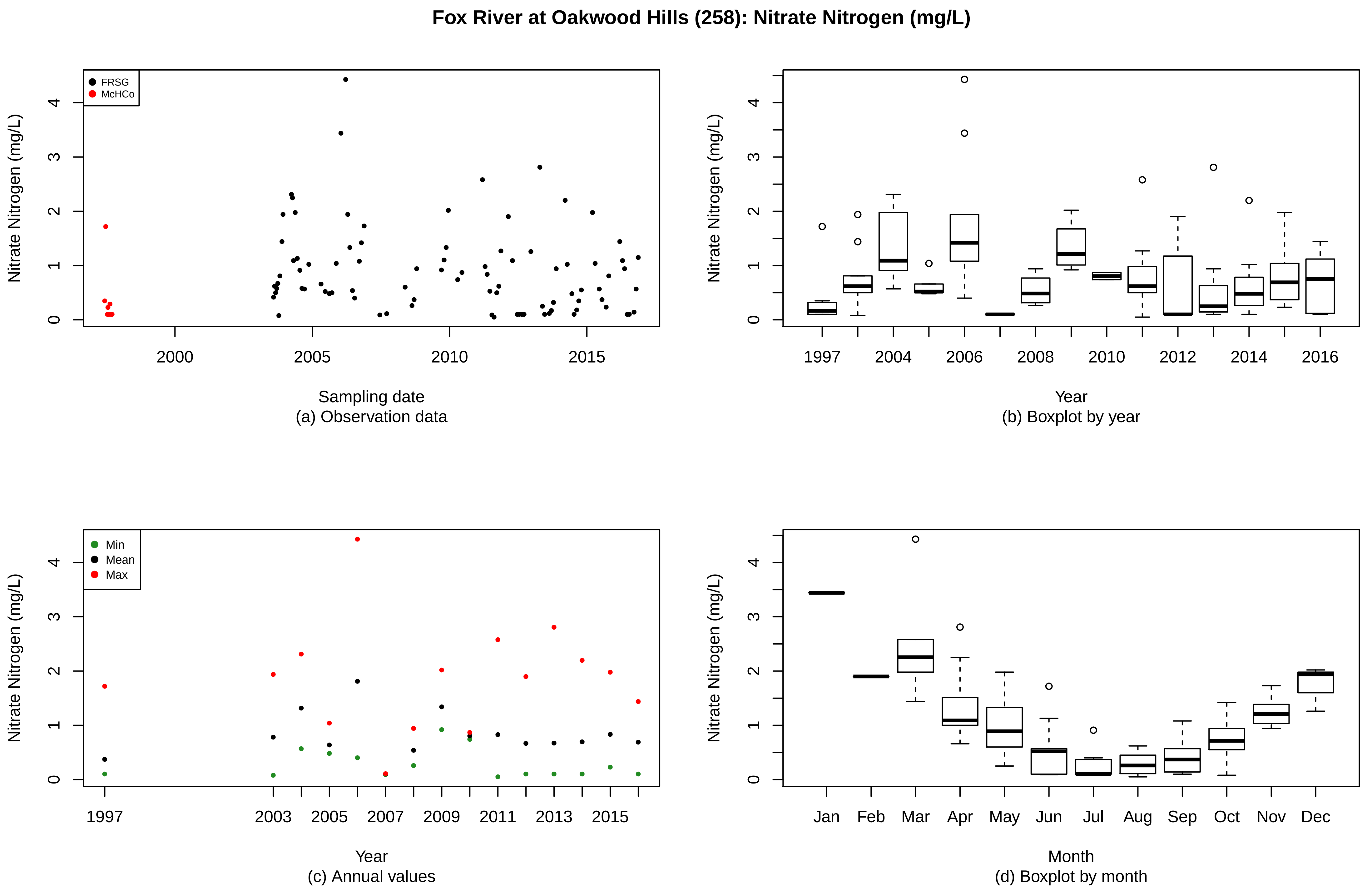
Fox River at Oakwood Hills (258): Dissolved Phosphorus (mg/L)




Fox River at Oakwood Hills (258): Organic Nitrogen (mg/L)
FRSG
Organic Nitrogen (mg/L)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Month
(d) Boxplot by month
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

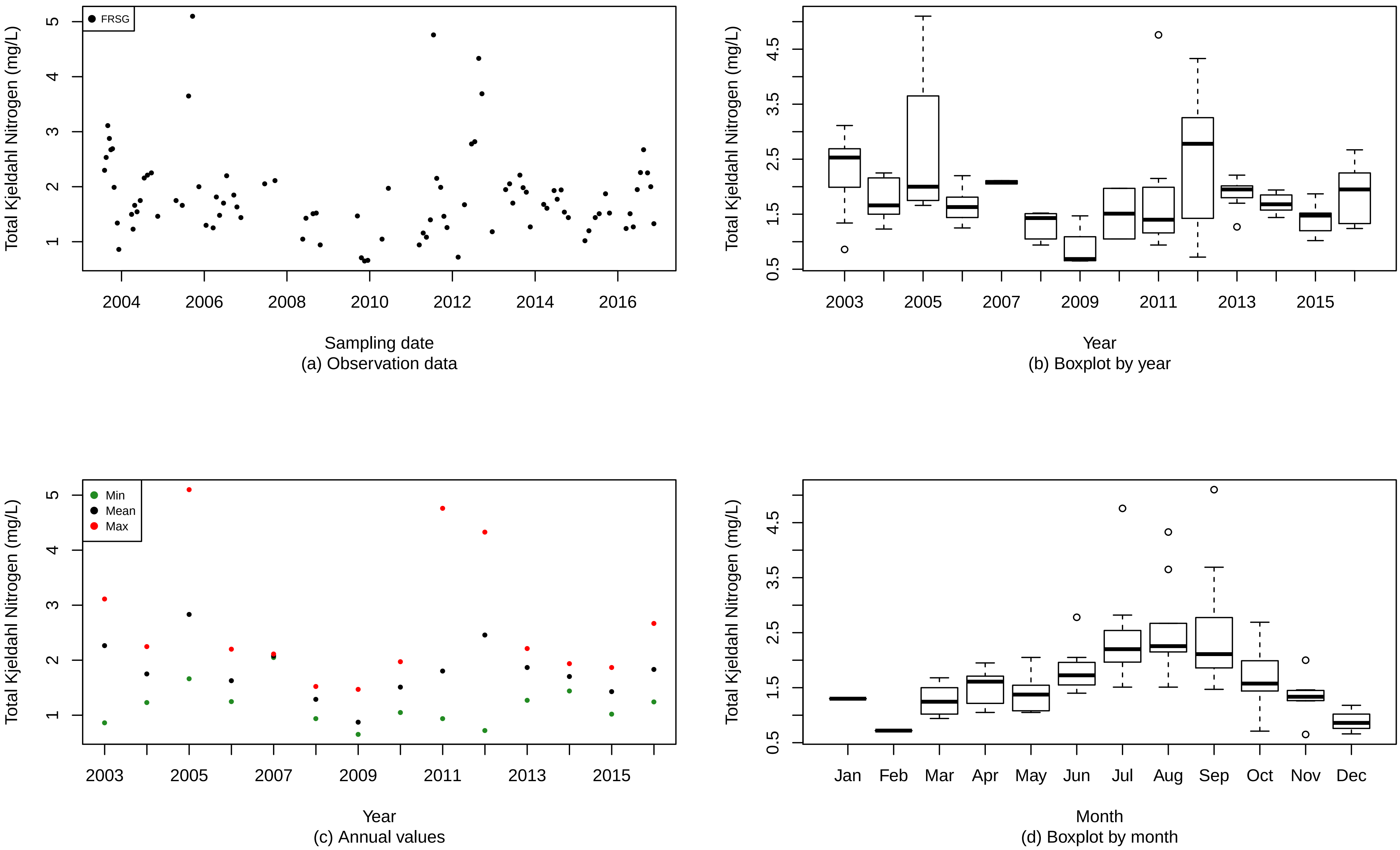
Fox River at Oakwood Hills (258): Ammonia Nitrogen (mg/L)



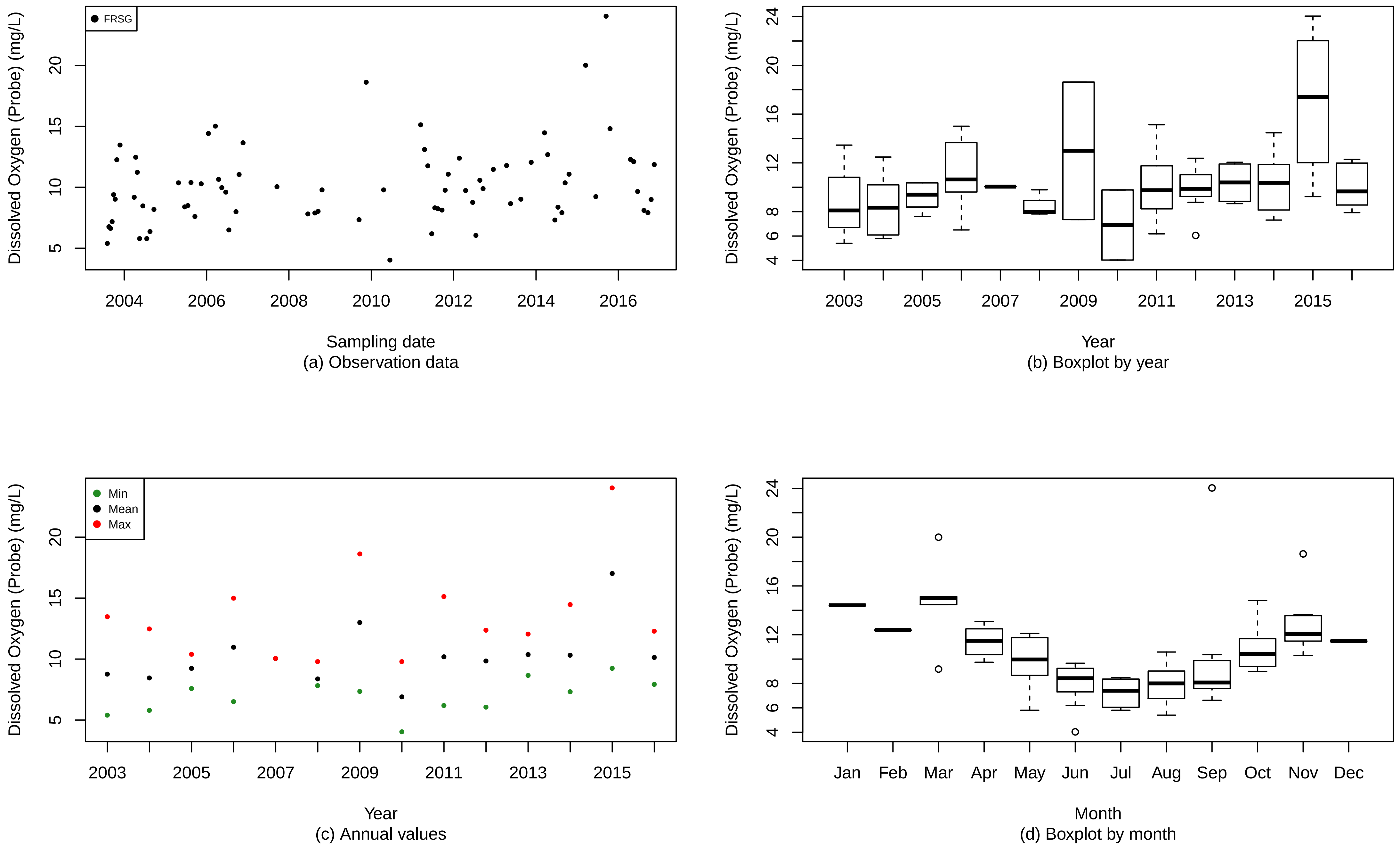


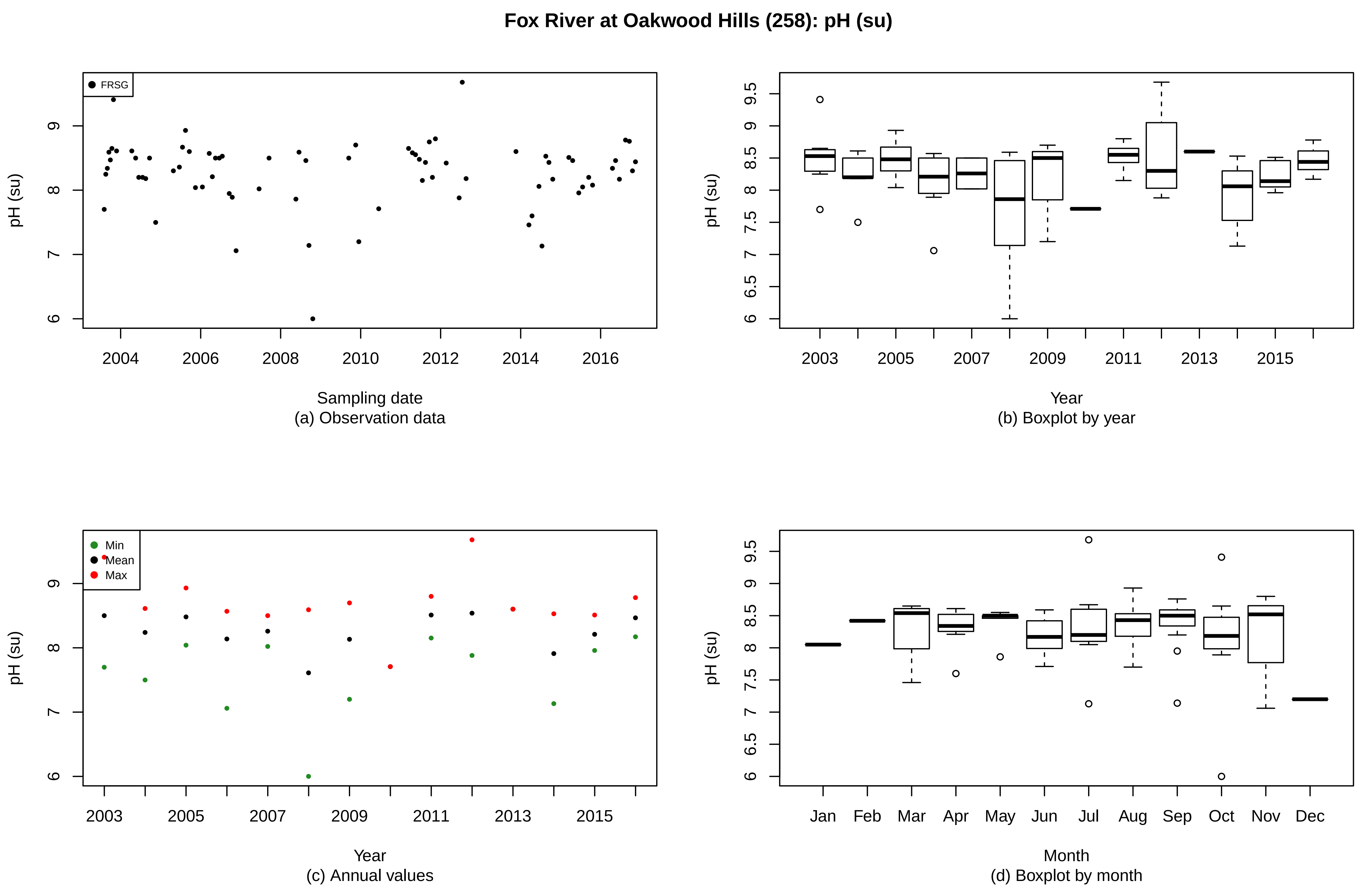
Fox River at Oakwood Hills (258): Nitrate Nitrogen (mg/L)
FRSG
McHCo
Nitrate Nitrogen (mg/L)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Month
(d) Boxplot by month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Fox River at Oakwood Hills (258): Total Kjeldahl Nitrogen (mg/L)



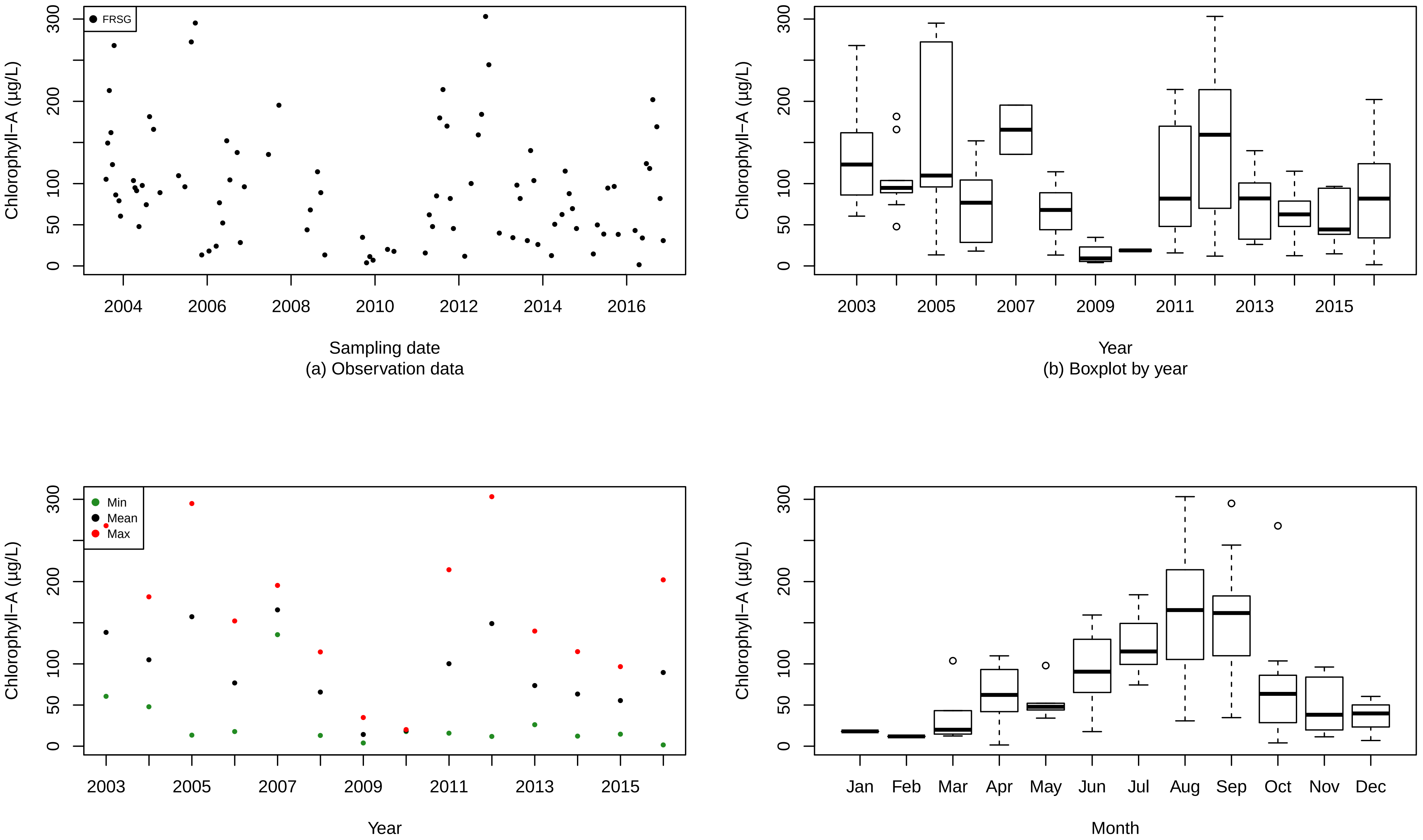
Fox River at Oakwood Hills (258): Dissolved Oxygen (Probe) (mg/L)





Fox River at Oakwood Hills (258): pH (su)
FRSG
pH (su)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
(c) Annual values
Month
(d) Boxplot by month

Fox River at Oakwood Hills (258): Chlorophyll−A (µg/L)



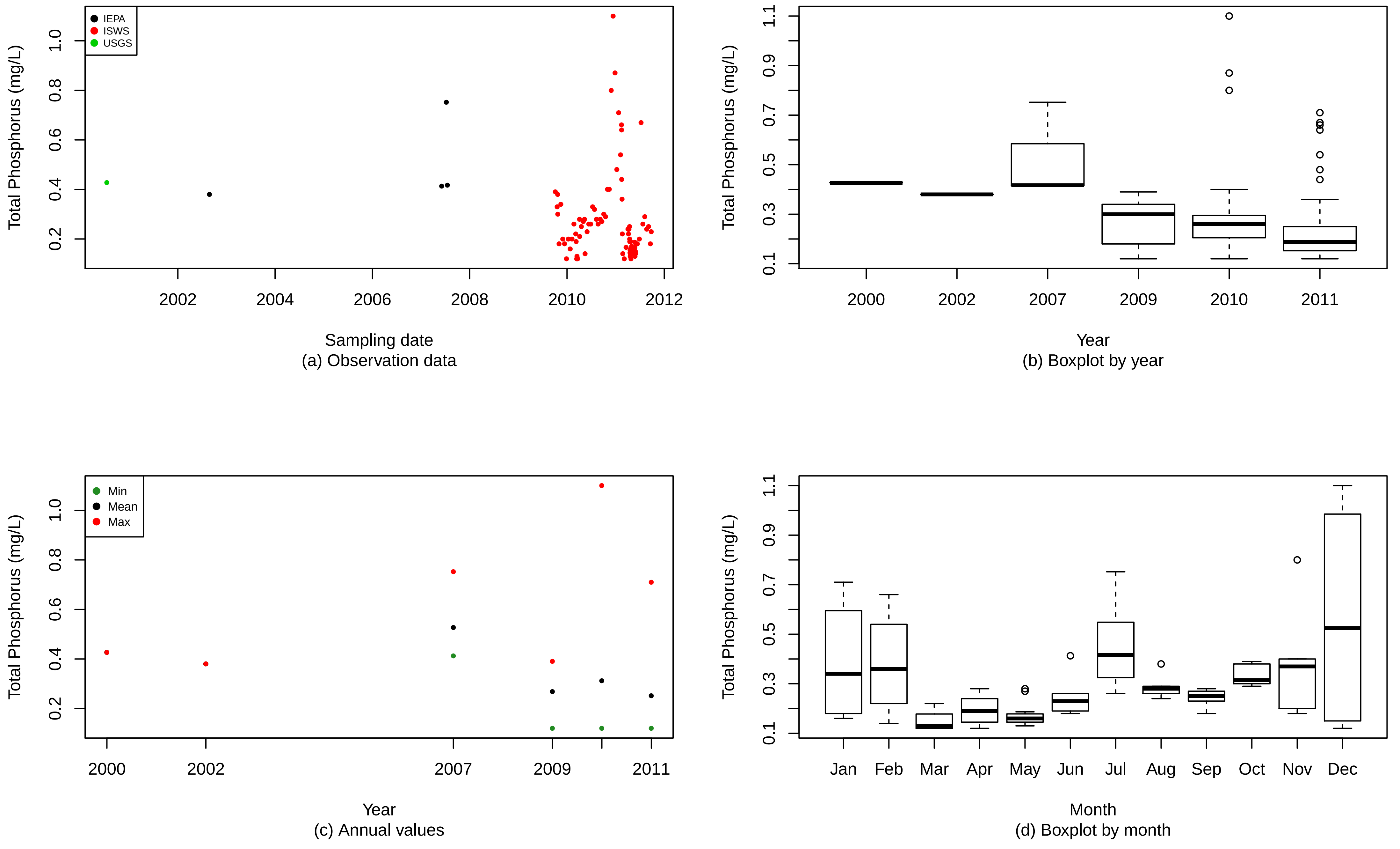
(a) Observation data

(b) Boxplot by year

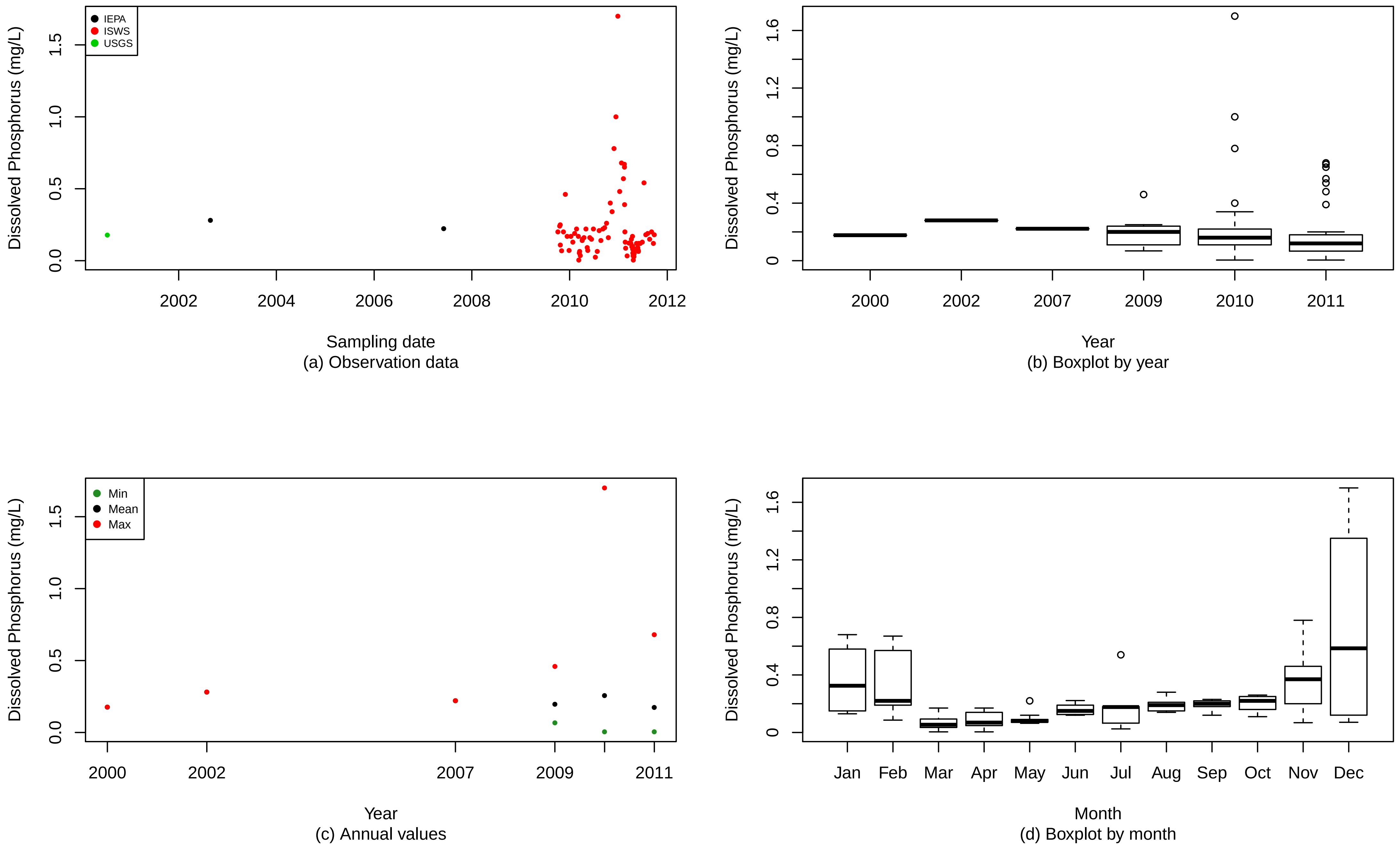
(c) Annual values

(d) Boxplot by month

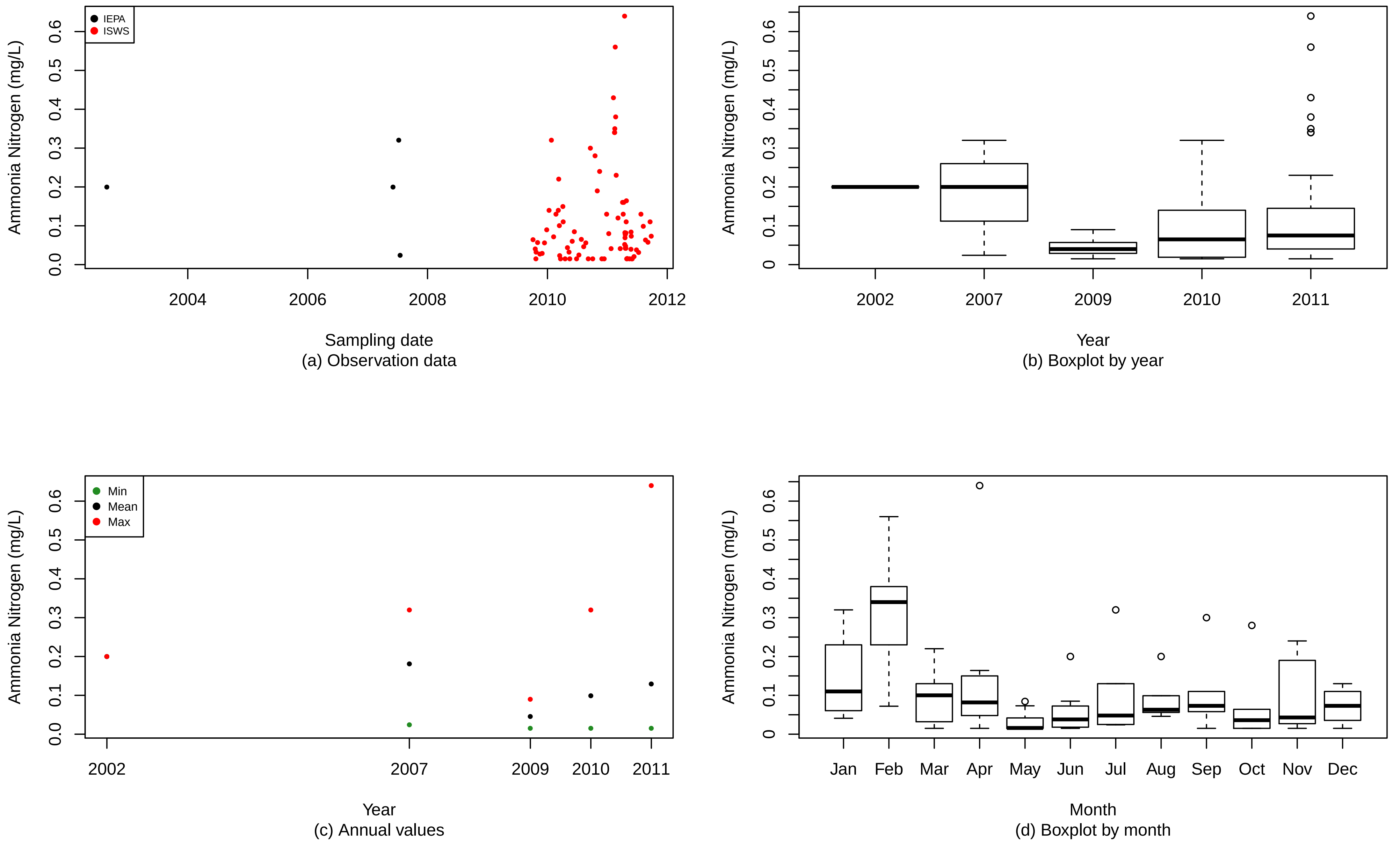
Flint Cr at Kelsey Rd−Lk Barrington (4): Total Phosphorus (mg/L)



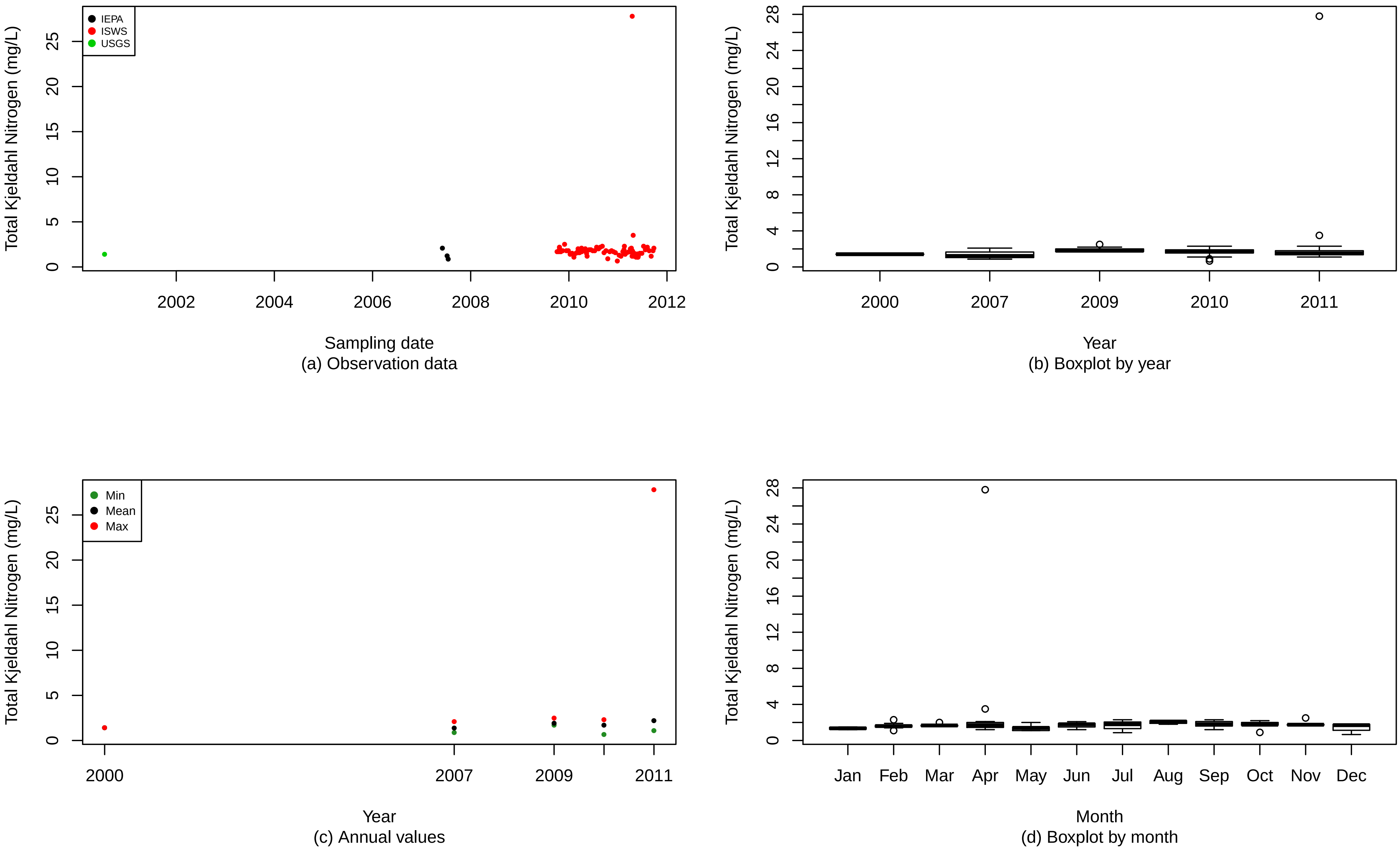
Flint Cr at Kelsey Rd−Lk Barrington (4): Dissolved Phosphorus (mg/L)



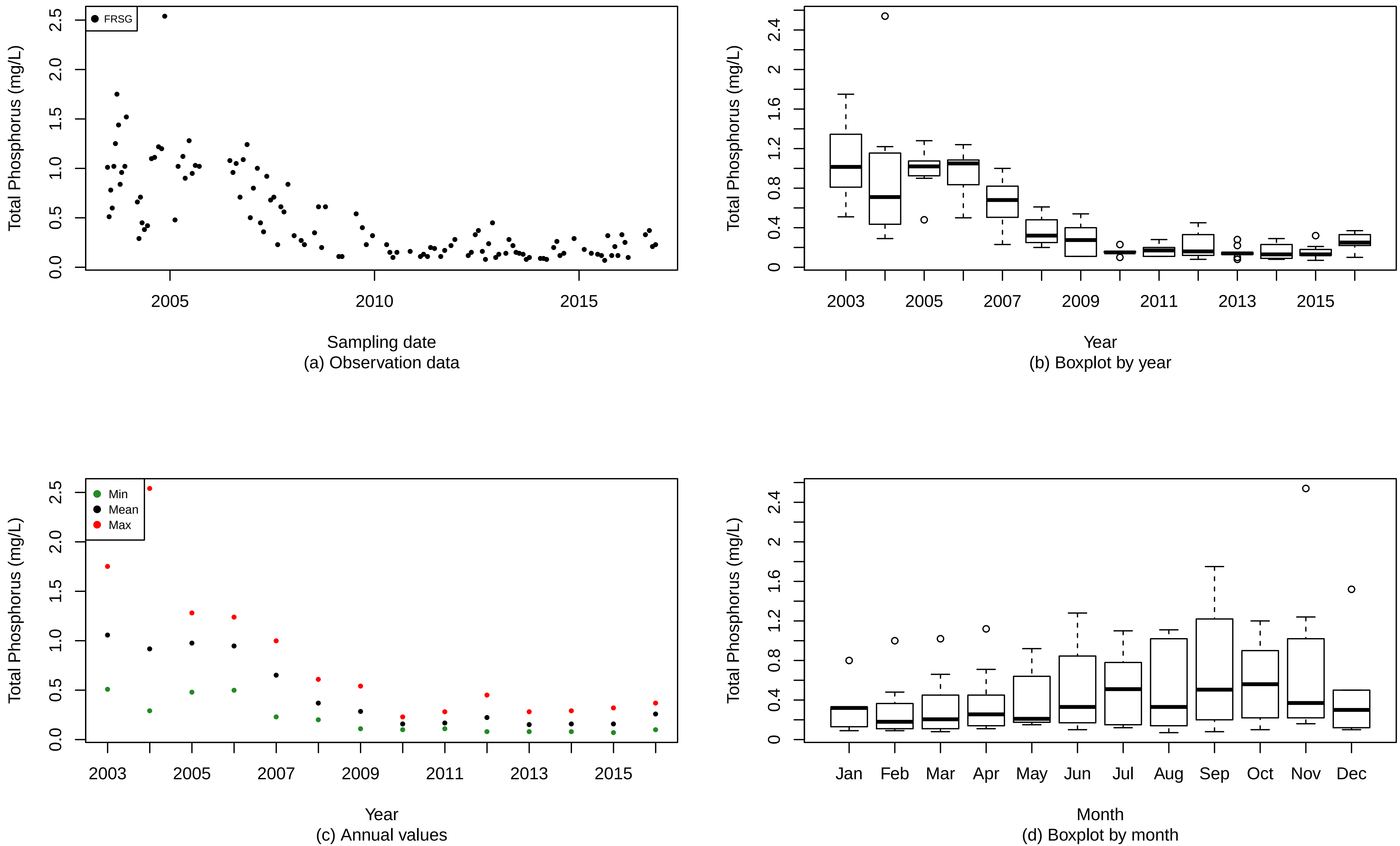
Flint Cr at Kelsey Rd−Lk Barrington (4): Ammonia Nitrogen (mg/L)

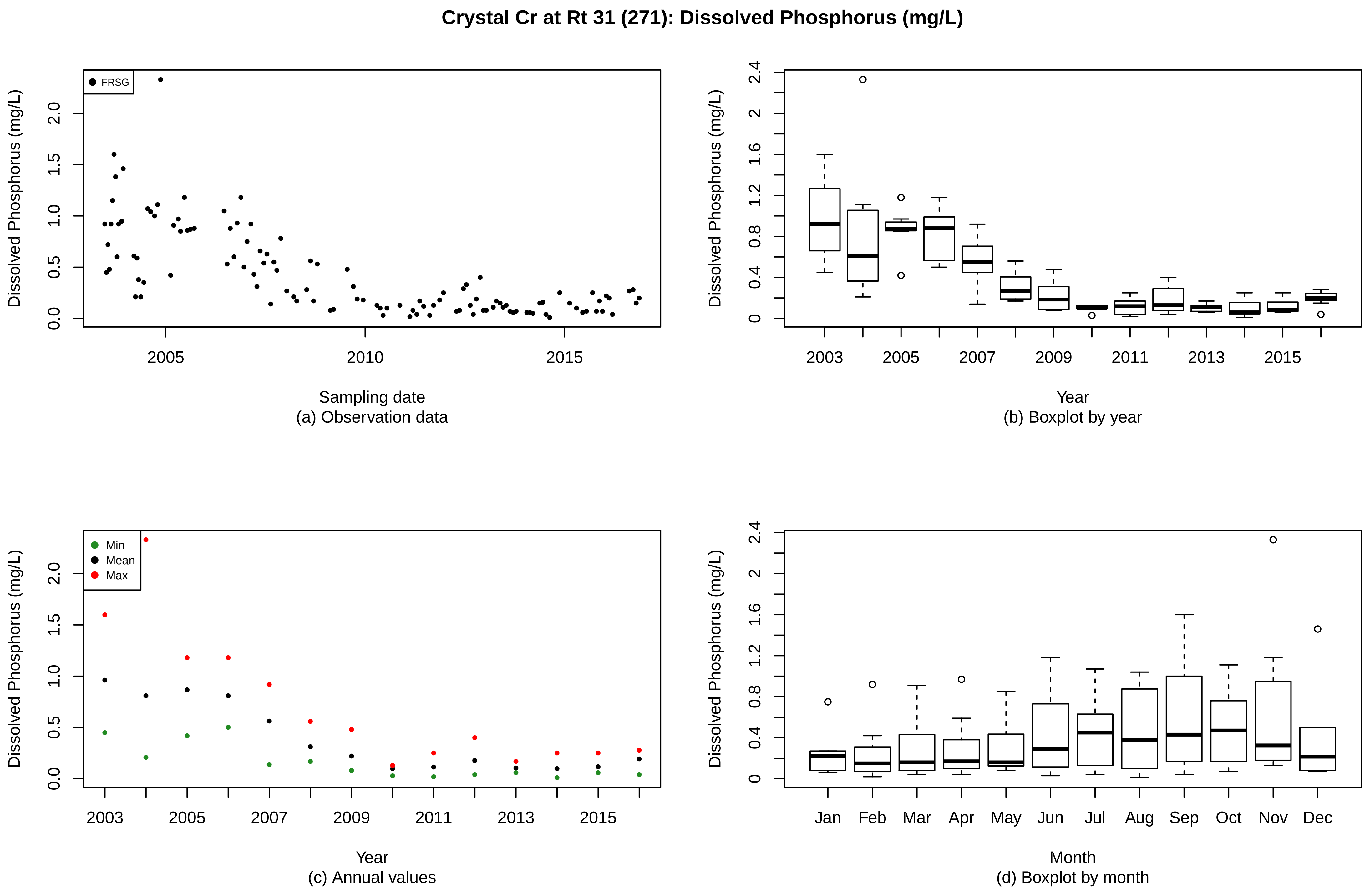


Flint Cr at Kelsey Rd−Lk Barrington (4): Total Kjeldahl Nitrogen (mg/L)

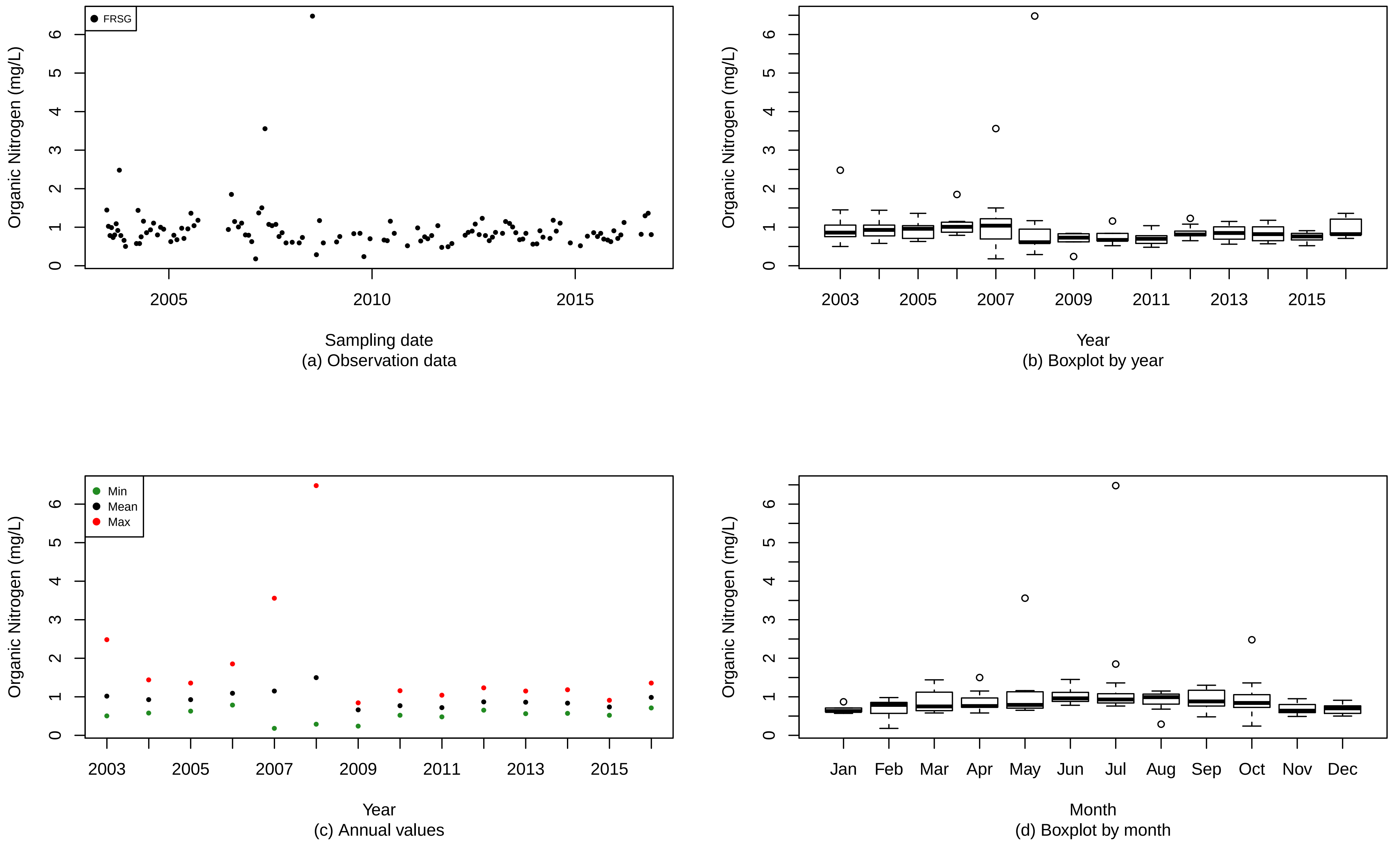


Crystal Cr at Rt 31 (271): Total Phosphorus (mg/L)

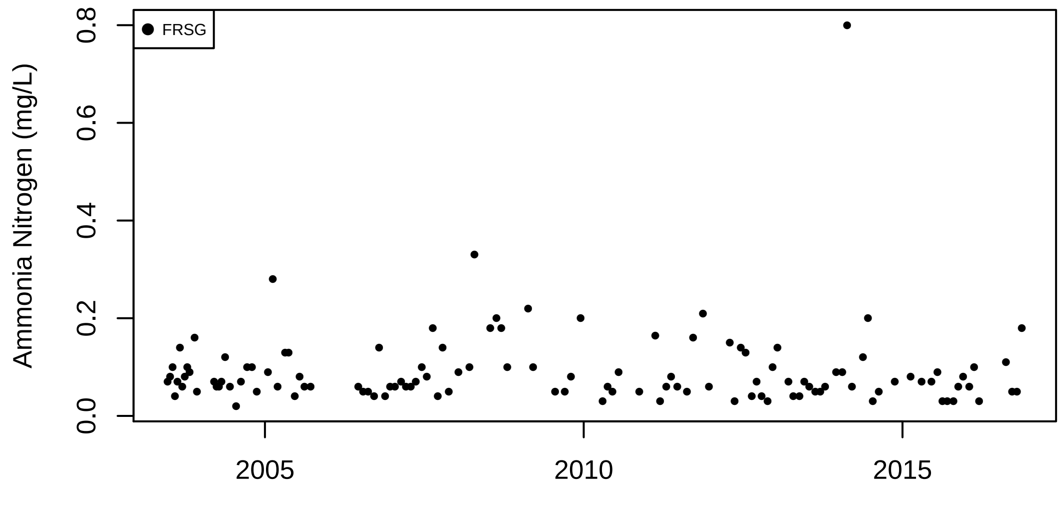



Crystal Cr at Rt 31 (271): Dissolved Phosphorus (mg/L)
FRSG
Dissolved Phosphorus (mg/L)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Month
(d) Boxplot by month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

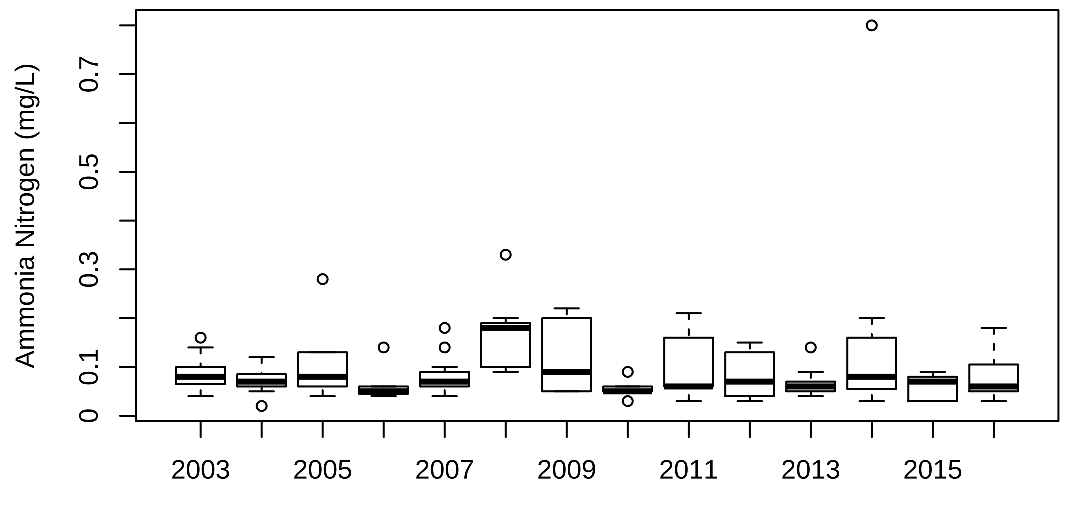
Crystal Cr at Rt 31 (271): Organic Nitrogen (mg/L)



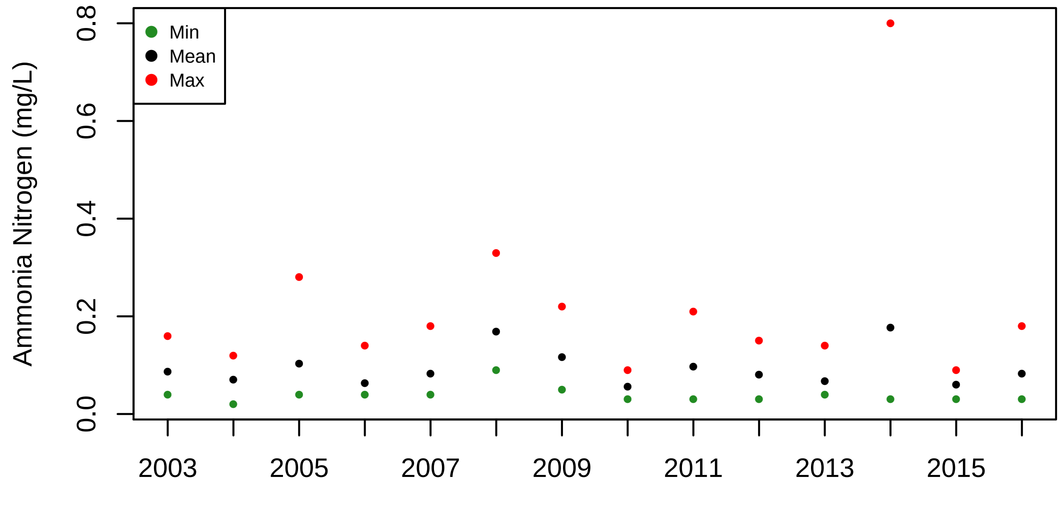
Crystal Cr at Rt 31 (271): Ammonia Nitrogen (mg/L)



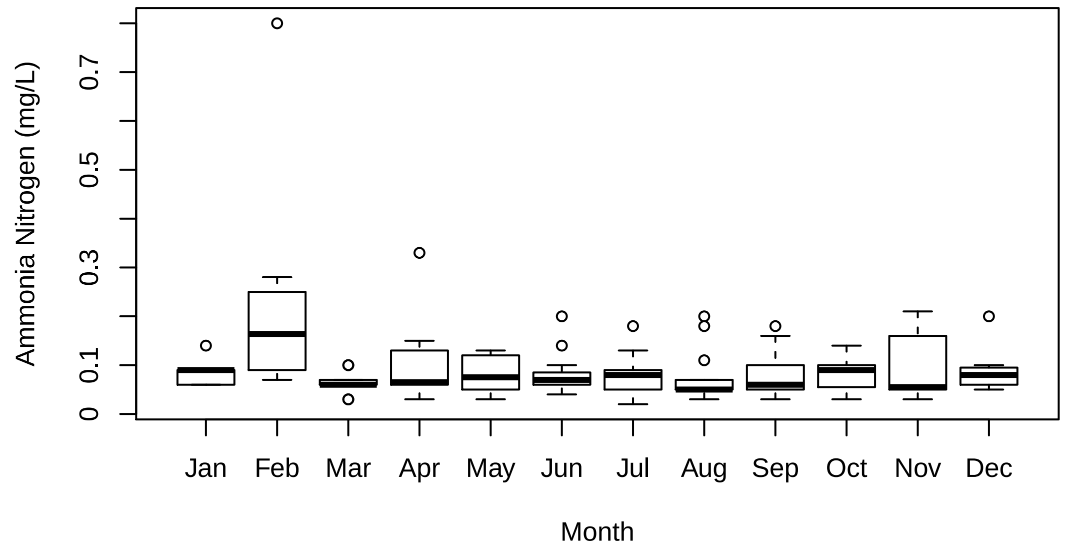
(a) Observation data



(b) Boxplot by year

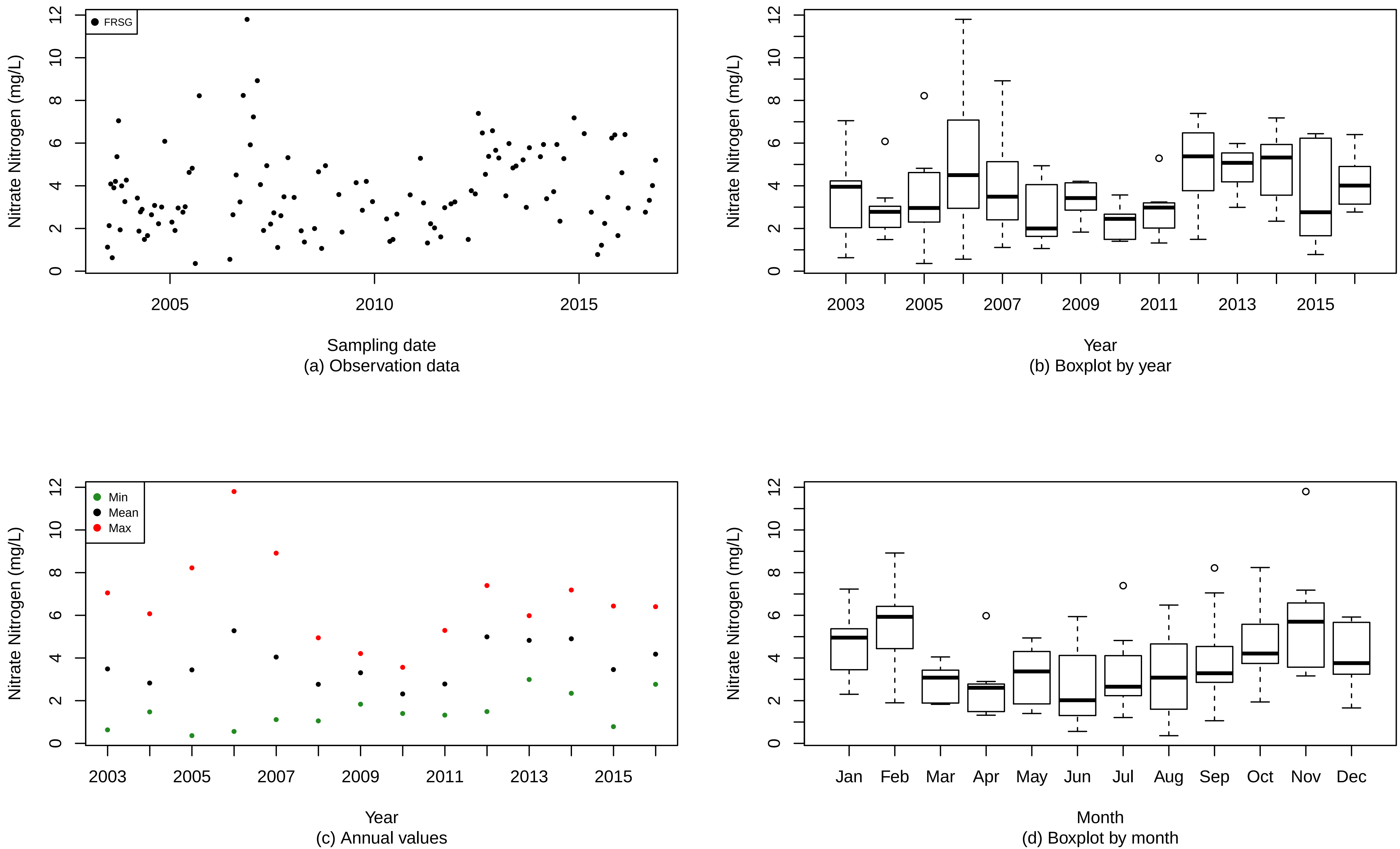


(c) Annual values

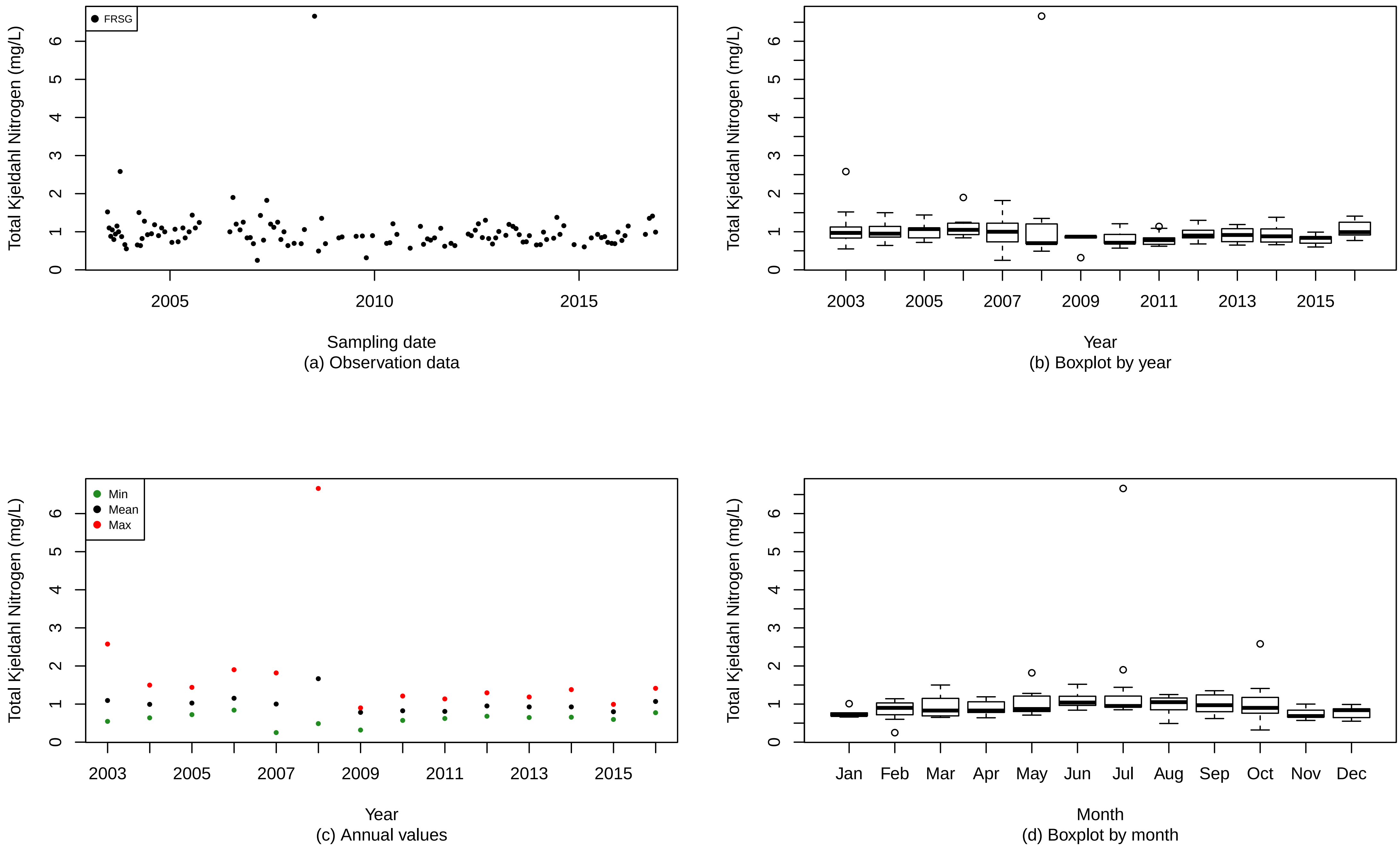


(d) Boxplot by month

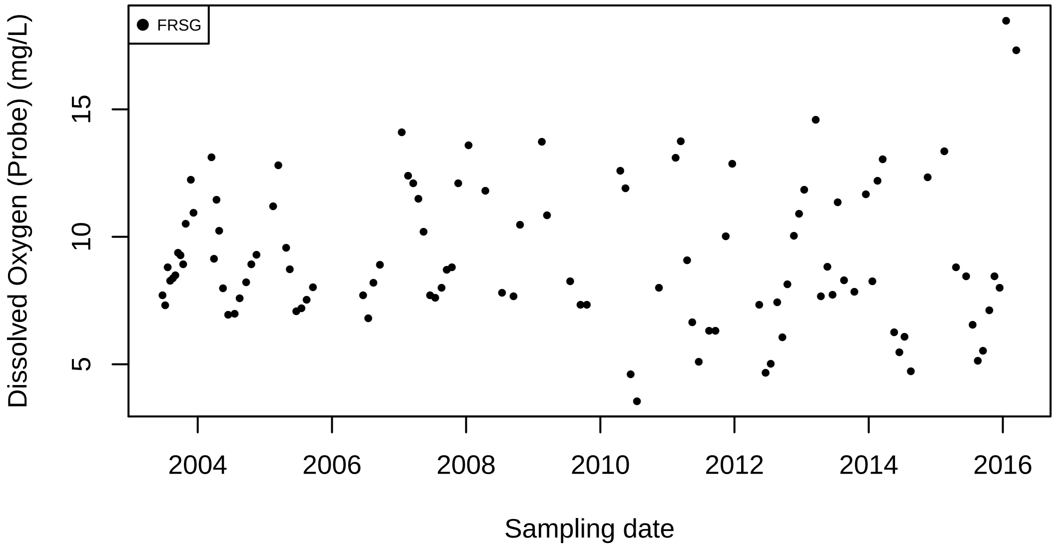
Crystal Cr at Rt 31 (271): Nitrate Nitrogen (mg/L)



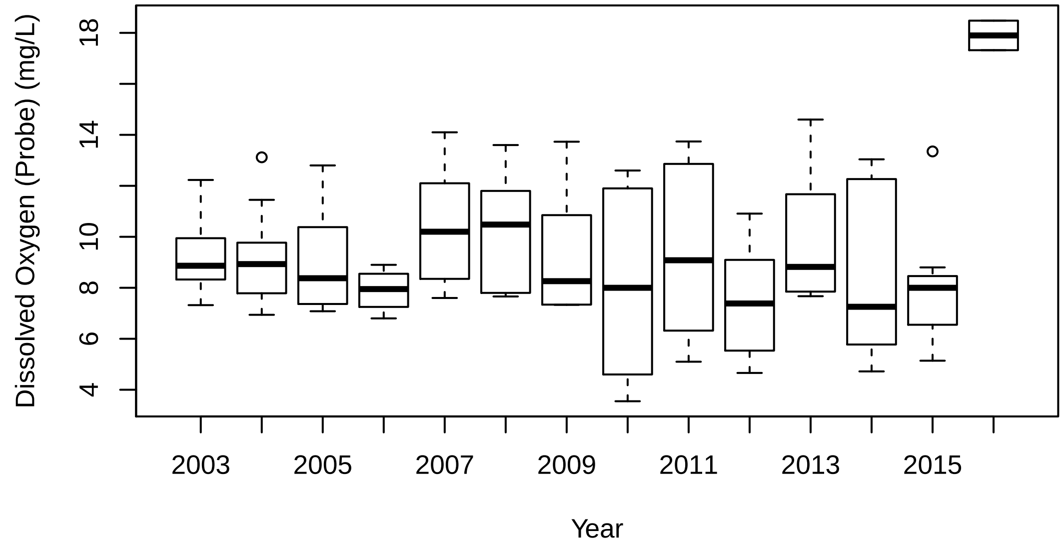
Crystal Cr at Rt 31 (271): Total Kjeldahl Nitrogen (mg/L)



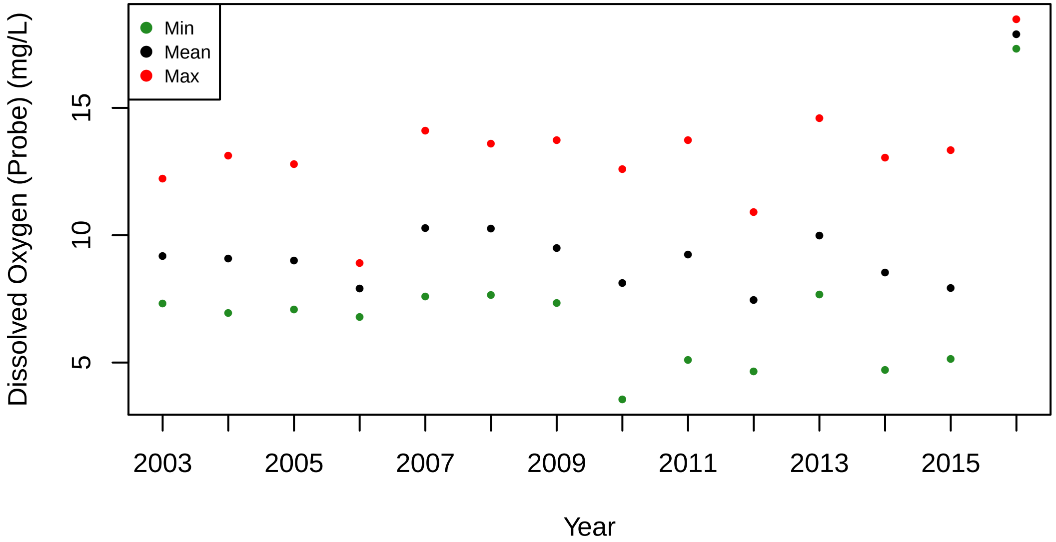
Crystal Cr at Rt 31 (271): Dissolved Oxygen (Probe) (mg/L)



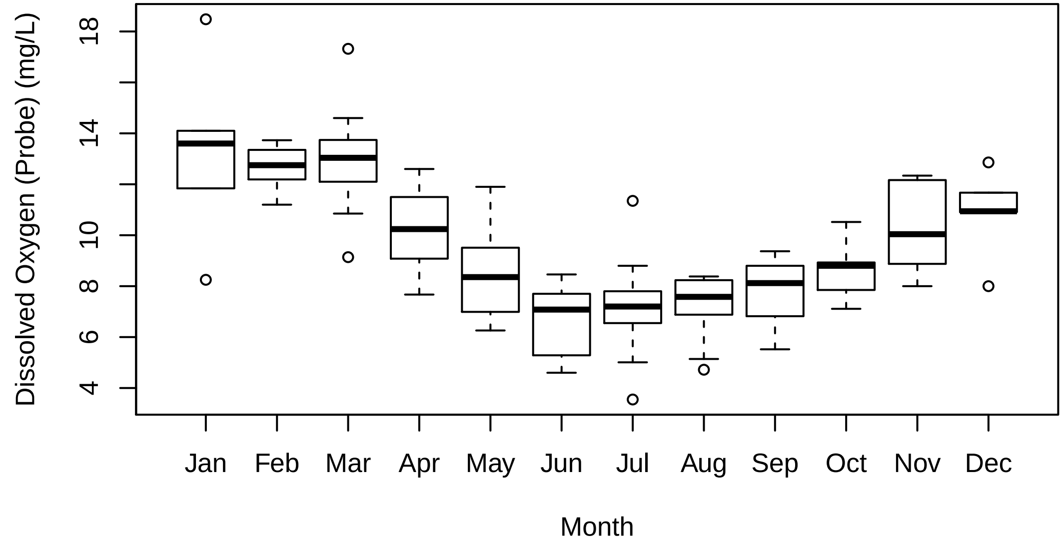
(a) Observation data



(b) Boxplot by year

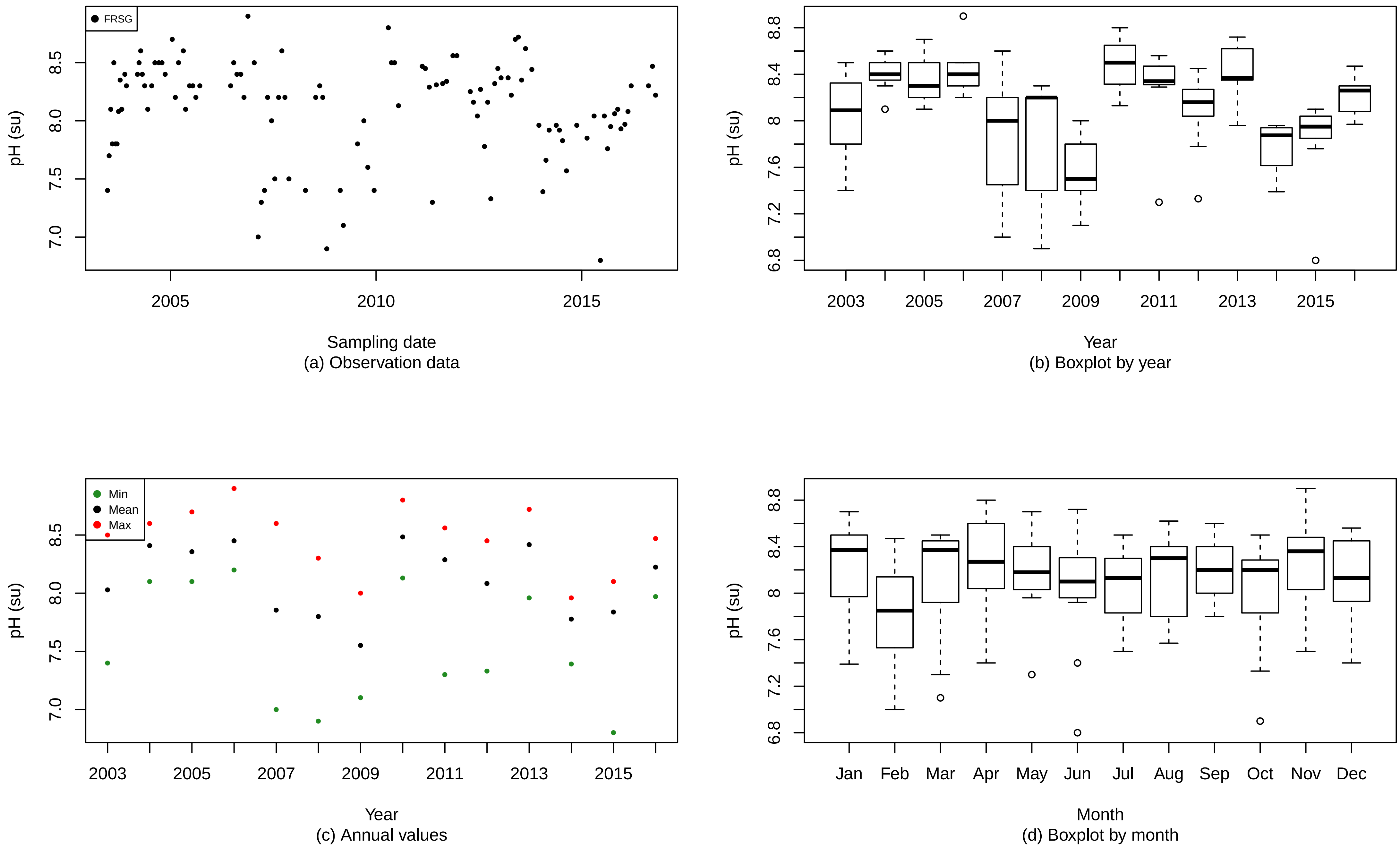


(c) Annual values

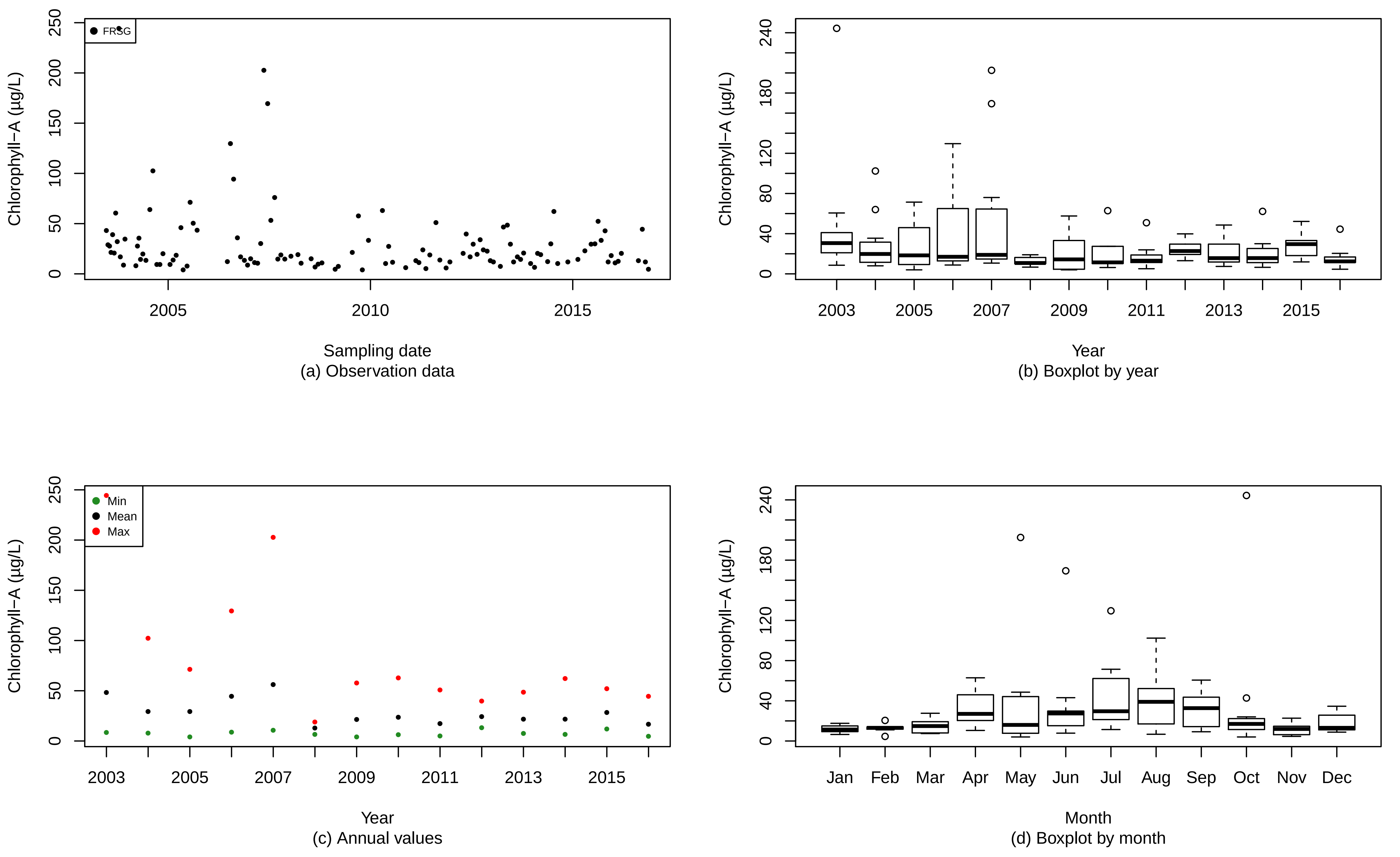


(d) Boxplot by month

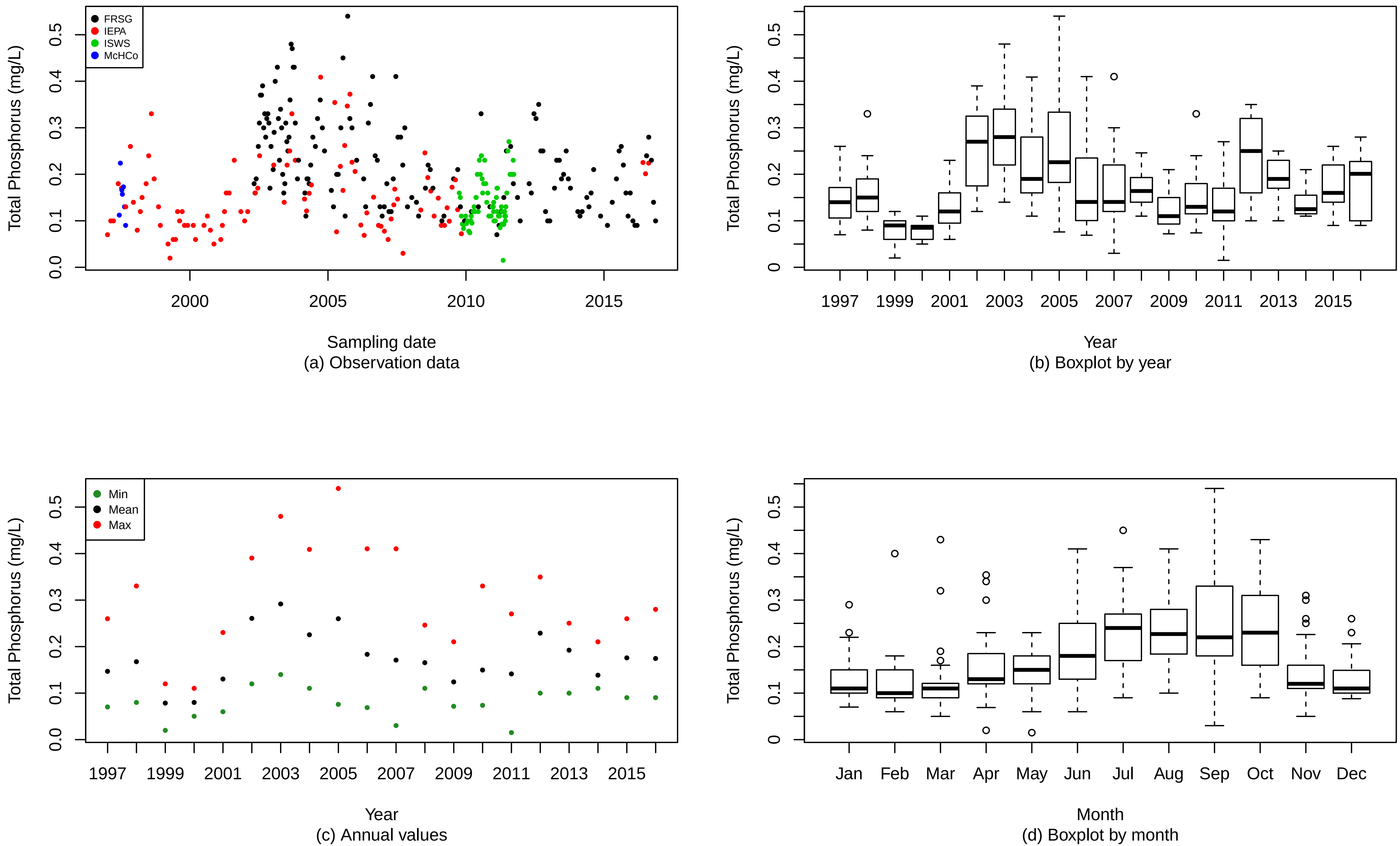
Crystal Cr at Rt 31 (271): pH (su)

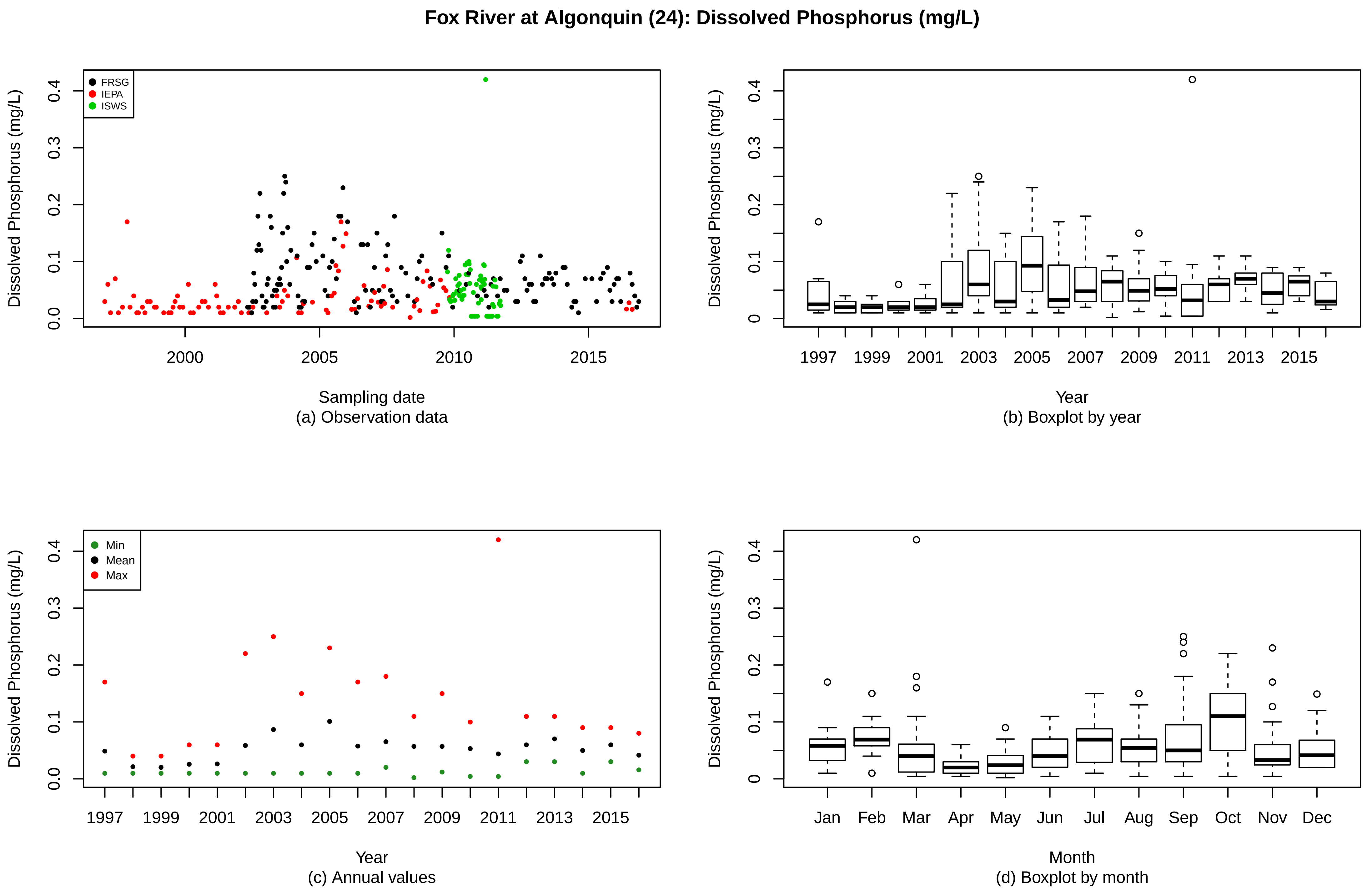


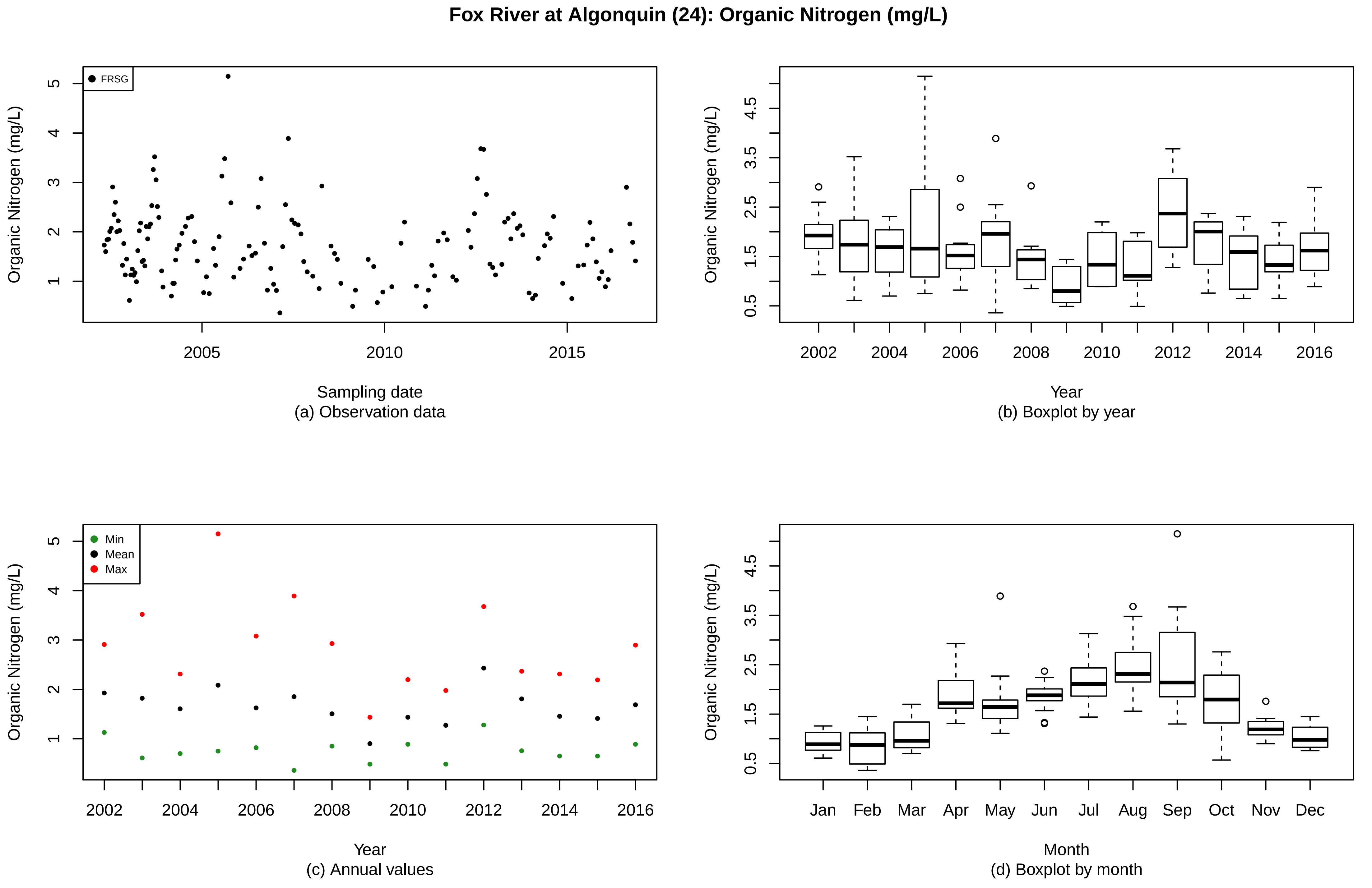
Crystal Cr at Rt 31 (271): Chlorophyll−A (µg/L)



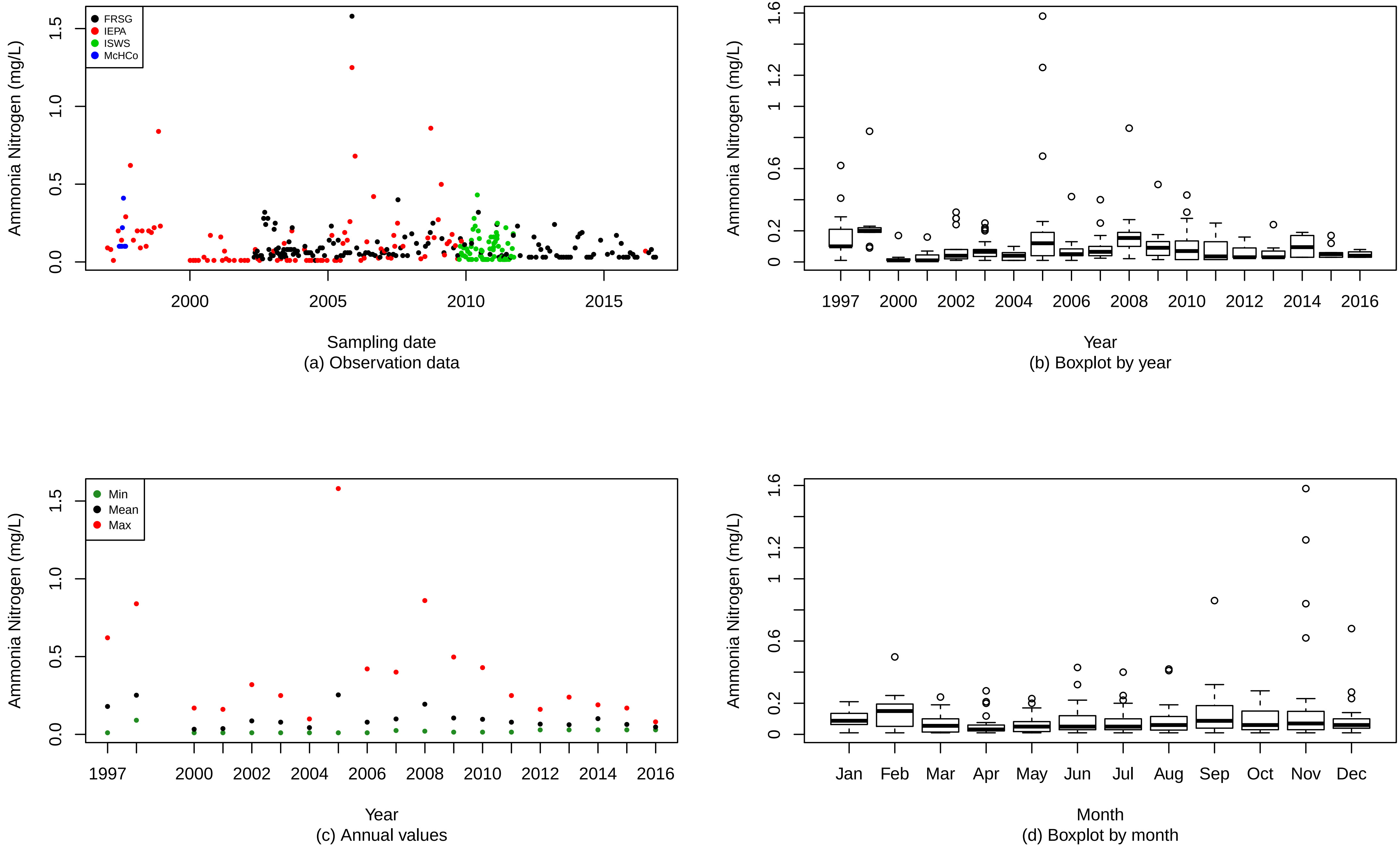
Fox River at Algonquin (24): Total Phosphorus (mg/L)



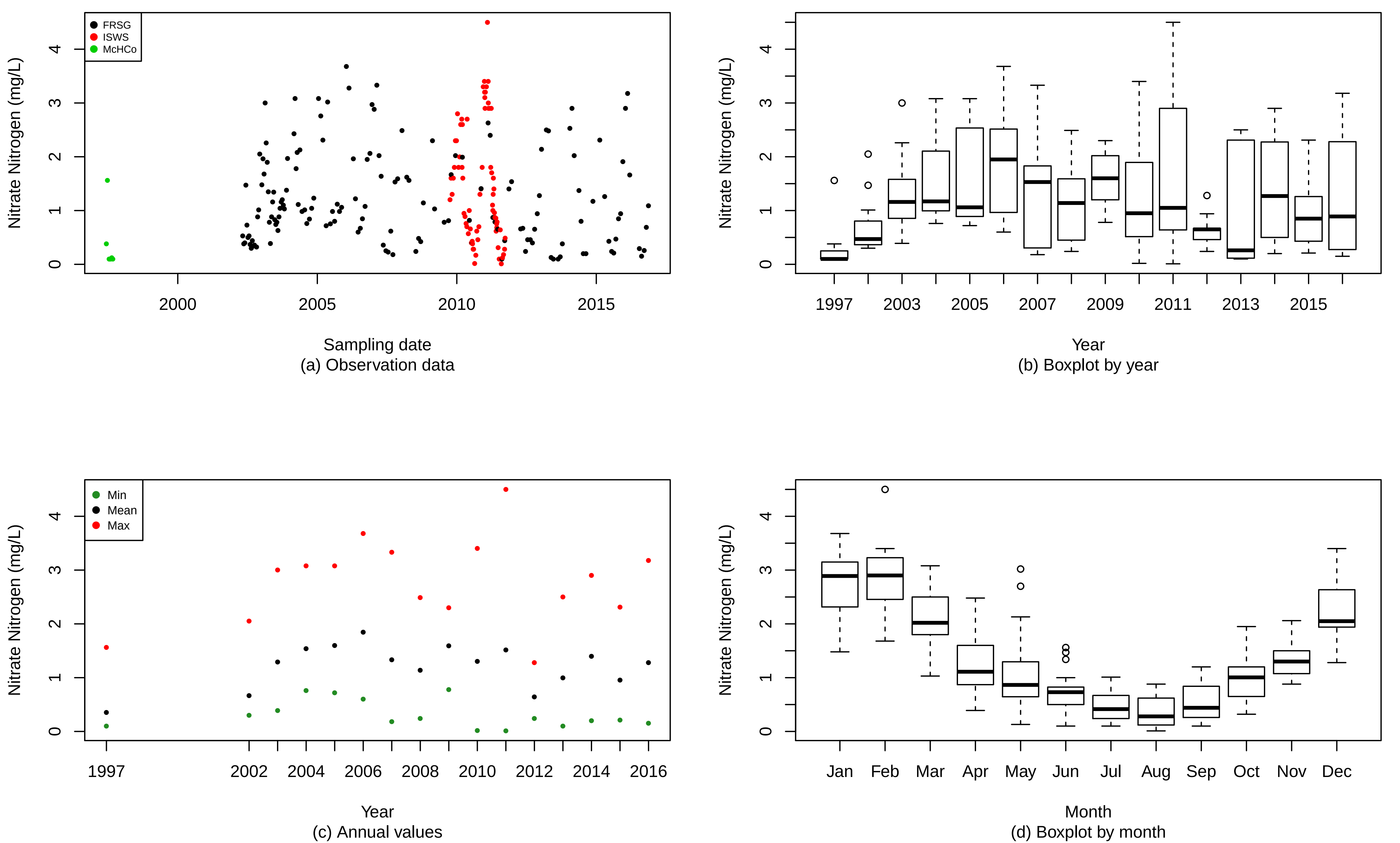

Fox River at Algonquin (24): Dissolved Phosphorus (mg/L)
FRSG
IEPA
ISWS
Dissolved Phosphorus (mg/L)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Month
(d) Boxplot by month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

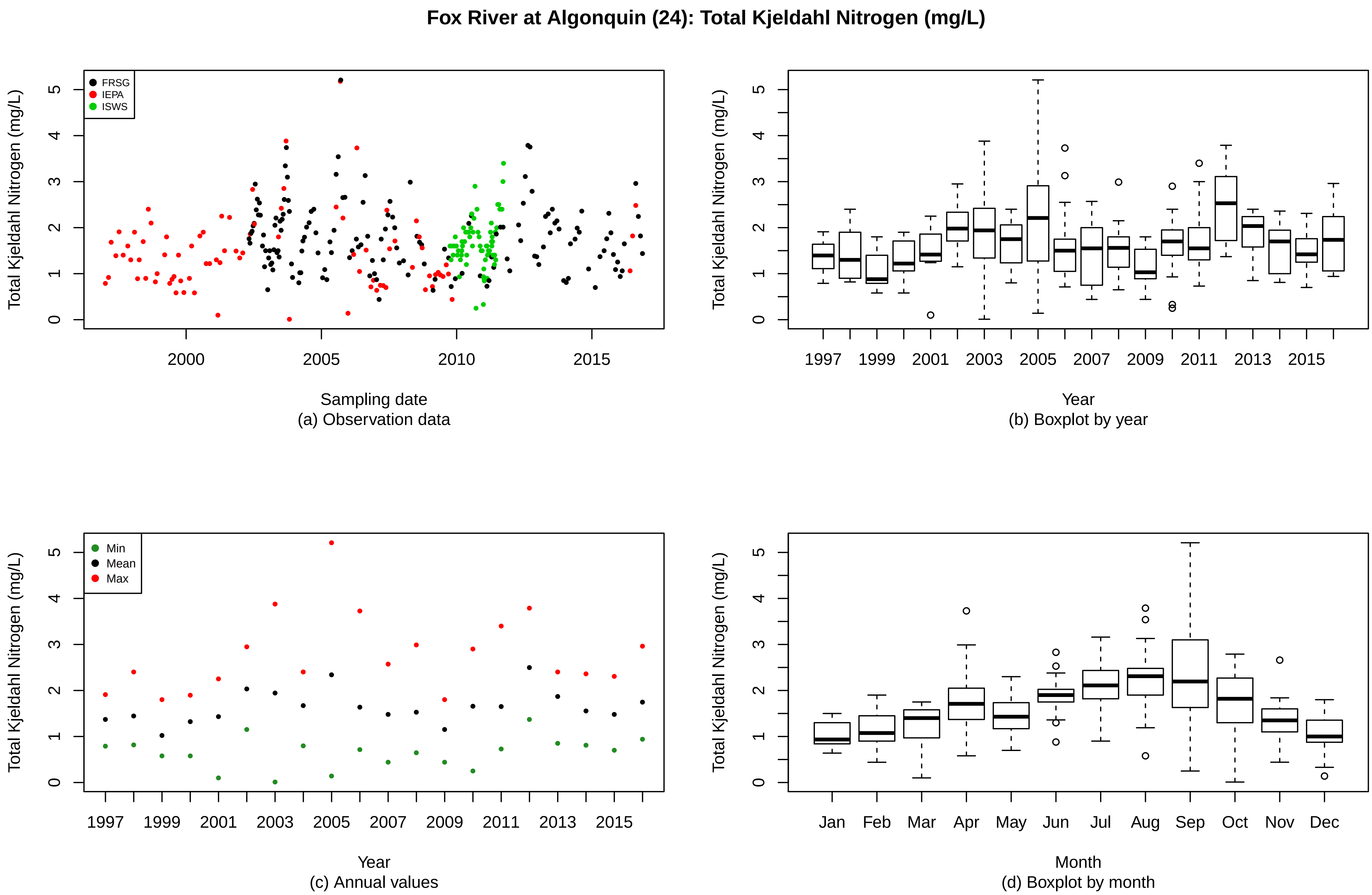

Fox River at Algonquin (24): Organic Nitrogen (mg/L)
FRSG
Organic Nitrogen (mg/L)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
(d) Boxplot by month

Fox River at Algonquin (24): Ammonia Nitrogen (mg/L)

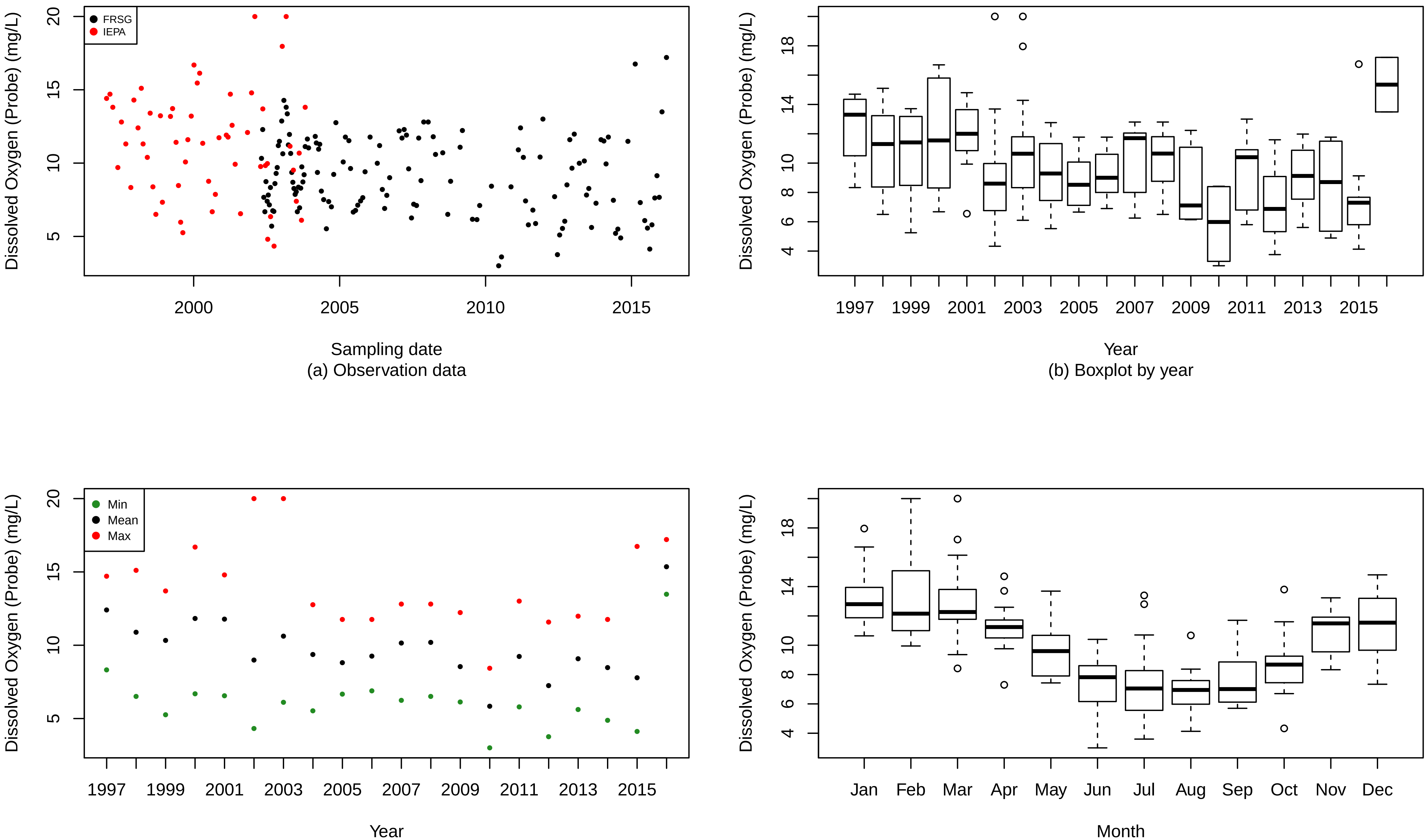


Fox River at Algonquin (24): Nitrate Nitrogen (mg/L)




Fox River at Algonquin (24): Total Kjeldahl Nitrogen (mg/L)
FRSG
IEPA
ISWS
Total Kjeldahl Nitrogen (mg/L)
0
1
2
3
4
5
2000
2005
2010
2015
Sampling date
(a) Observation data
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
(d) Boxplot by month

Fox River at Algonquin (24): Dissolved Oxygen (Probe) (mg/L)



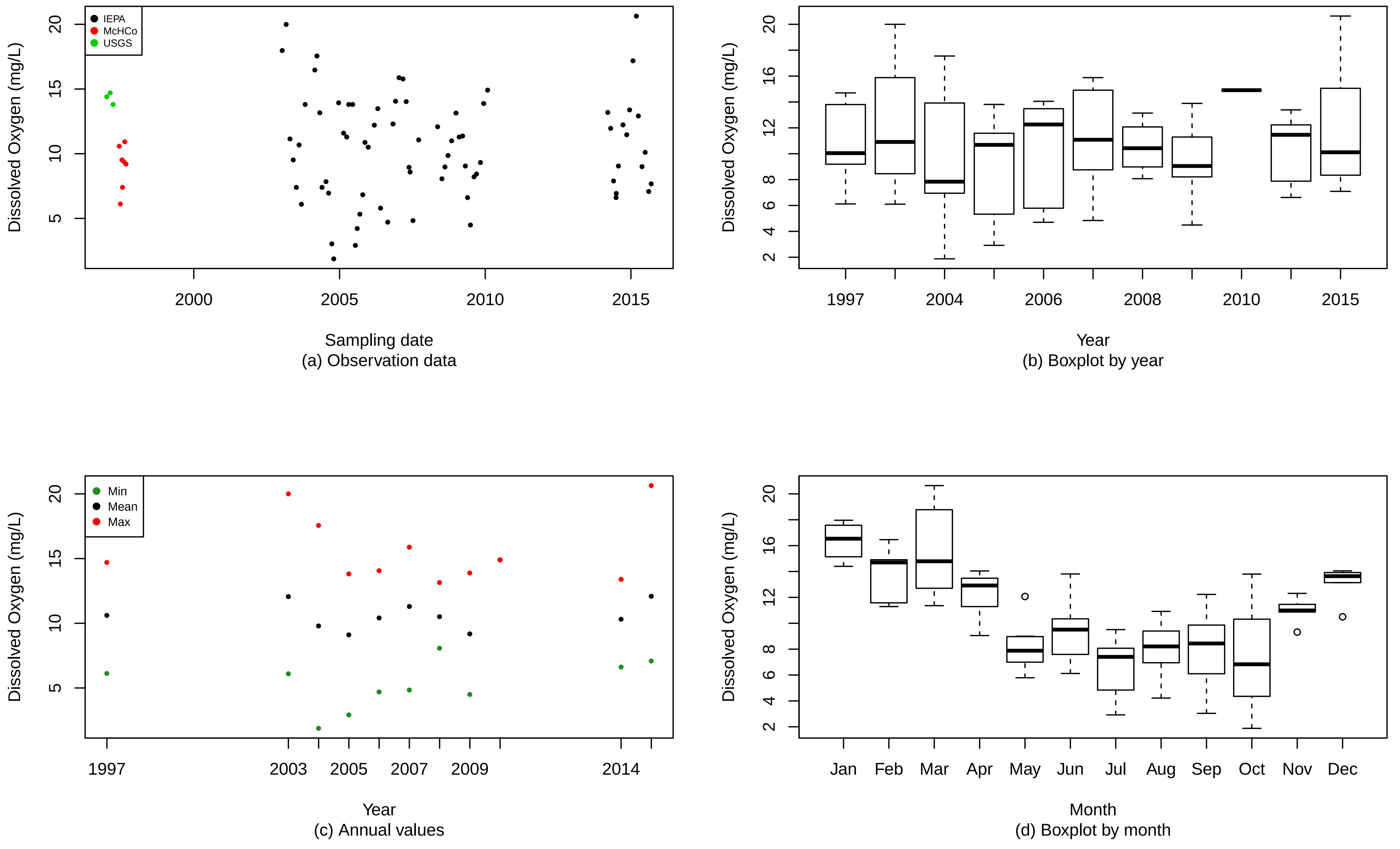
(a) Observation data

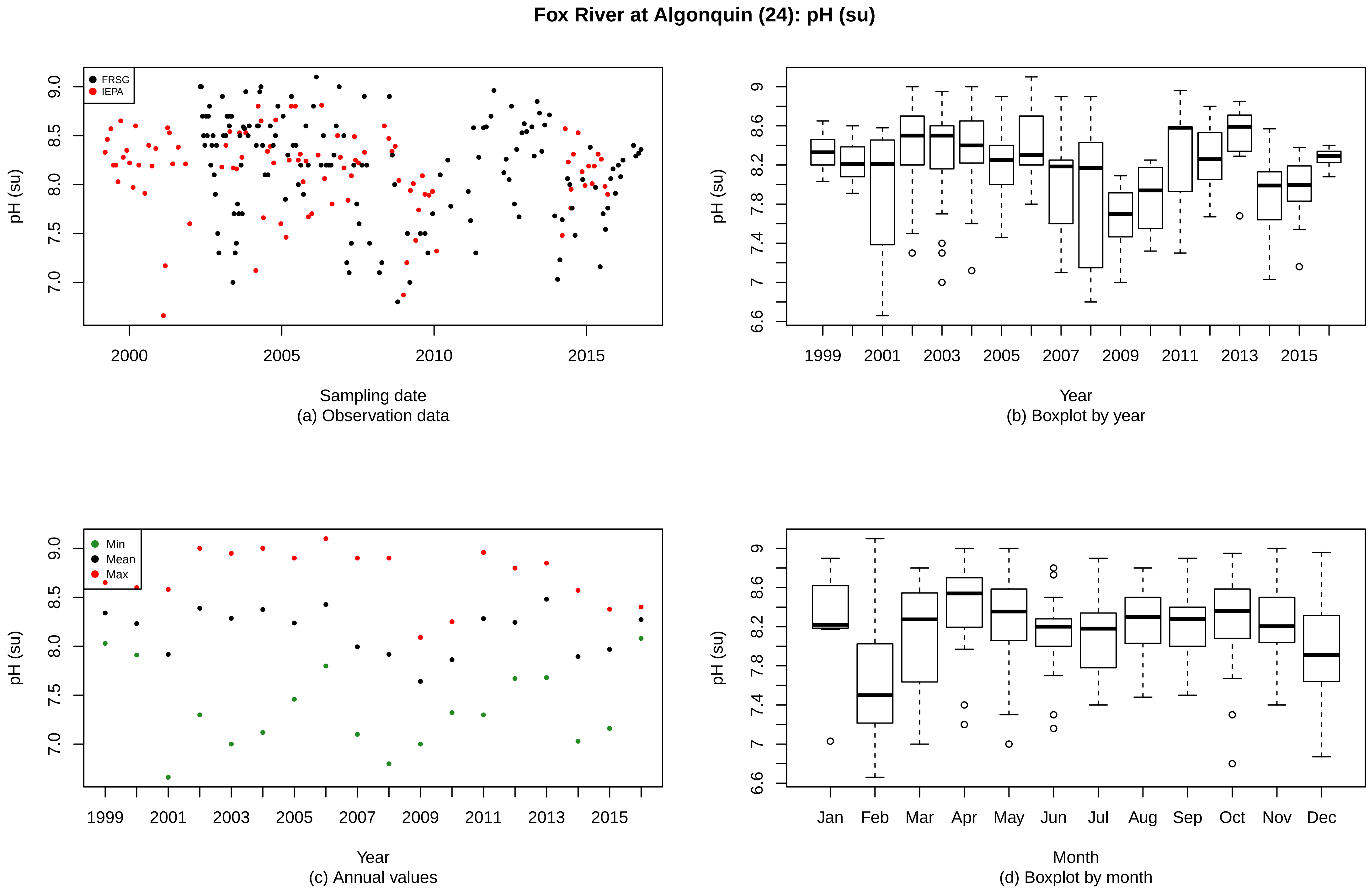
(b) Boxplot by year

(c) Annual values

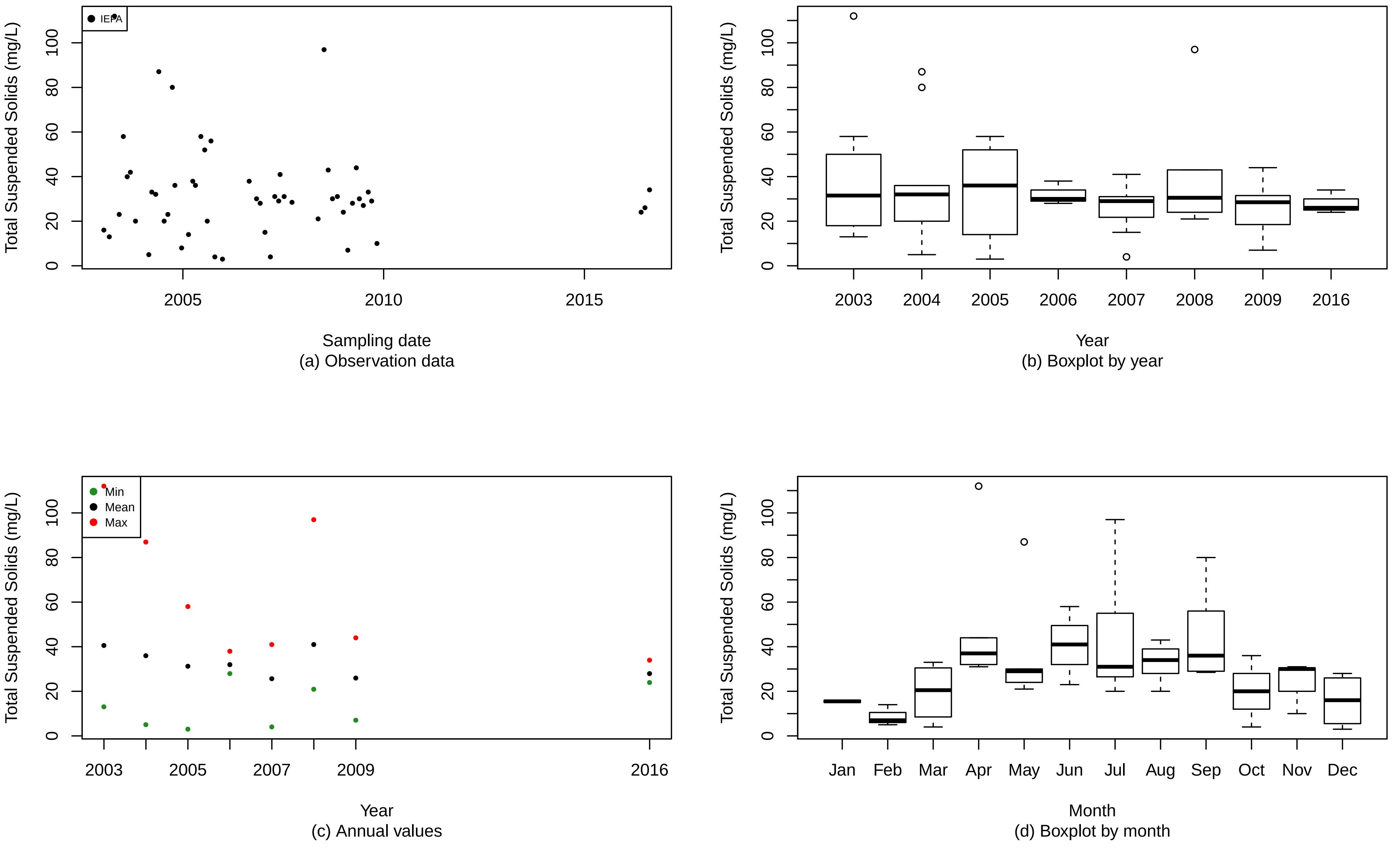
(d) Boxplot by month

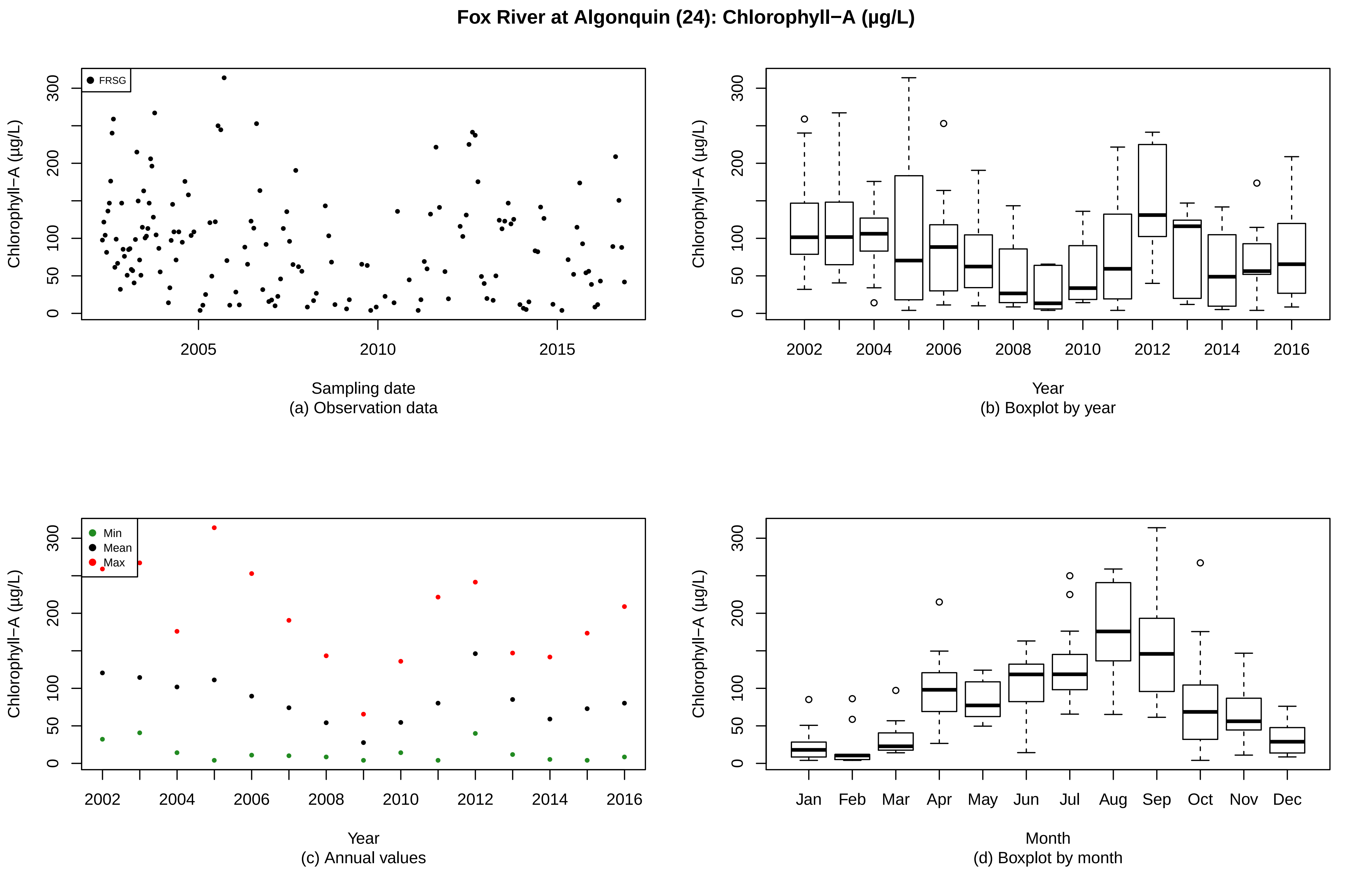
Fox River at Algonquin (24): Dissolved Oxygen (mg/L)



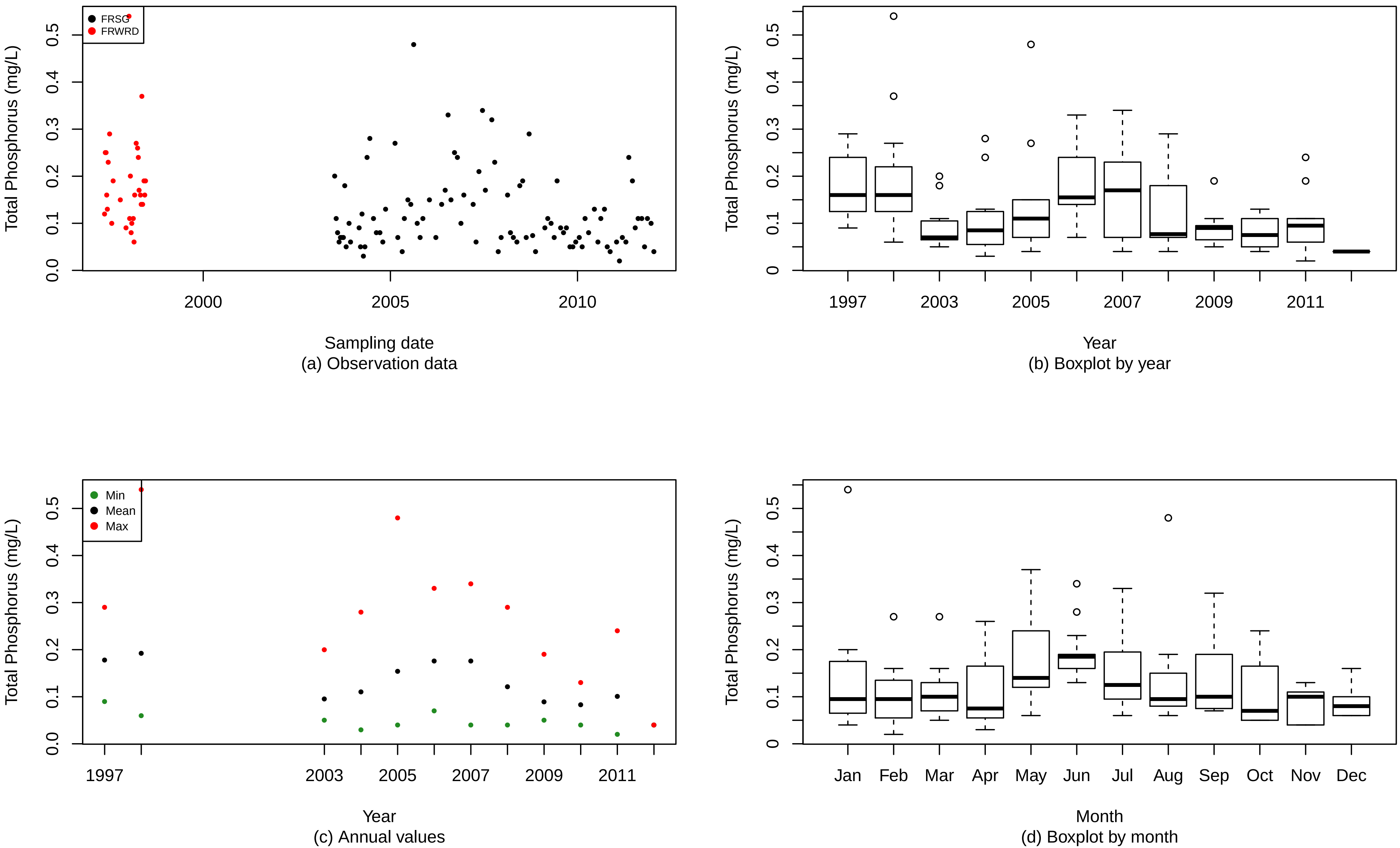

Fox River at Algonquin (24): pH (su)
FRSG
IEPA
pH (su)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Month
(d) Boxplot by month

Fox River at Algonquin (24): Total Suspended Solids (mg/L)

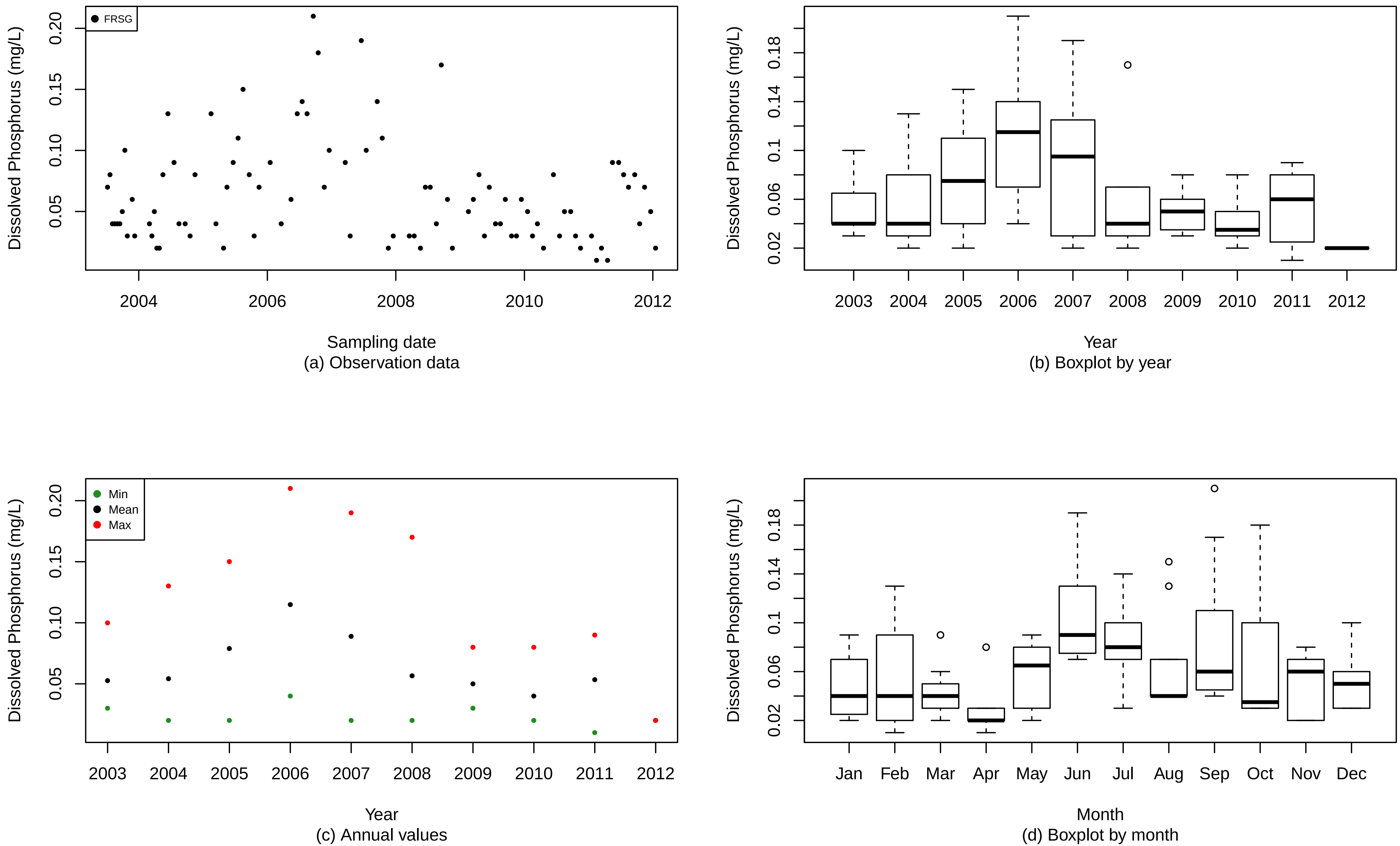



Fox River at Algonquin (24): Chlorophyll−A (µg/L)
FRSG
Chlorophyll−A (µg/L)
0
50
100
200
300
2005
2010
2015
Sampling date
(a) Observation data
2002
2004
2006
2008
2010
2012
2014
2016
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
(d) Boxplot by month

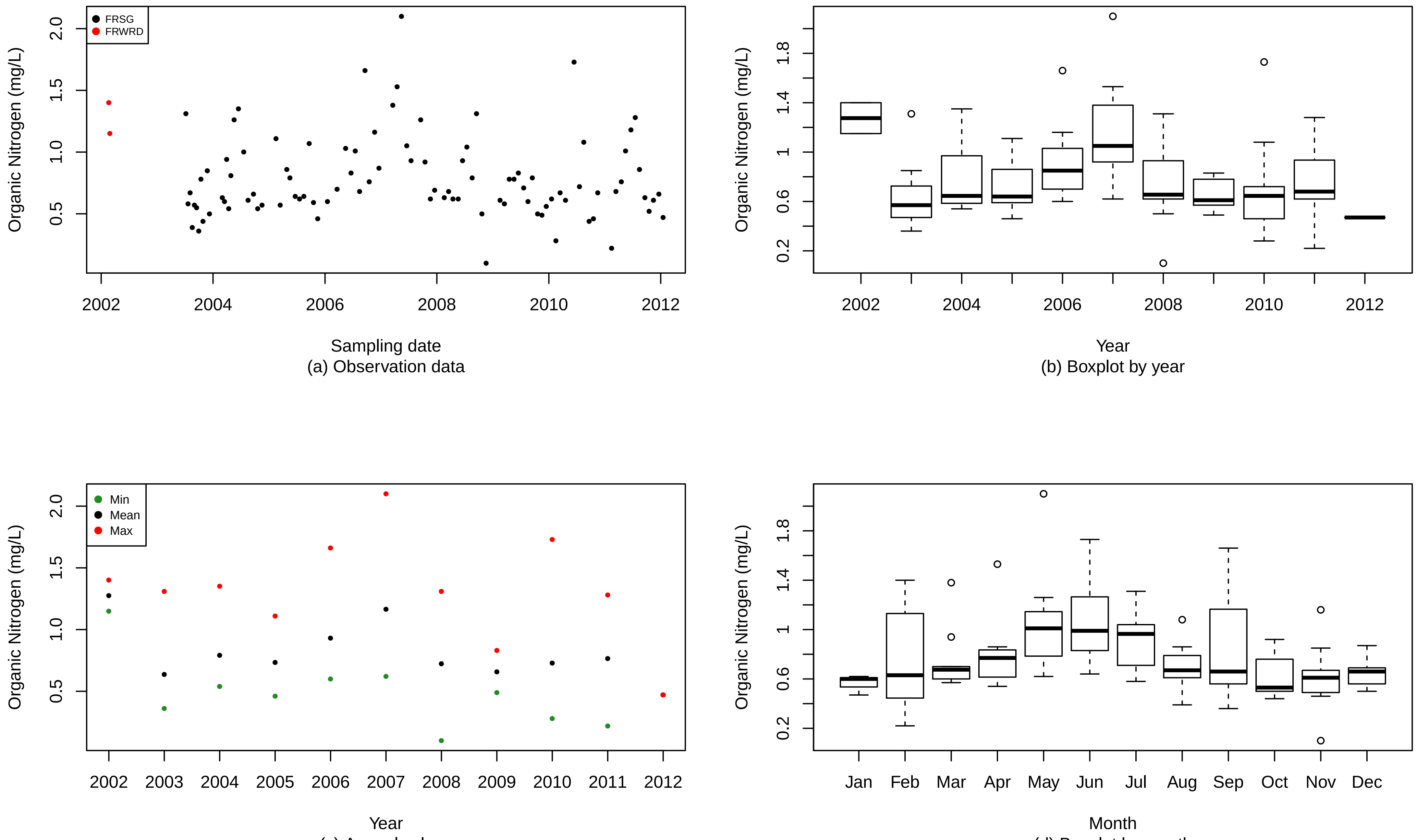
Tyler Cr at Rt. 31−Elgin (268): Total Phosphorus (mg/L)



Tyler Cr at Rt. 31−Elgin (268): Dissolved Phosphorus (mg/L)



Tyler Cr at Rt. 31−Elgin (268): Organic Nitrogen (mg/L)



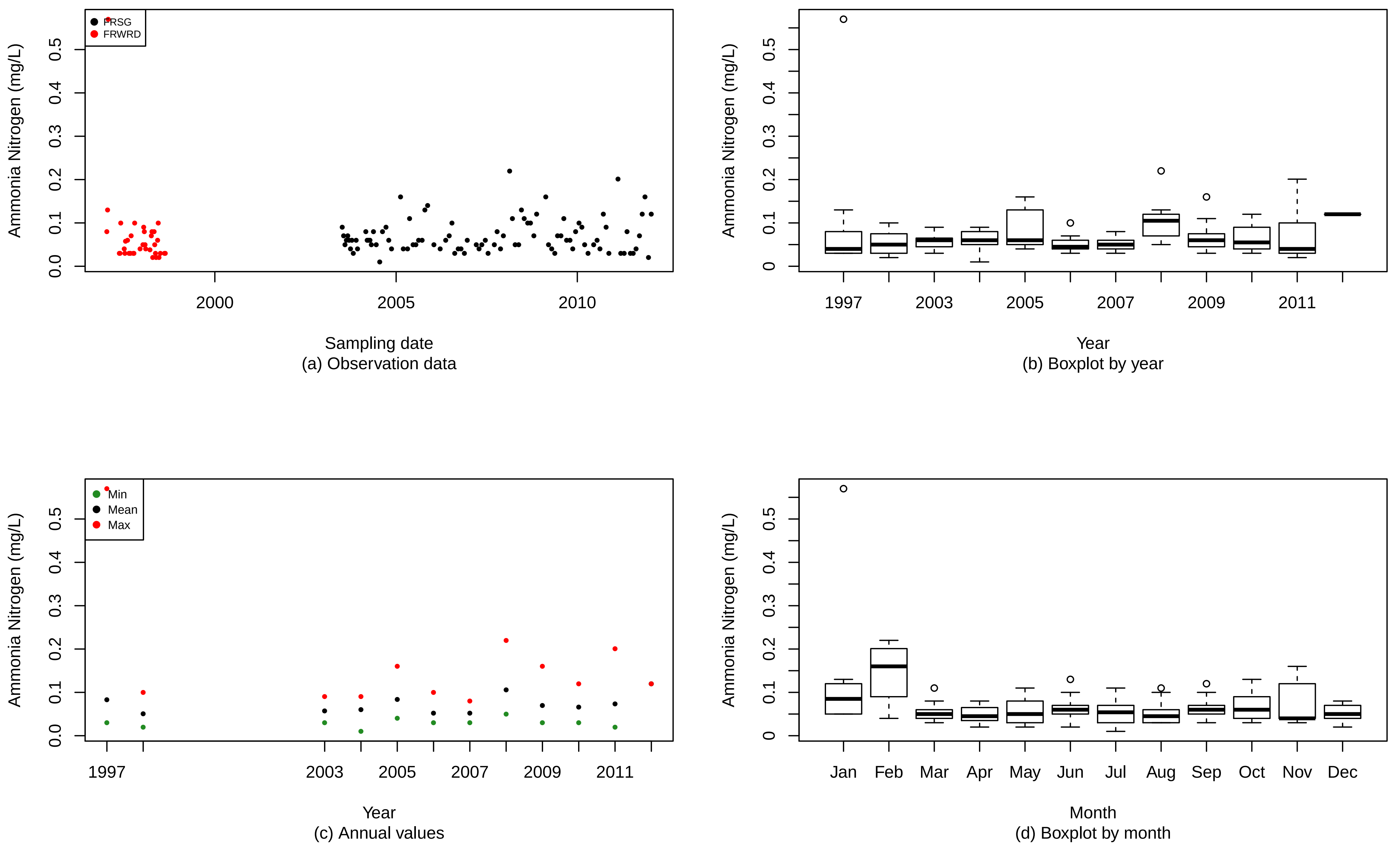
(a) Observation data

(b) Boxplot by year

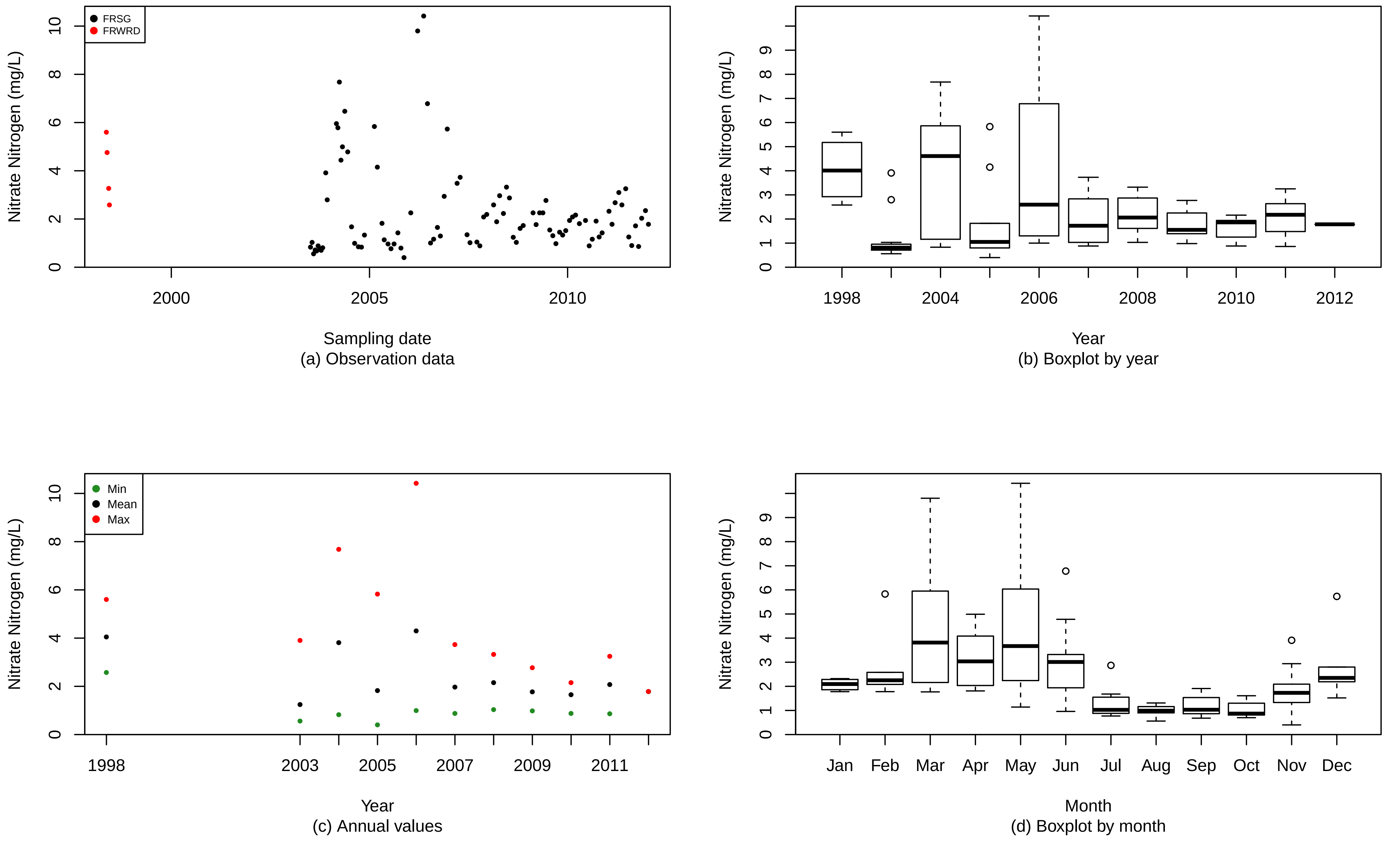
(c) Annual values

(d) Boxplot by month

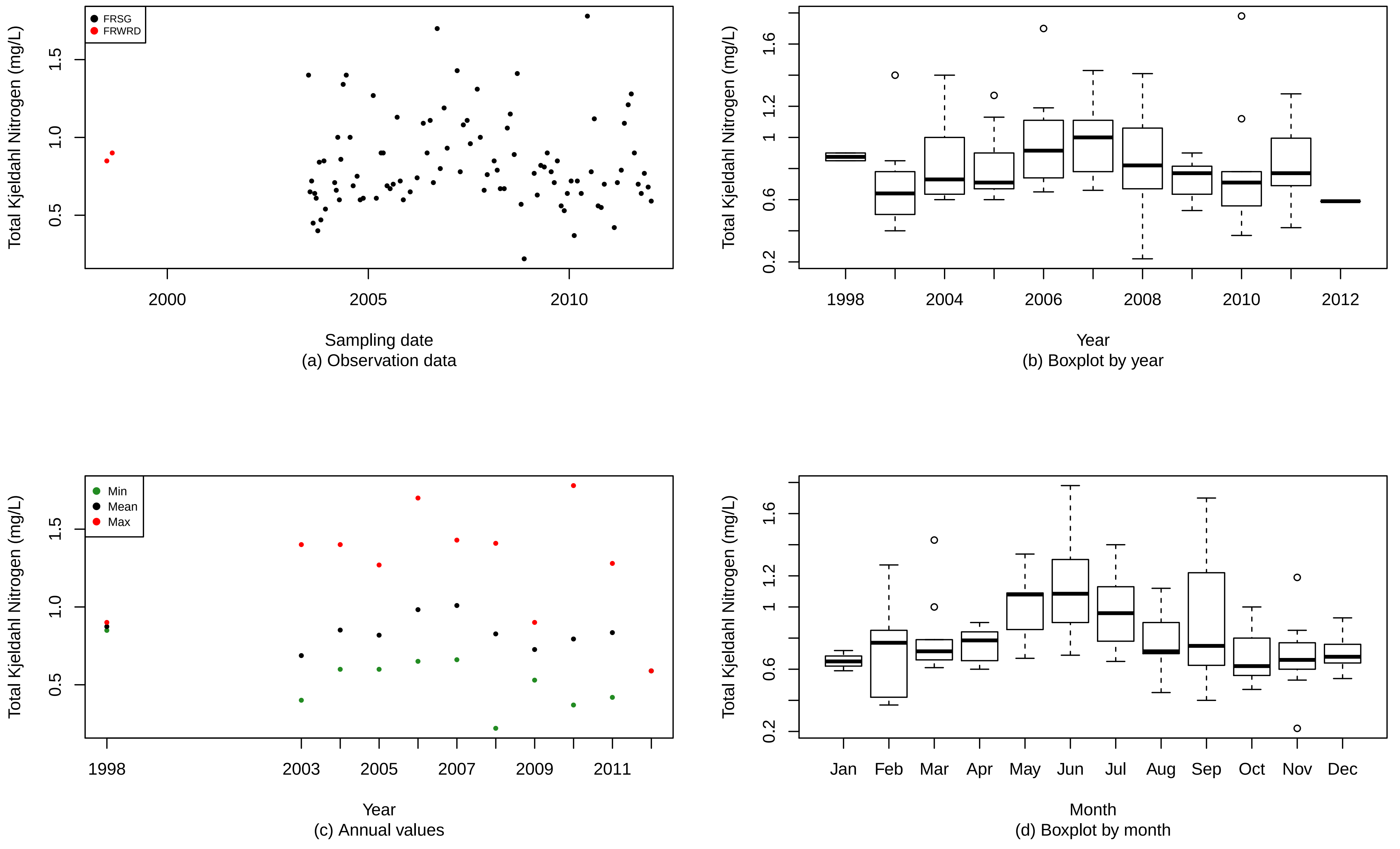
Tyler Cr at Rt. 31−Elgin (268): Ammonia Nitrogen (mg/L)



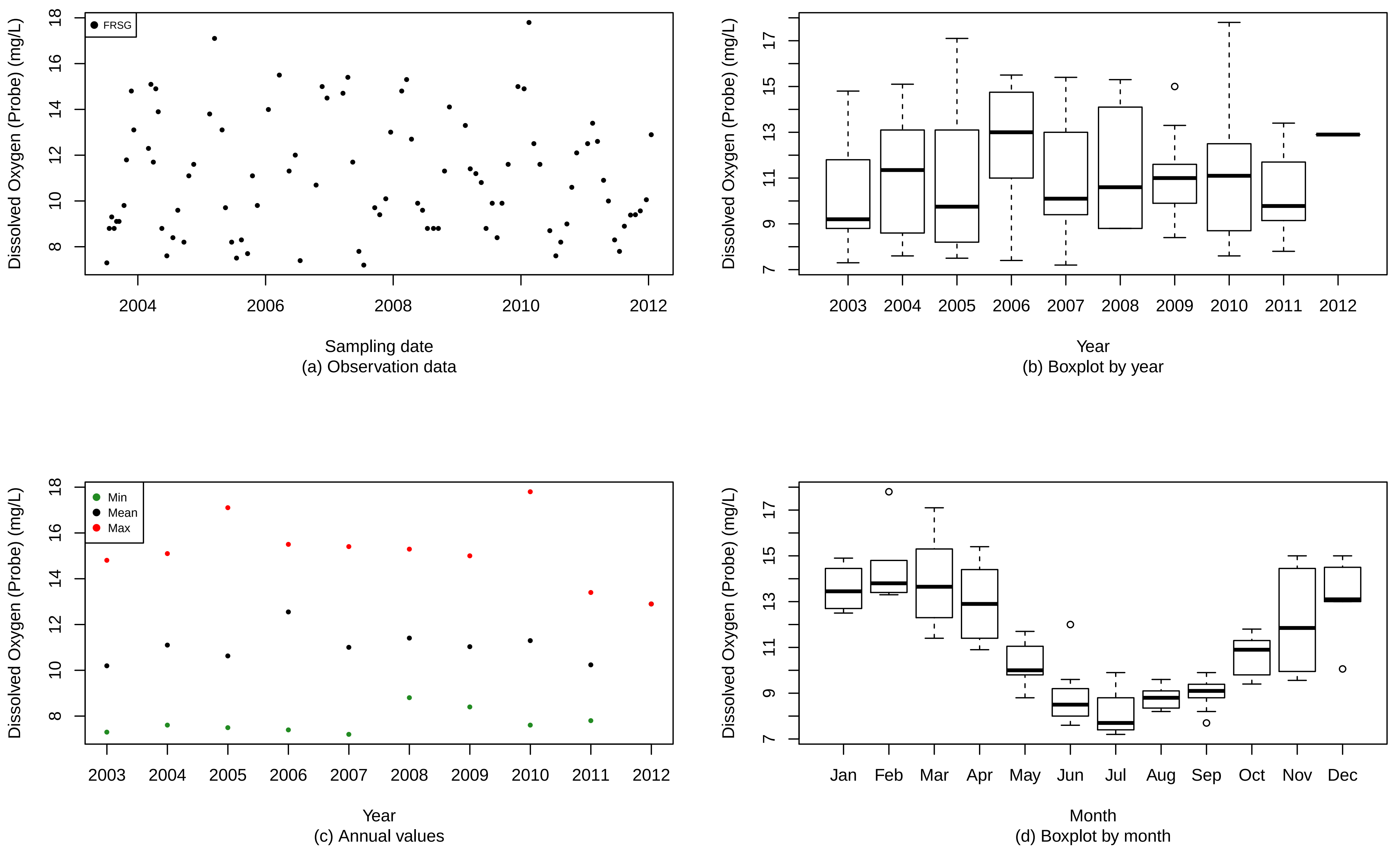
Tyler Cr at Rt. 31−Elgin (268): Nitrate Nitrogen (mg/L)



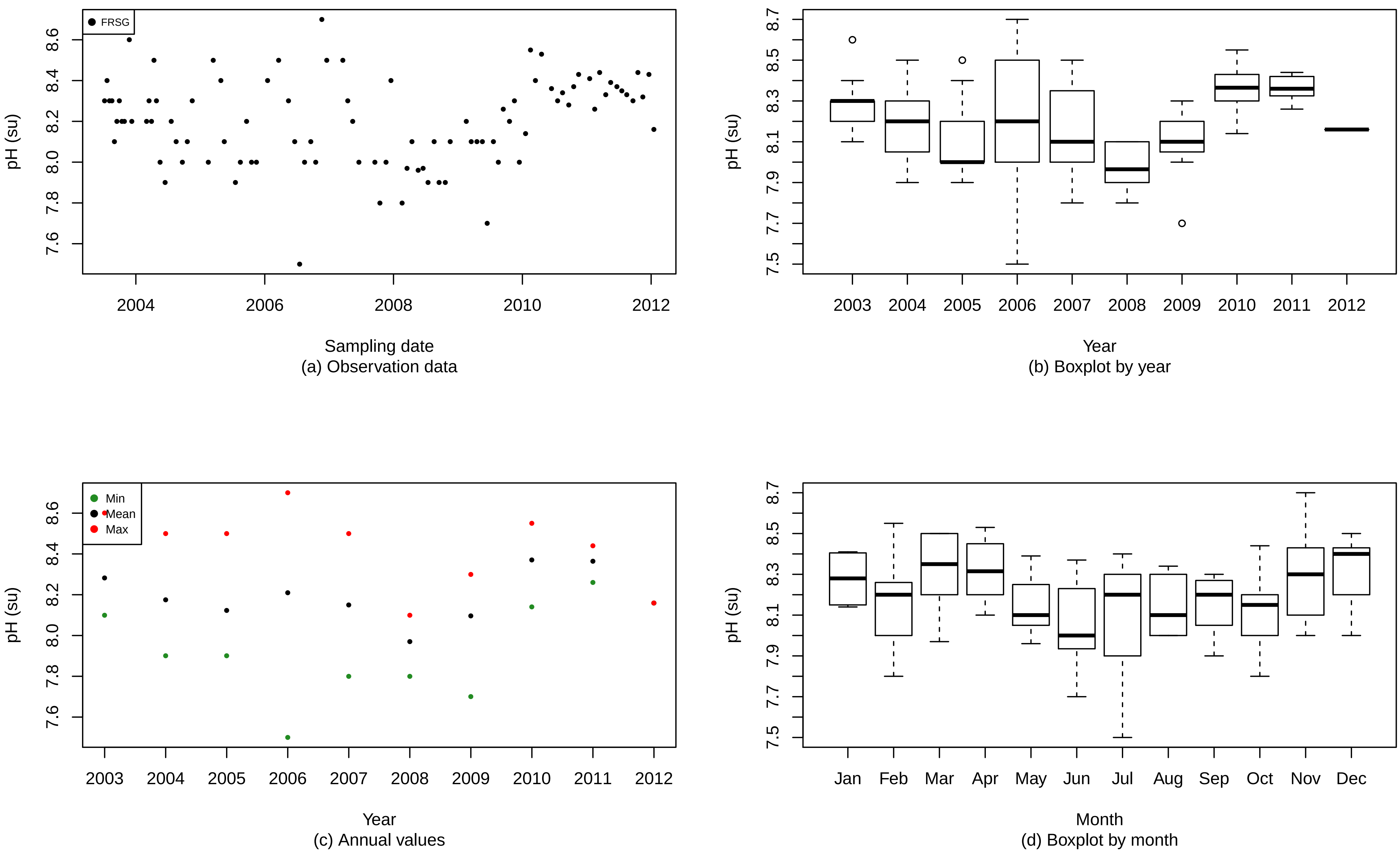
Tyler Cr at Rt. 31−Elgin (268): Total Kjeldahl Nitrogen (mg/L)



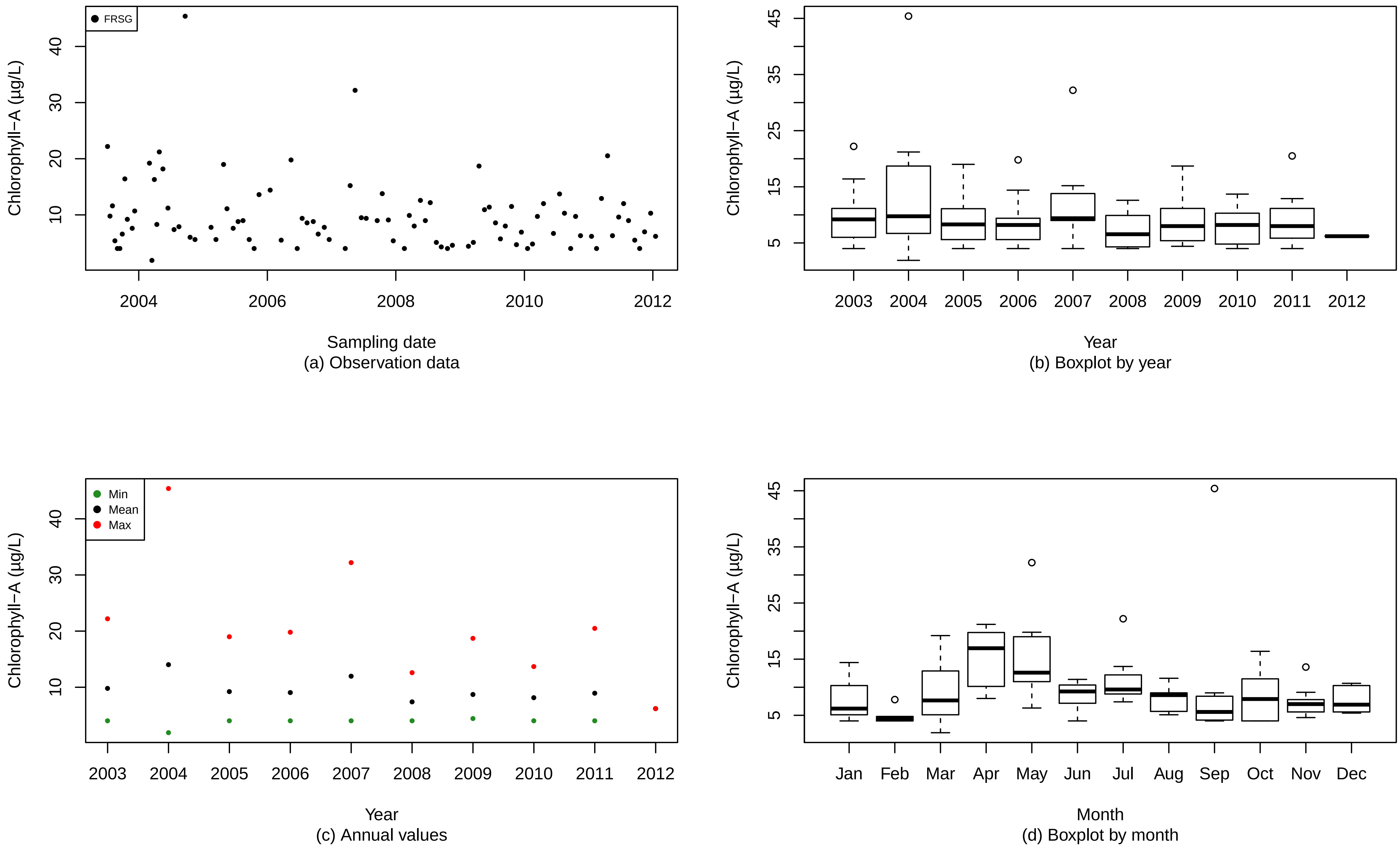
Tyler Cr at Rt. 31−Elgin (268): Dissolved Oxygen (Probe) (mg/L)



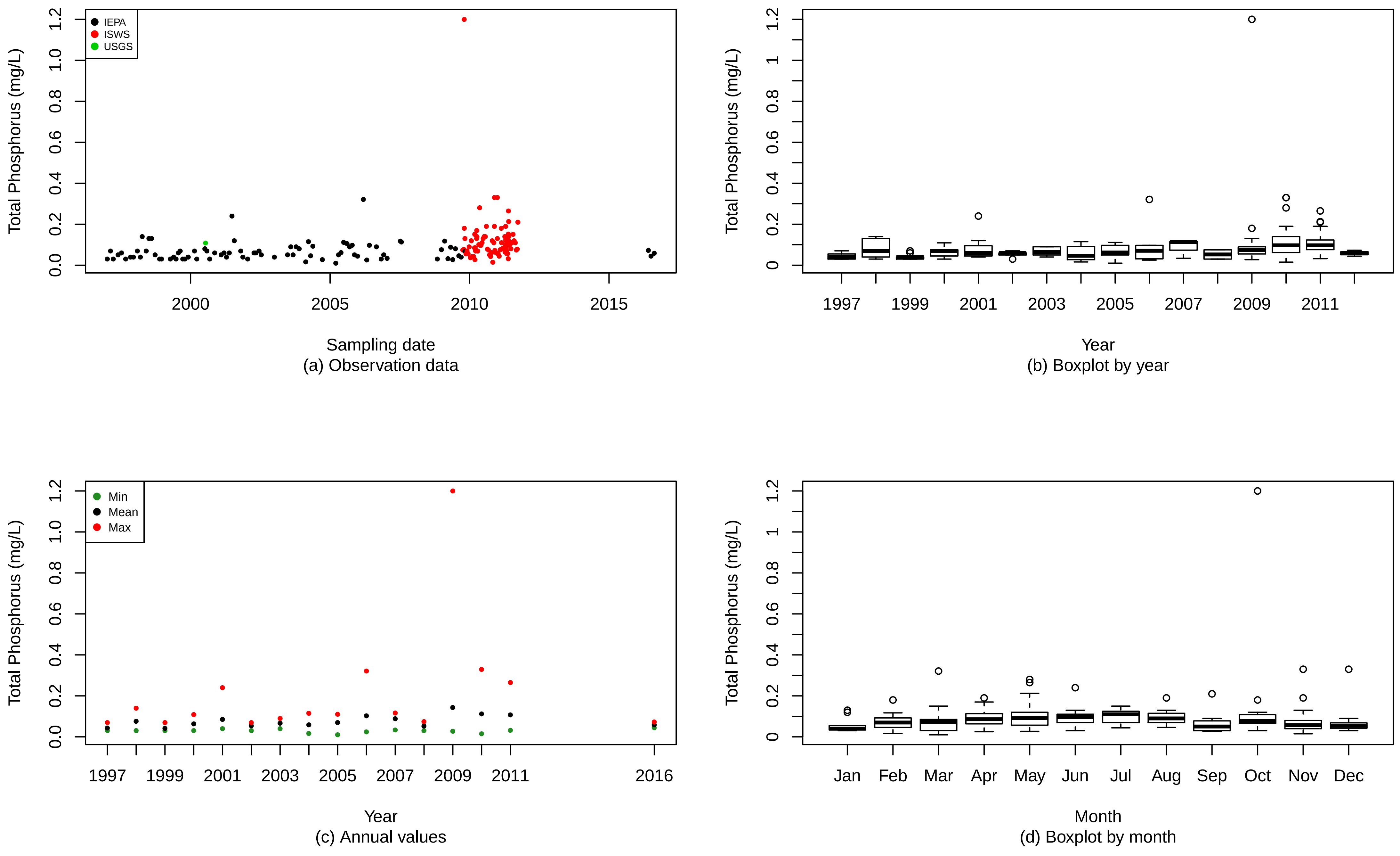
Tyler Cr at Rt. 31−Elgin (268): pH (su)



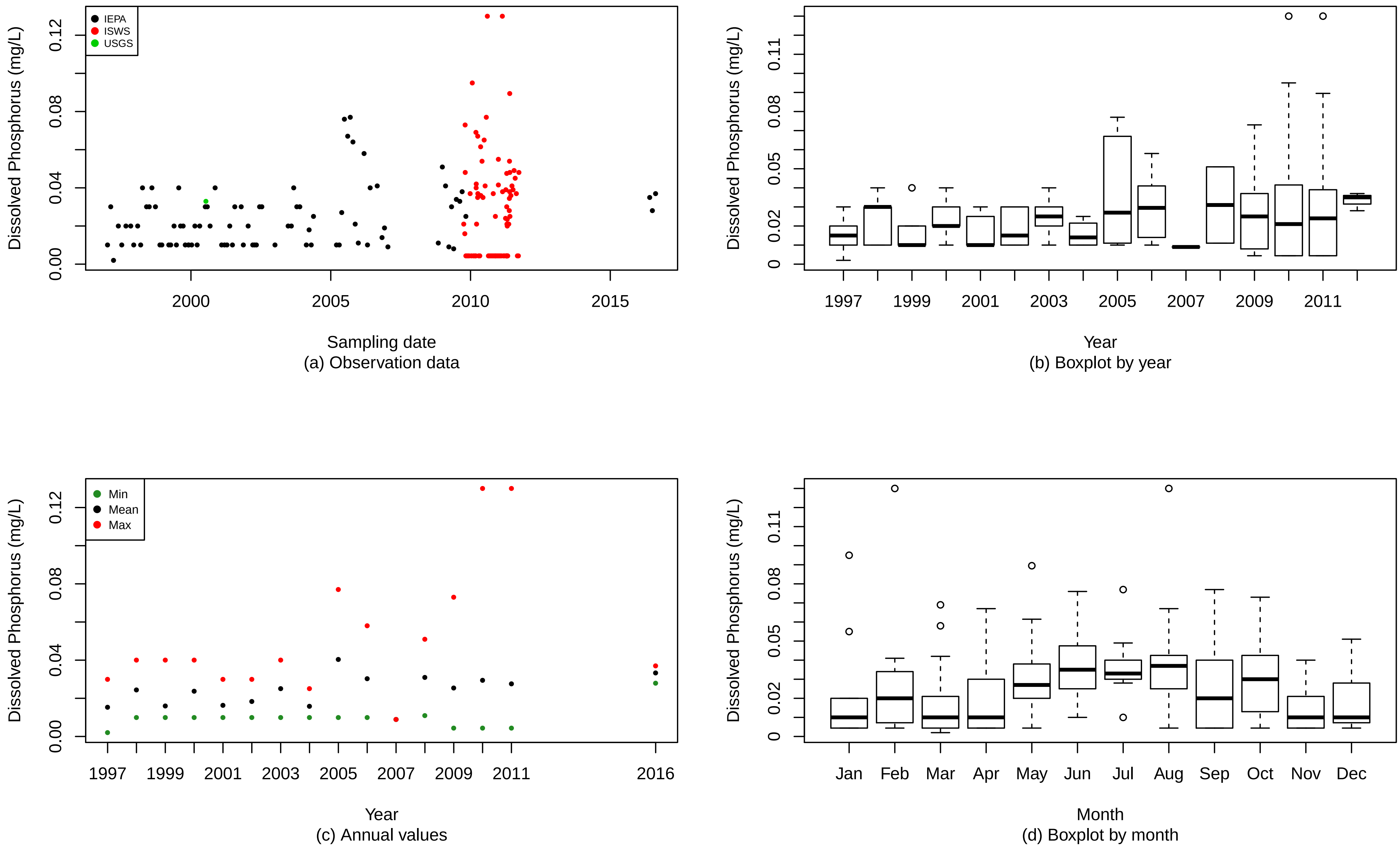
Tyler Cr at Rt. 31−Elgin (268): Chlorophyll−A (µg/L)



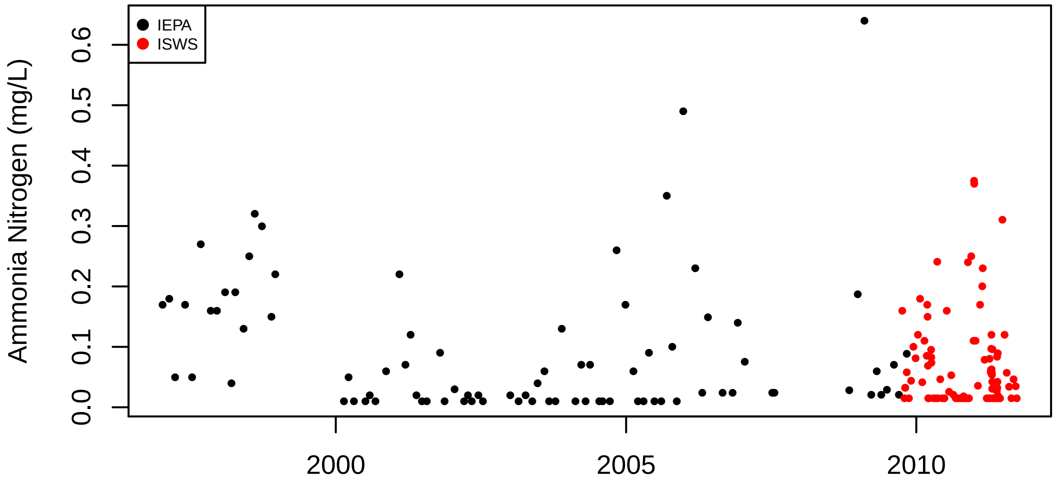
Poplar Cr near Mouth−Elgin (25): Total Phosphorus (mg/L)



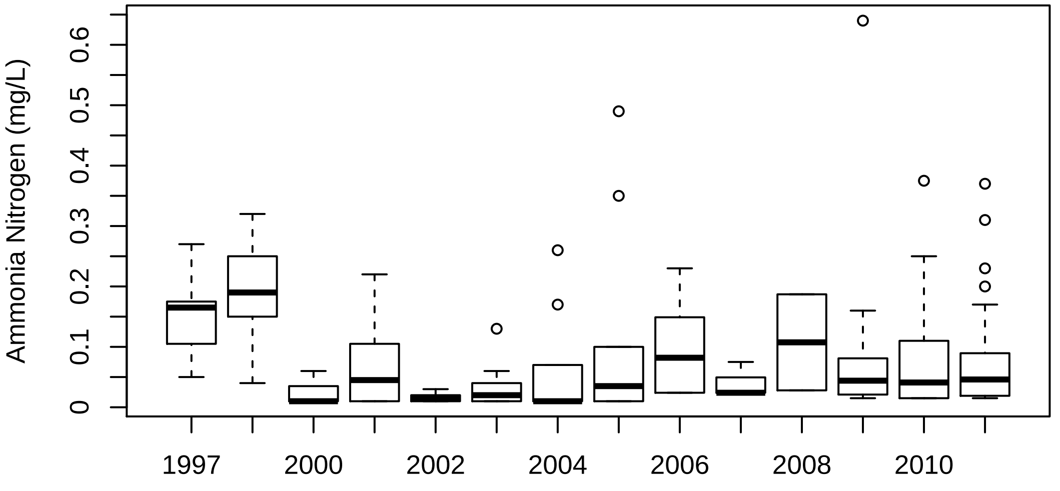
Poplar Cr near Mouth−Elgin (25): Dissolved Phosphorus (mg/L)



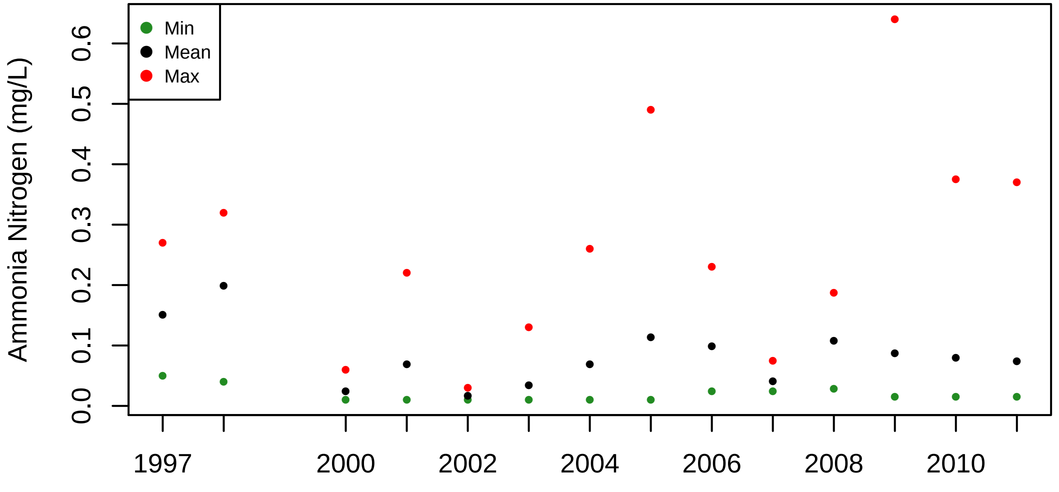
Poplar Cr near Mouth−Elgin (25): Ammonia Nitrogen (mg/L)



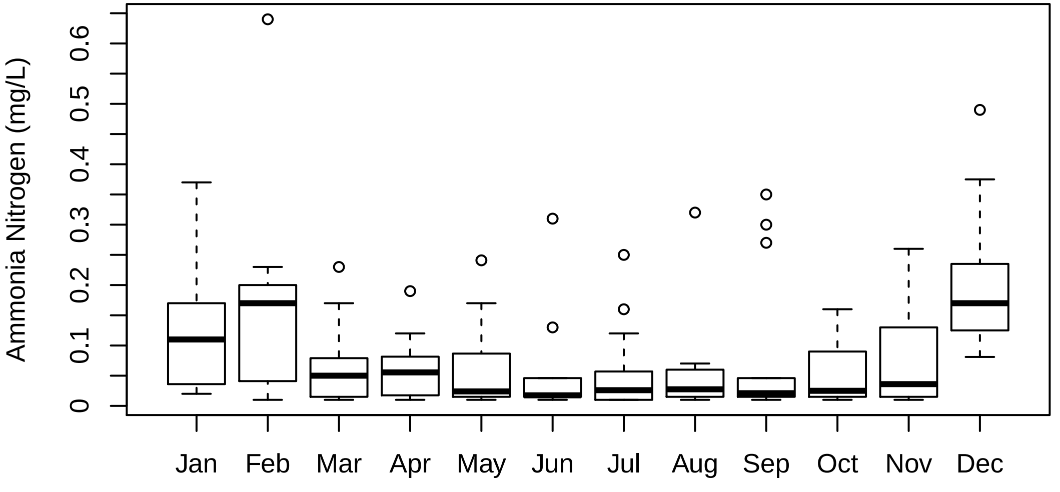
(a) Observation data



(b) Boxplot by year

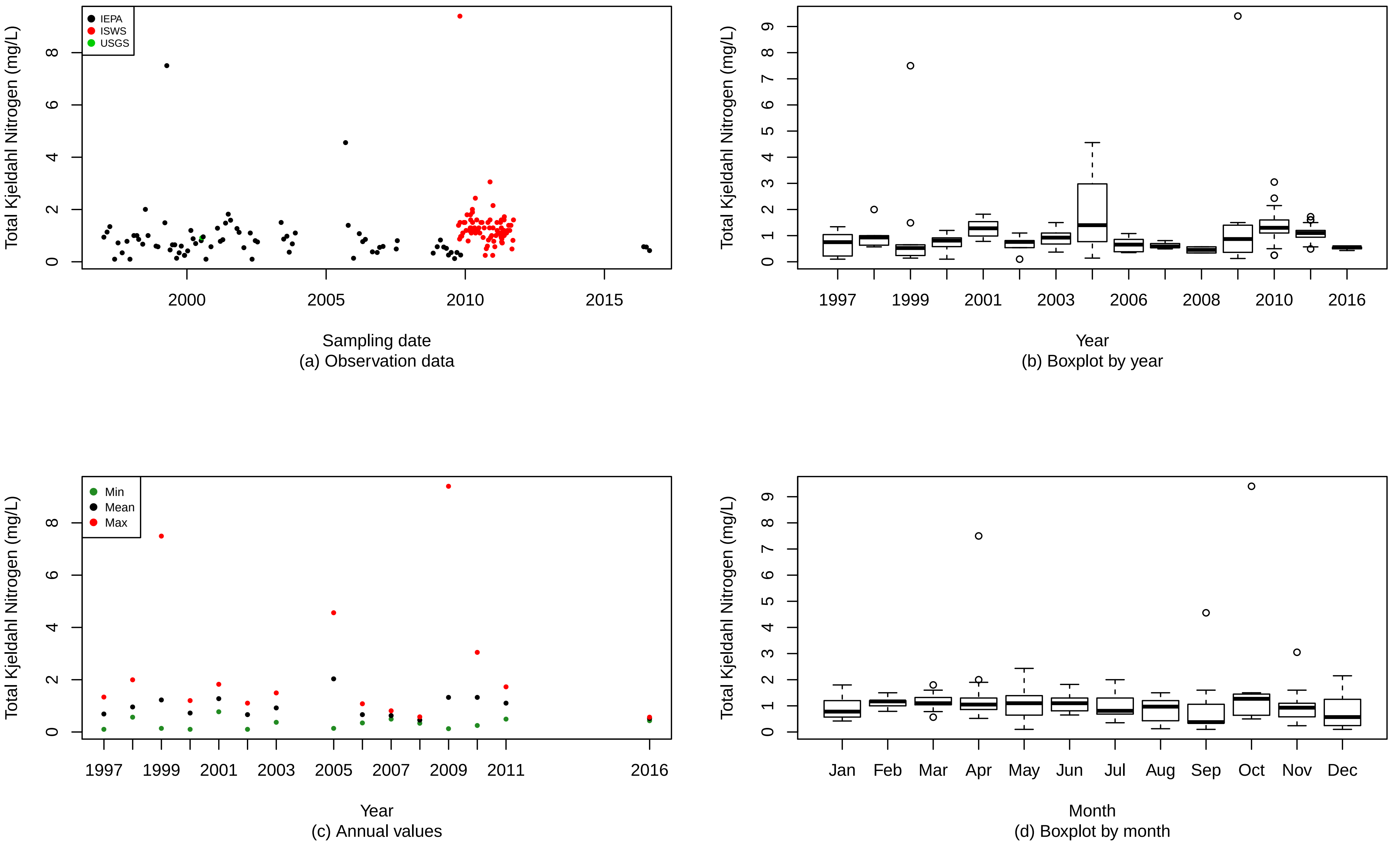


(c) Annual values

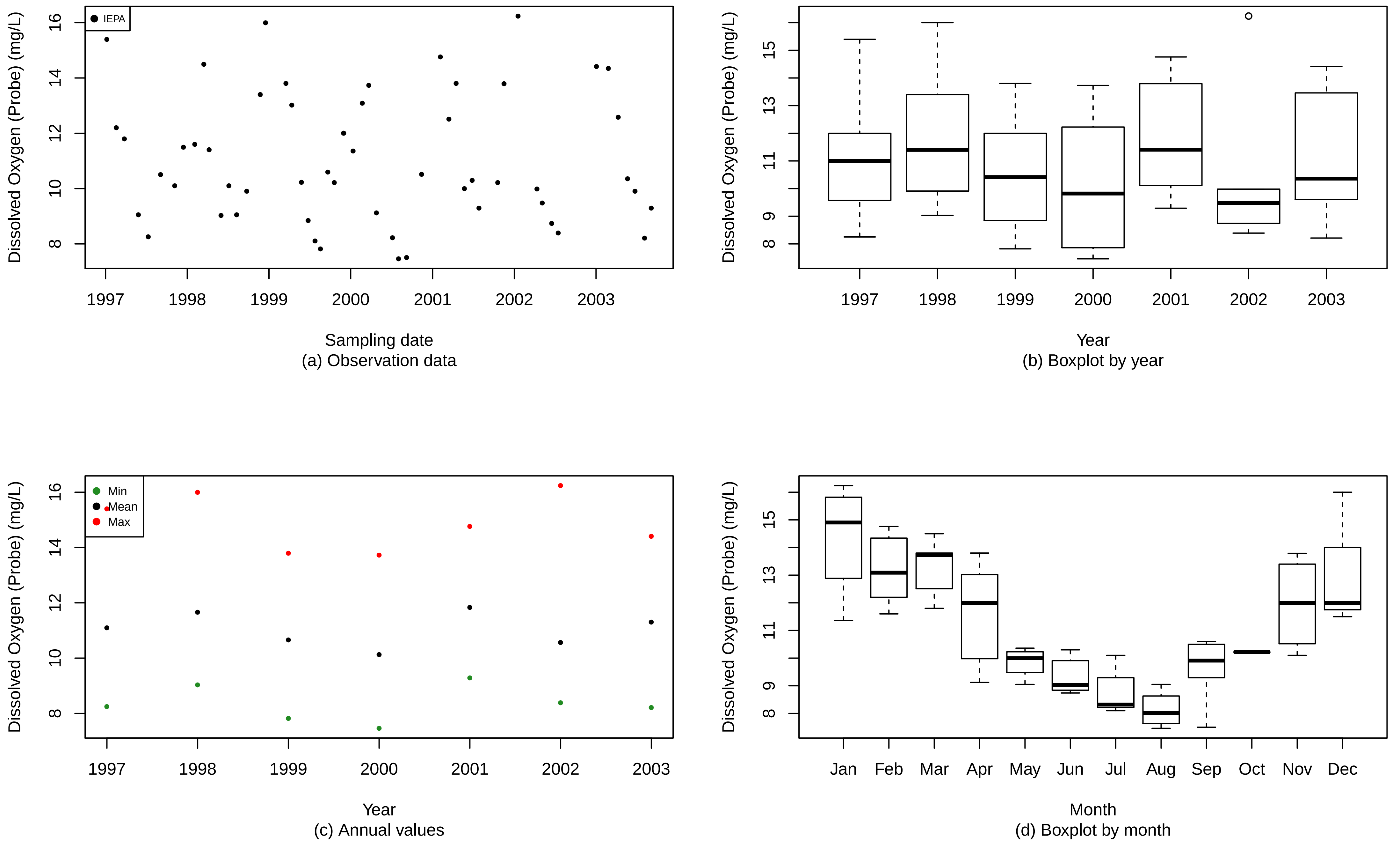


(d) Boxplot by month

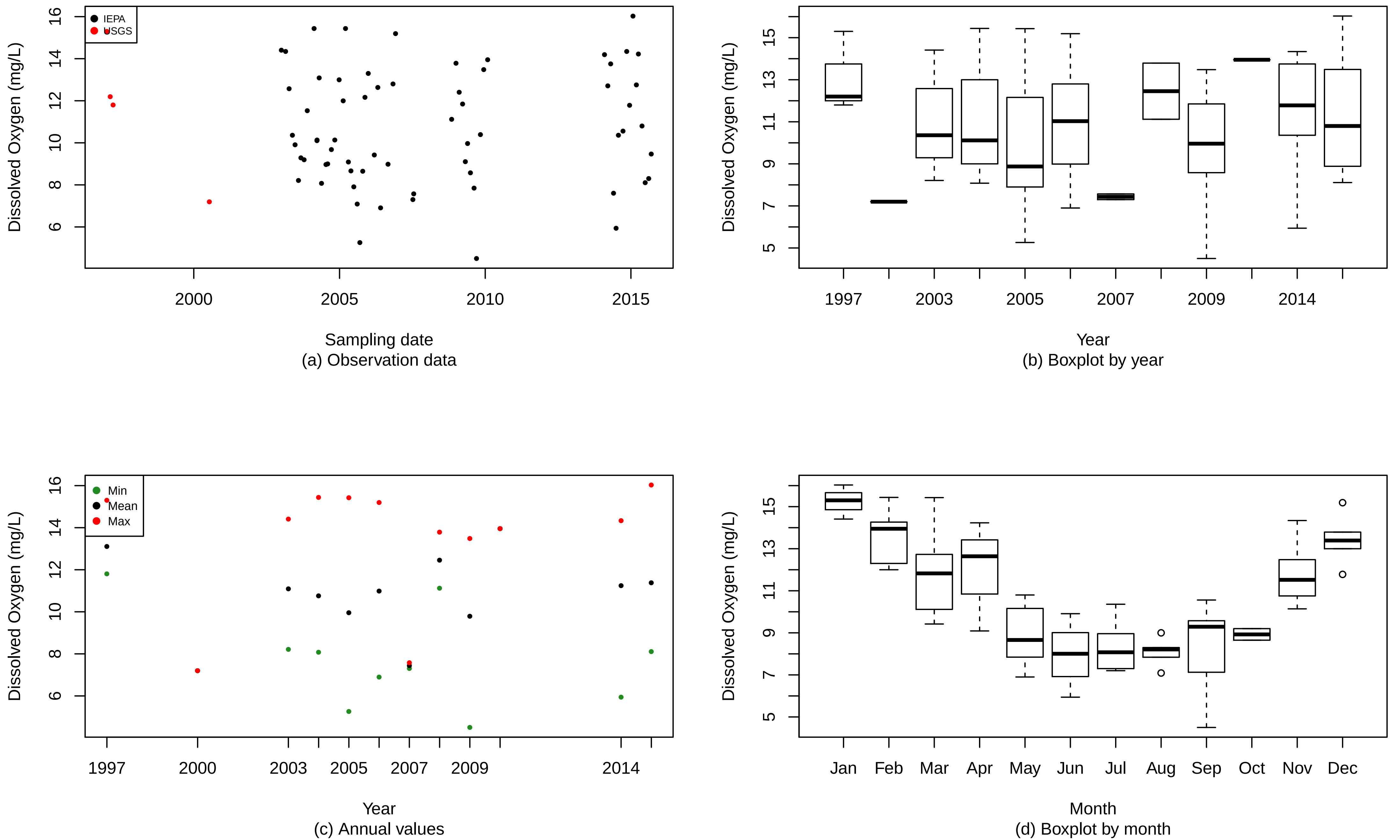
Poplar Cr near Mouth−Elgin (25): Total Kjeldahl Nitrogen (mg/L)



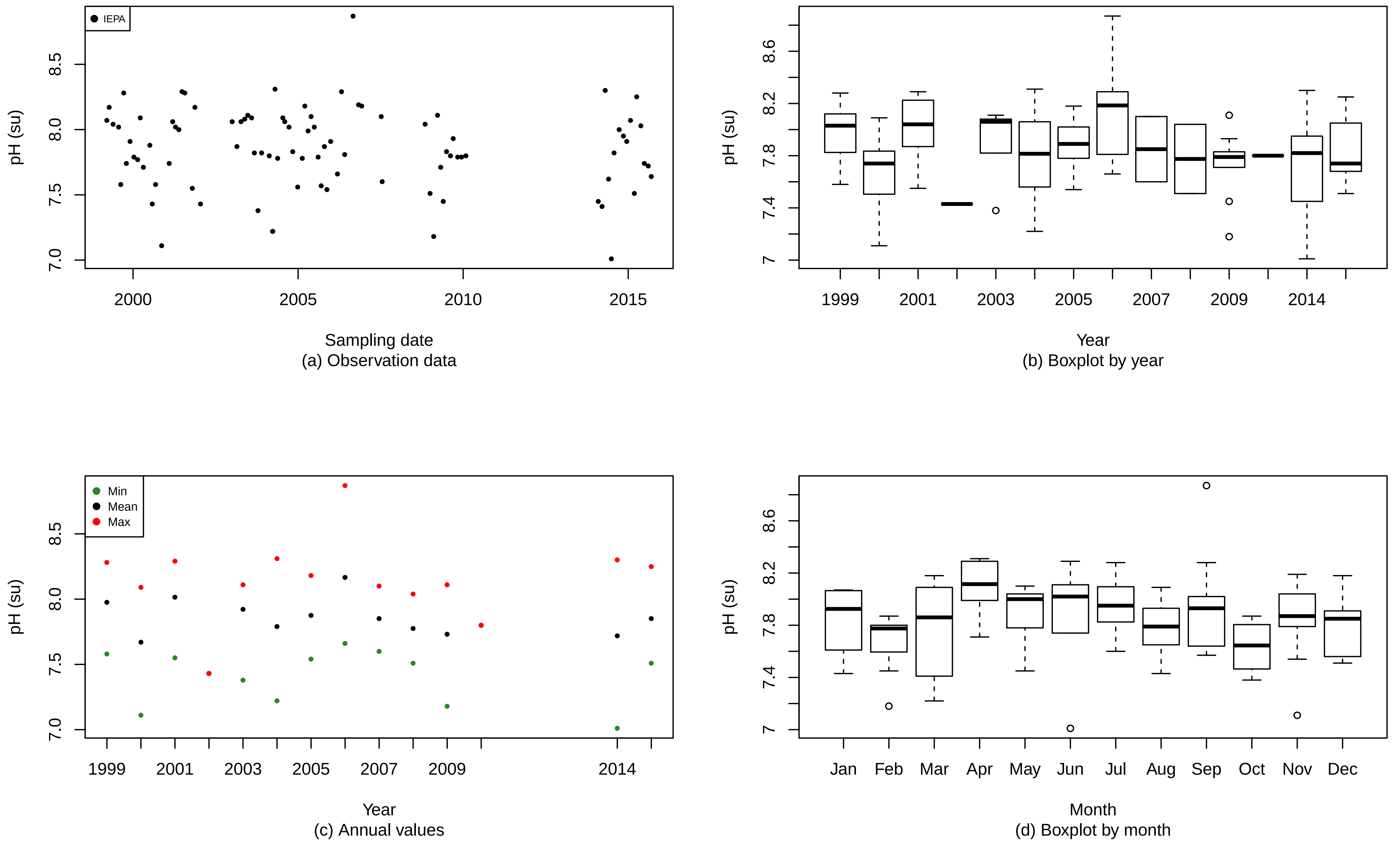
Poplar Cr near Mouth−Elgin (25): Dissolved Oxygen (Probe) (mg/L)



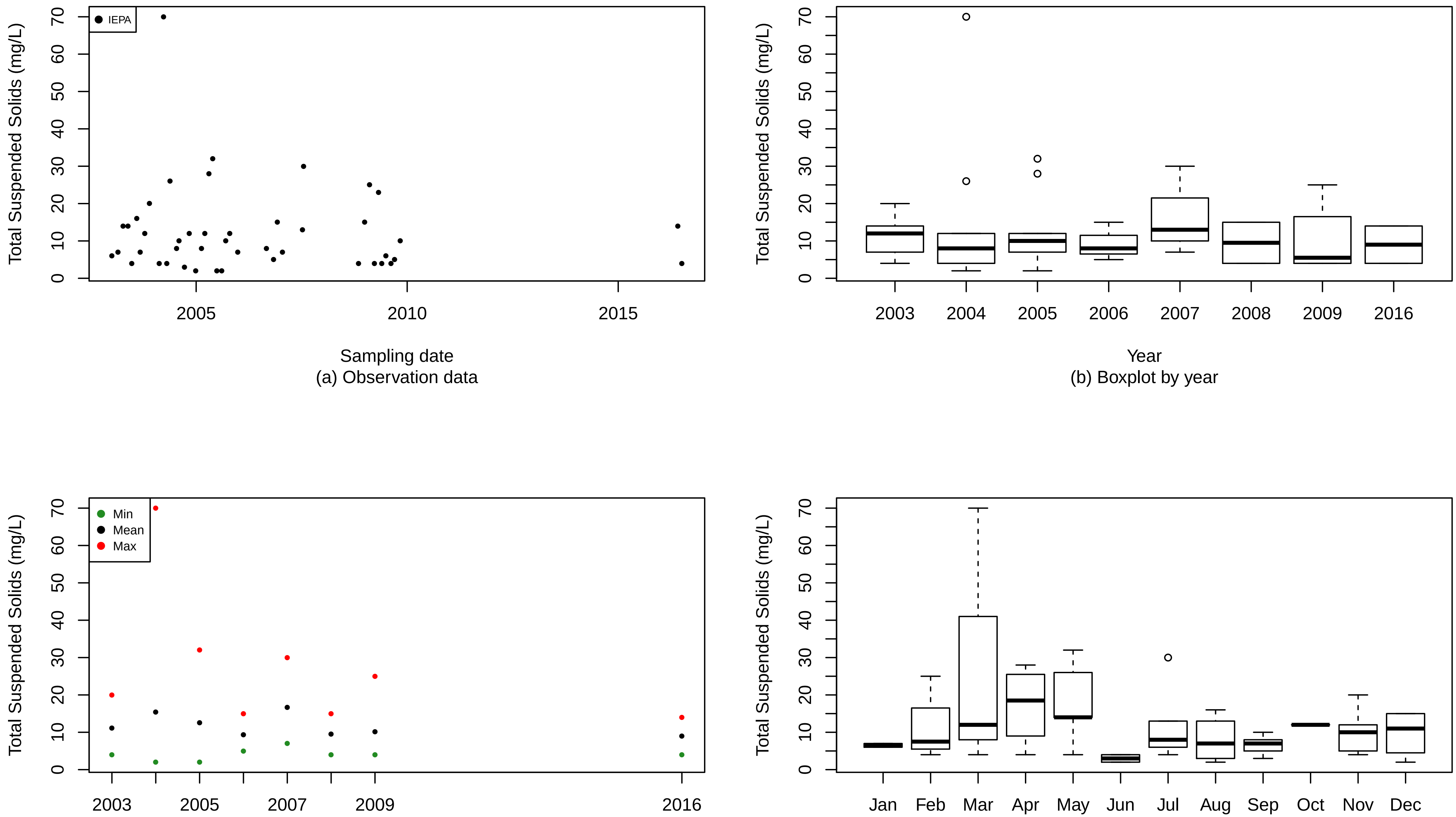
Poplar Cr near Mouth−Elgin (25): Dissolved Oxygen (mg/L)



Poplar Cr near Mouth−Elgin (25): pH (su)



Poplar Cr near Mouth−Elgin (25): Total Suspended Solids (mg/L)



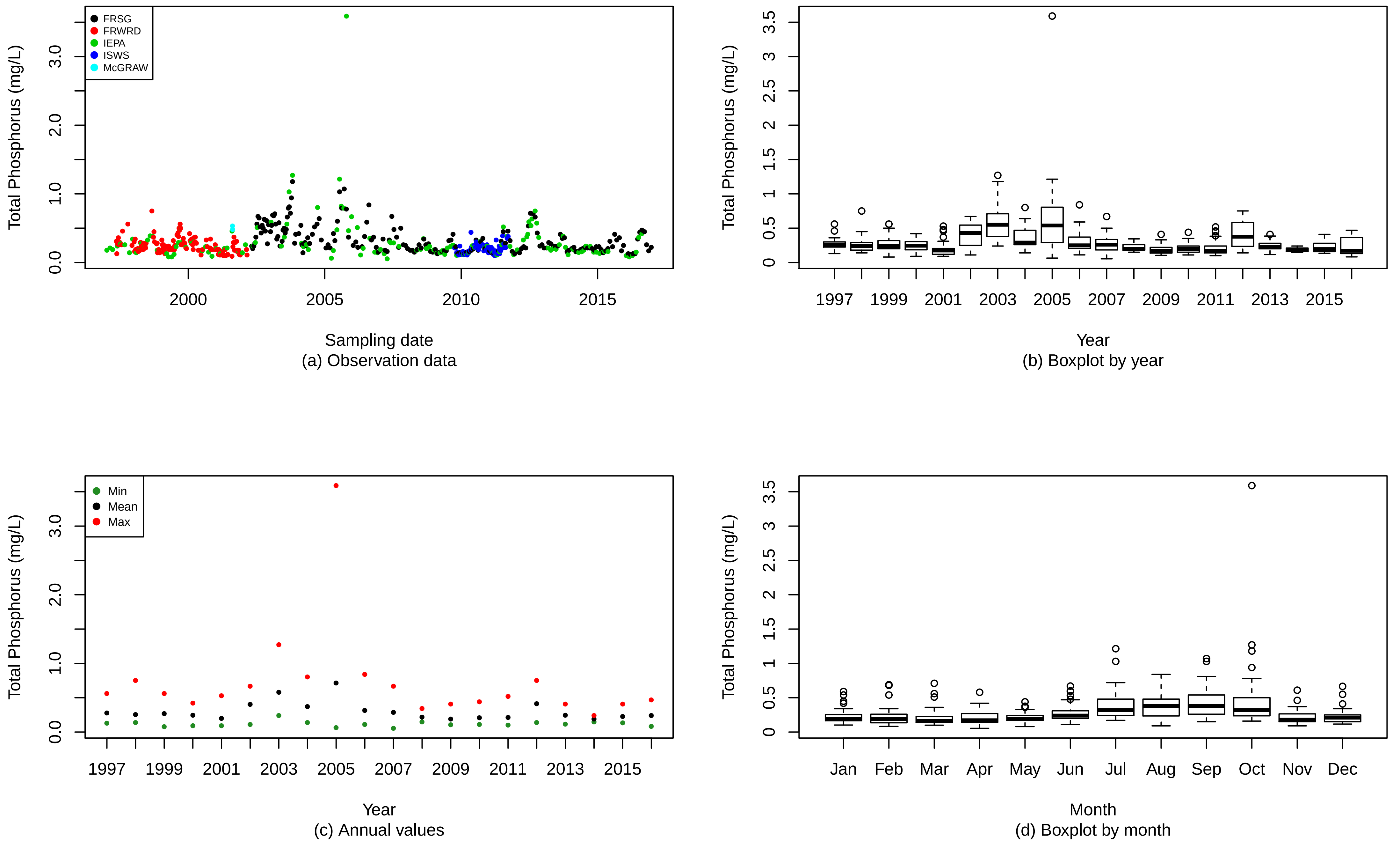
(a) Observation data

(b) Boxplot by year

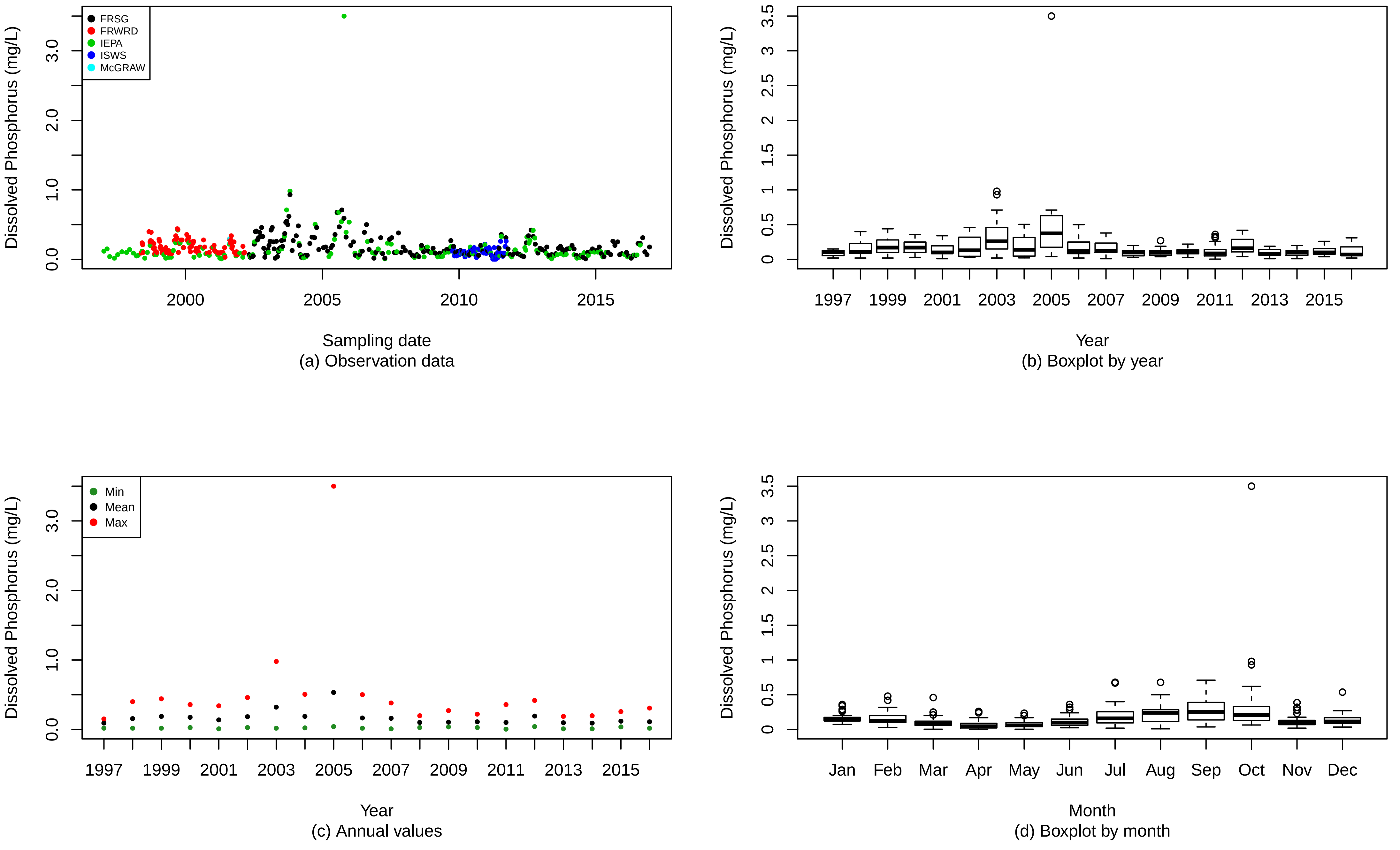
(c) Annual values

(d) Boxplot by month

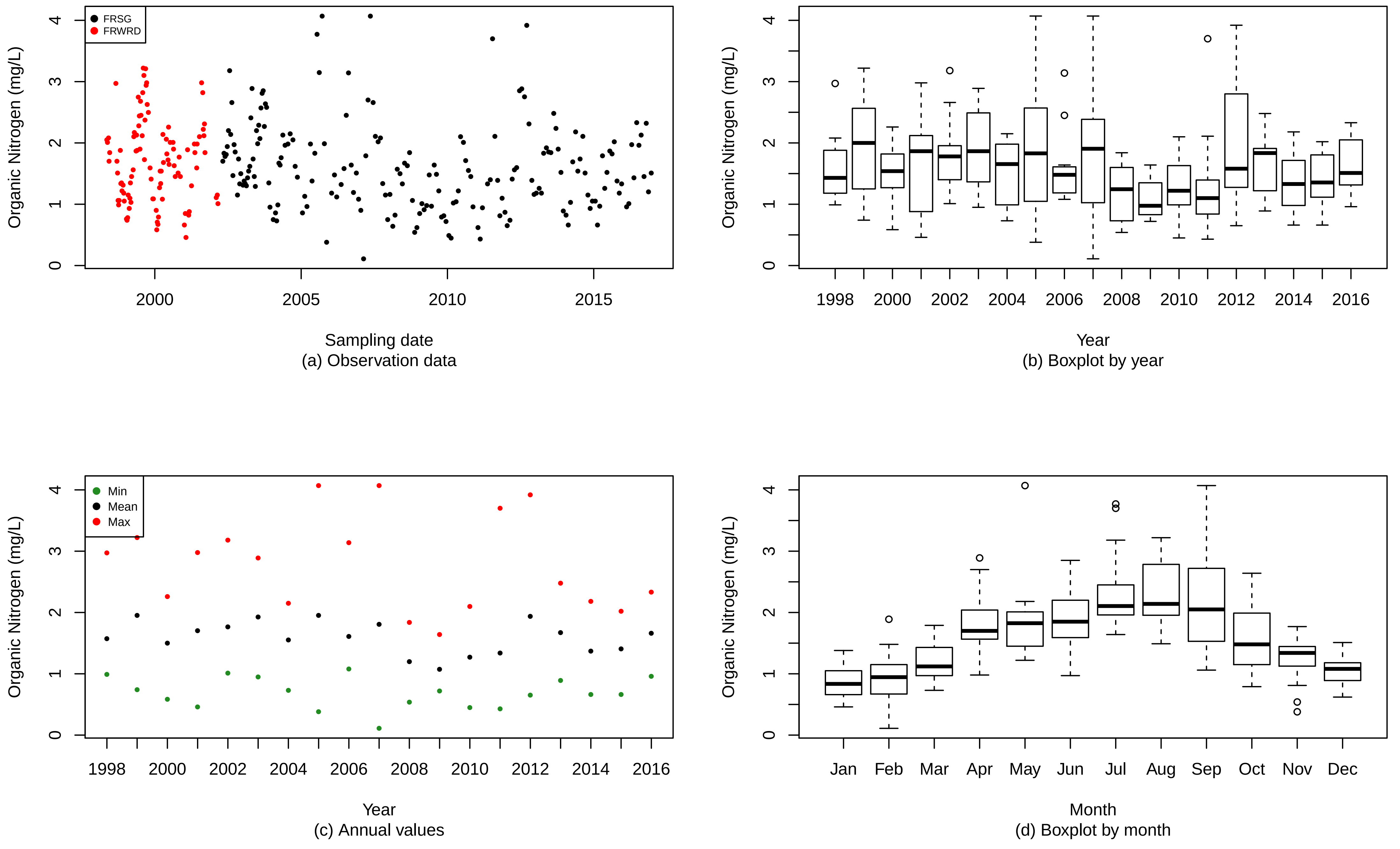
Fox River at South Elgin (26): Total Phosphorus (mg/L)

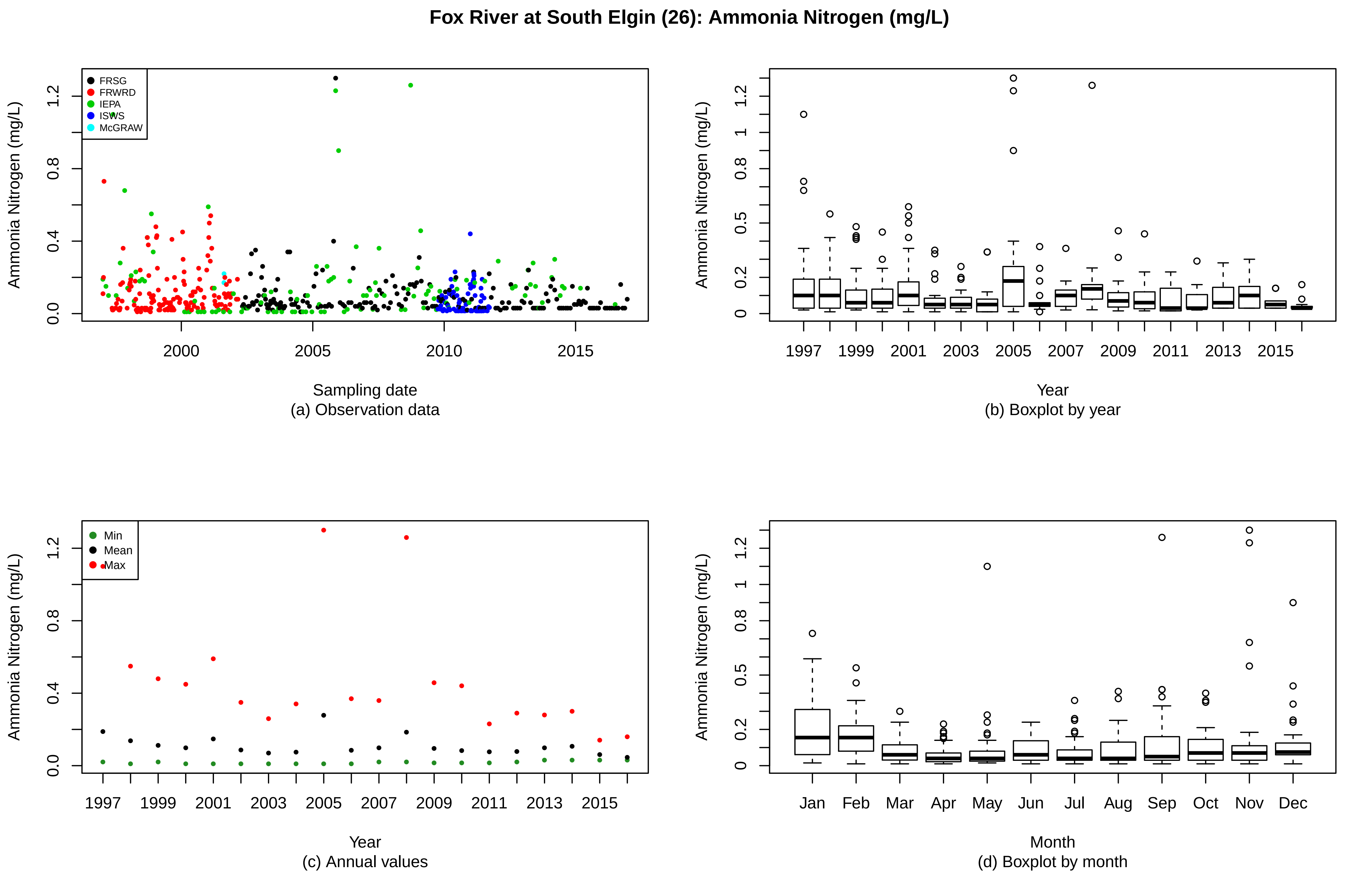


Fox River at South Elgin (26): Dissolved Phosphorus (mg/L)

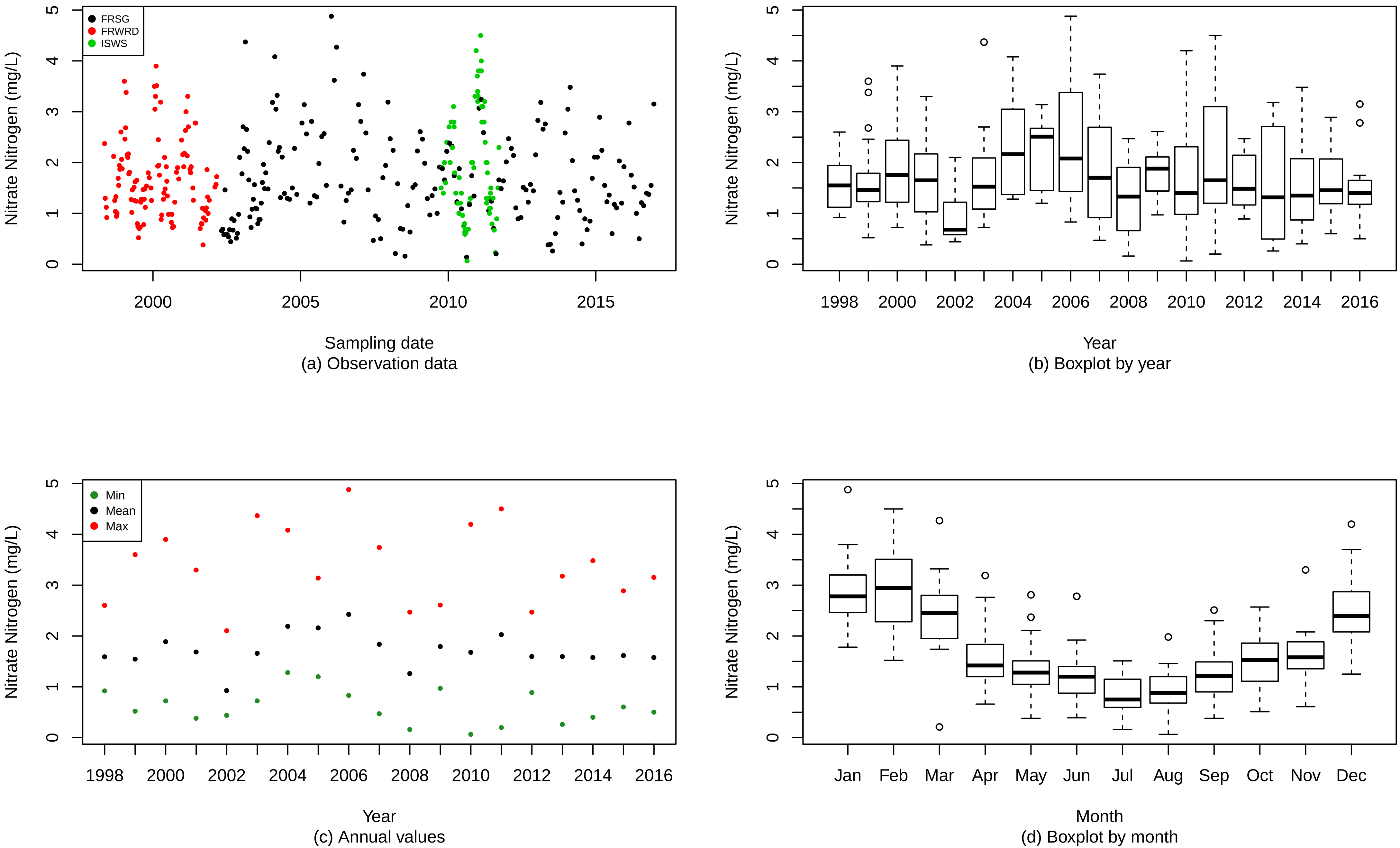


Fox River at South Elgin (26): Organic Nitrogen (mg/L)

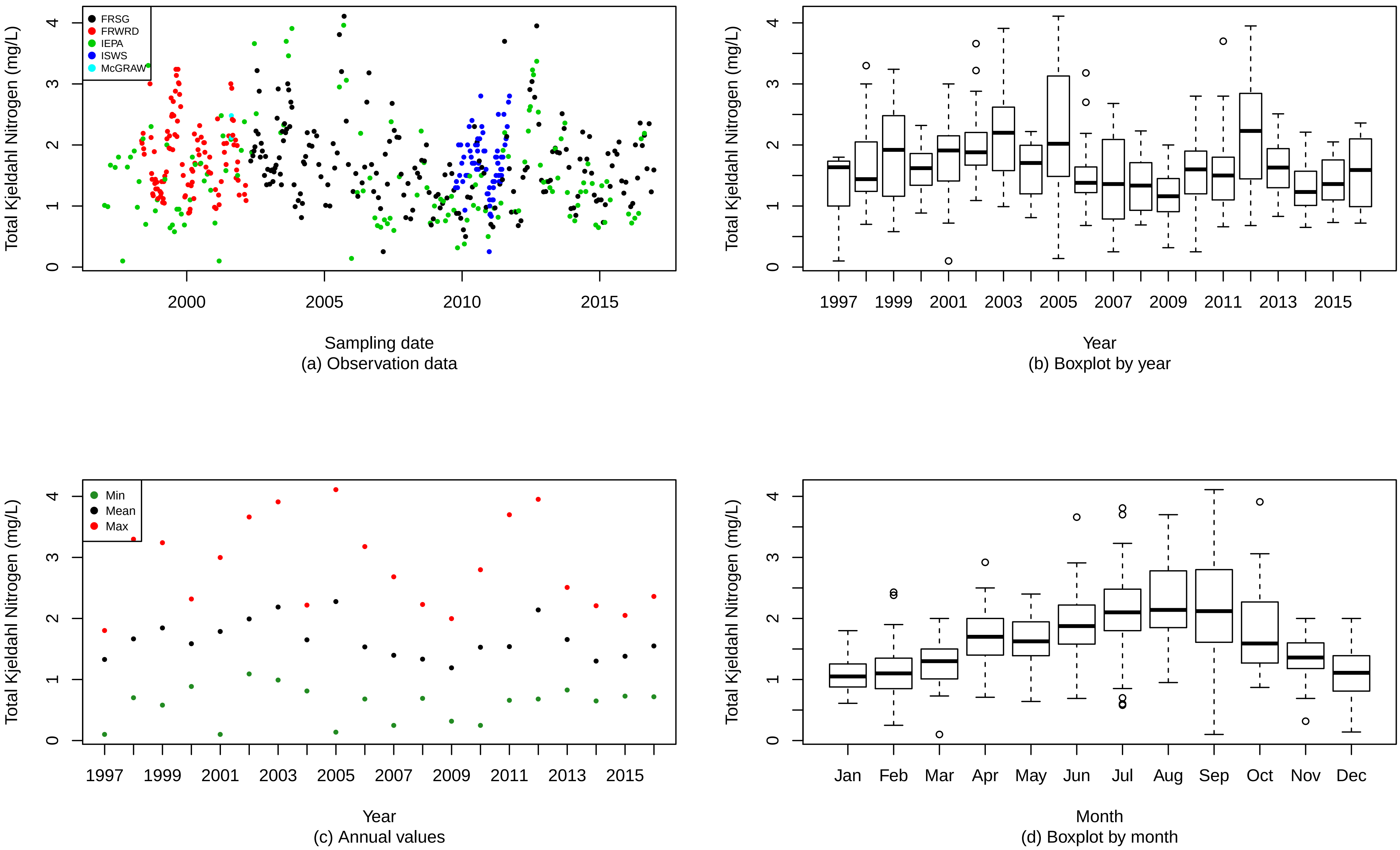



Fox River at South Elgin (26): Ammonia Nitrogen (mg/L)
FRSG
FRWRD
IEPA
ISWS
McGRAW
Ammonia Nitrogen (mg/L)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Month
(d) Boxplot by month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

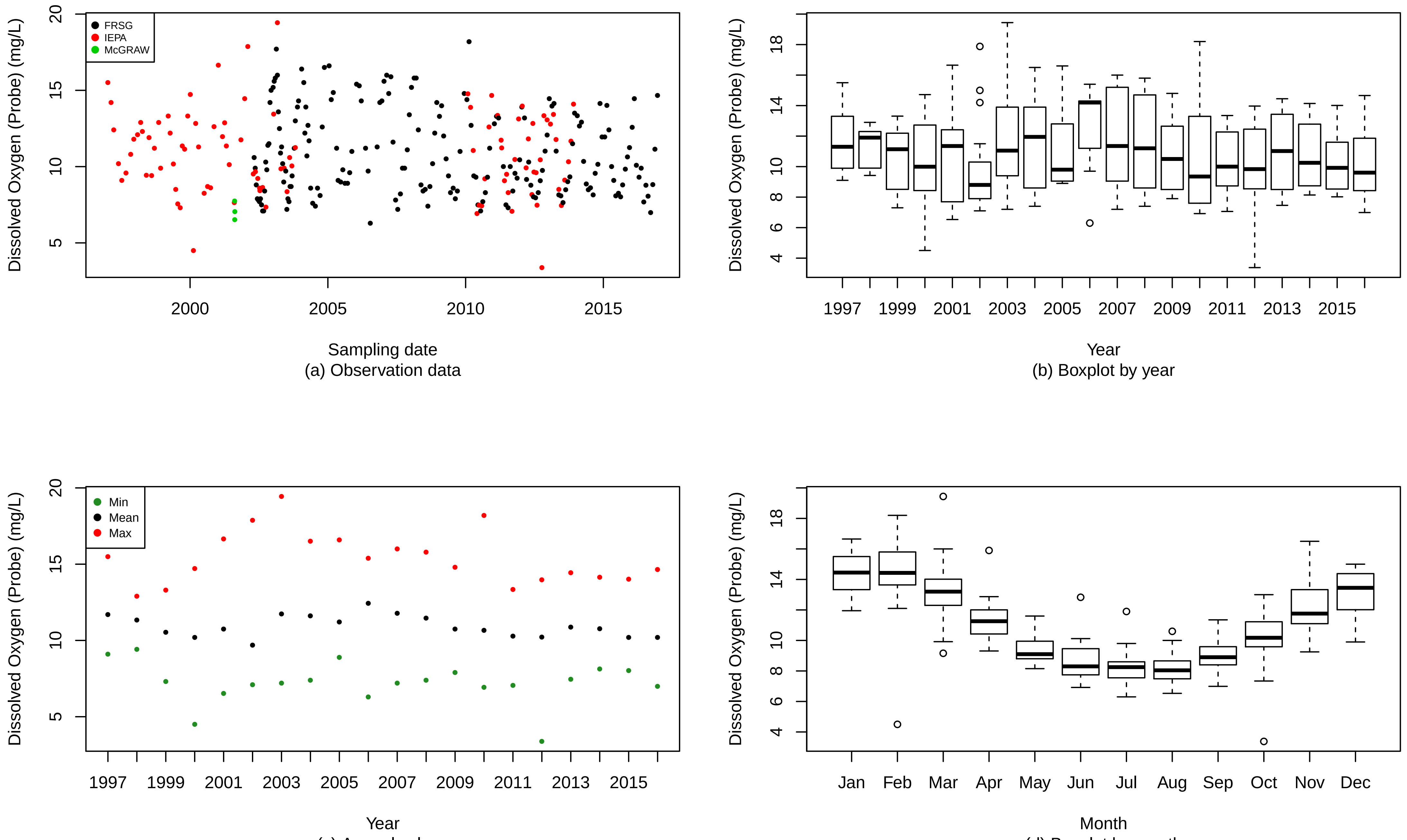
Fox River at South Elgin (26): Nitrate Nitrogen (mg/L)



Fox River at South Elgin (26): Total Kjeldahl Nitrogen (mg/L)



Fox River at South Elgin (26): Dissolved Oxygen (Probe) (mg/L)



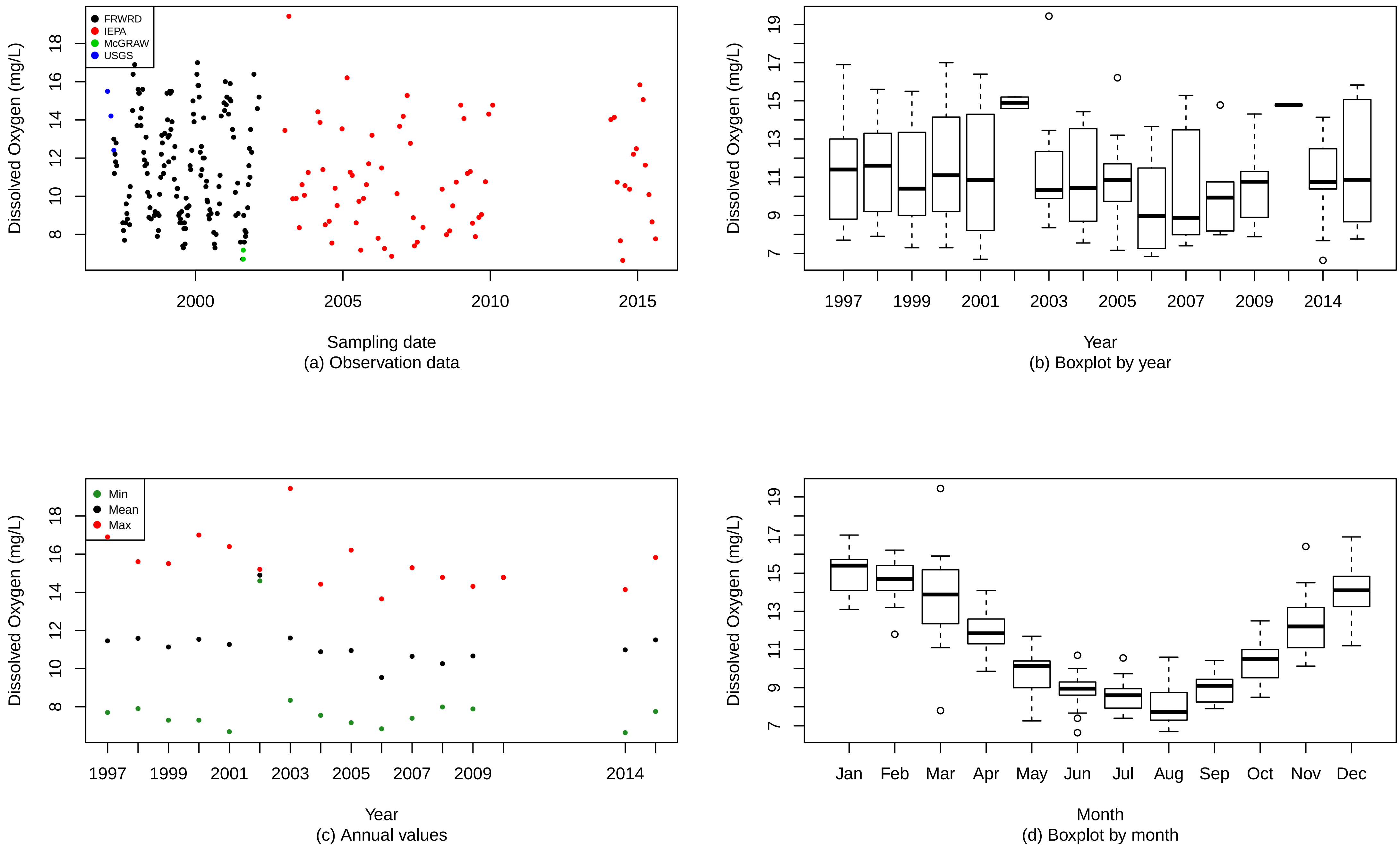
(a) Observation data

(b) Boxplot by year

(c) Annual values

(d) Boxplot by month

Fox River at South Elgin (26): Dissolved Oxygen (mg/L)



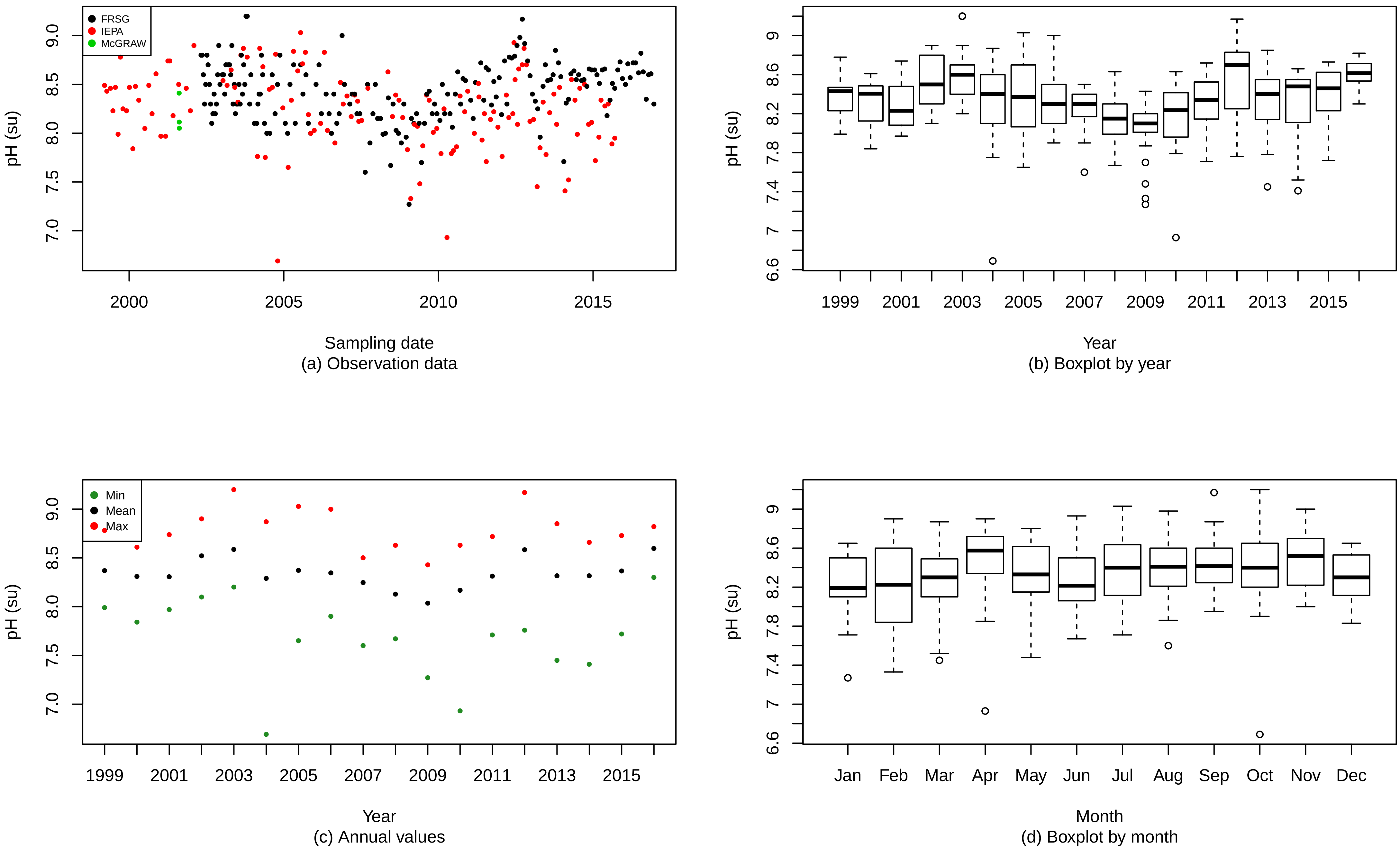
(a) Observation data

(b) Boxplot by year

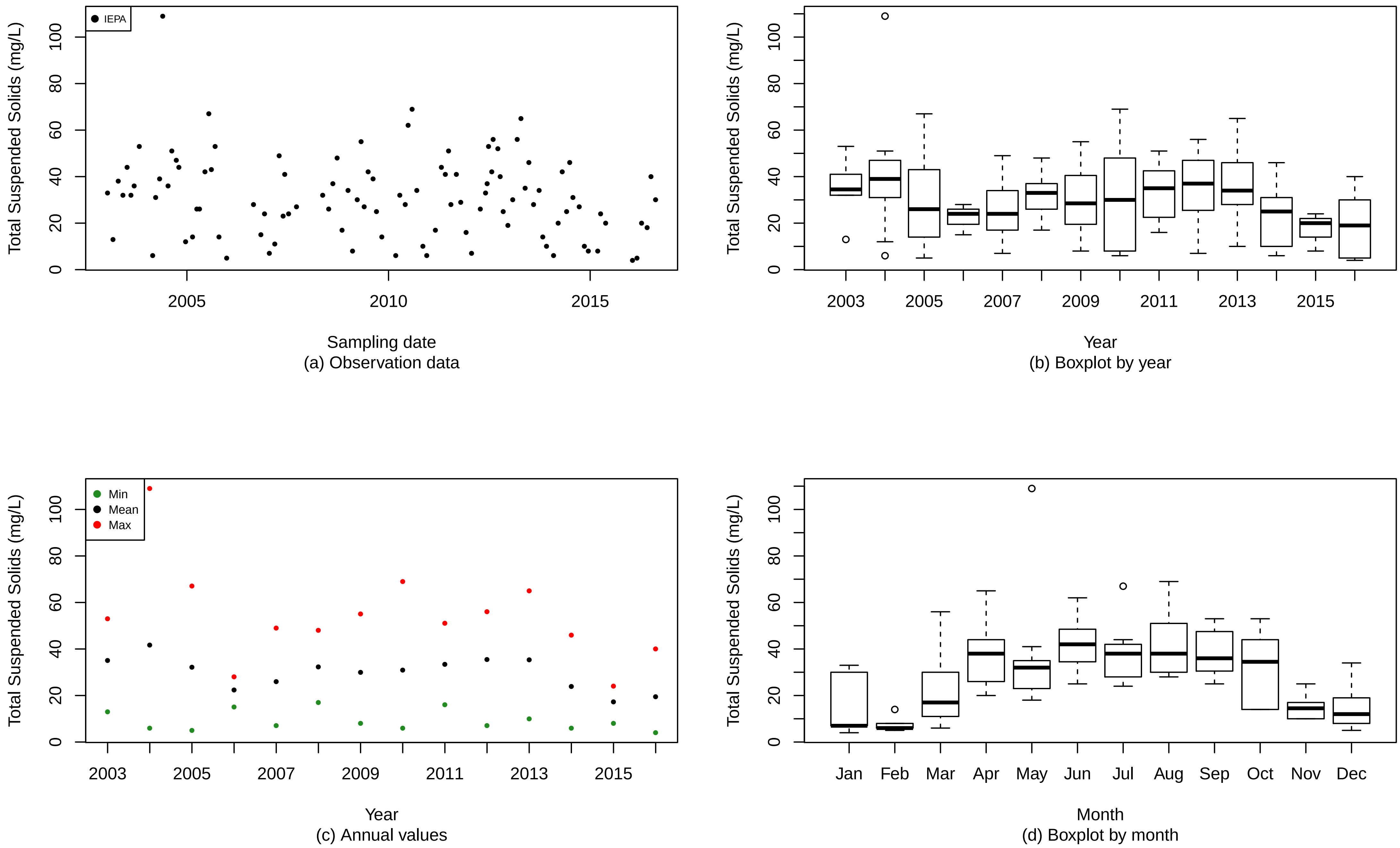
(c) Annual values

(d) Boxplot by month

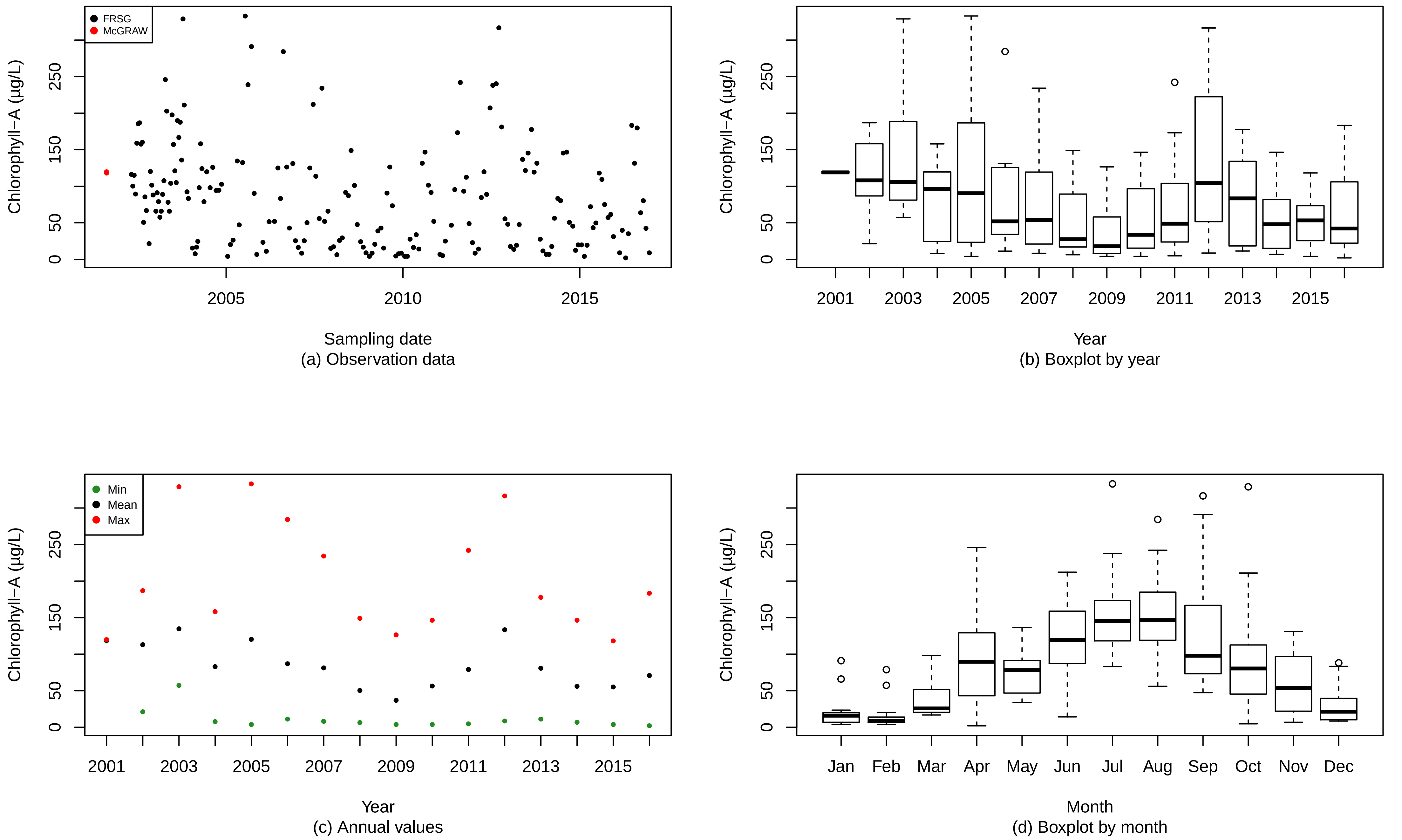
Fox River at South Elgin (26): pH (su)

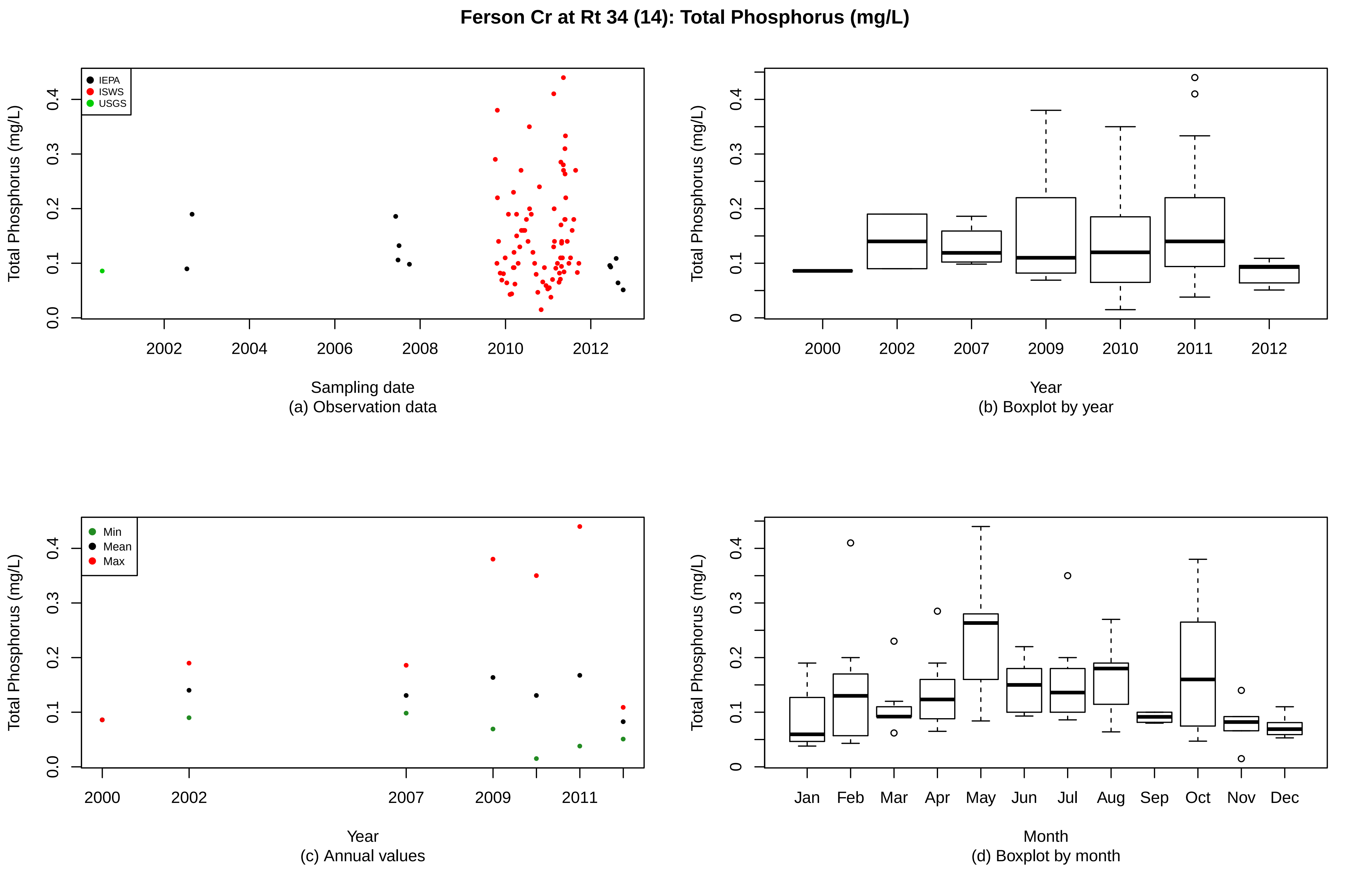


Fox River at South Elgin (26): Total Suspended Solids (mg/L)

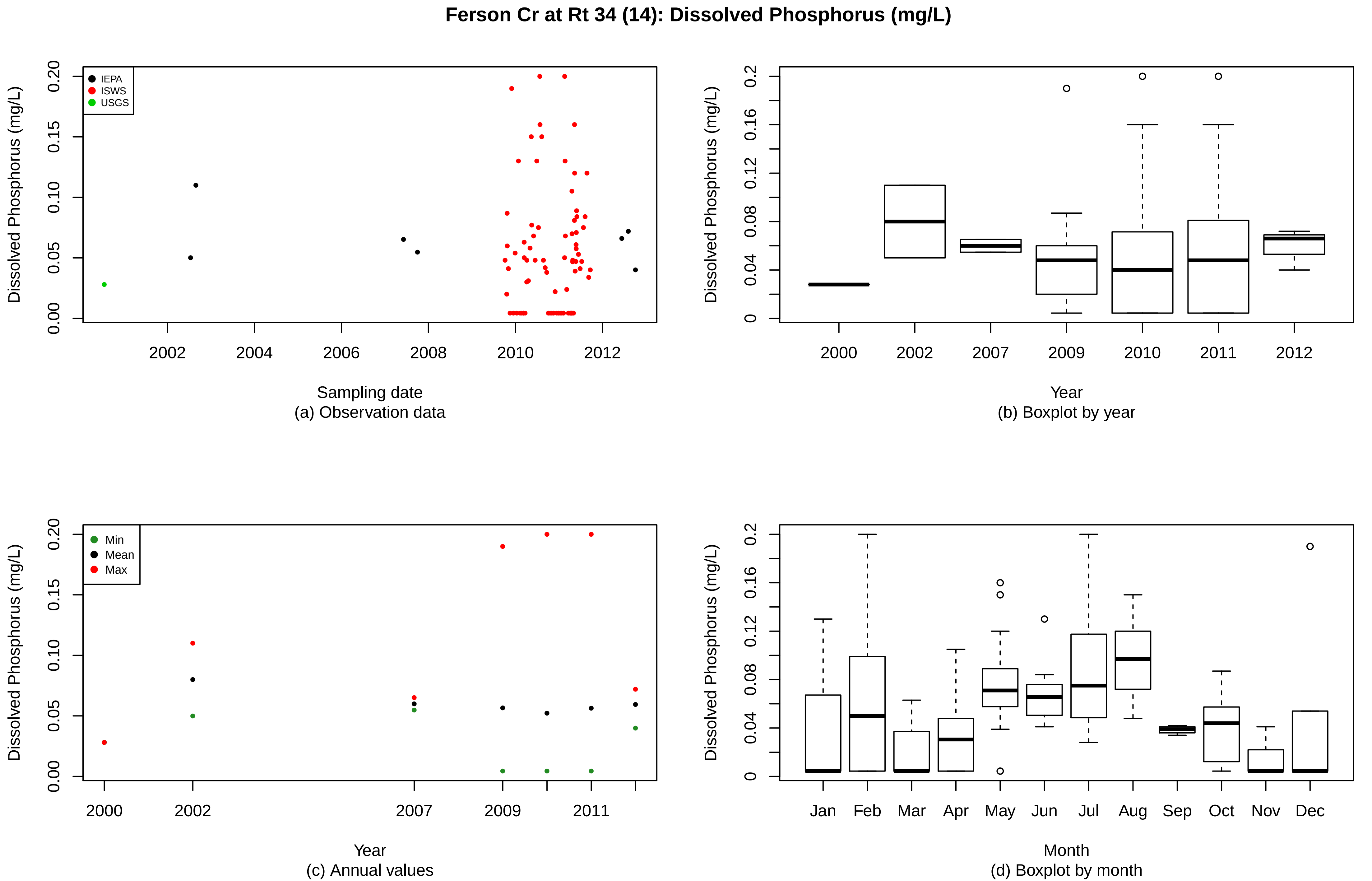


Fox River at South Elgin (26): Chlorophyll−A (µg/L)

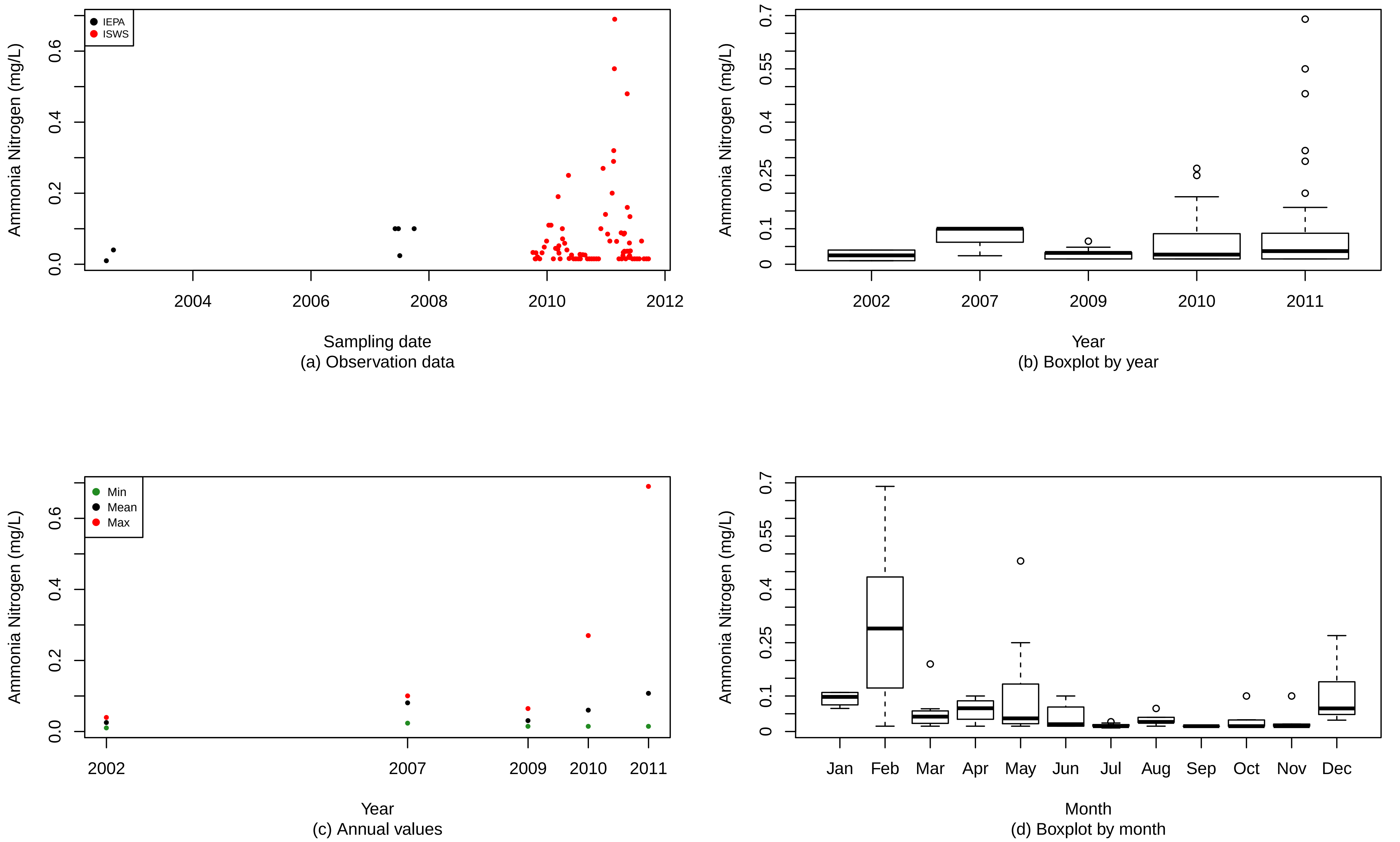




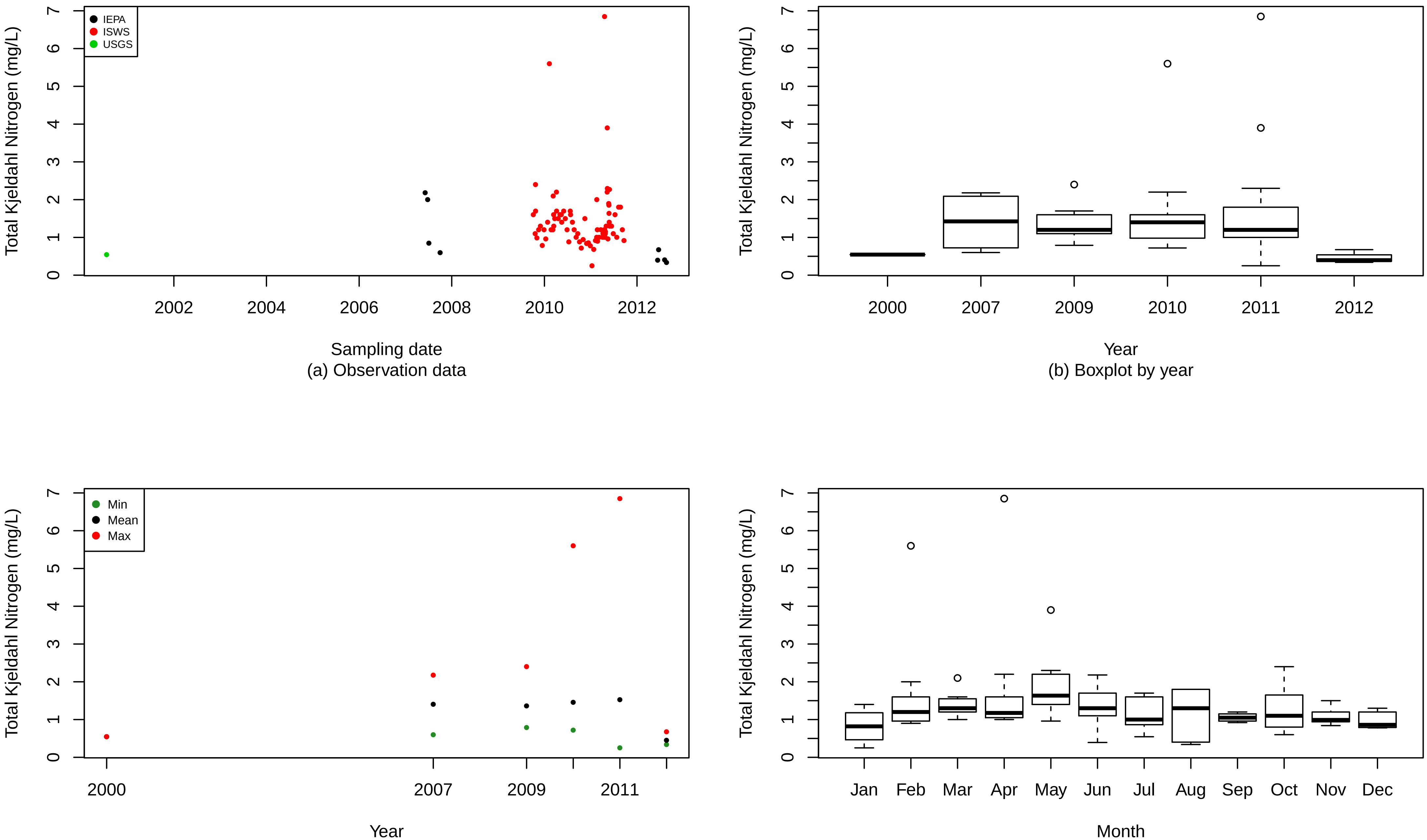
Ferson Cr at Rt 34 (14): Total Phosphorus (mg/L)
IEPA
ISWS
USGS
Total Phosphorus (mg/L)
0.0
0.1
0.2
0.3
0.4
2002
2004
2006
2008
2010
2012
Sampling date
(a) Observation data
0
2000
2002
2007
2009
2010
2011
2012
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
(d) Boxplot by month


Ferson Cr at Rt 34 (14): Dissolved Phosphorus (mg/L)
IEPA
ISWS
USGS
Dissolved Phosphorus (mg/L)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Month
(d) Boxplot by month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Ferson Cr at Rt 34 (14): Ammonia Nitrogen (mg/L)



Ferson Cr at Rt 34 (14): Total Kjeldahl Nitrogen (mg/L)



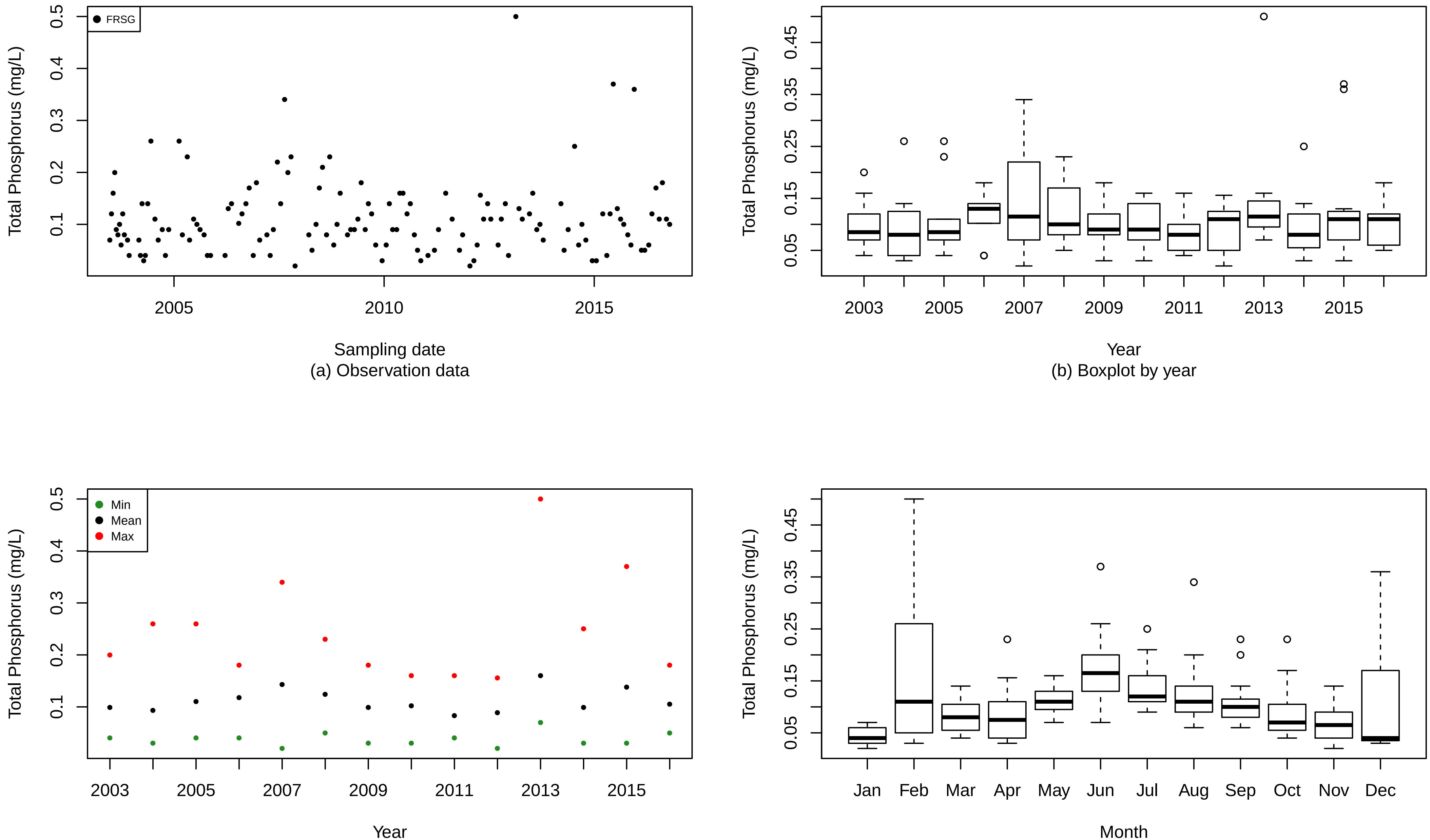
(a) Observation data

(b) Boxplot by year

(c) Annual values

(d) Boxplot by month

Ferson Cr near Mouth−Elgin (79): Total Phosphorus (mg/L)



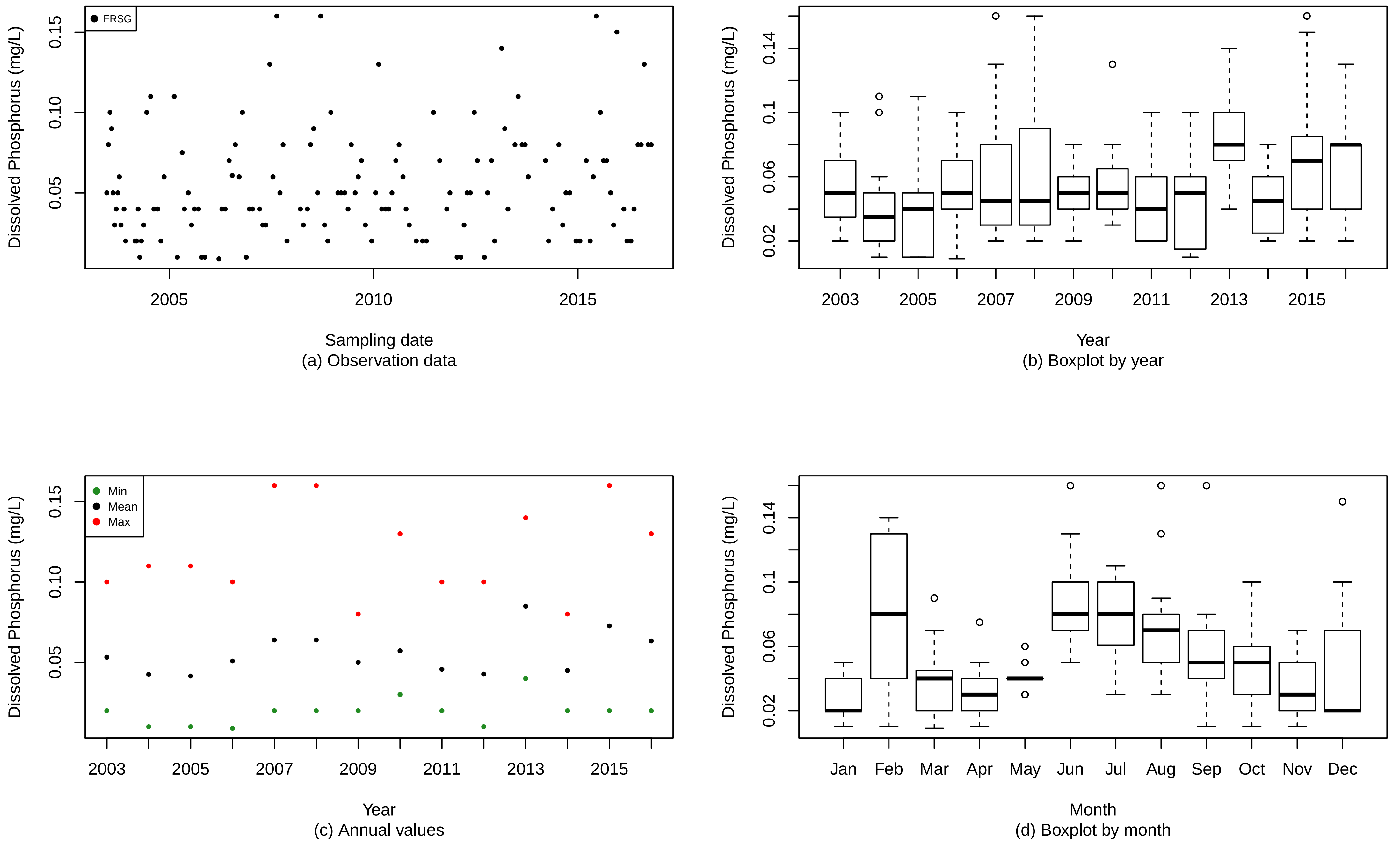
(a) Observation data

(b) Boxplot by year

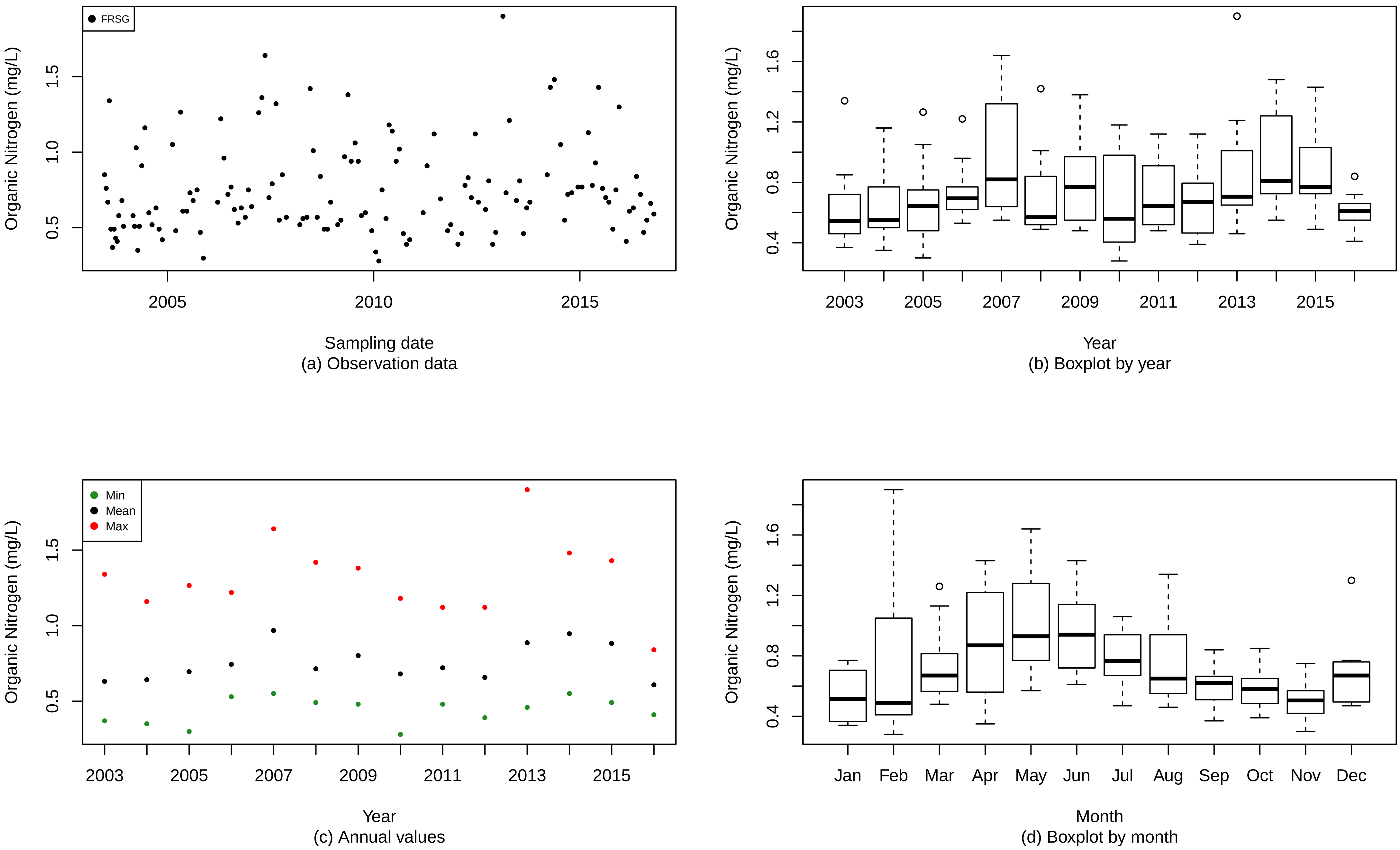
(c) Annual values

(d) Boxplot by month

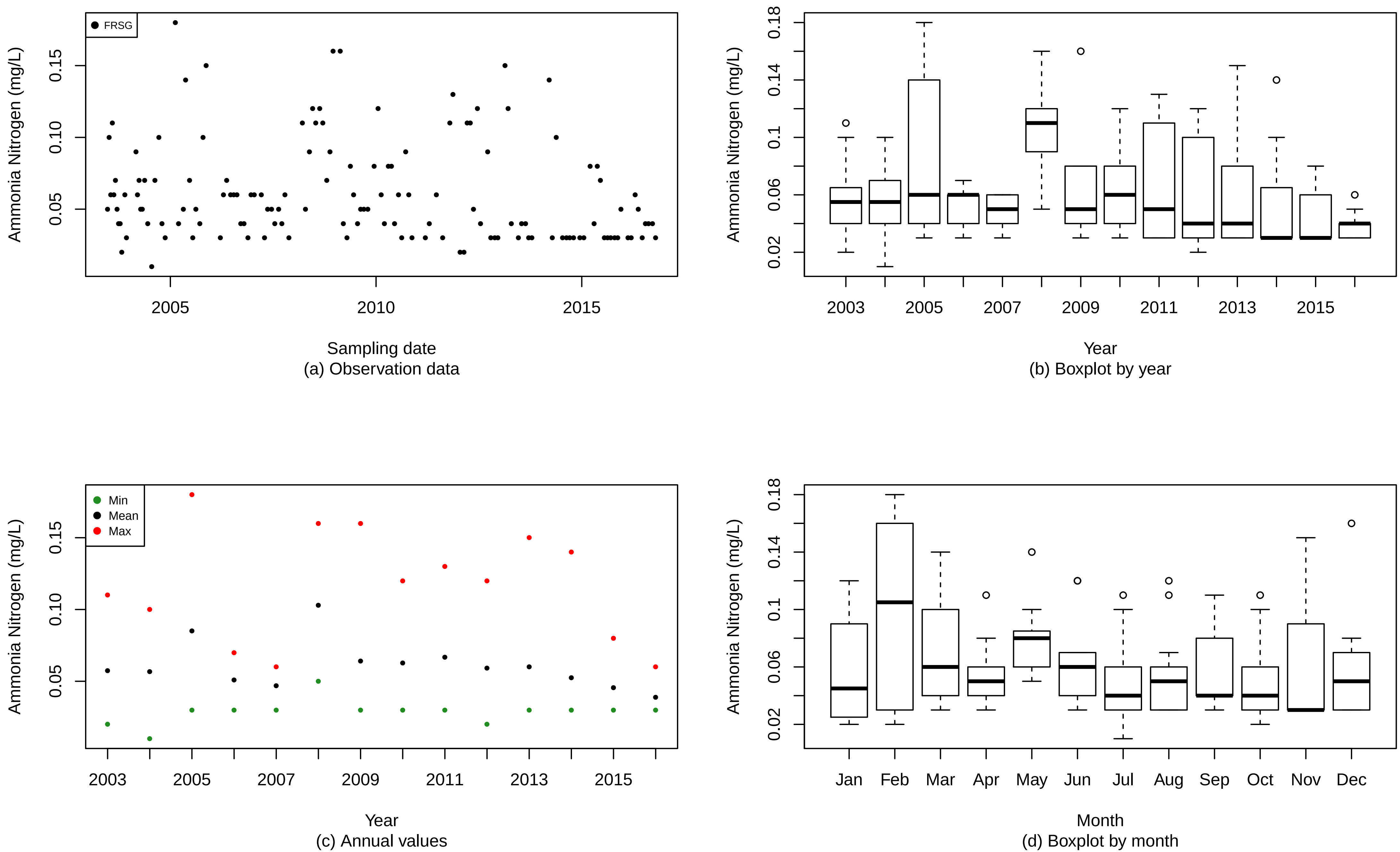
Ferson Cr near Mouth−Elgin (79): Dissolved Phosphorus (mg/L)



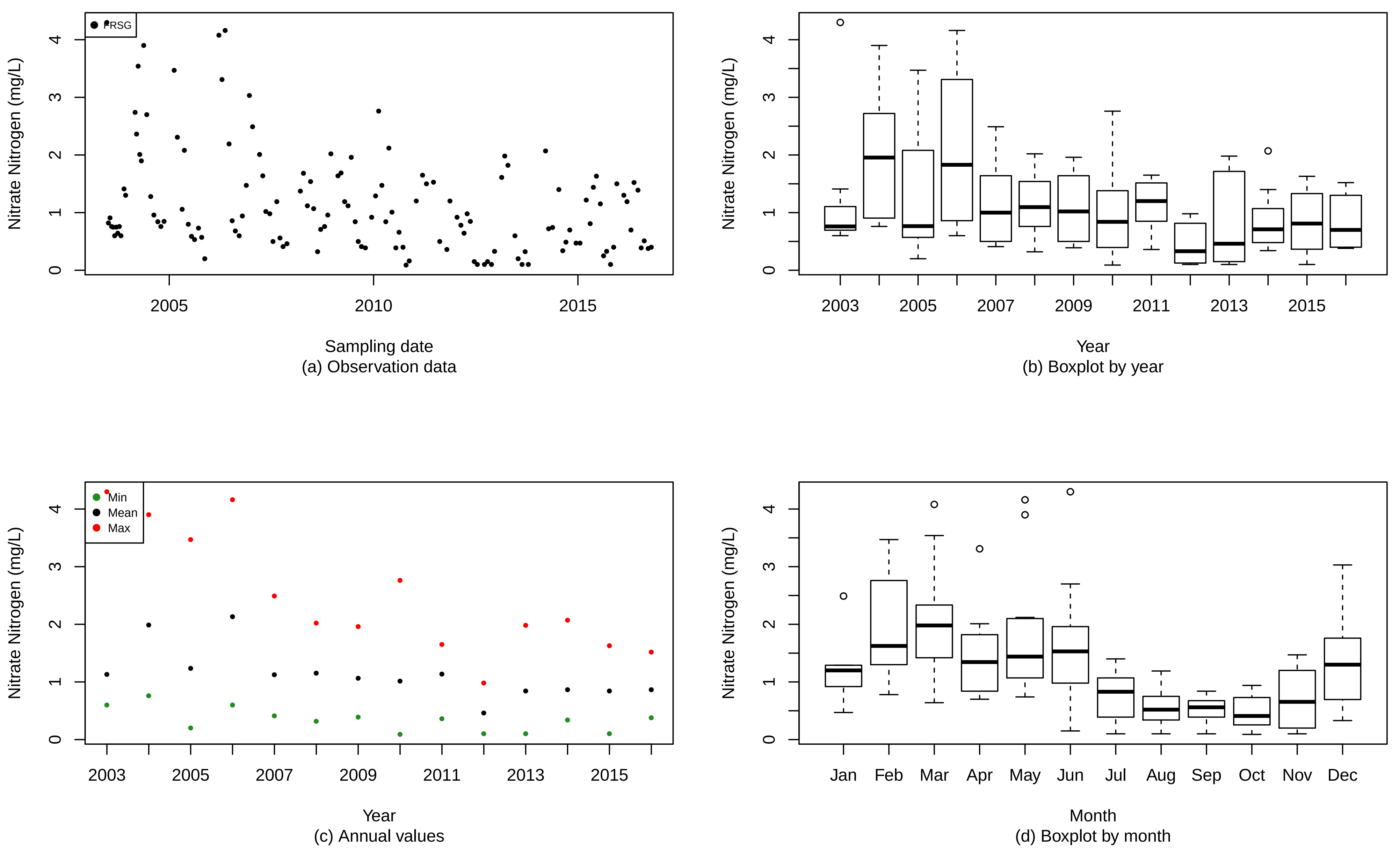
Ferson Cr near Mouth−Elgin (79): Organic Nitrogen (mg/L)



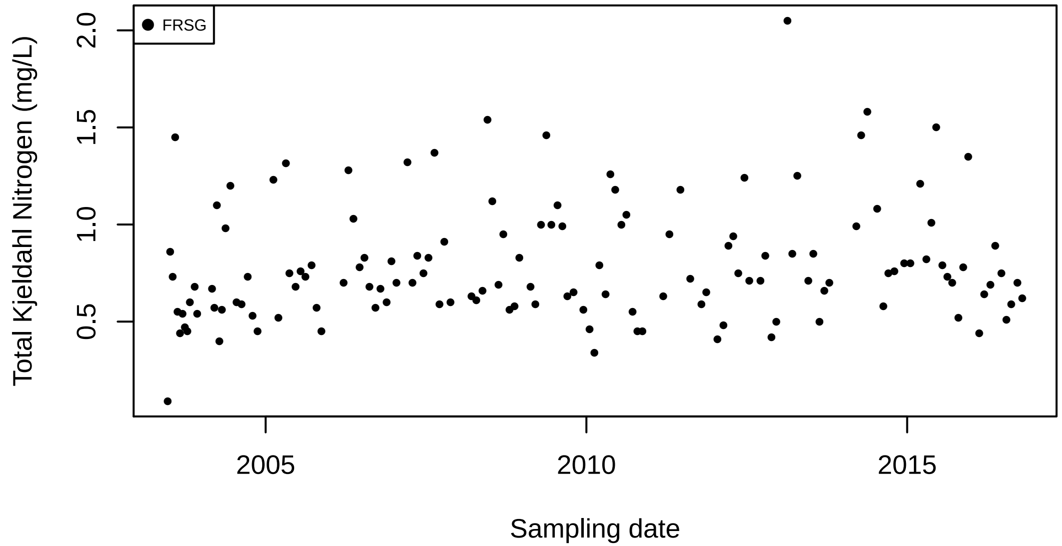
Ferson Cr near Mouth−Elgin (79): Ammonia Nitrogen (mg/L)



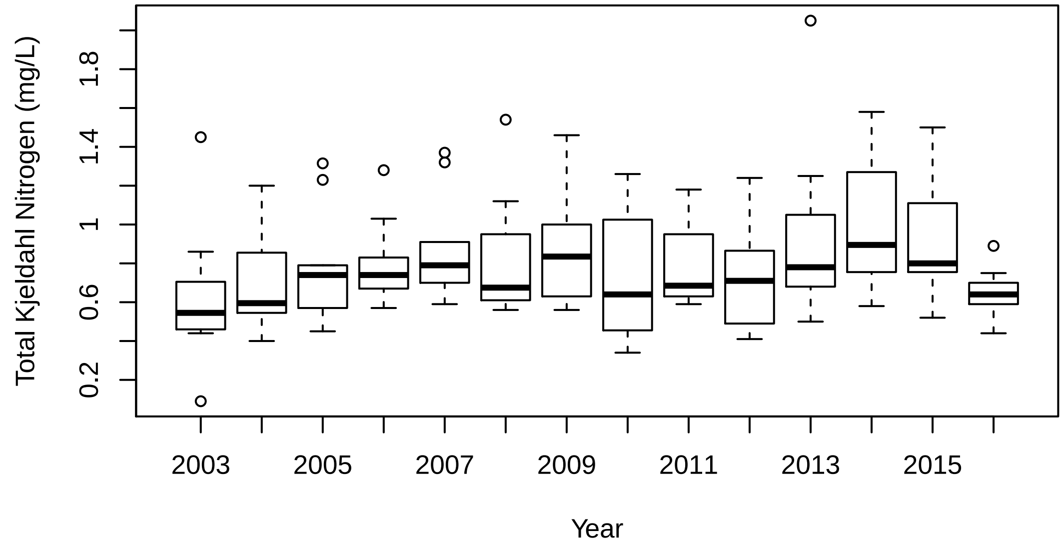
Ferson Cr near Mouth−Elgin (79): Nitrate Nitrogen (mg/L)



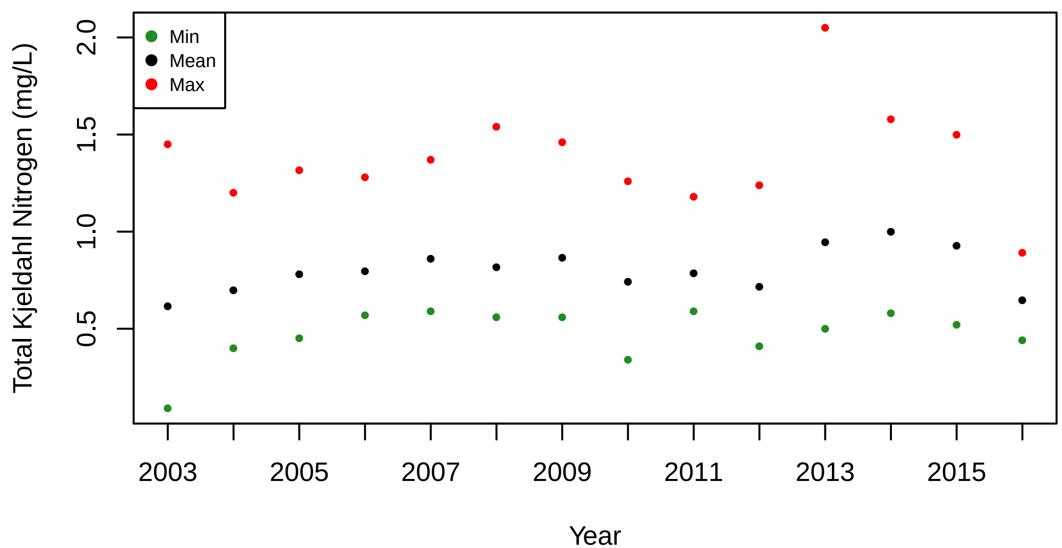
Ferson Cr near Mouth−Elgin (79): Total Kjeldahl Nitrogen (mg/L)



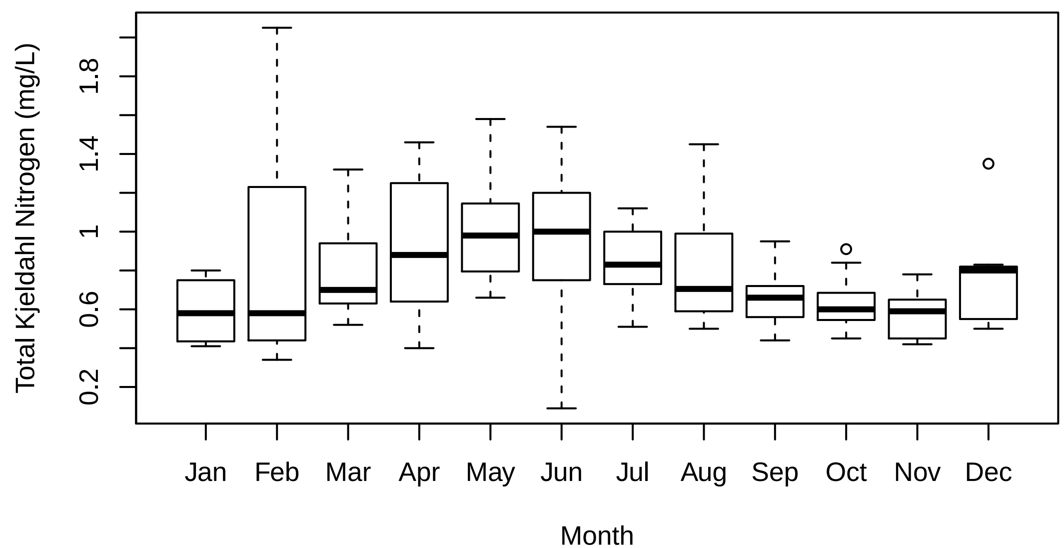
(a) Observation data



(b) Boxplot by year

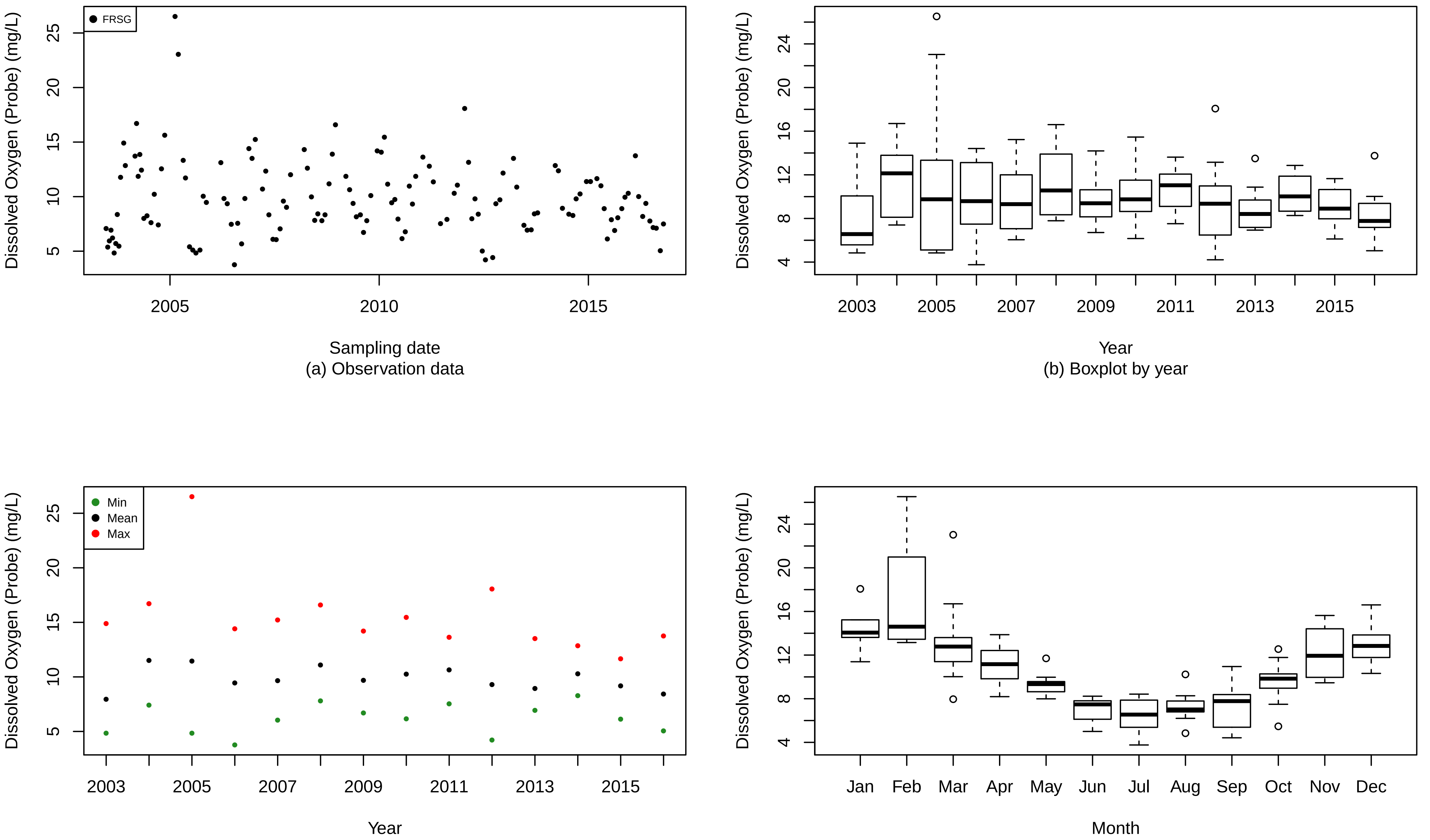


(c) Annual values



(d) Boxplot by month

Ferson Cr near Mouth−Elgin (79): Dissolved Oxygen (Probe) (mg/L)



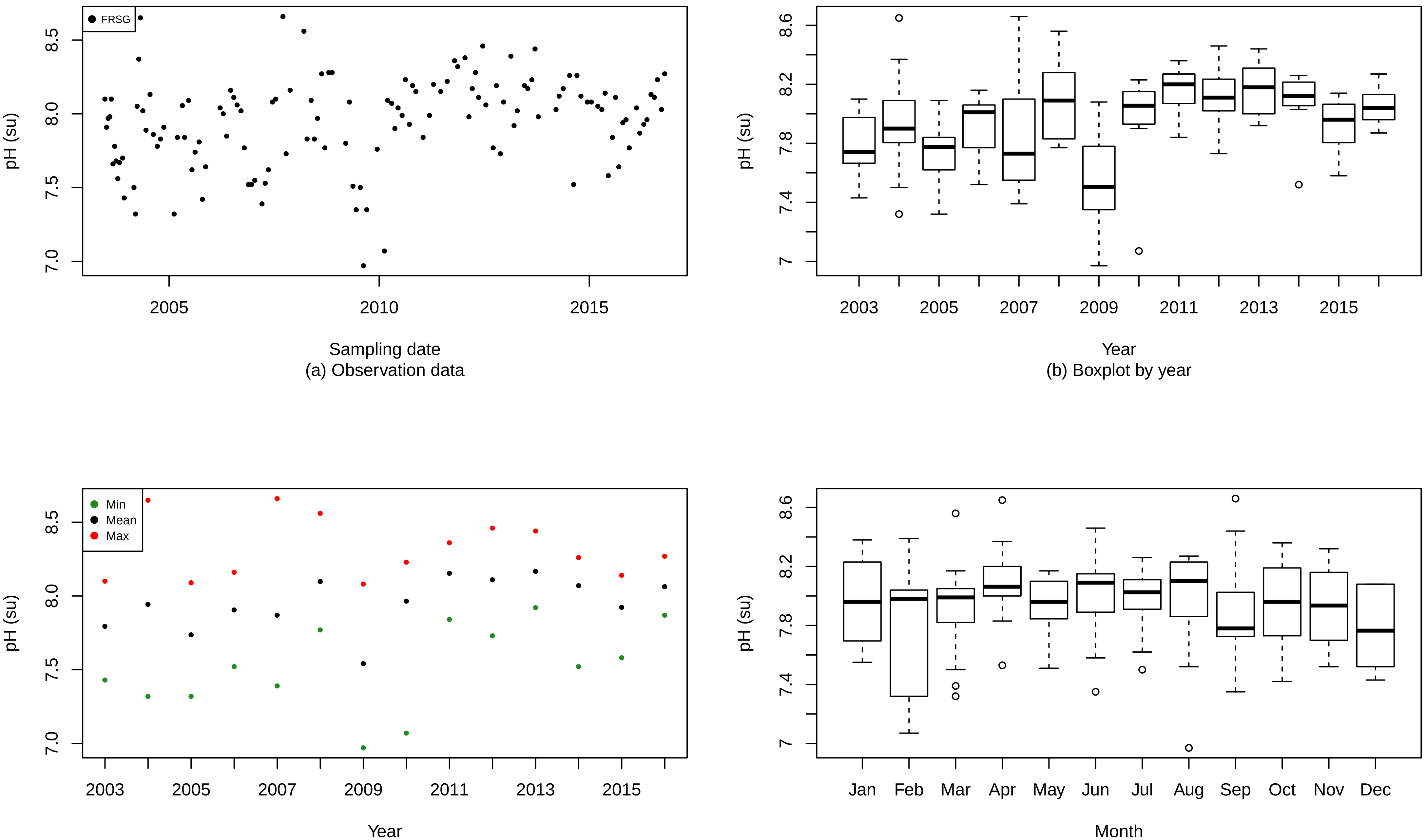
(a) Observation data

(b) Boxplot by year

(c) Annual values

(d) Boxplot by month

Ferson Cr near Mouth−Elgin (79): pH (su)

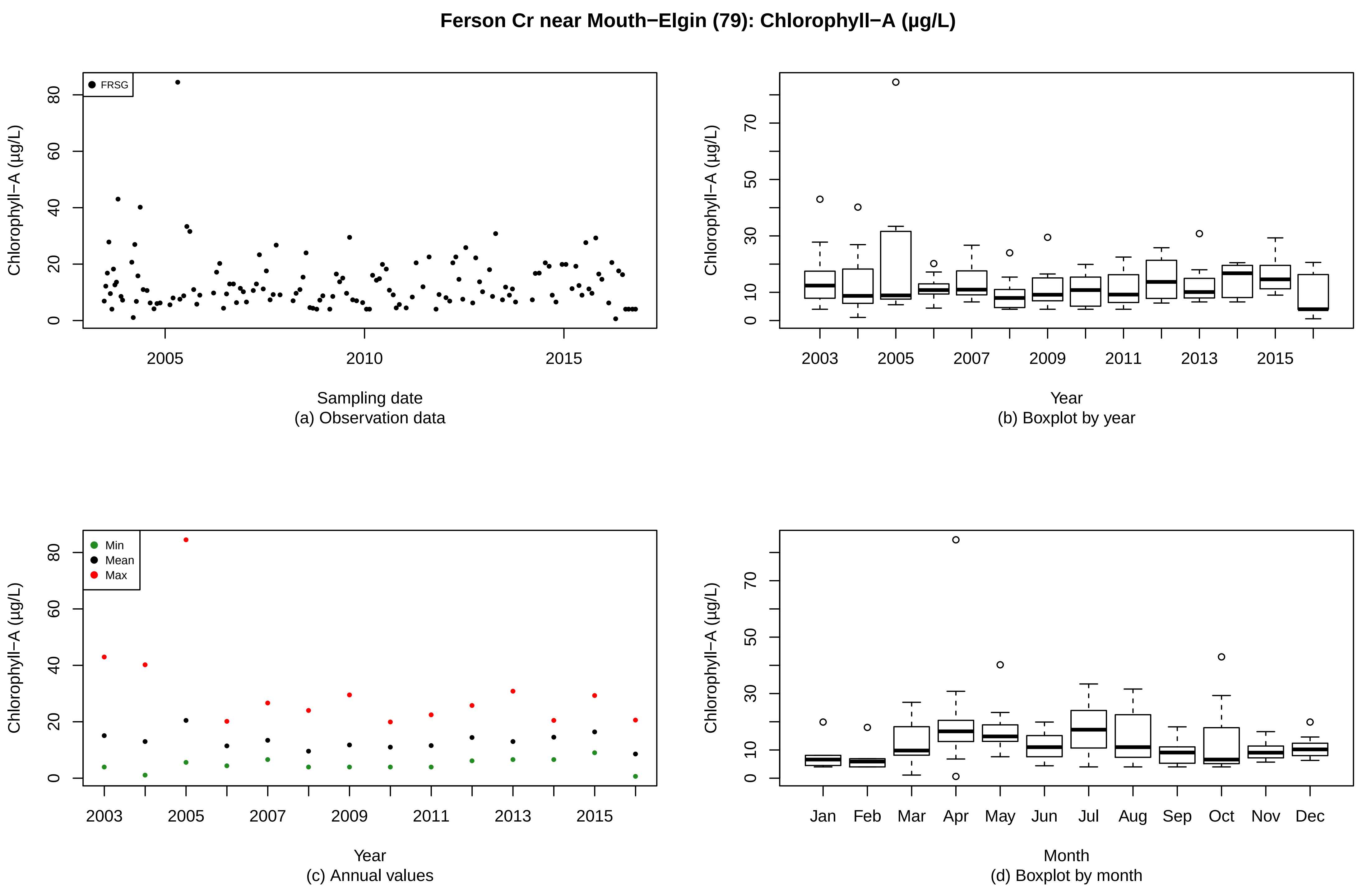


(a) Observation data

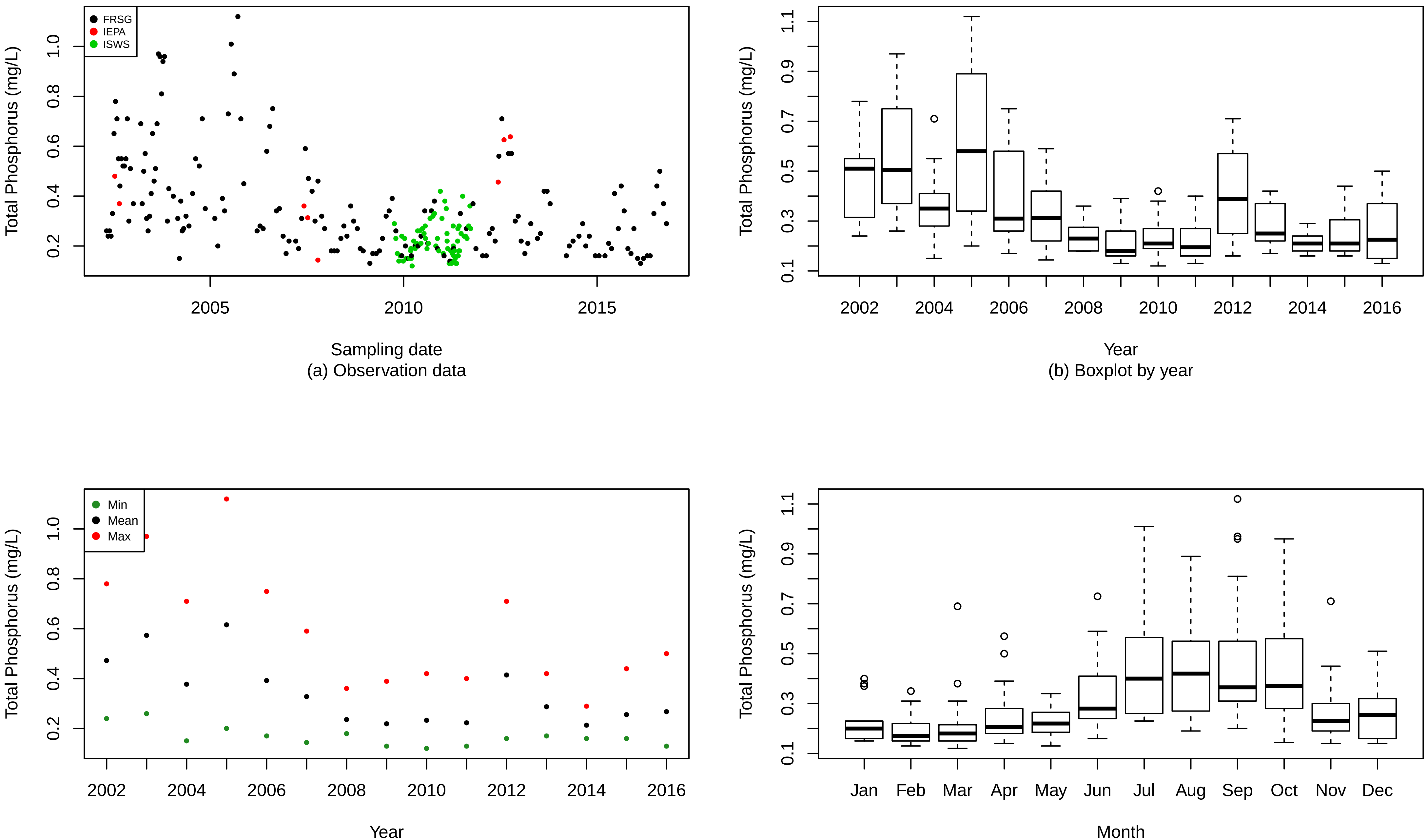
(b) Boxplot by year

(c) Annual values

(d) Boxplot by month


Ferson Cr near Mouth−Elgin (79): Chlorophyll−A (µg/L)
Chlorophyll−A (µg/L)
FRSG
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Month
(d) Boxplot by month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Fox River at Geneva (40): Total Phosphorus (mg/L)

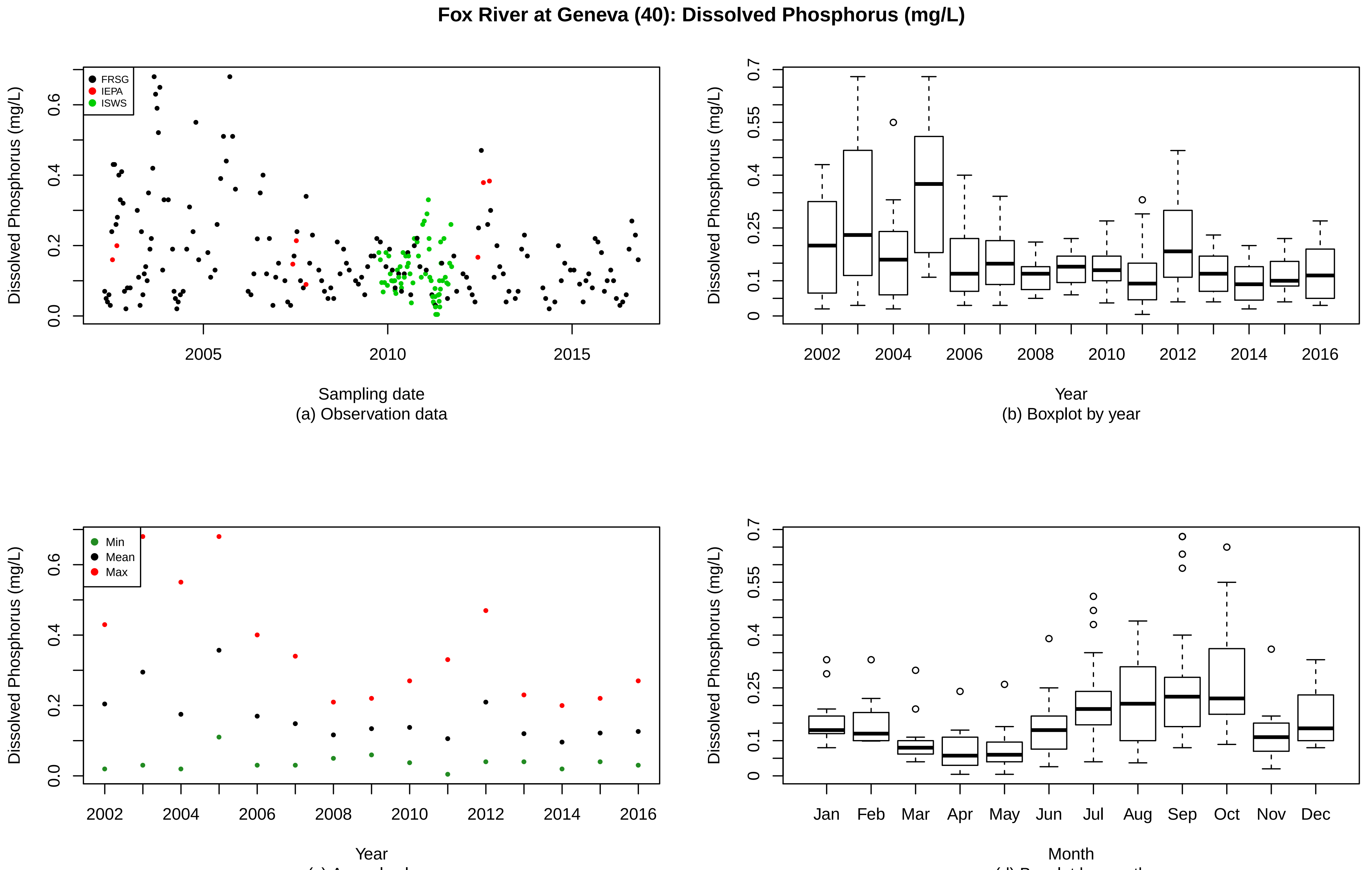


(a) Observation data

(b) Boxplot by year

(c) Annual values

(d) Boxplot by month



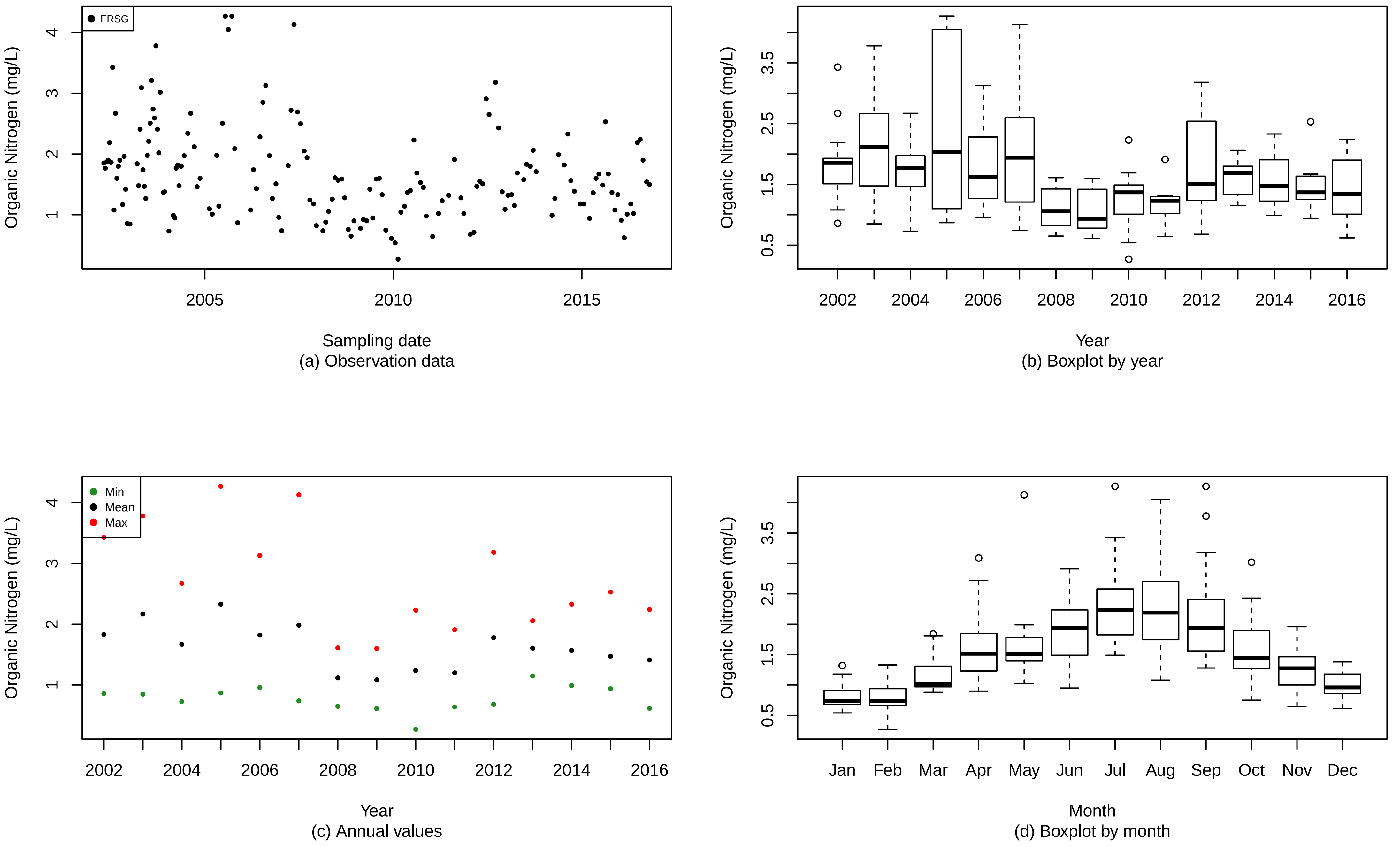
(a) Observation data

(b) Boxplot by year

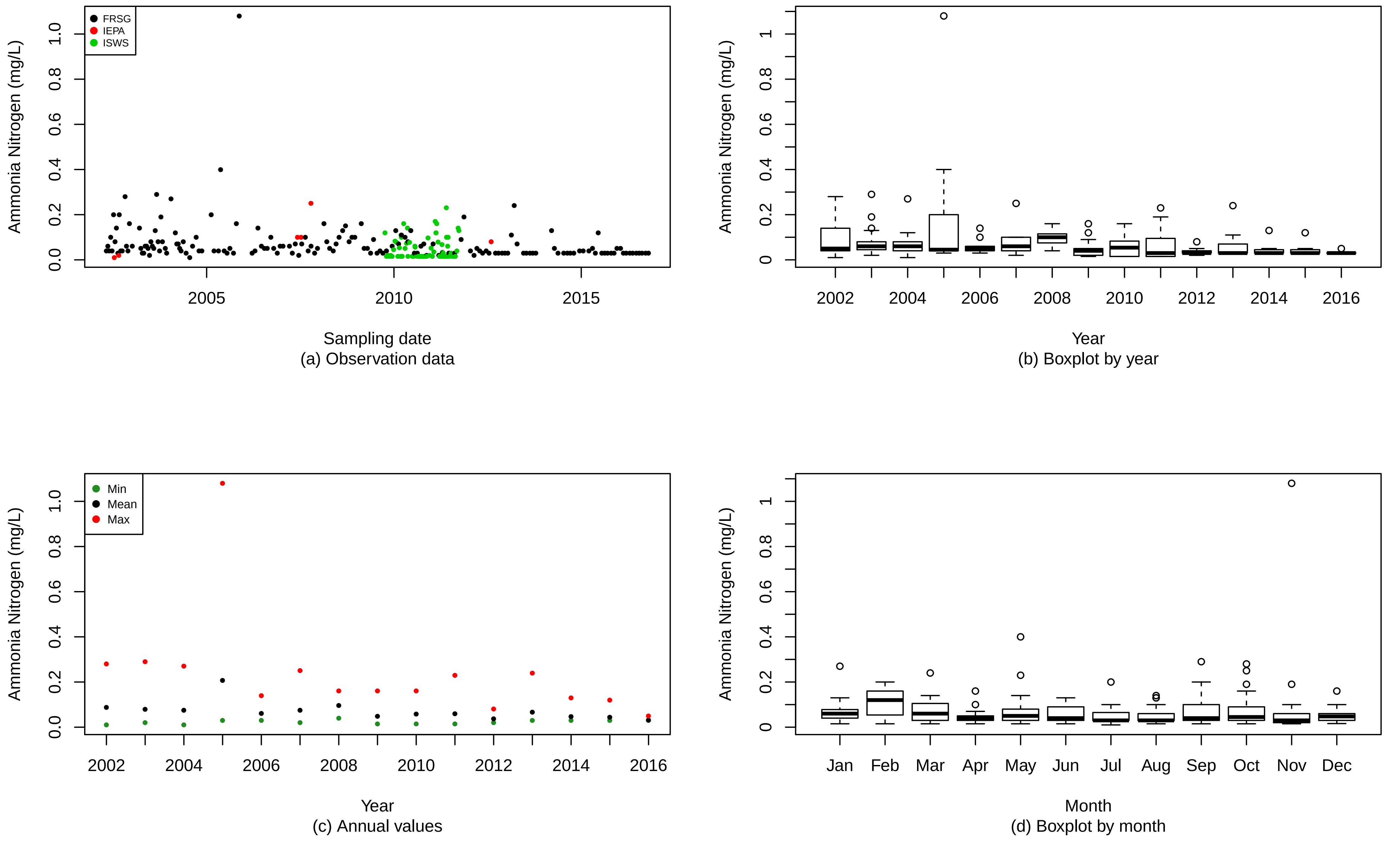
(c) Annual values

(d) Boxplot by month

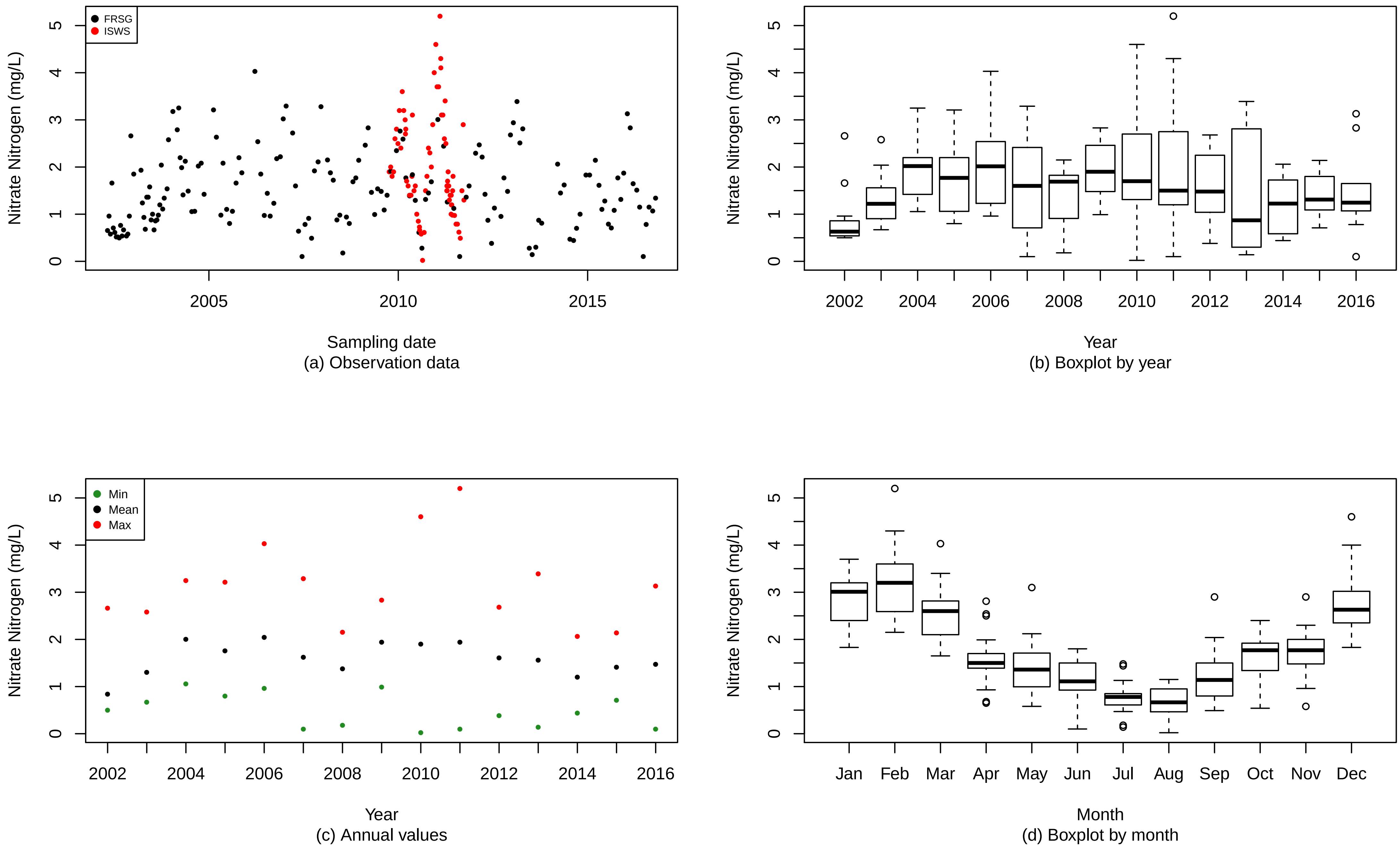
Fox River at Geneva (40): Organic Nitrogen (mg/L)



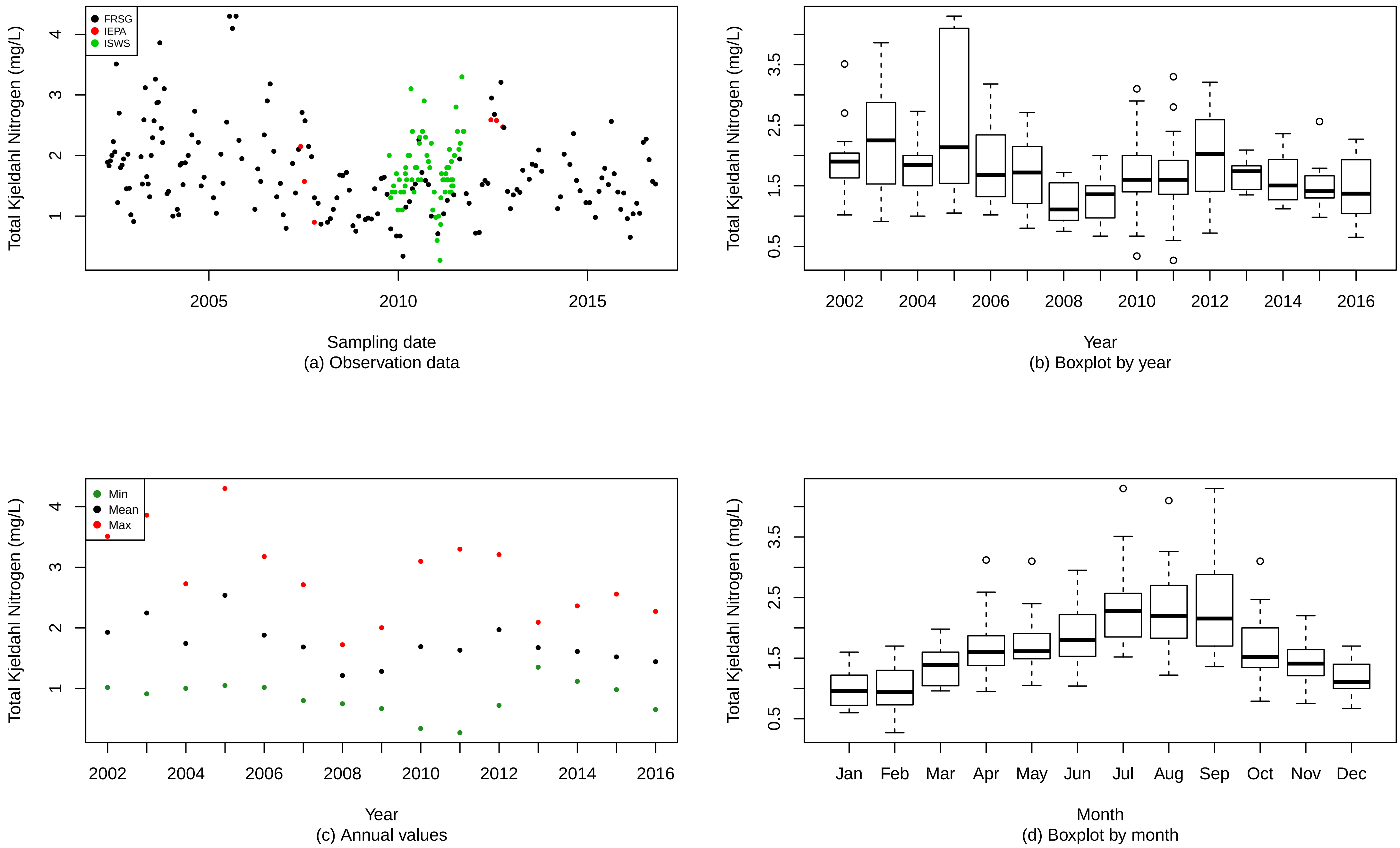
Fox River at Geneva (40): Ammonia Nitrogen (mg/L)



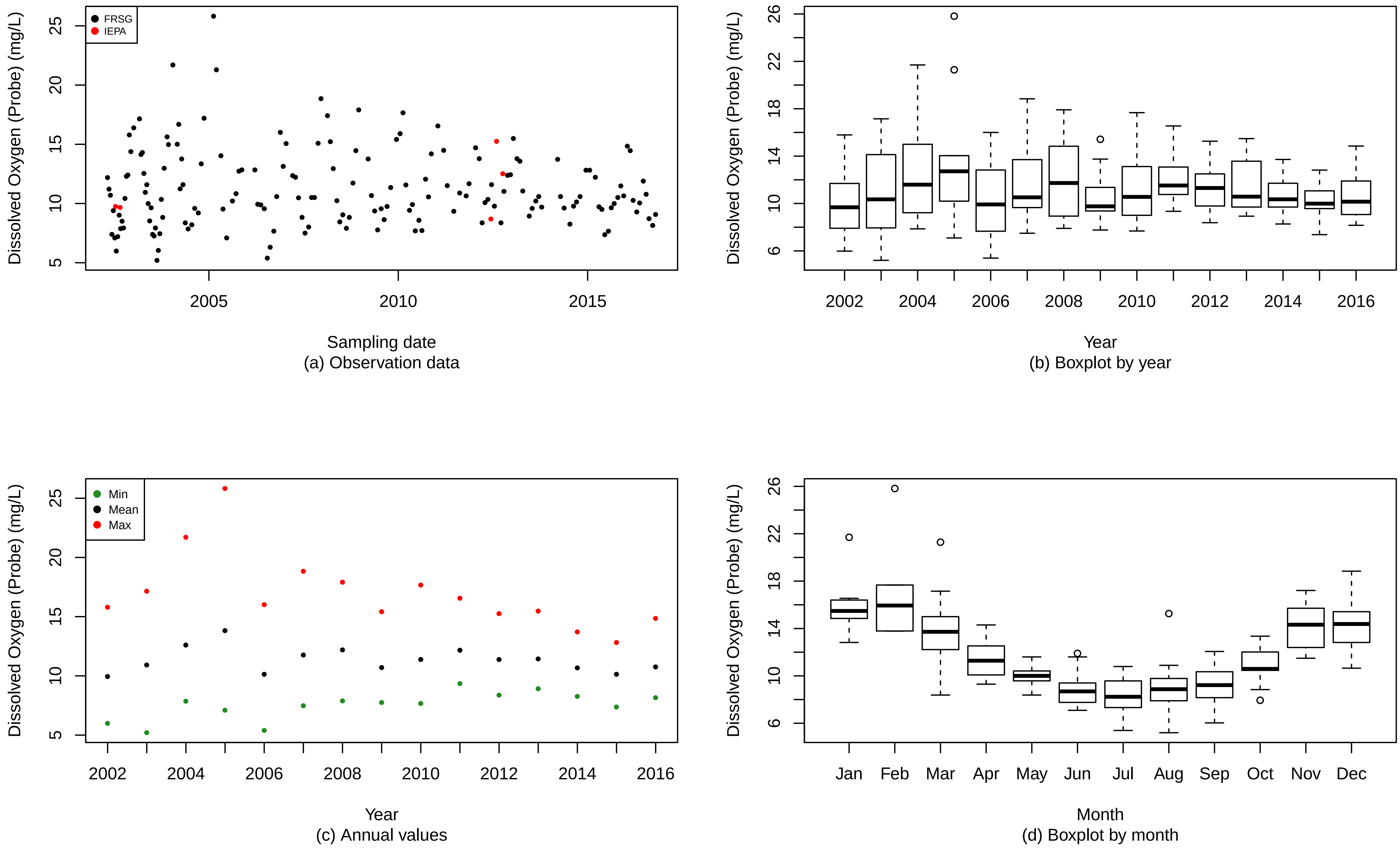
Fox River at Geneva (40): Nitrate Nitrogen (mg/L)



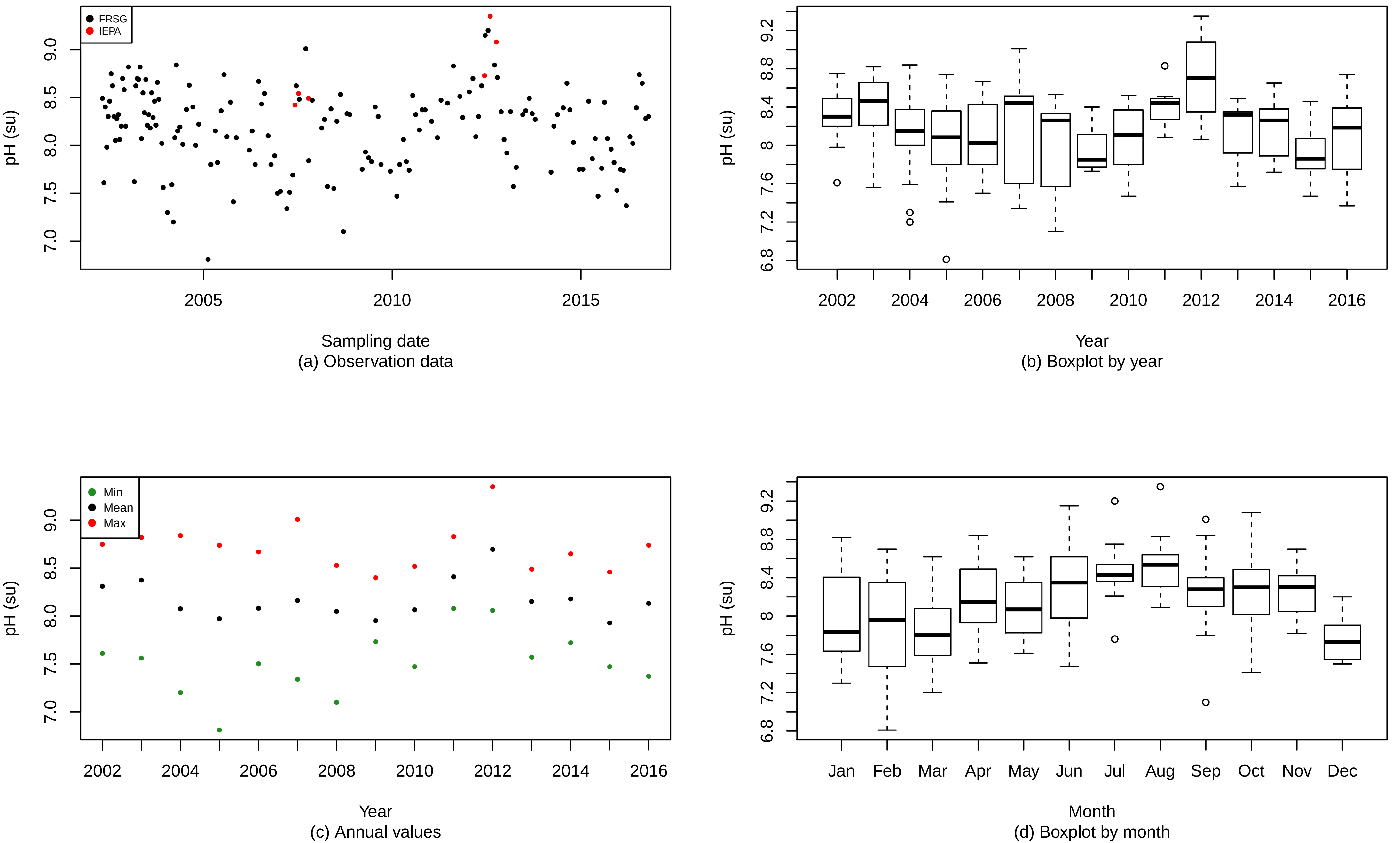
Fox River at Geneva (40): Total Kjeldahl Nitrogen (mg/L)



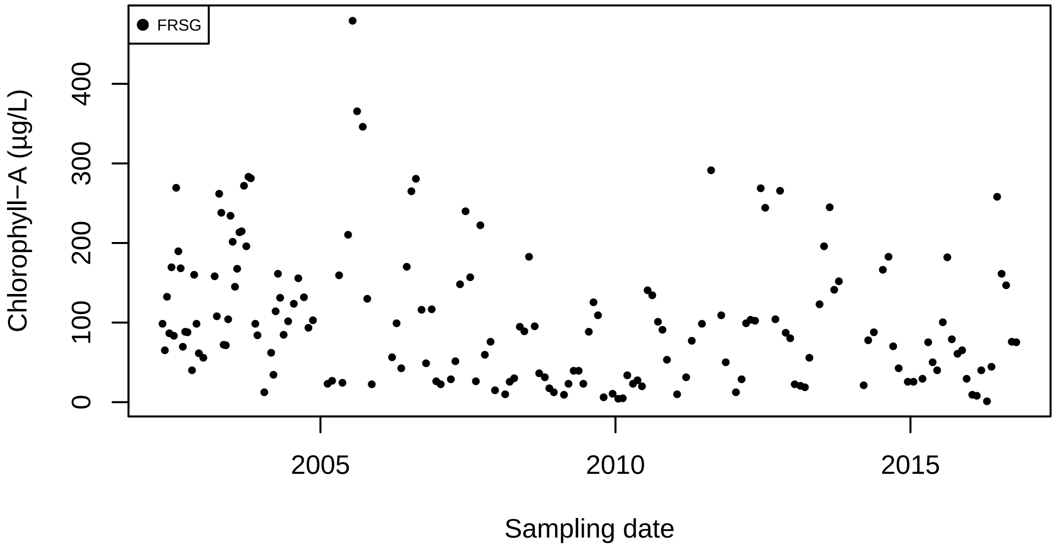
Fox River at Geneva (40): Dissolved Oxygen (Probe) (mg/L)



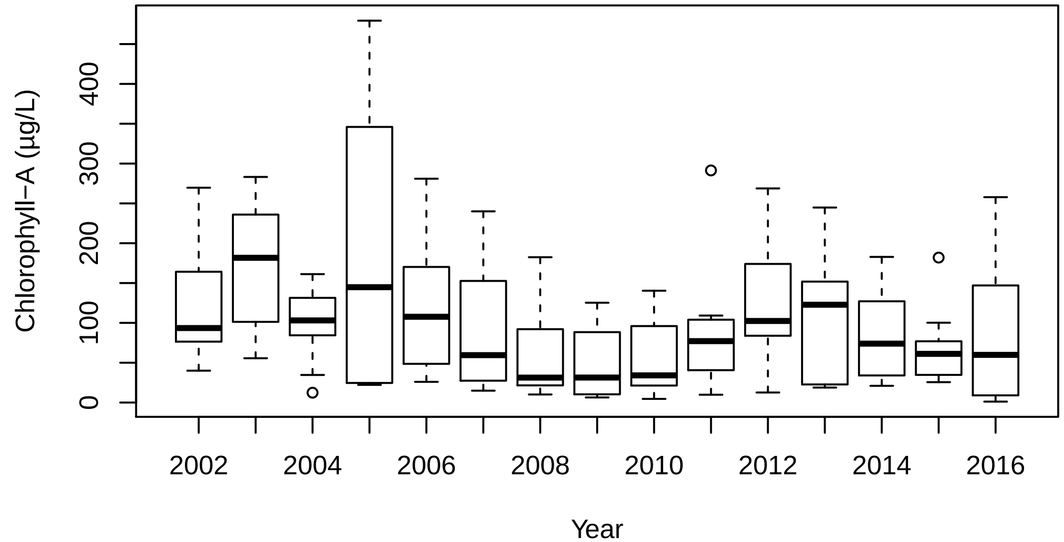
Fox River at Geneva (40): pH (su)



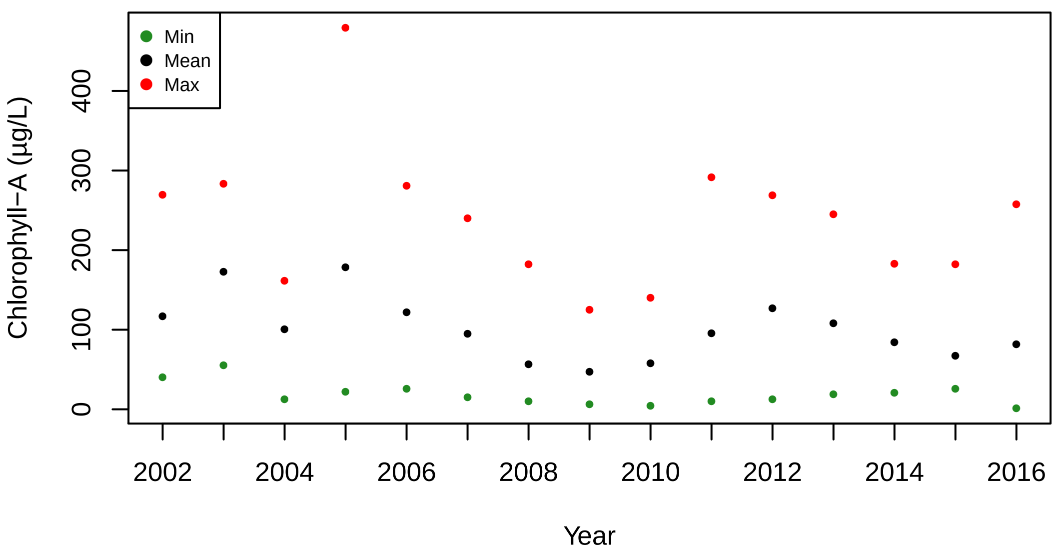
Fox River at Geneva (40): Chlorophyll−A (µg/L)



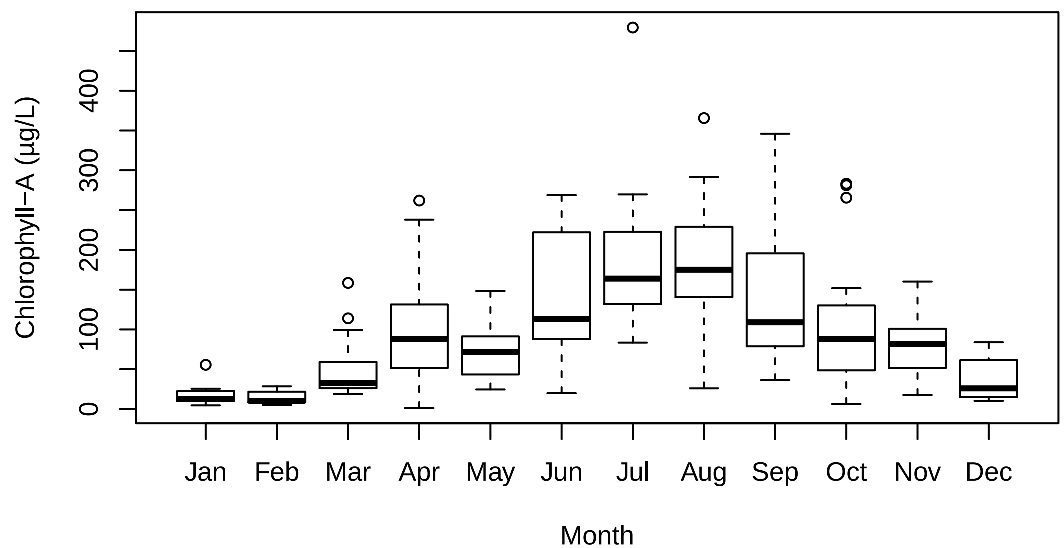
(a) Observation data



(b) Boxplot by year

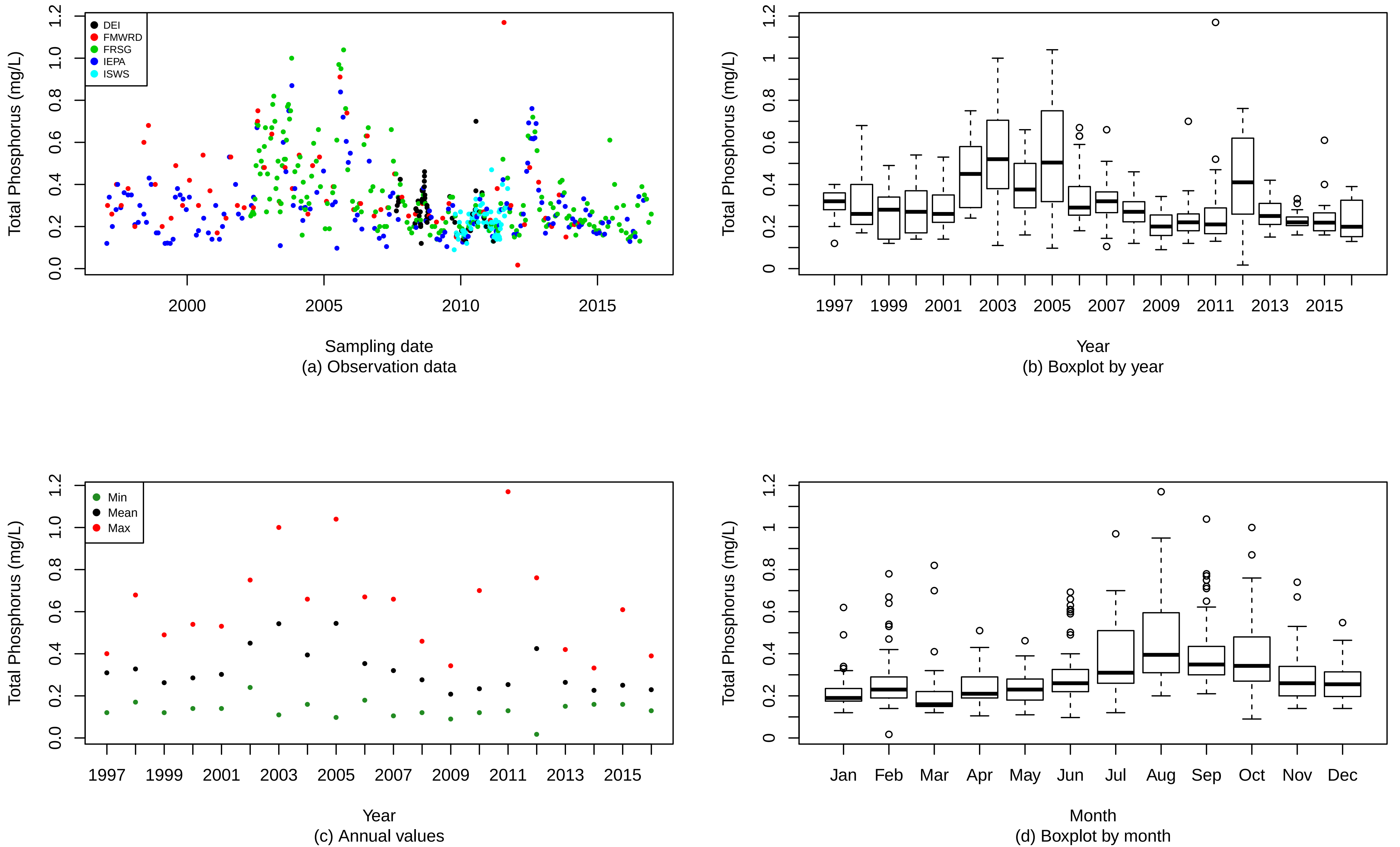


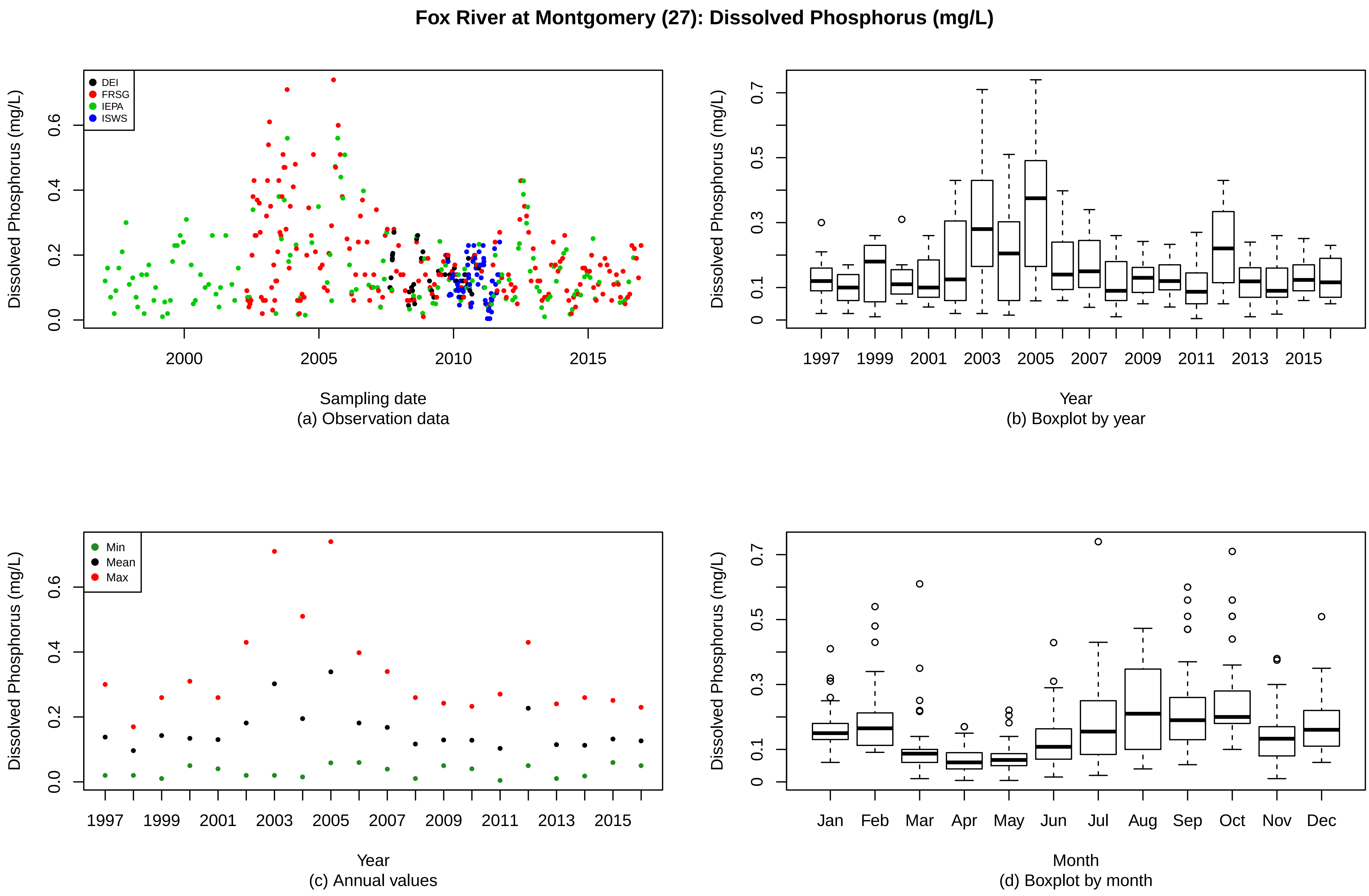
(c) Annual values



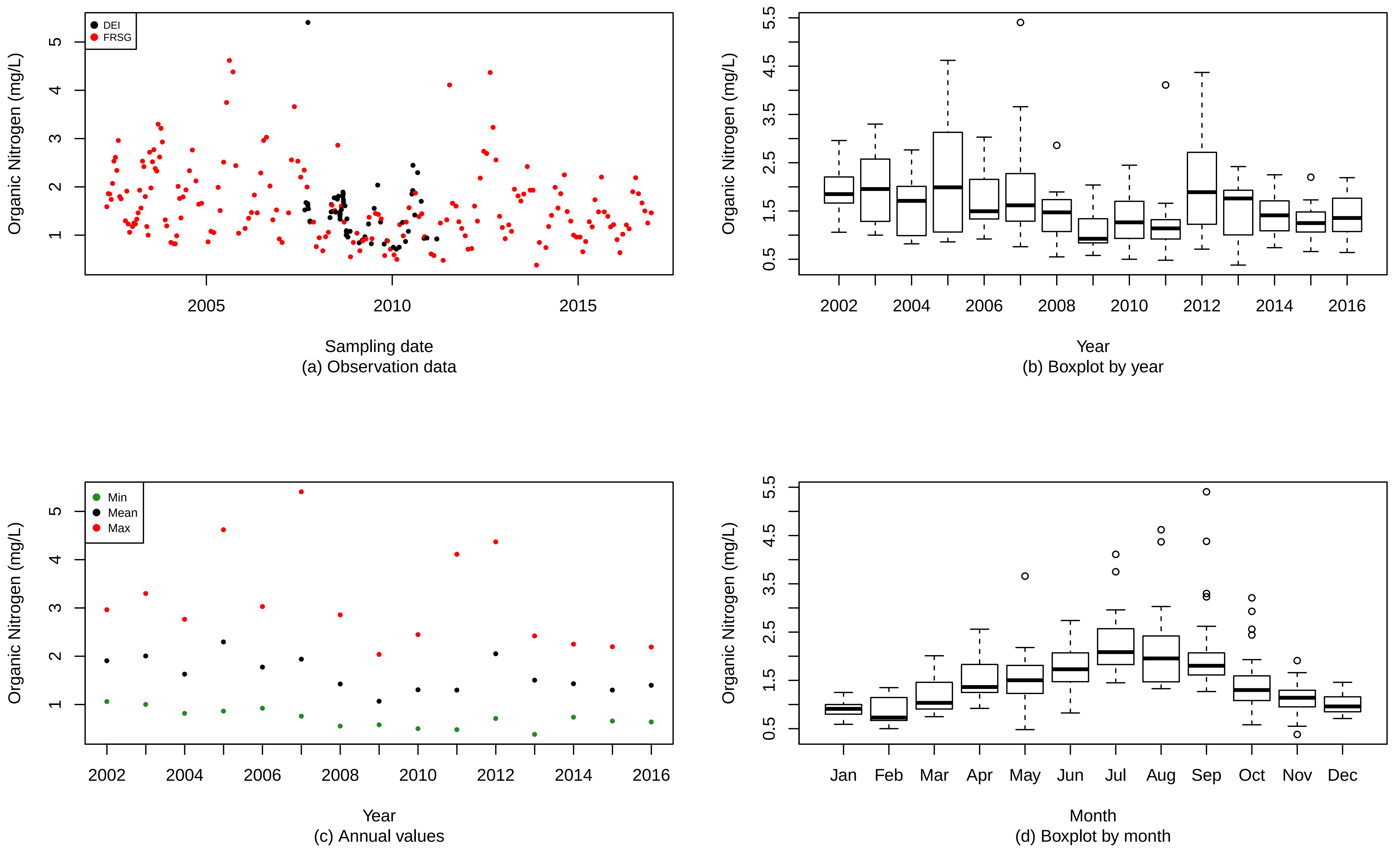
(d) Boxplot by month

Fox River at Montgomery (27): Total Phosphorus (mg/L)

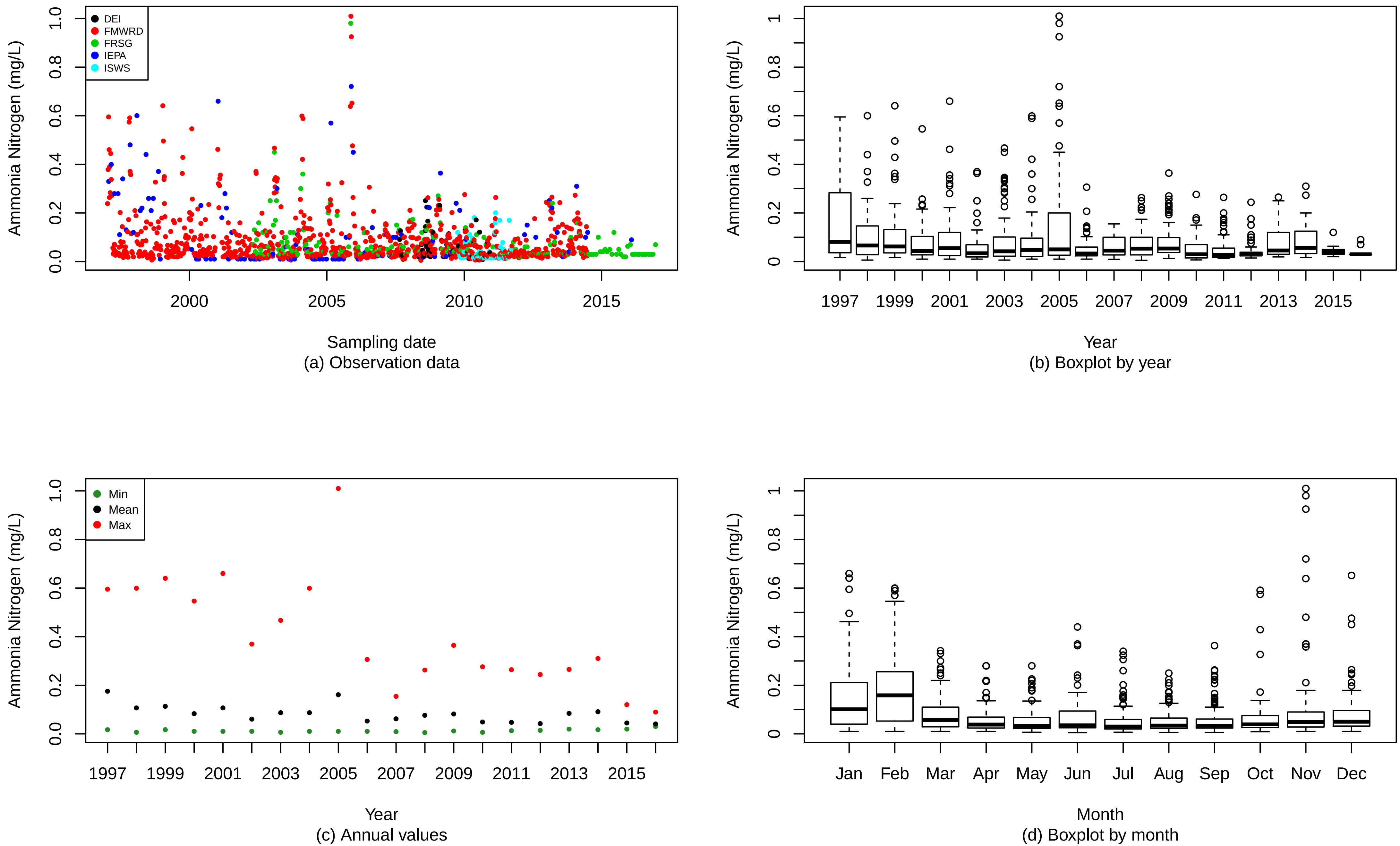



Fox River at Montgomery (27): Dissolved Phosphorus (mg/L)
DEI
FRSG
IEPA
ISWS
Dissolved Phosphorus (mg/L)
0.0
0.2
0.4
0.6
2000
2005
2010
2015
Sampling date
(a) Observation data
Dissolved Phosphorus (mg/L)
0
0.1
0.3
0.5
0.7
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
Year
(b) Boxplot by year
Min
Mean
Max
Dissolved Phosphorus (mg/L)
0.0
0.2
0.4
0.6
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
Year
(c) Annual values
Dissolved Phosphorus (mg/L)
0
0.1
0.3
0.5
0.7
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
(d) Boxplot by month

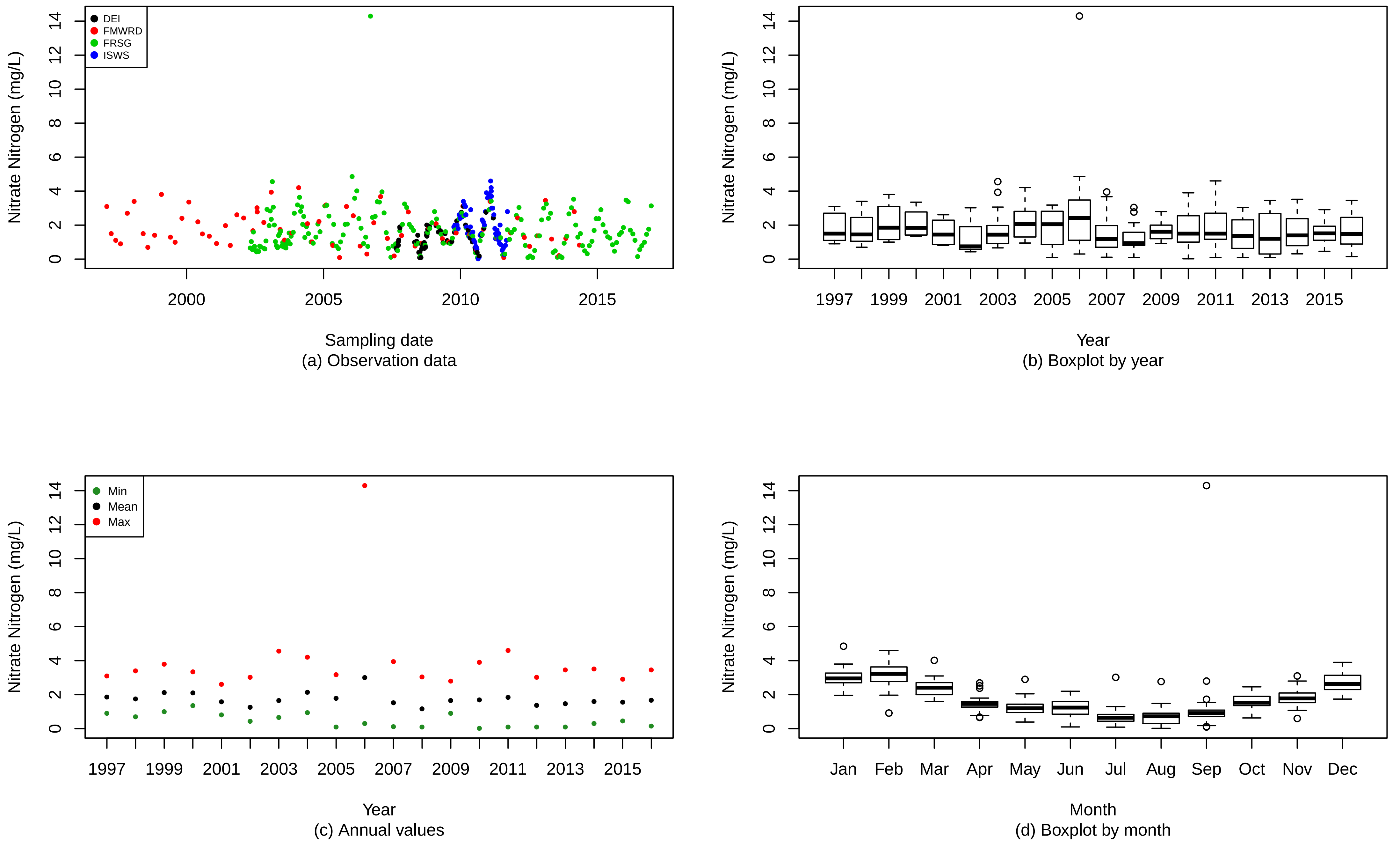
Fox River at Montgomery (27): Organic Nitrogen (mg/L)

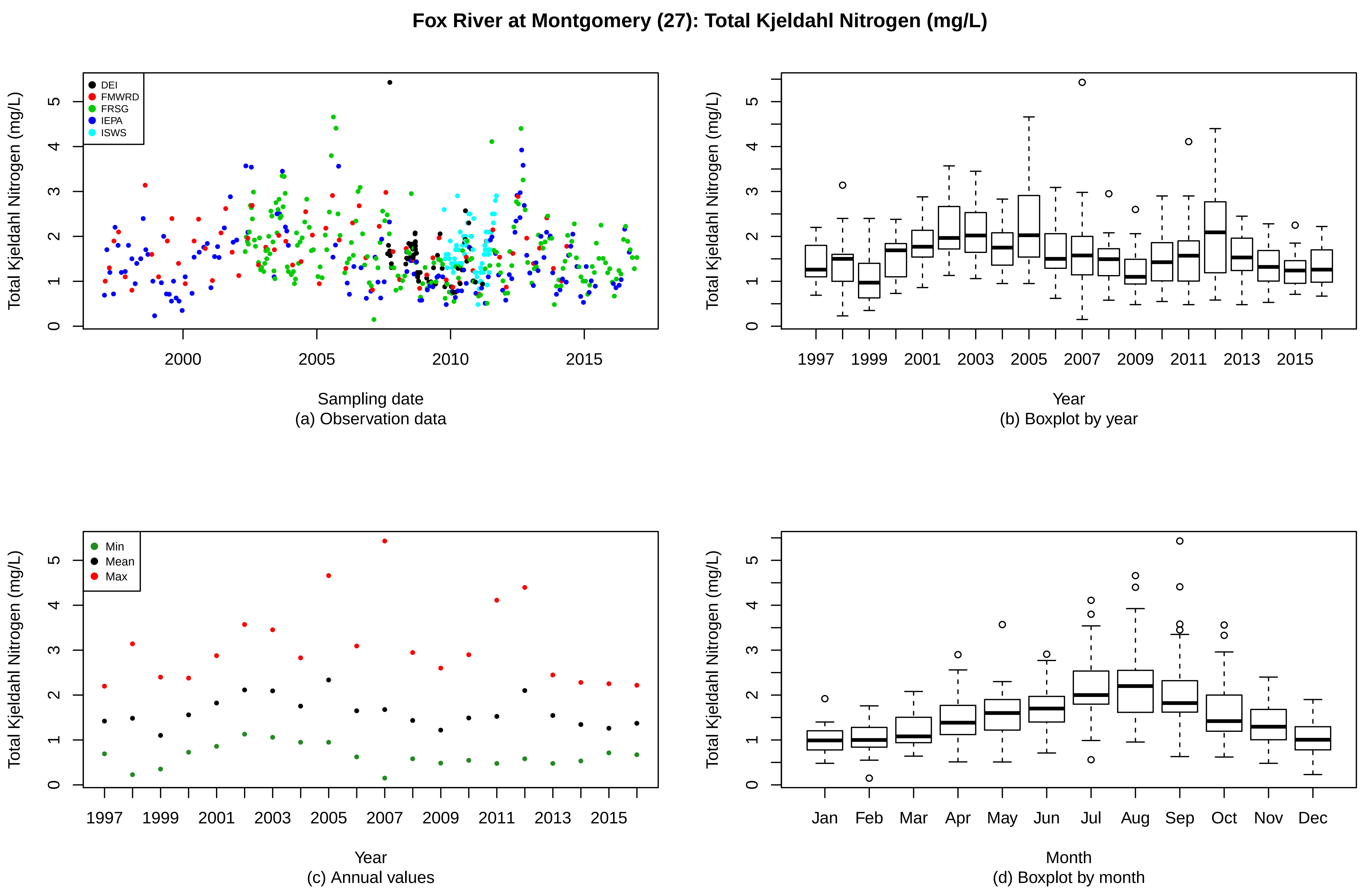


Fox River at Montgomery (27): Ammonia Nitrogen (mg/L)

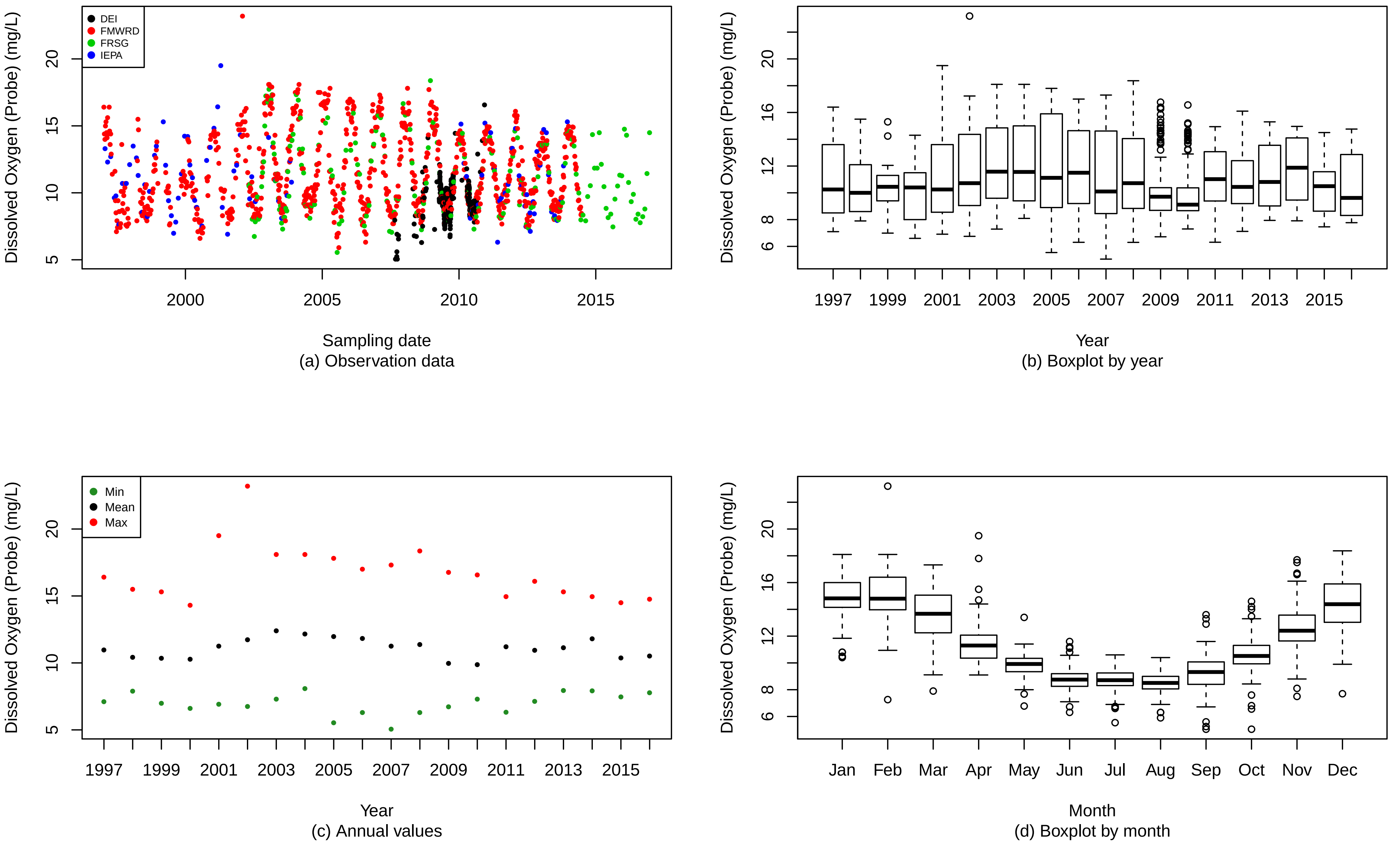


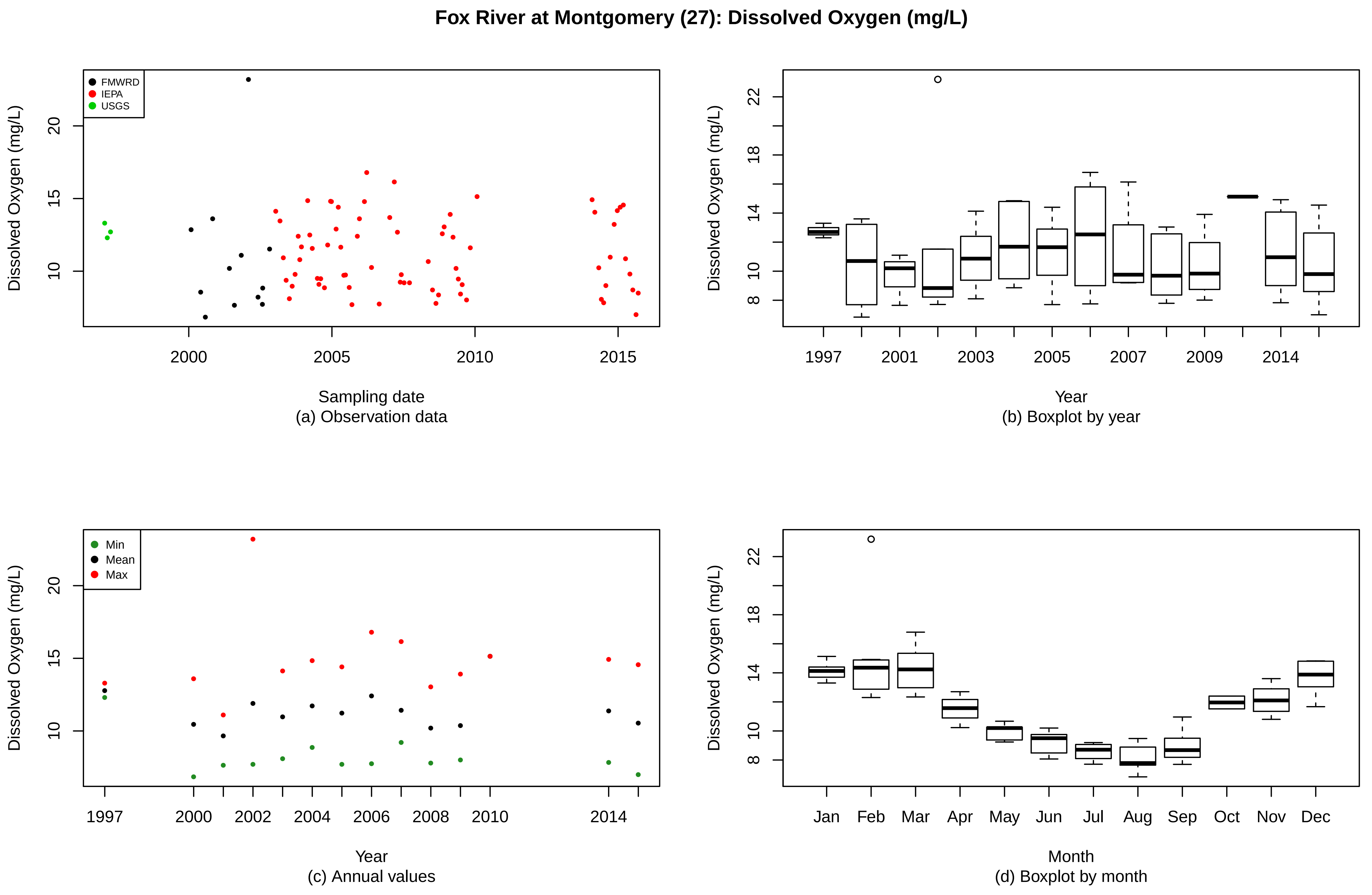
Fox River at Montgomery (27): Nitrate Nitrogen (mg/L)



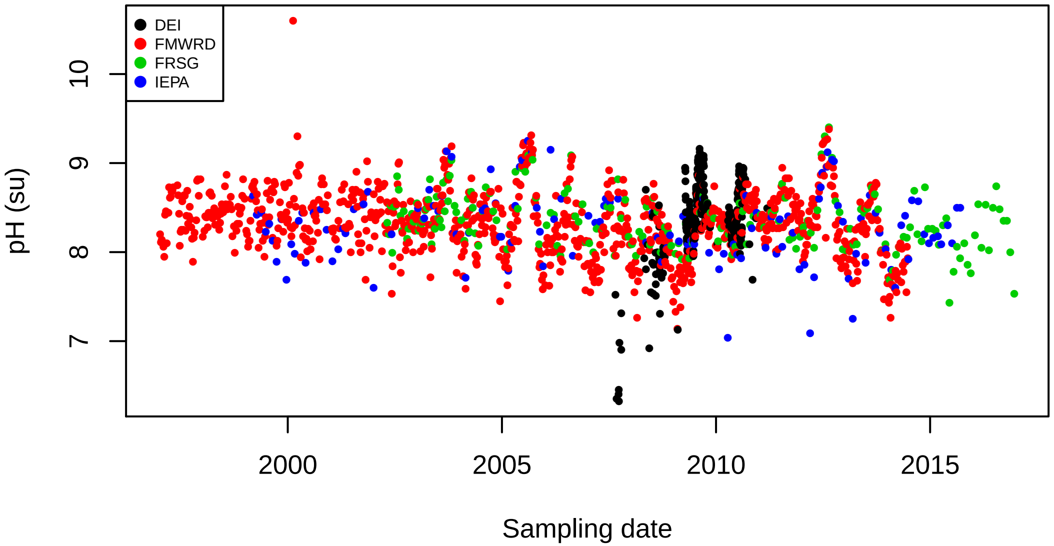

Fox River at Montgomery (27): Total Kjeldahl Nitrogen (mg/L)
DEI
FMWRD
FRSG
IEPA
ISWS
Total Kjeldahl Nitrogen (mg/L)
0
1
2
3
4
5
2000
2005
2010
2015
Sampling date
(a) Observation data
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
(d) Boxplot by month

Fox River at Montgomery (27): Dissolved Oxygen (Probe) (mg/L)

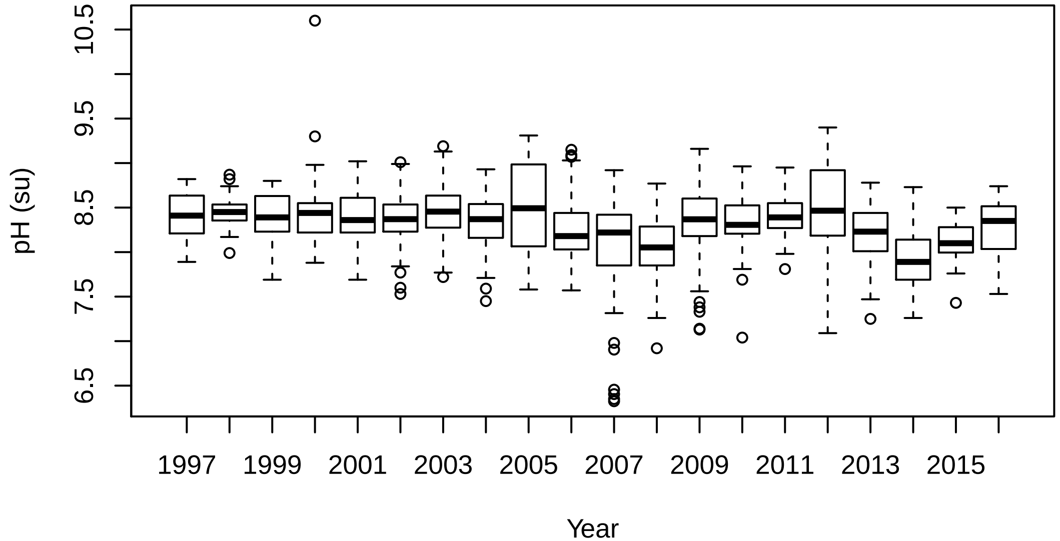



Fox River at Montgomery (27): Dissolved Oxygen (mg/L)
FMWRD
IEPA
USGS
Dissolved Oxygen (mg/L)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Month
(d) Boxplot by month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

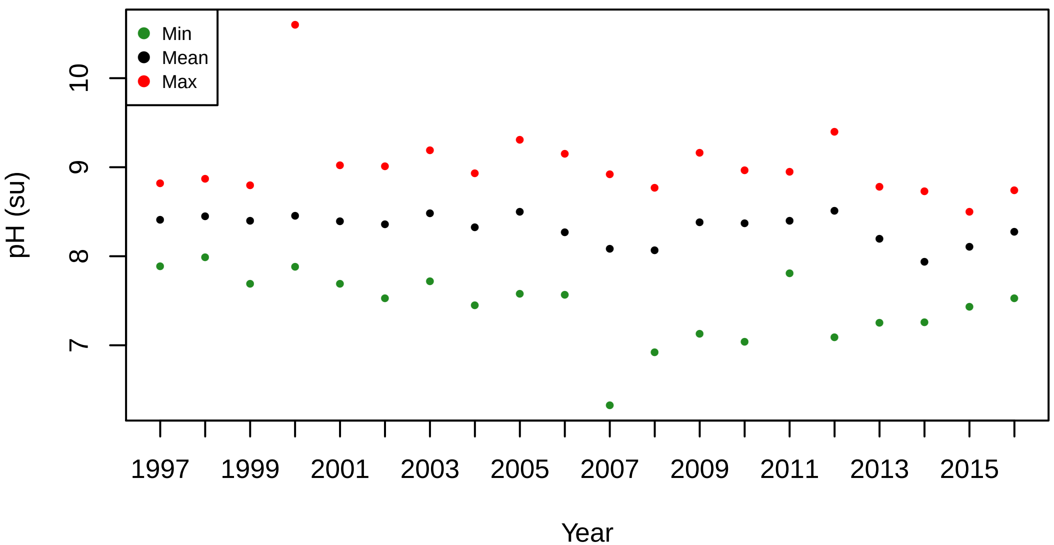
Fox River at Montgomery (27): pH (su)



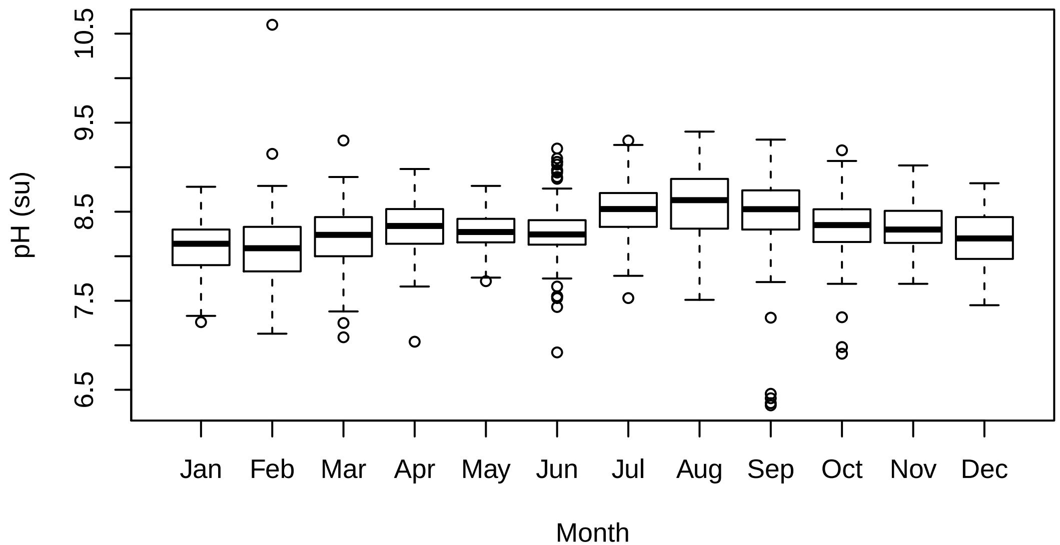
(a) Observation data



(b) Boxplot by year

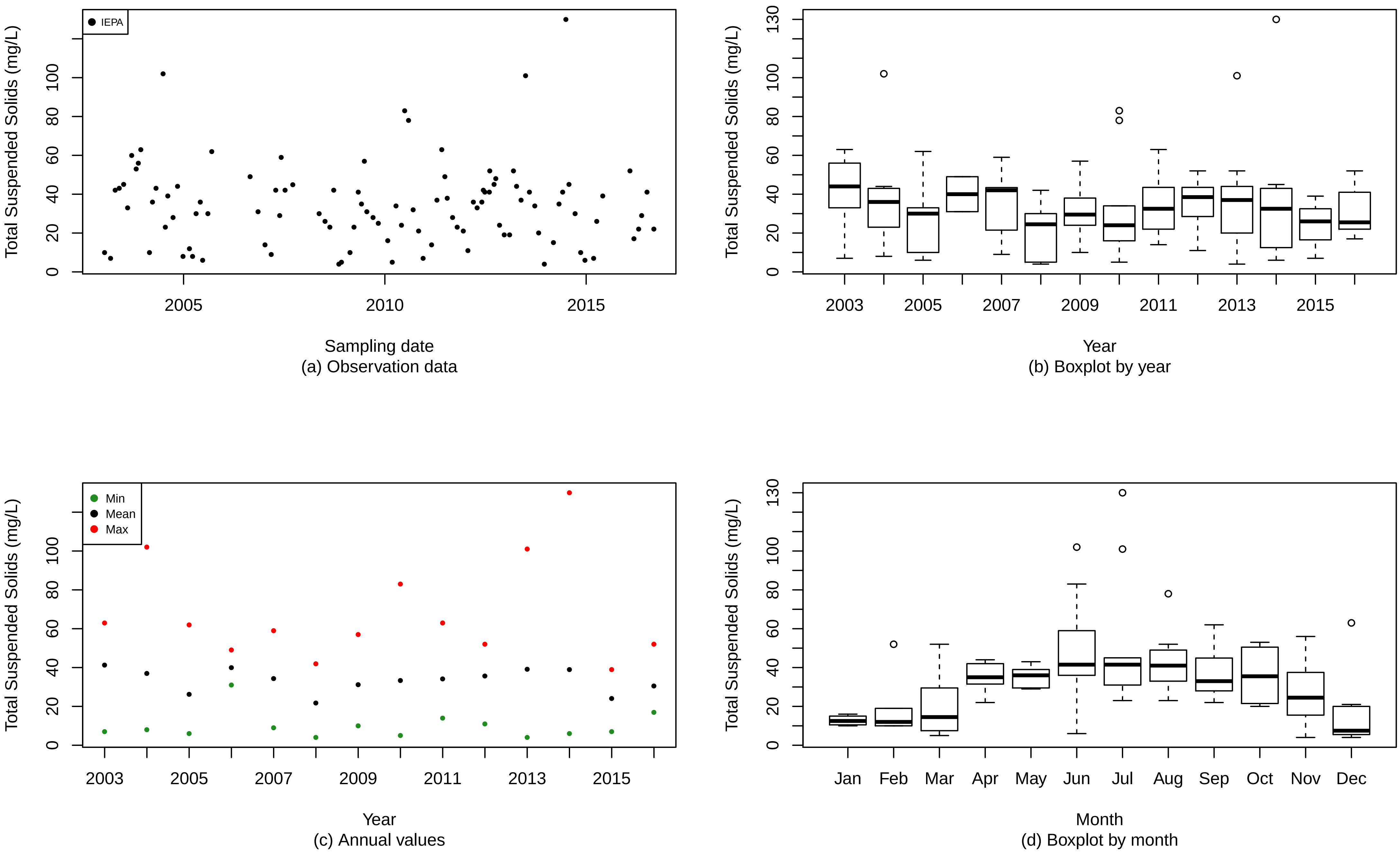


(c) Annual values

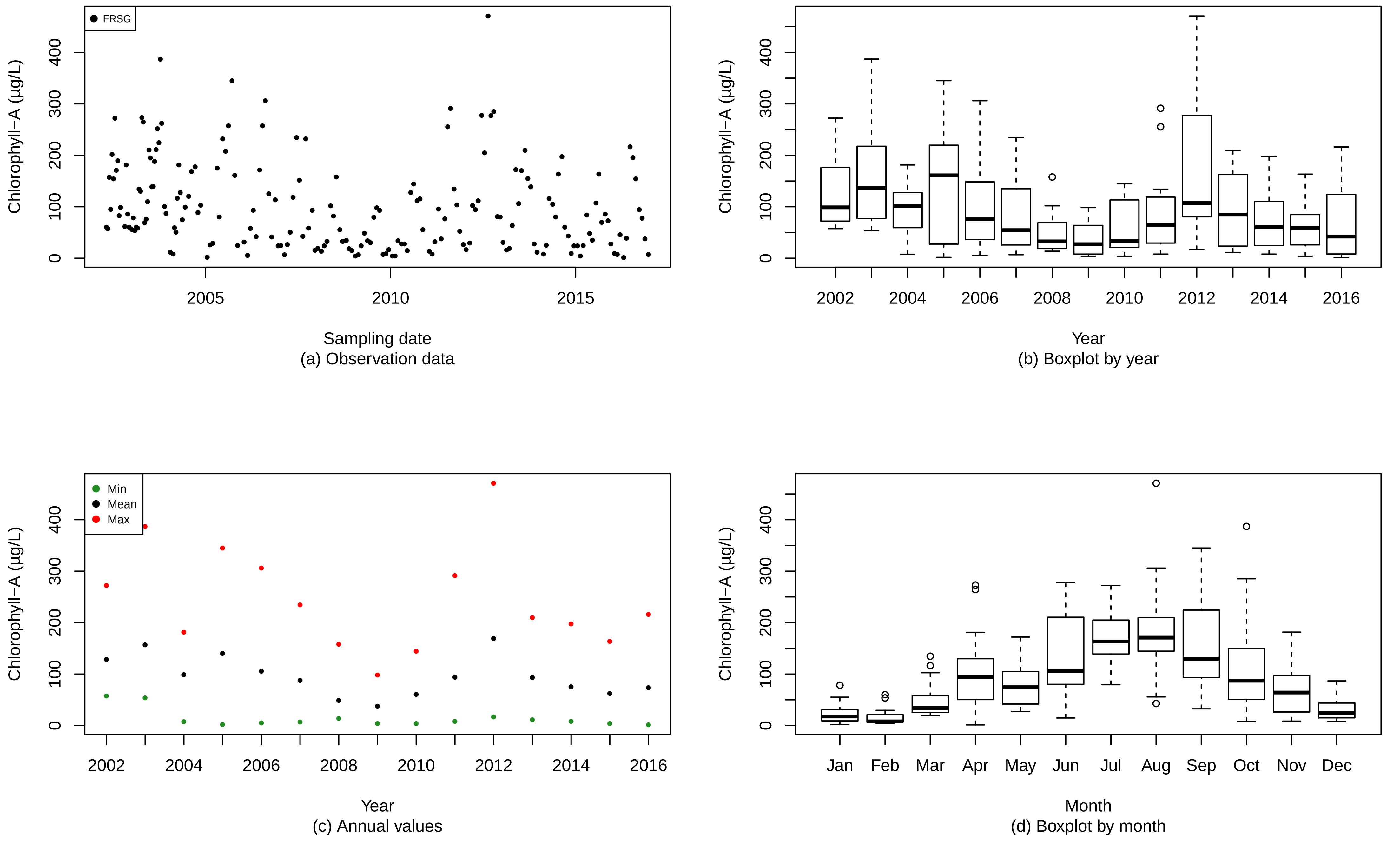


(d) Boxplot by month

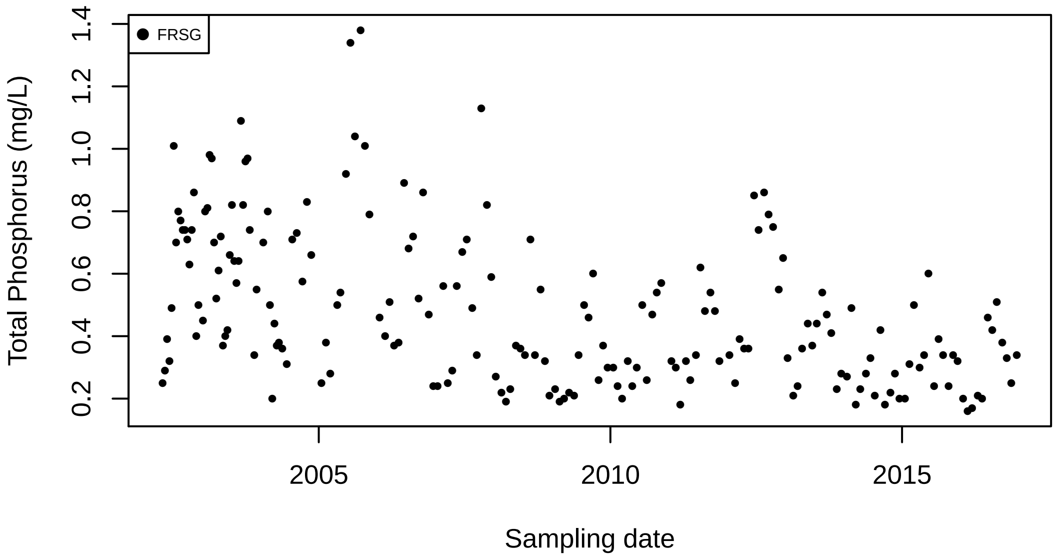
Fox River at Montgomery (27): Total Suspended Solids (mg/L)



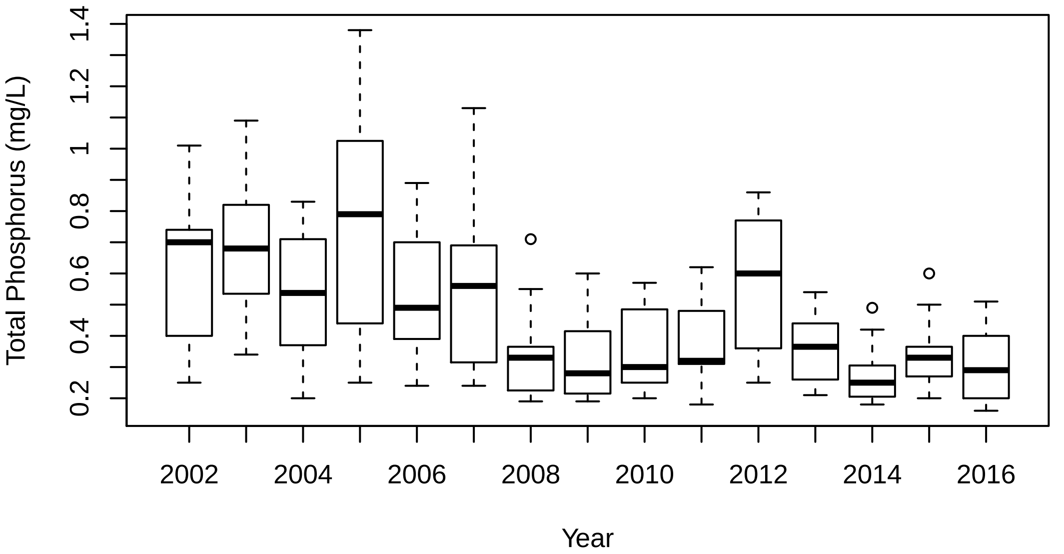
Fox River at Montgomery (27): Chlorophyll−A (µg/L)



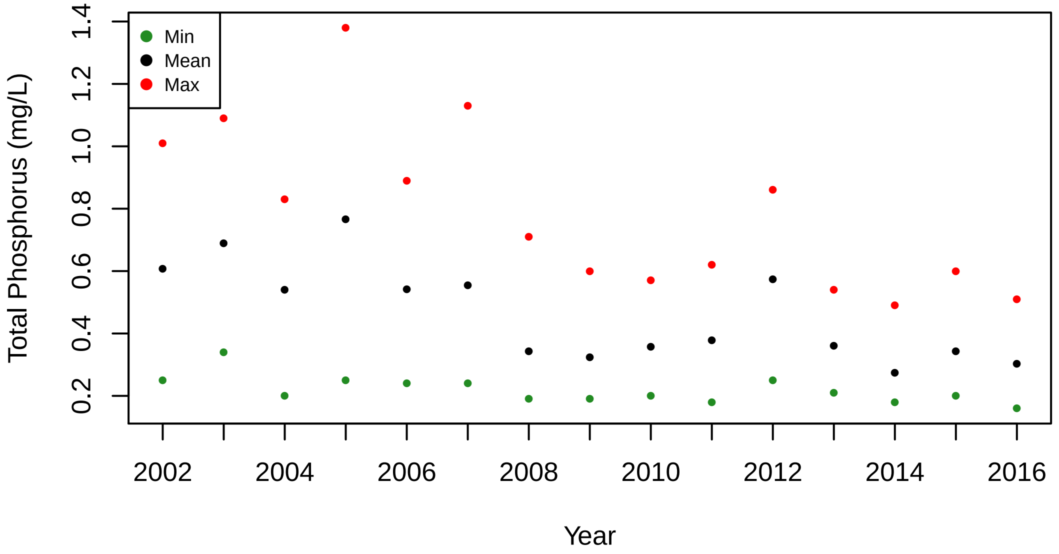
Fox River at Yorkville (34): Total Phosphorus (mg/L)



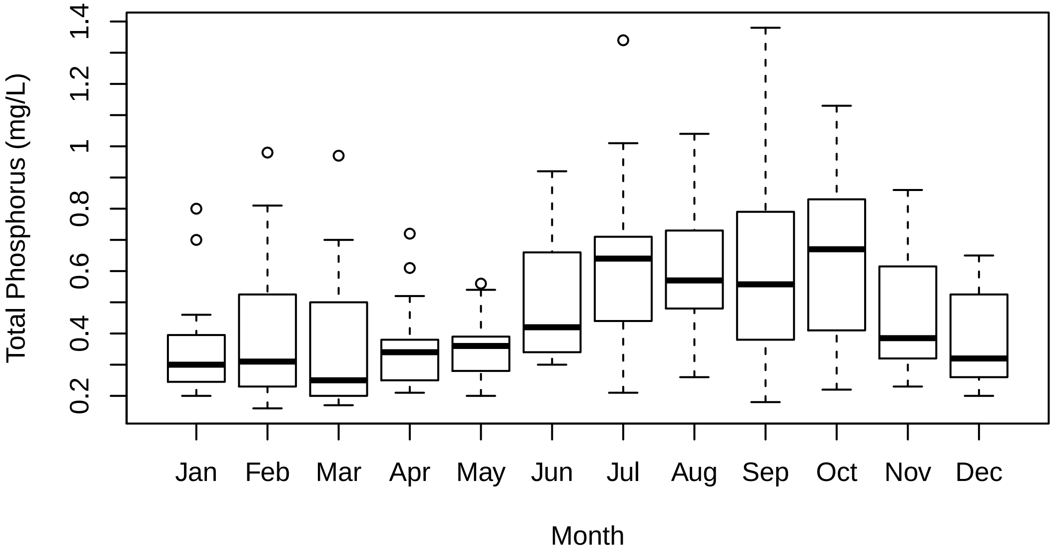
(a) Observation data



(b) Boxplot by year

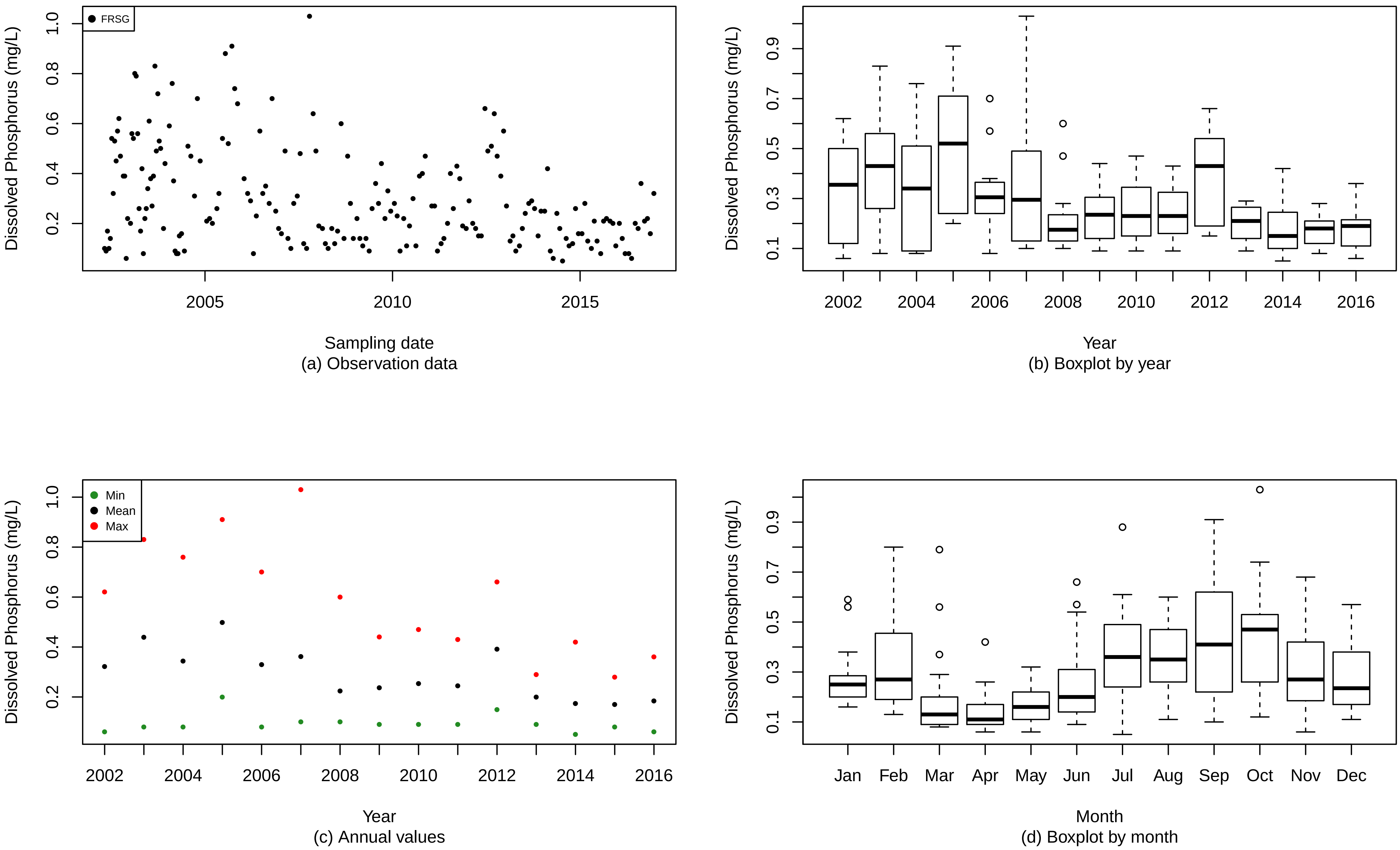


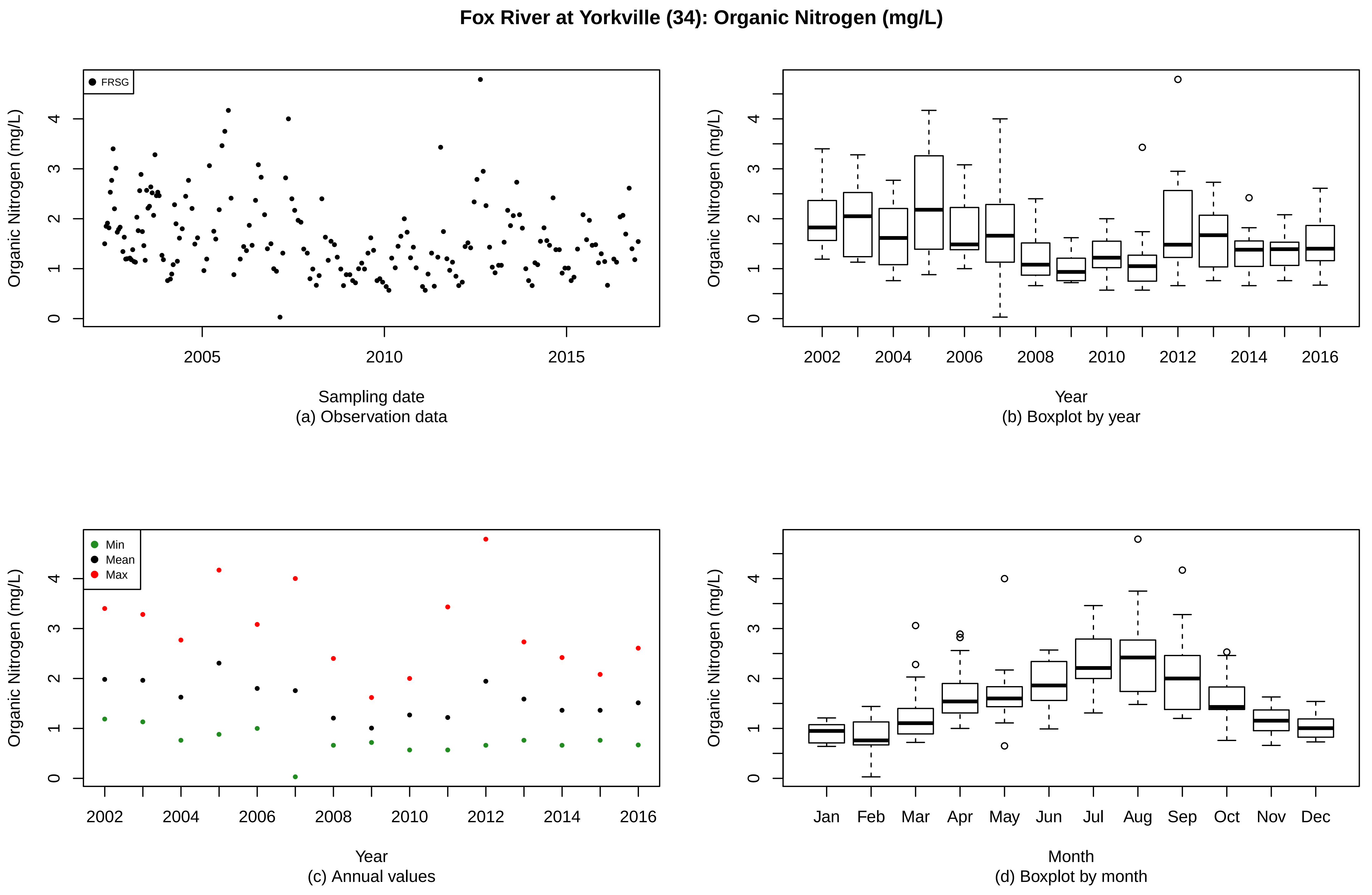
(c) Annual values



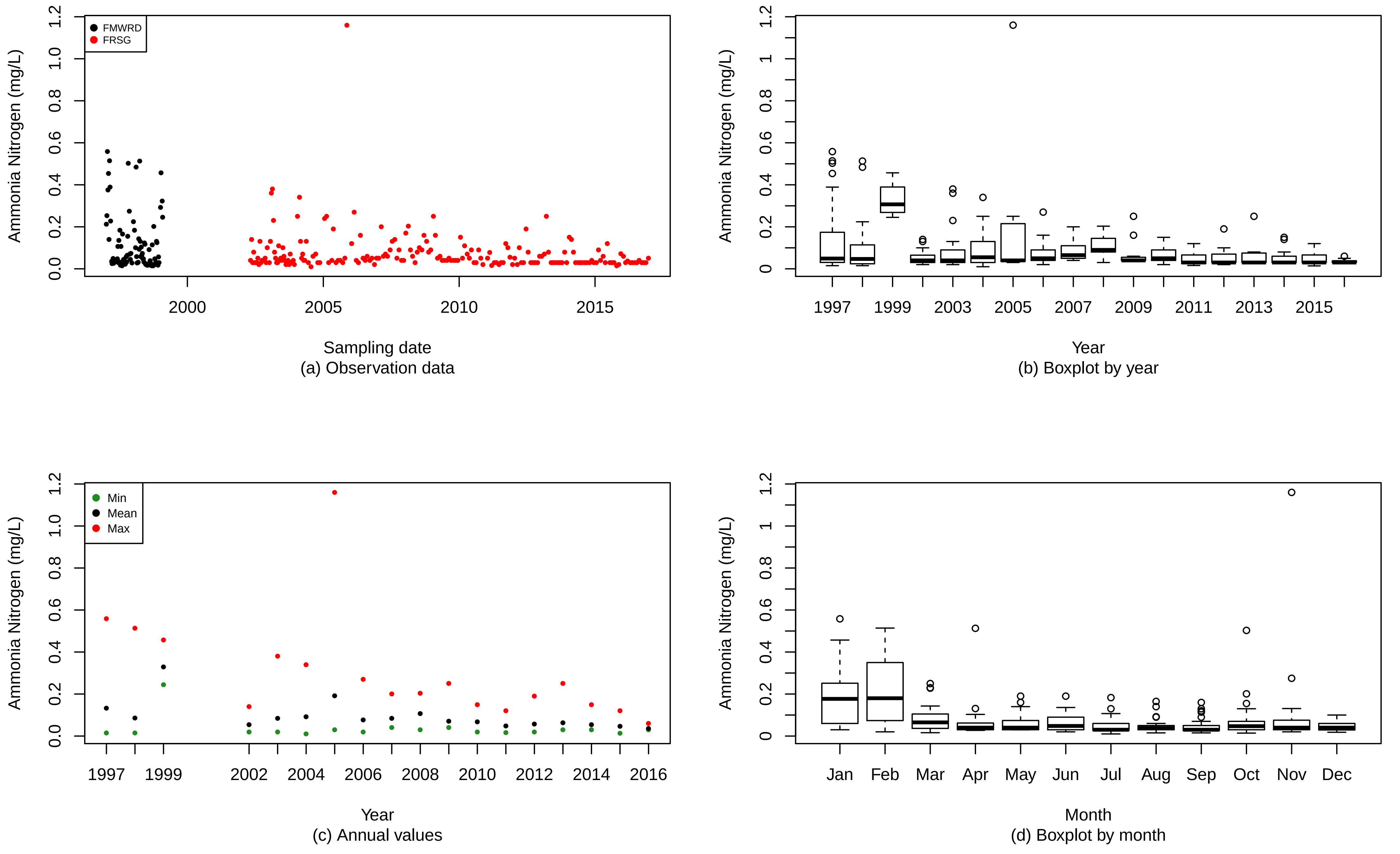
(d) Boxplot by month

Fox River at Yorkville (34): Dissolved Phosphorus (mg/L)

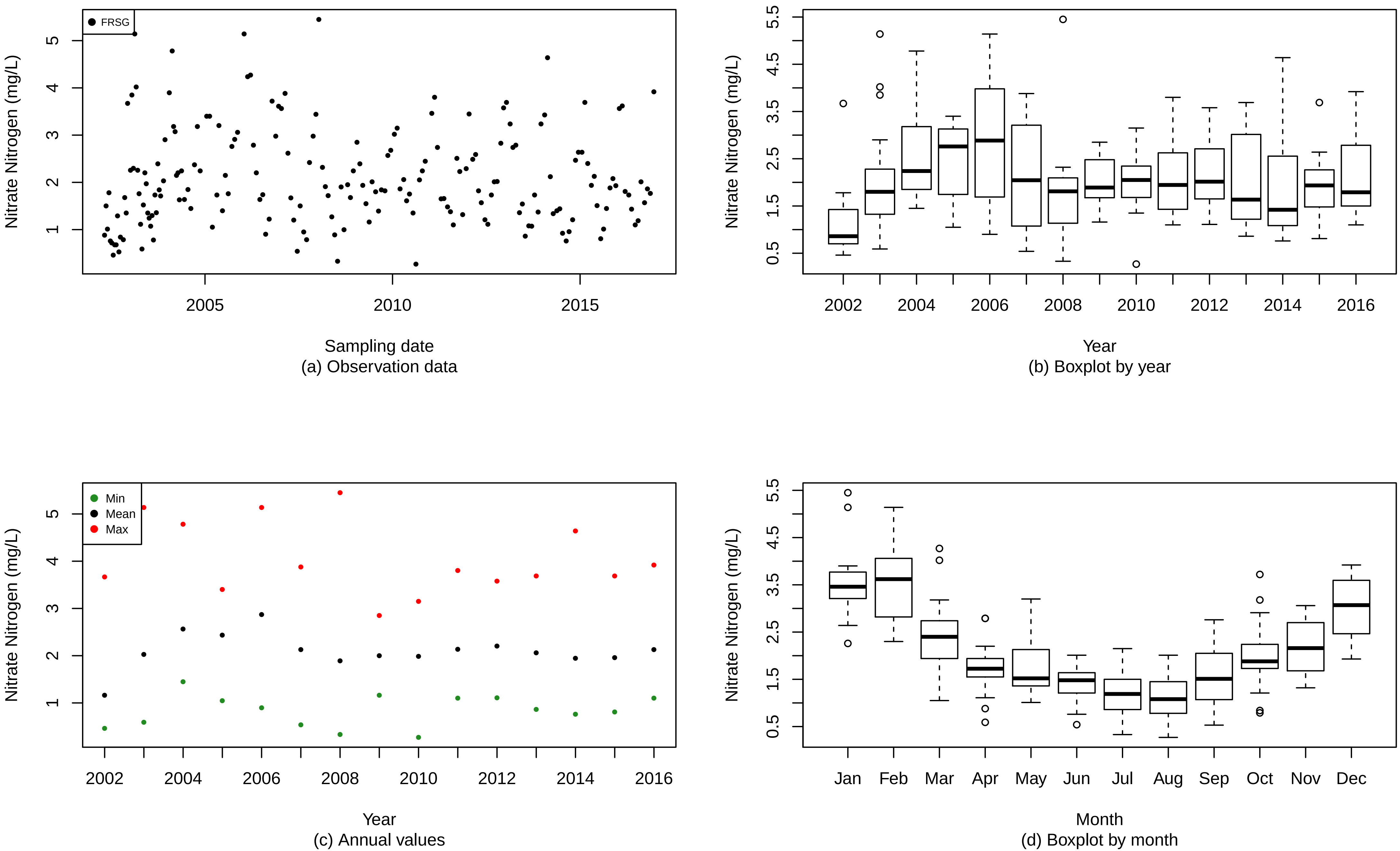



Fox River at Yorkville (34): Organic Nitrogen (mg/L)
FRSG
Organic Nitrogen (mg/L)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Month
(d) Boxplot by month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

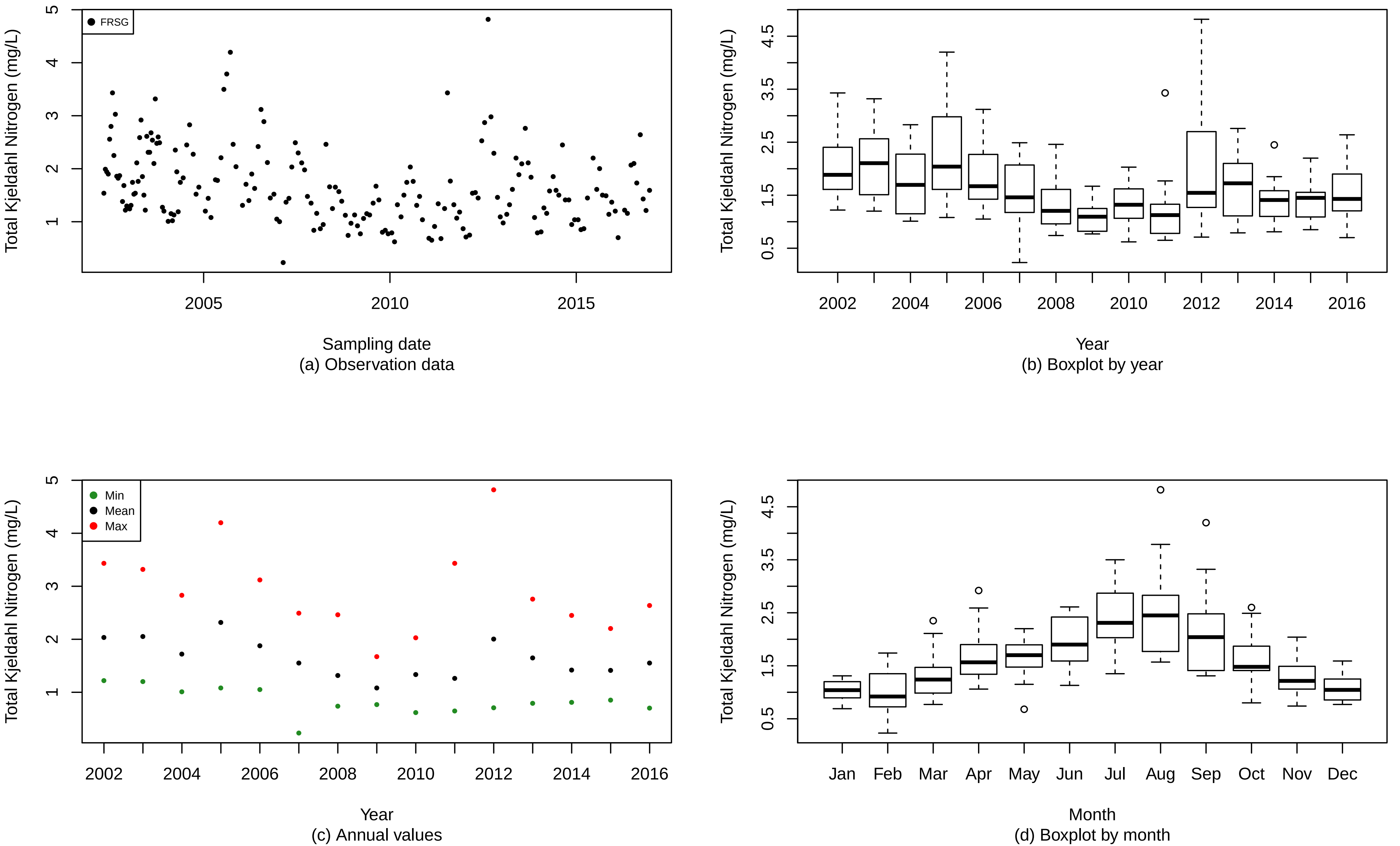
Fox River at Yorkville (34): Ammonia Nitrogen (mg/L)



Fox River at Yorkville (34): Nitrate Nitrogen (mg/L)

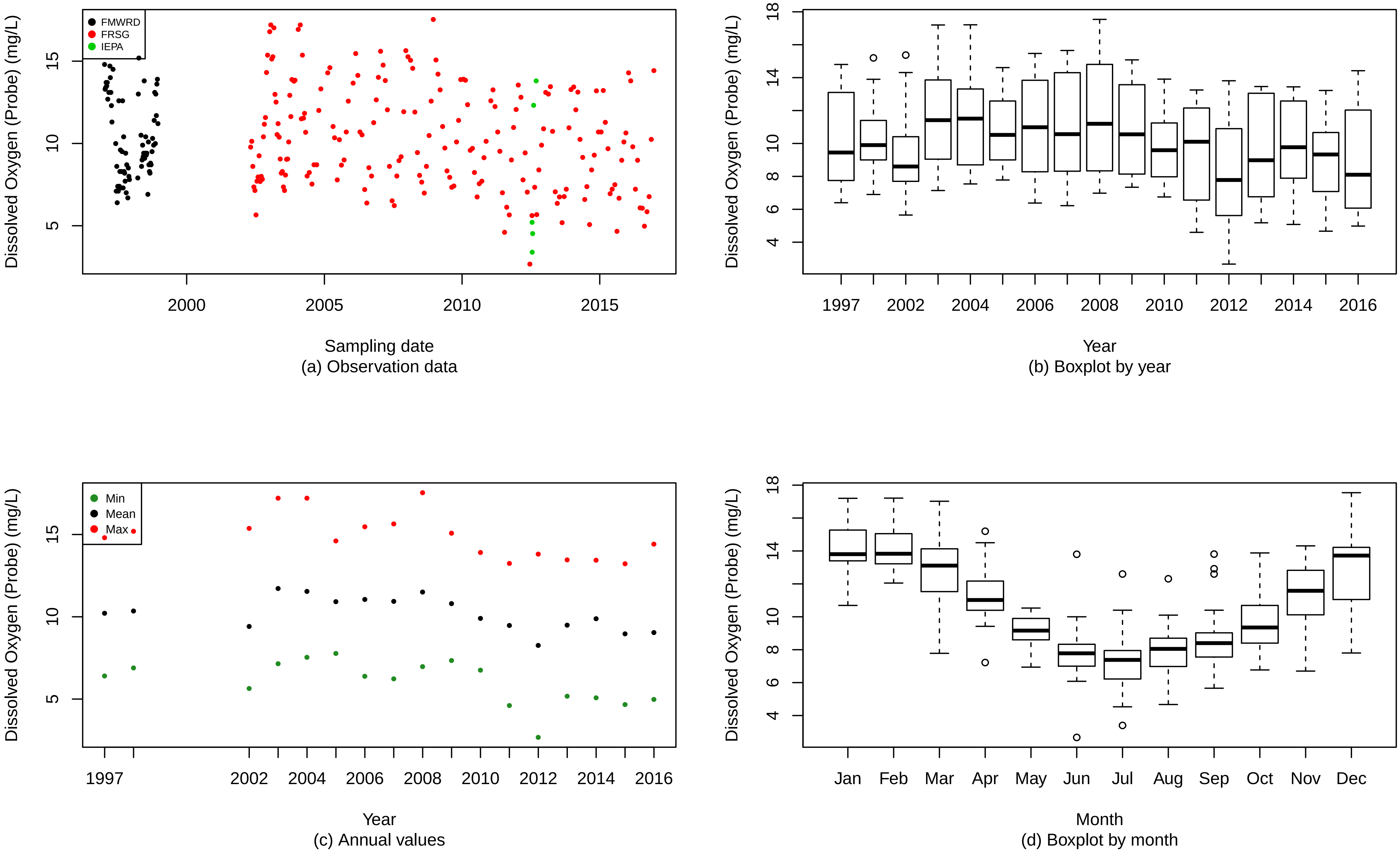


Fox River at Yorkville (34): Total Kjeldahl Nitrogen (mg/L)

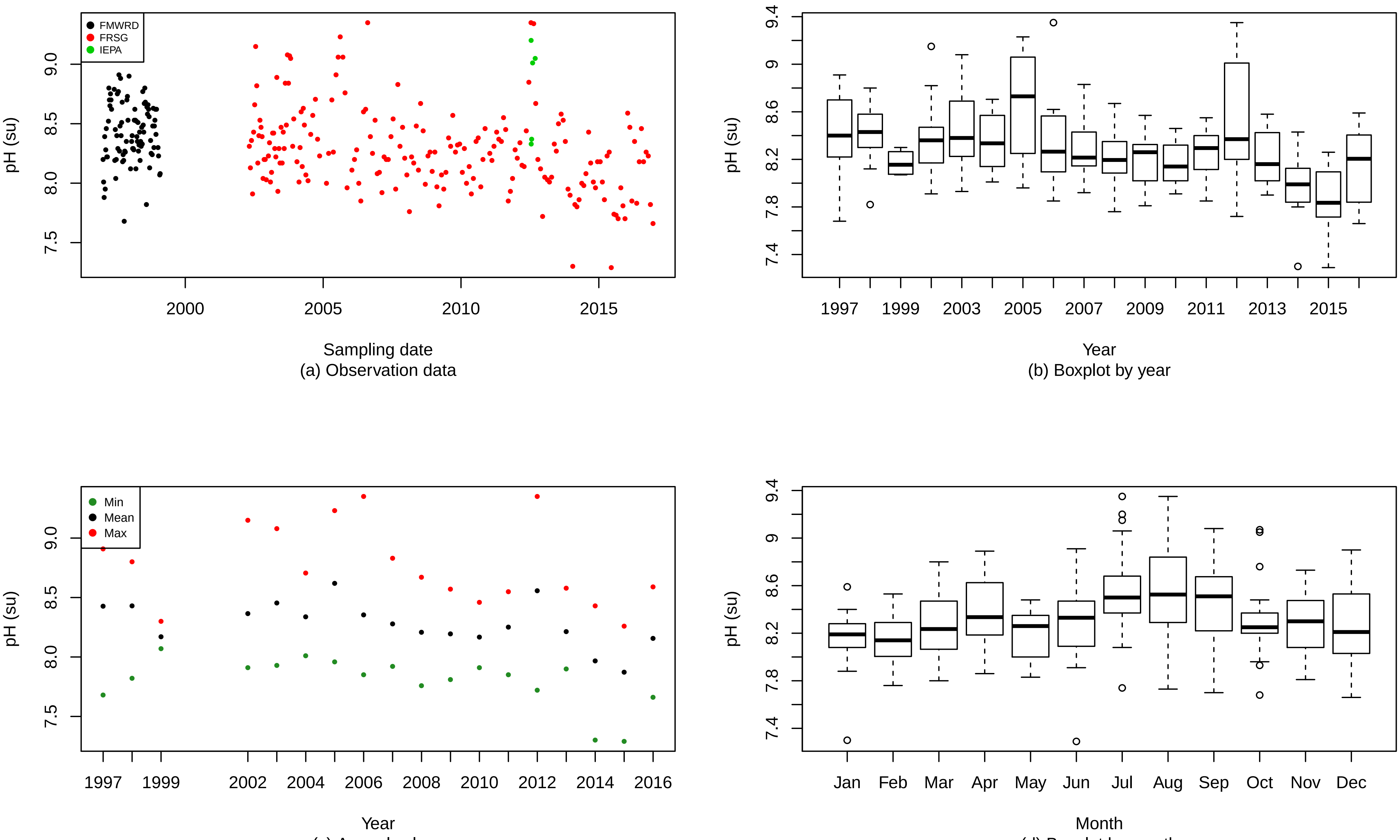


(a) Observation data
(b) Boxplot by year
(c) Annual values
(d) Boxplot by month

Fox River at Yorkville (34): Dissolved Oxygen (Probe) (mg/L)



Fox River at Yorkville (34): pH (su)



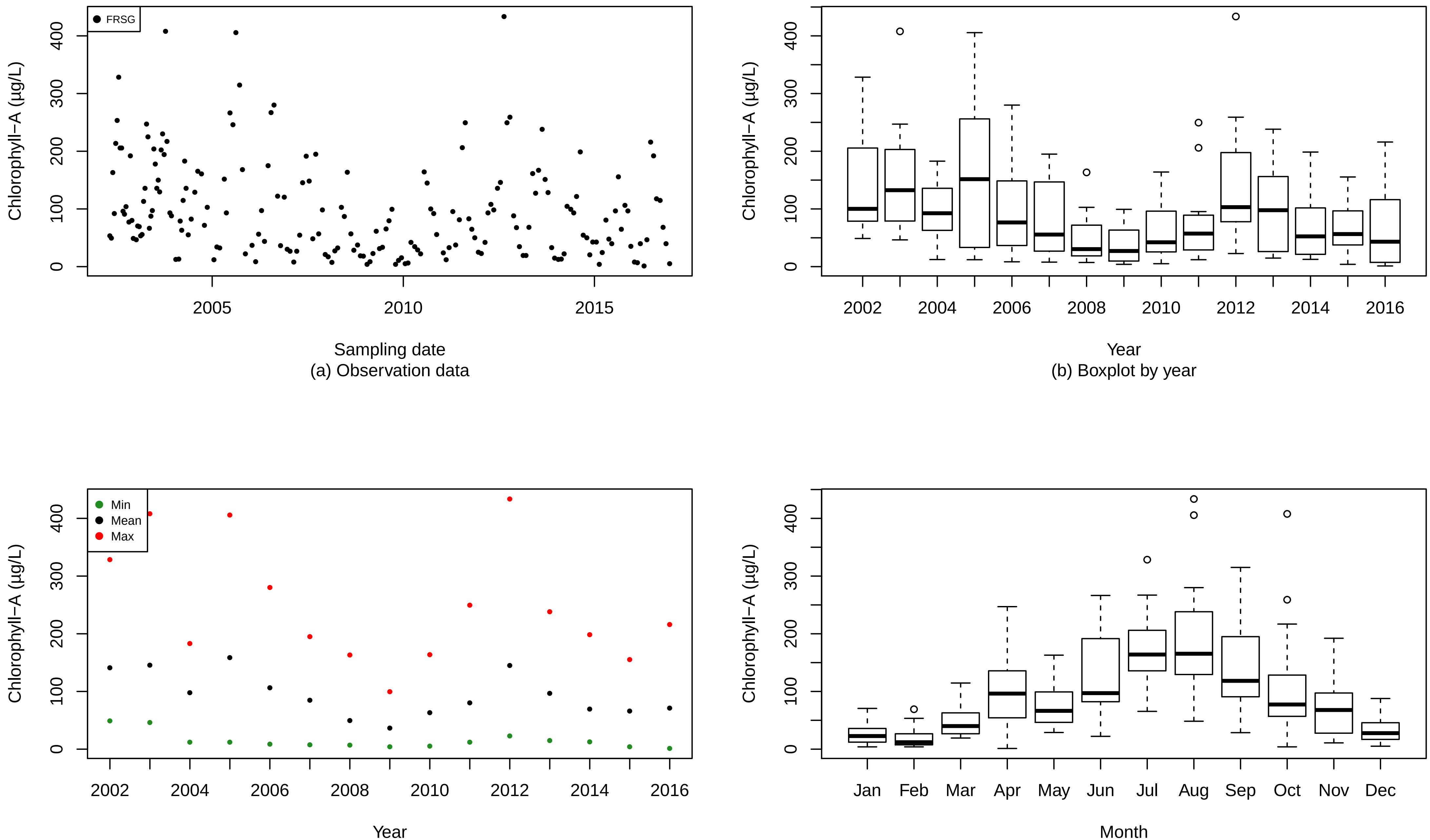
(a) Observation data

(b) Boxplot by year

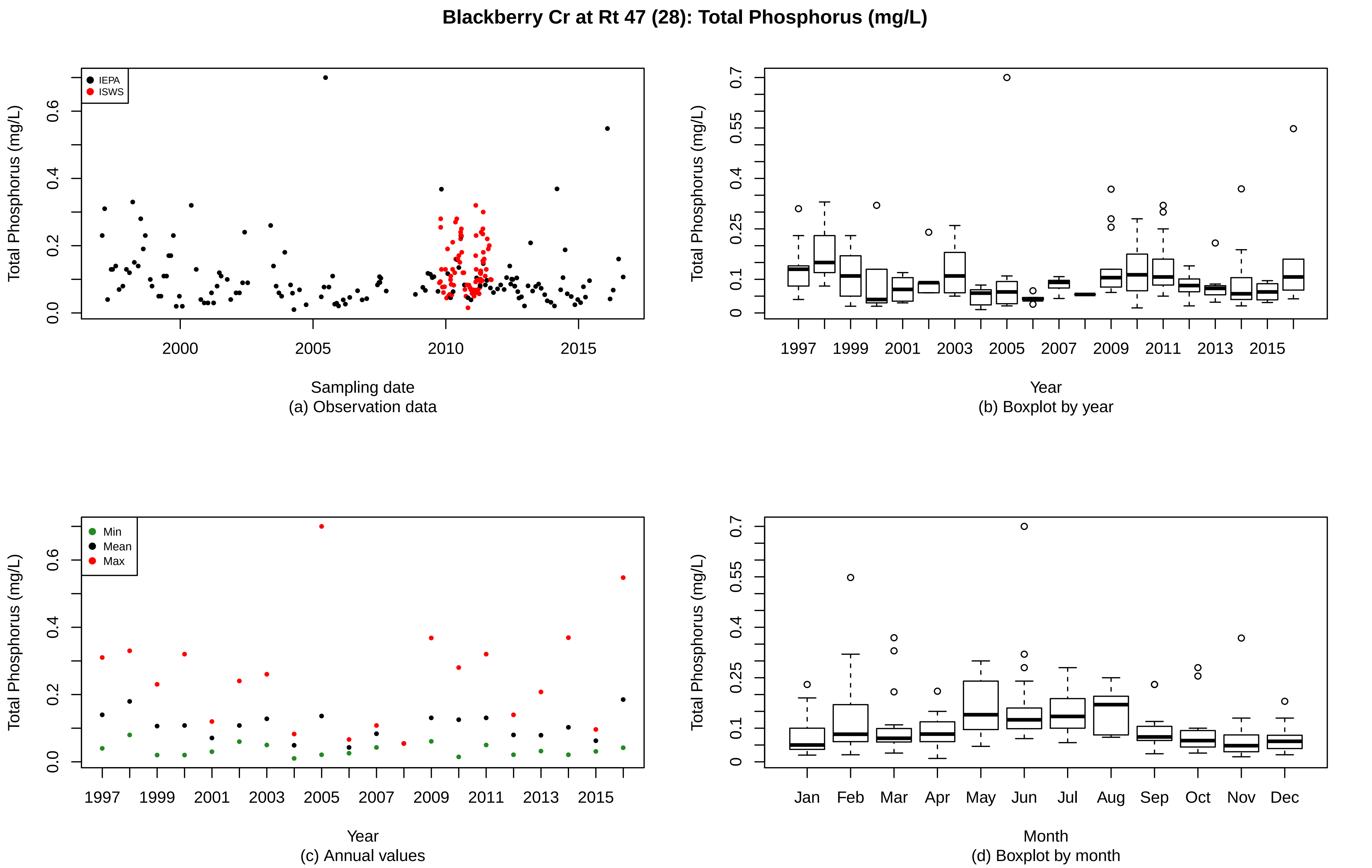
(c) Annual values

(d) Boxplot by month

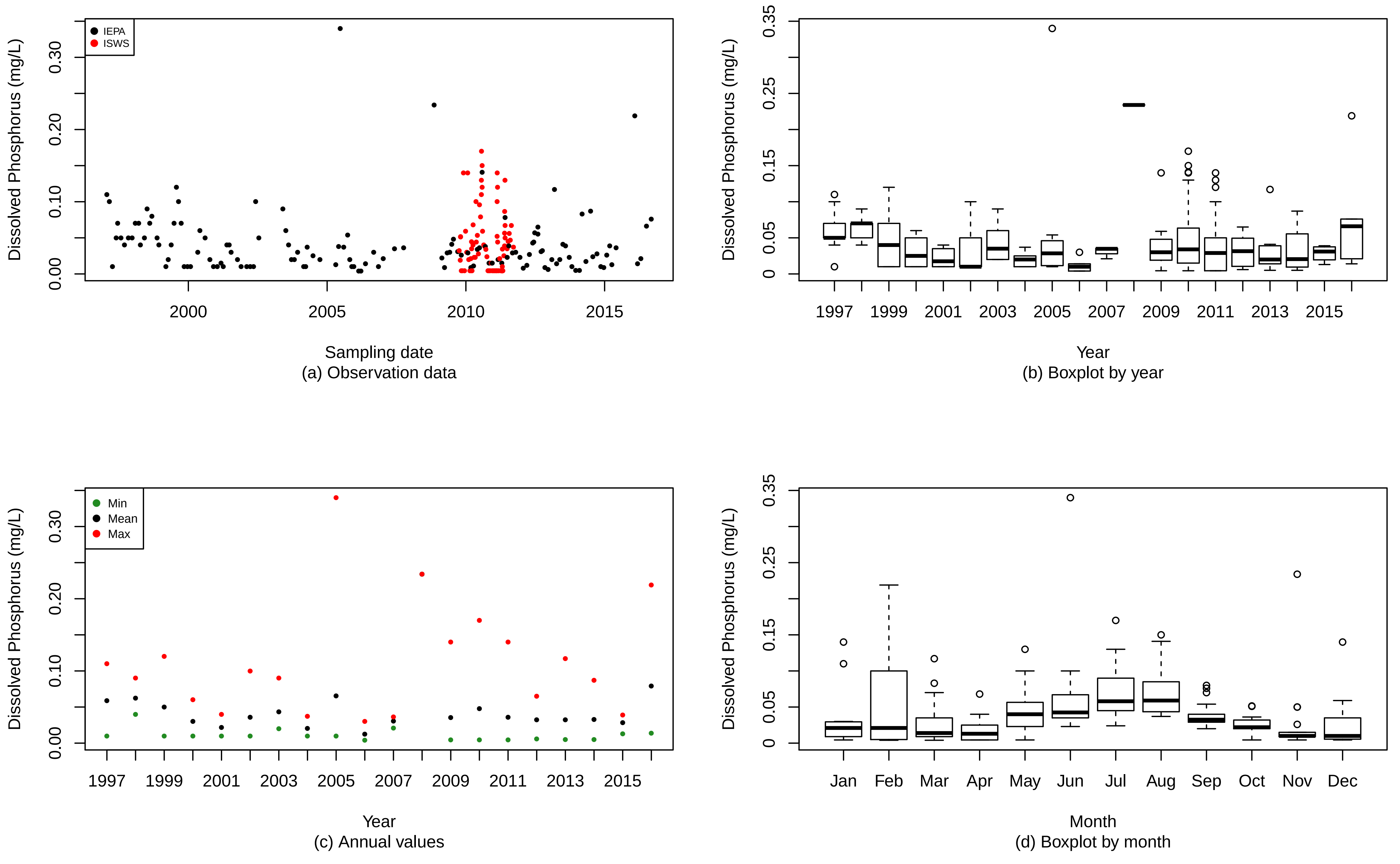
Fox River at Yorkville (34): Chlorophyll−A (µg/L)



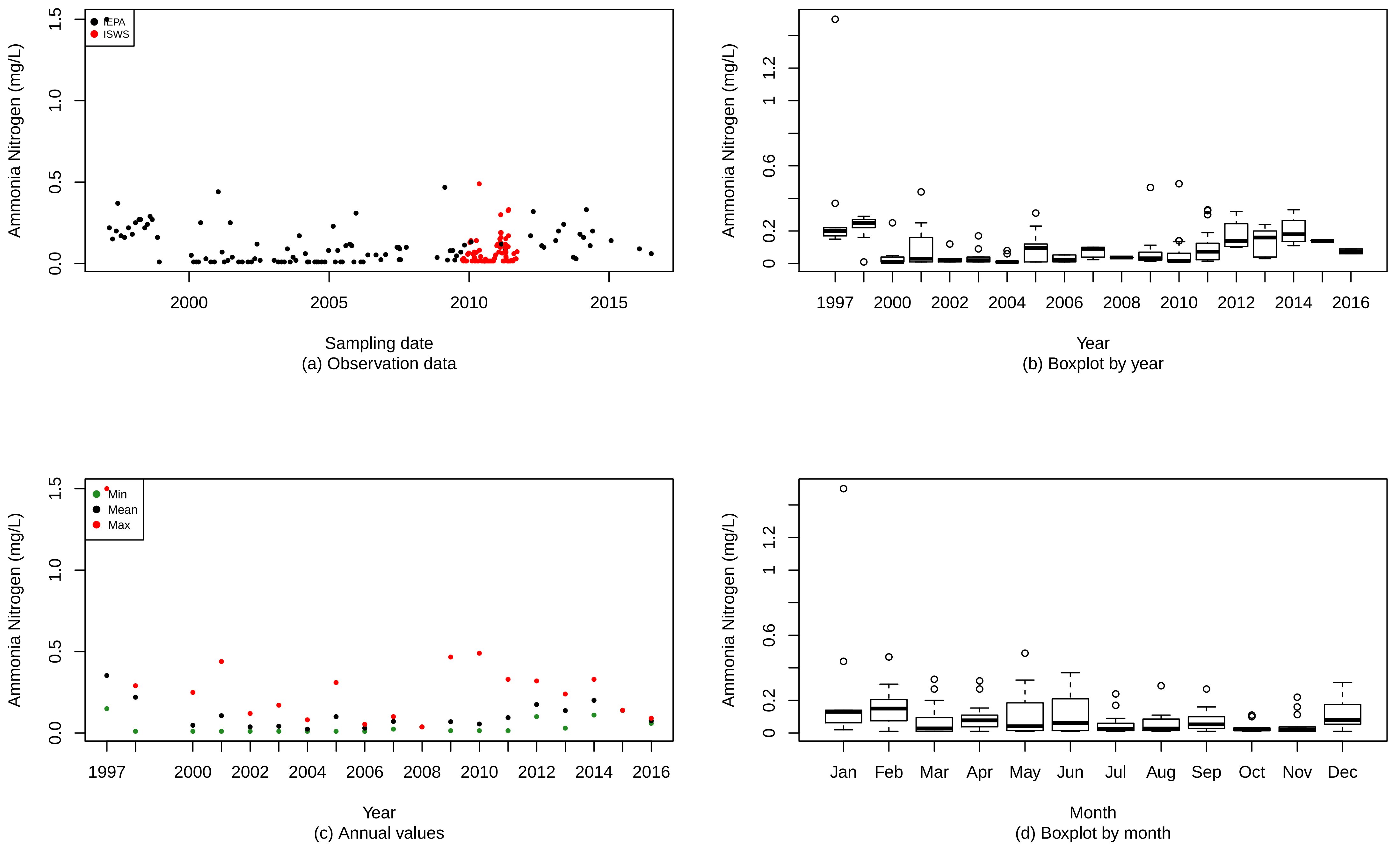
(a) Observation data
(b) Boxplot by year
(c) Annual values
(d) Boxplot by month


Blackberry Cr at Rt 47 (28): Total Phosphorus (mg/L)
IEPA
ISWS
Total Phosphorus (mg/L)
Sampling date
(a) Observation data
Total Phosphorus (mg/L)
Year
(b) Boxplot by year
Min
Mean
Max
Total Phosphorus (mg/L)
Year
(c) Annual values
Total Phosphorus (mg/L)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
(d) Boxplot by month

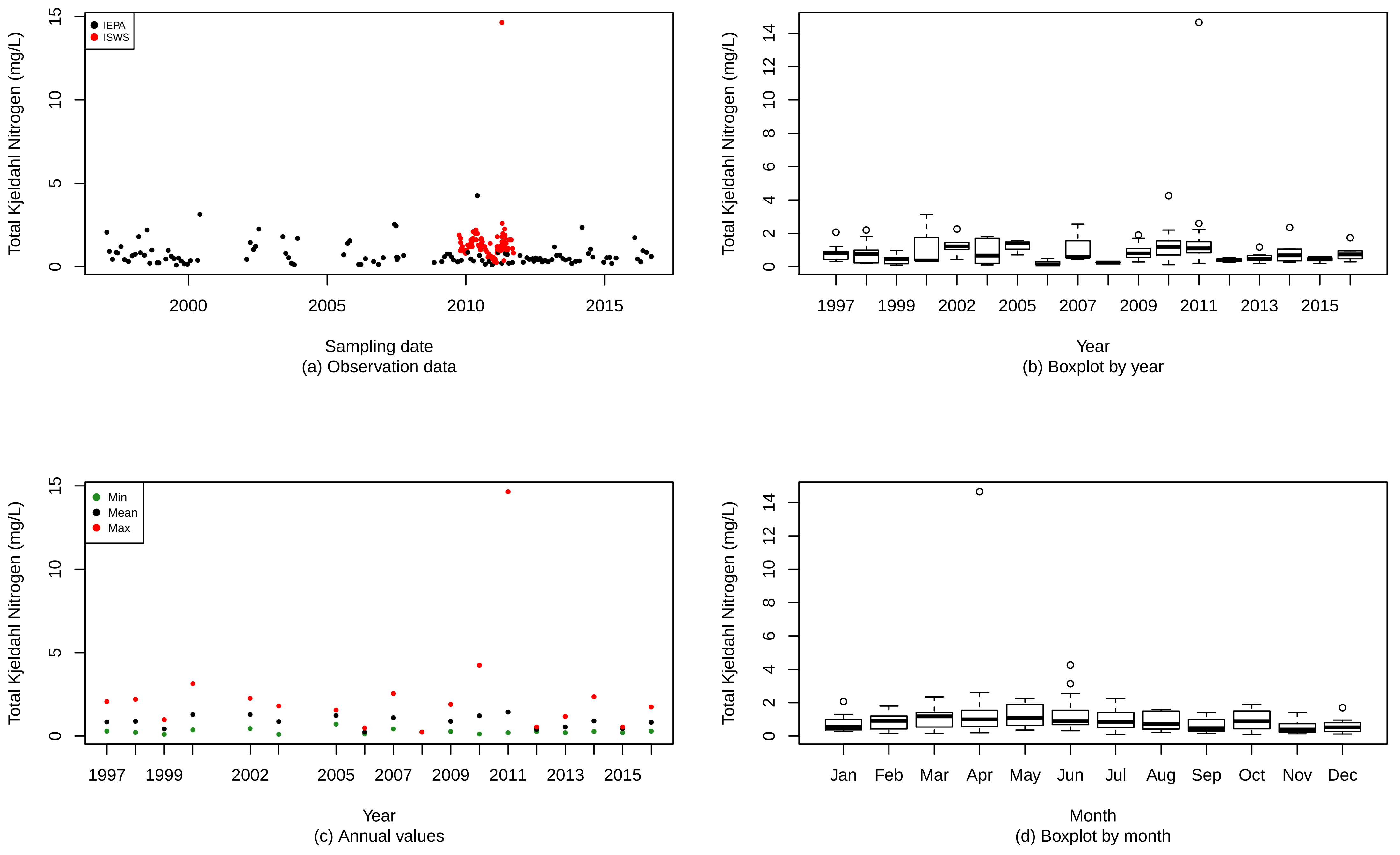
Blackberry Cr at Rt 47 (28): Dissolved Phosphorus (mg/L)

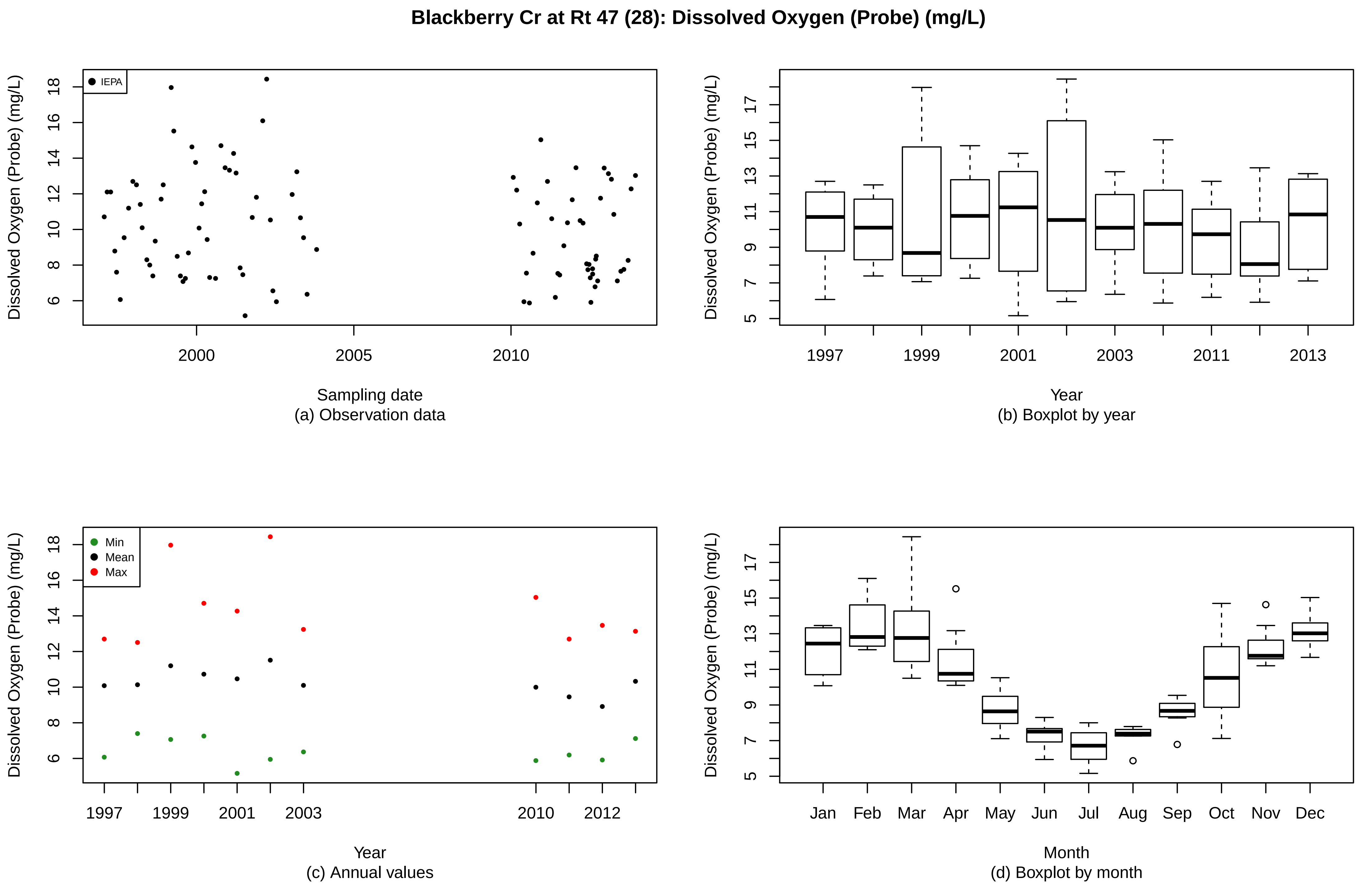


Blackberry Cr at Rt 47 (28): Ammonia Nitrogen (mg/L)



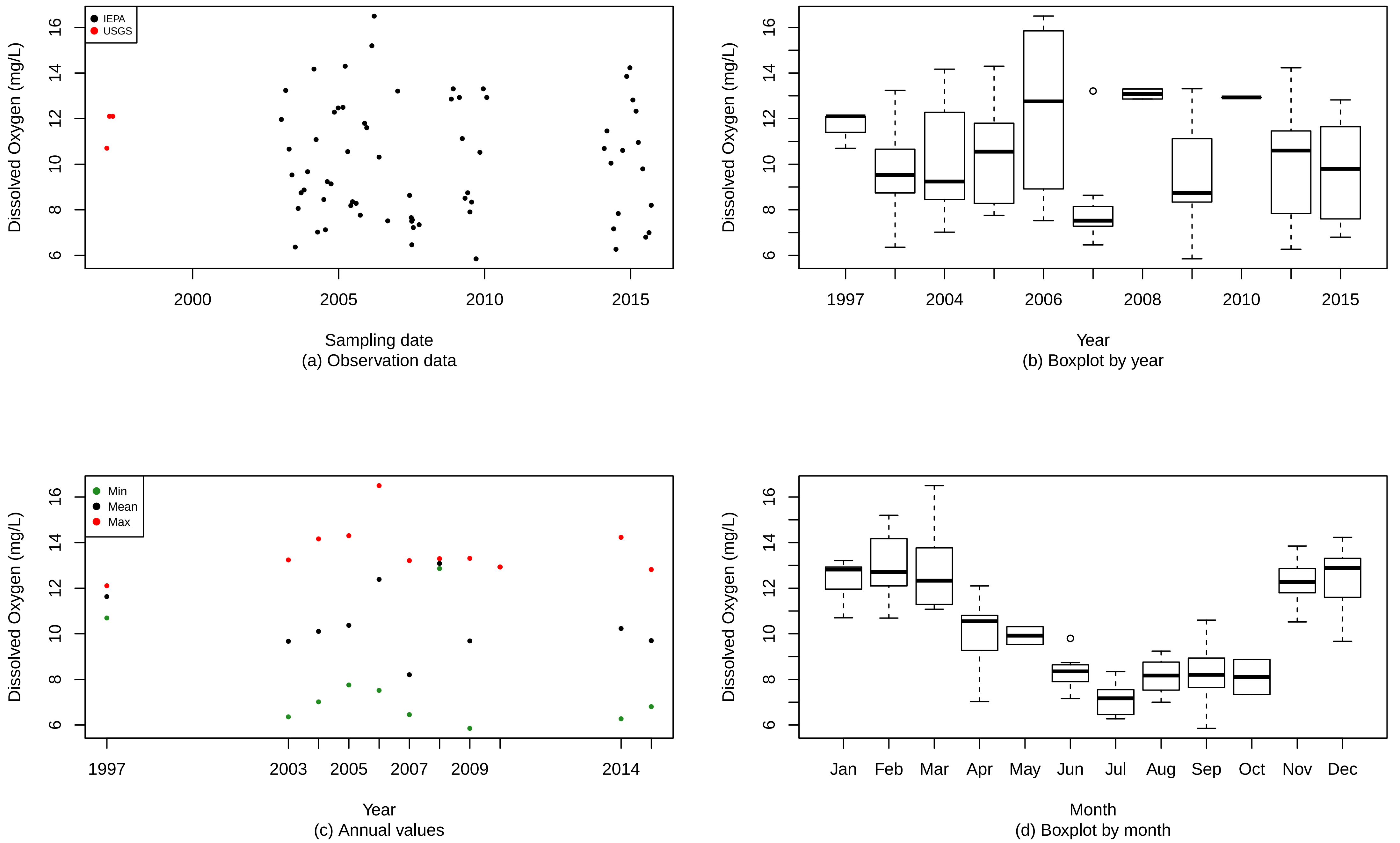
Blackberry Cr at Rt 47 (28): Total Kjeldahl Nitrogen (mg/L)

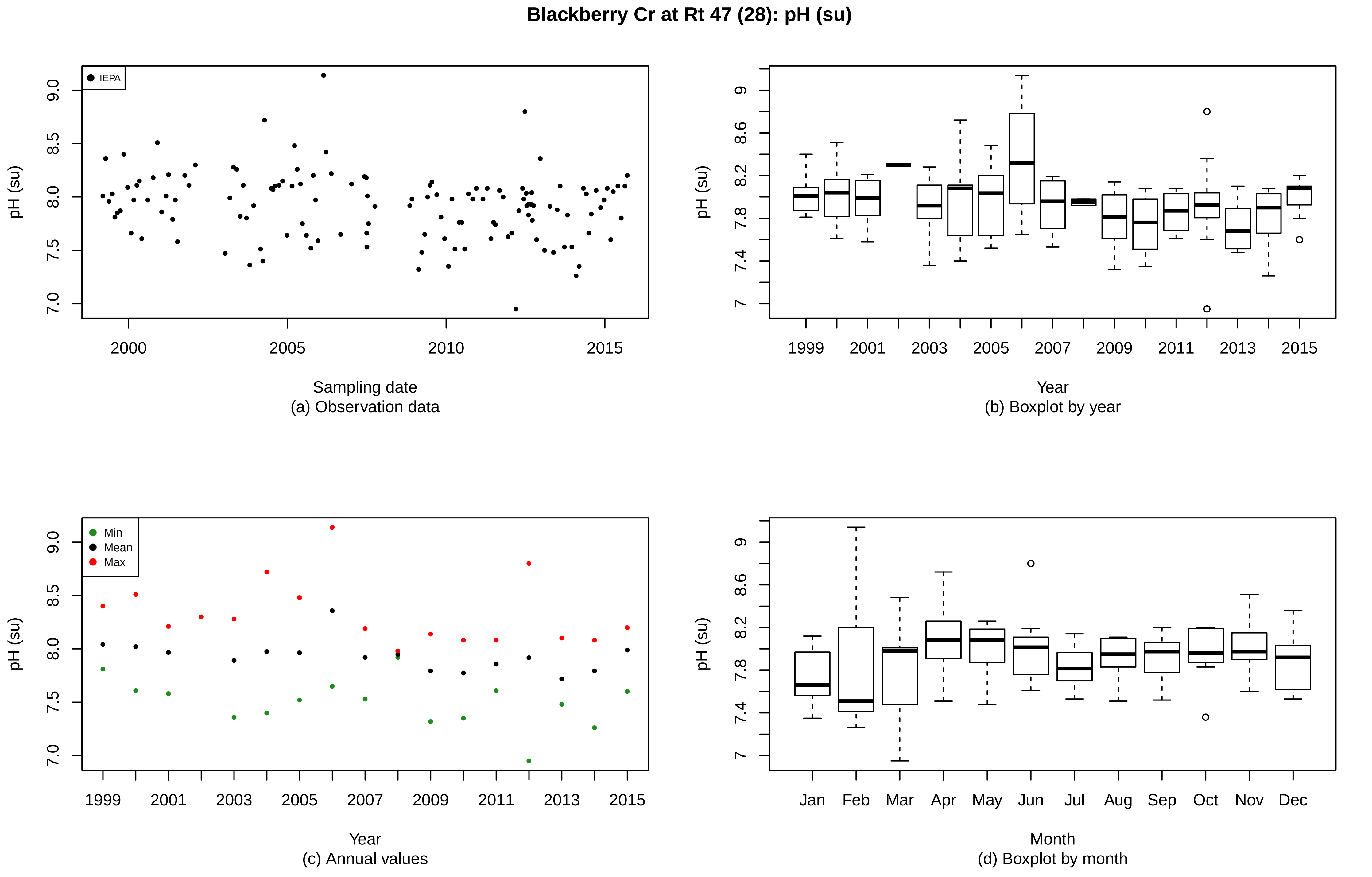




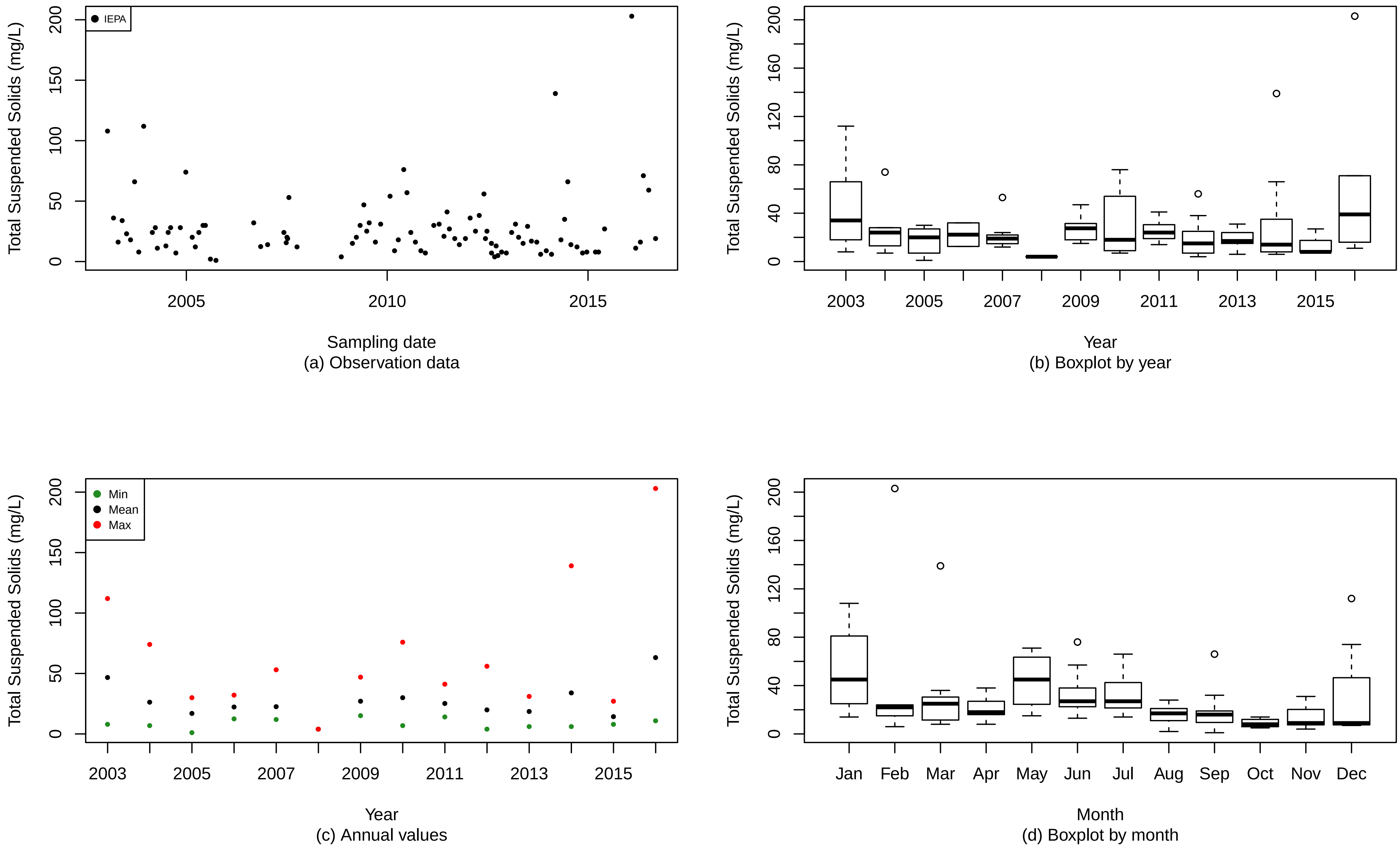
Blackberry Cr at Rt 47 (28): Dissolved Oxygen (Probe) (mg/L)
IEPA
Dissolved Oxygen (Probe) (mg/L)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Month
(d) Boxplot by month

Blackberry Cr at Rt 47 (28): Dissolved Oxygen (mg/L)

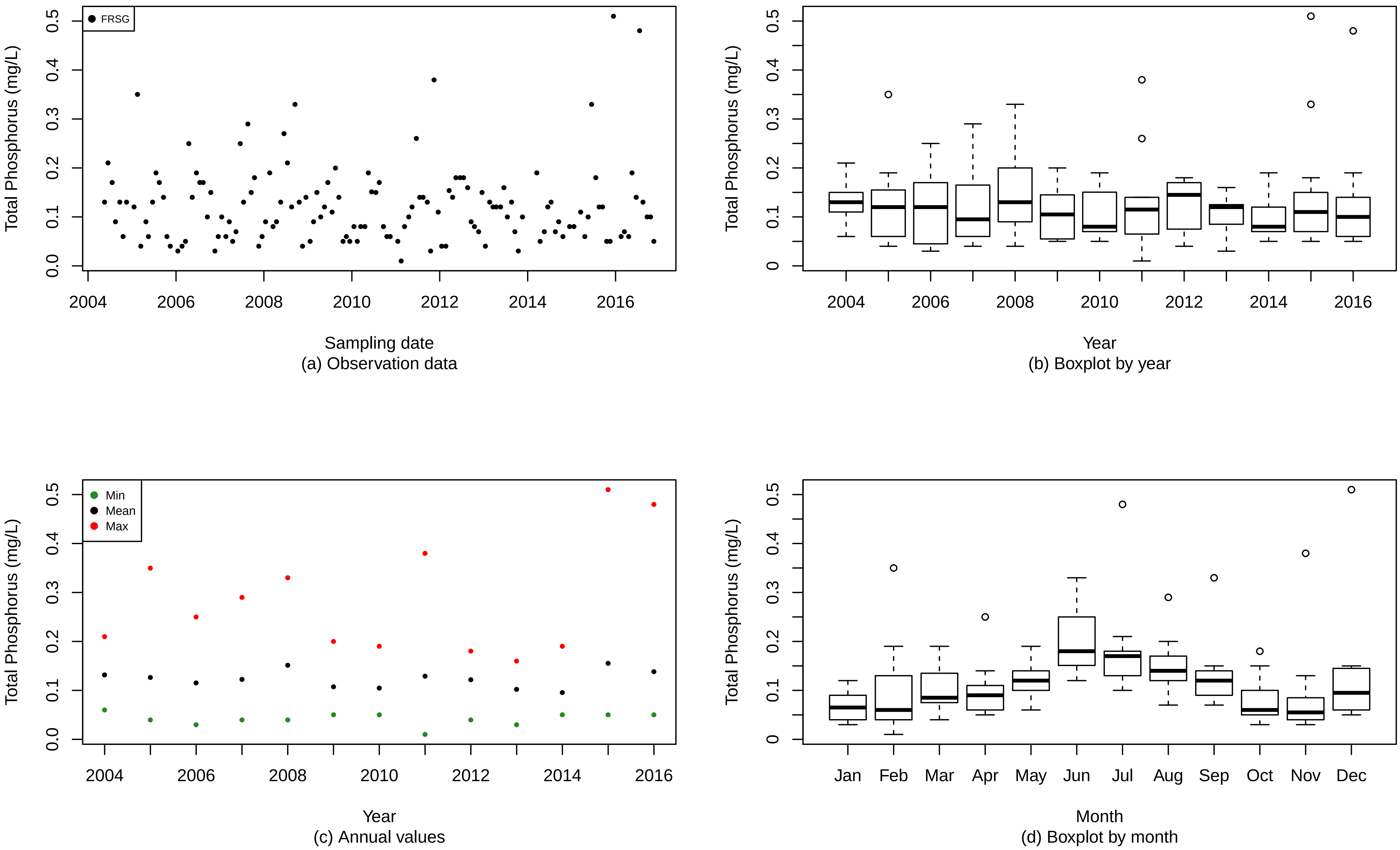



Blackberry Cr at Rt 47 (28): pH (su)
IEPA
pH (su)
Sampling date
(a) Observation data
pH (su)
Year
(b) Boxplot by year
Min
Mean
Max
pH (su)
Year
(c) Annual values
pH (su)
Month
(d) Boxplot by month

Blackberry Cr at Rt 47 (28): Total Suspended Solids (mg/L)



Blackberry Cr near Mouth (287): Total Phosphorus (mg/L)



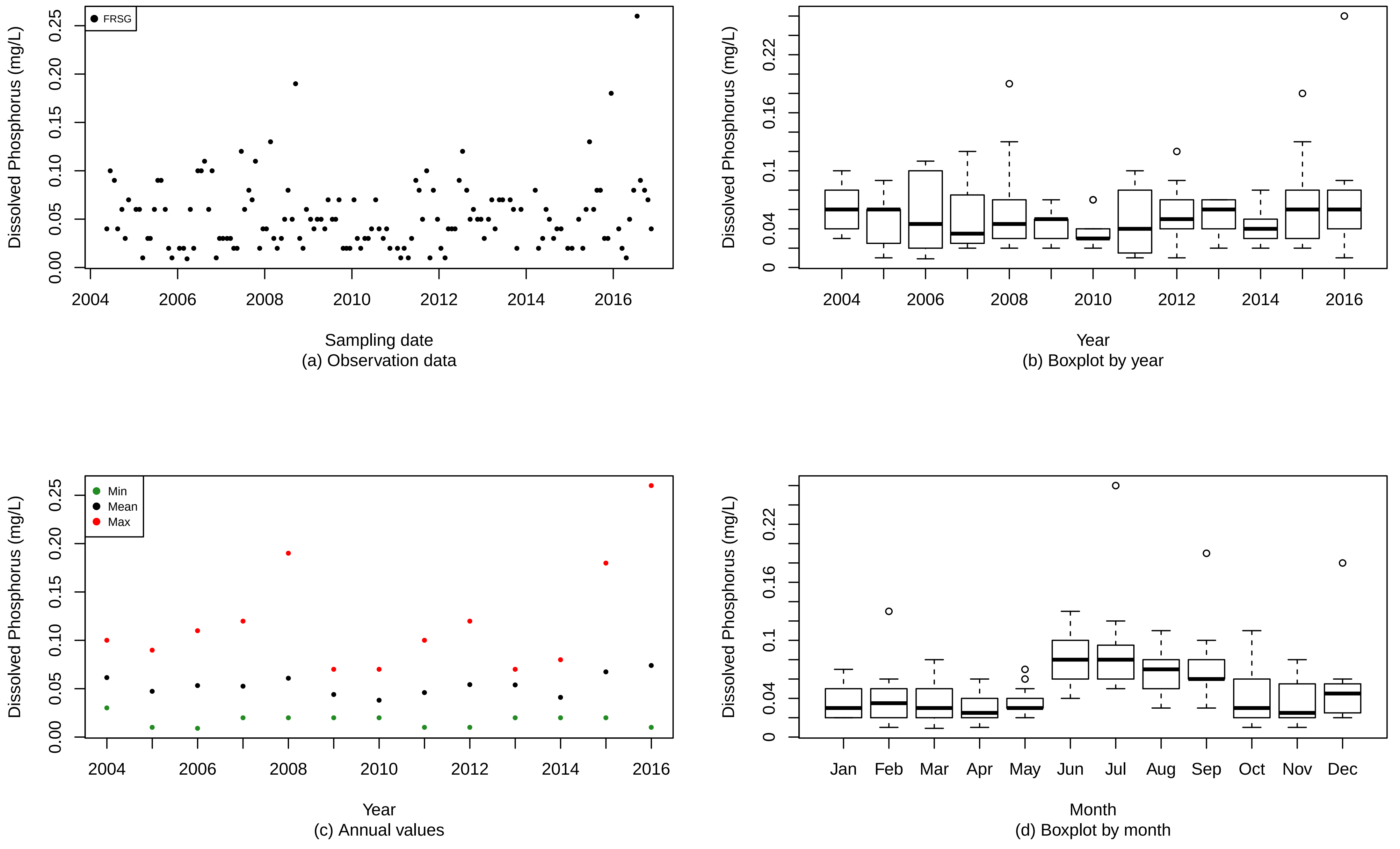
(a) Observation data

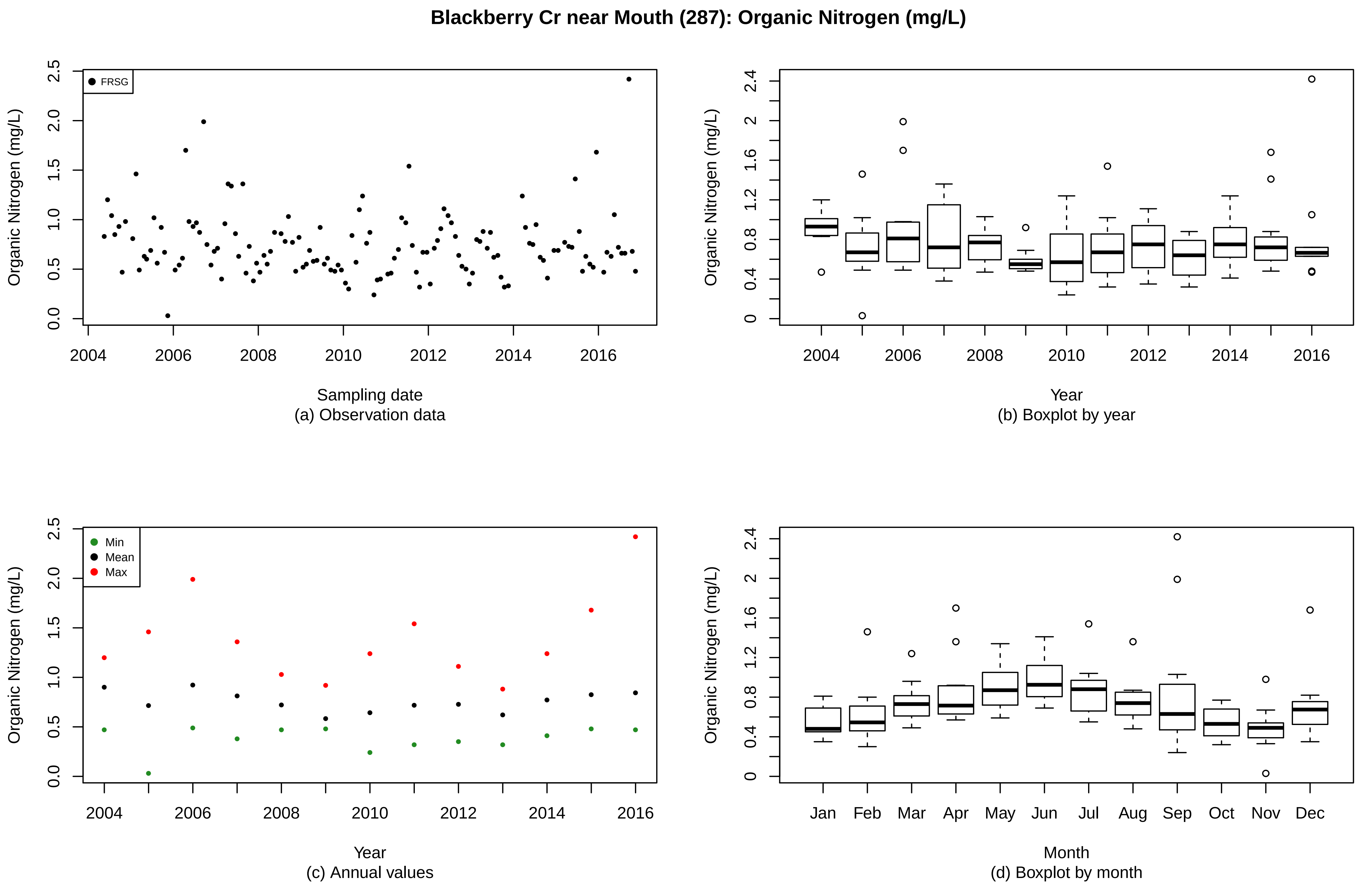
(b) Boxplot by year

(c) Annual values

(d) Boxplot by month

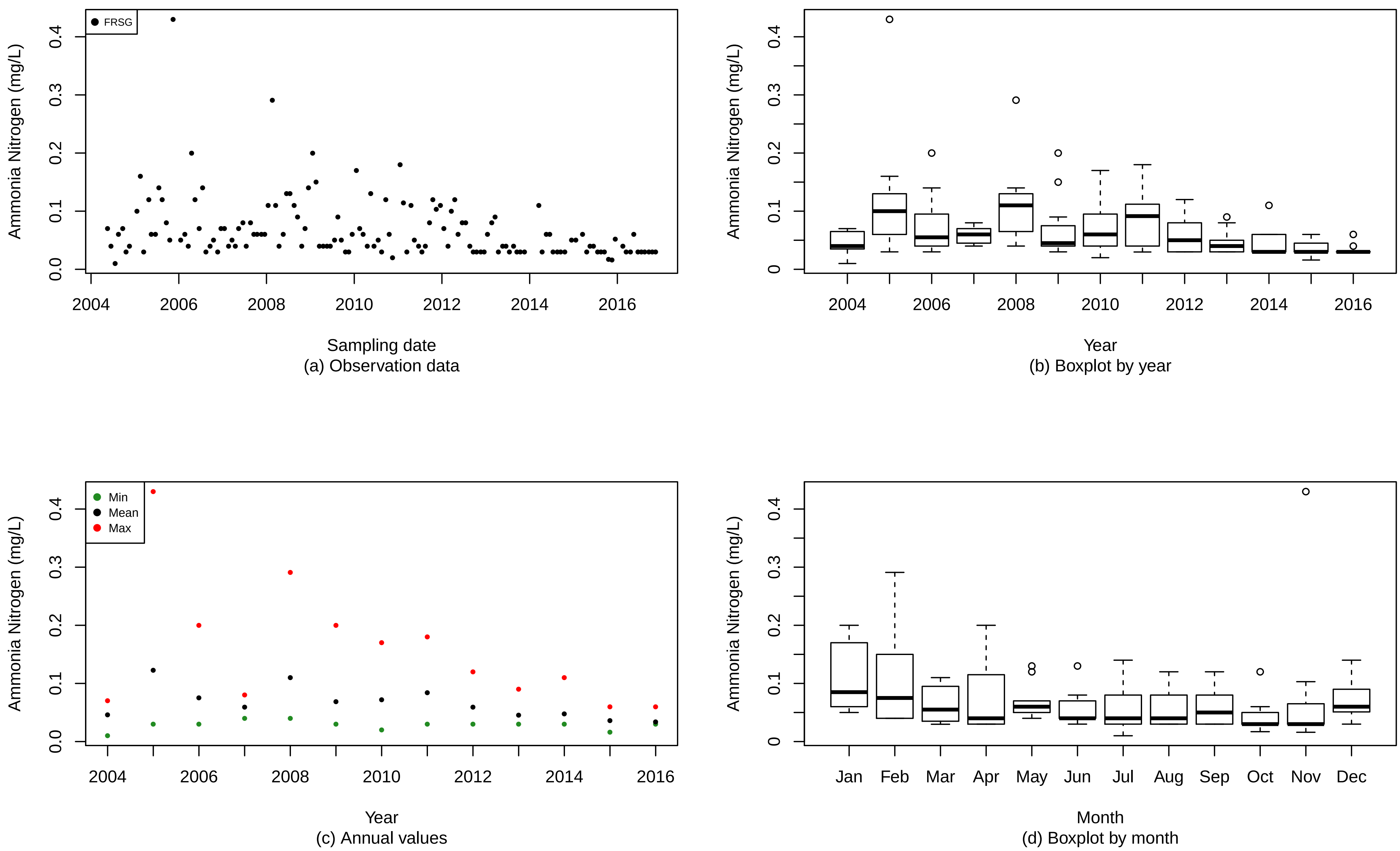
Blackberry Cr near Mouth (287): Dissolved Phosphorus (mg/L)



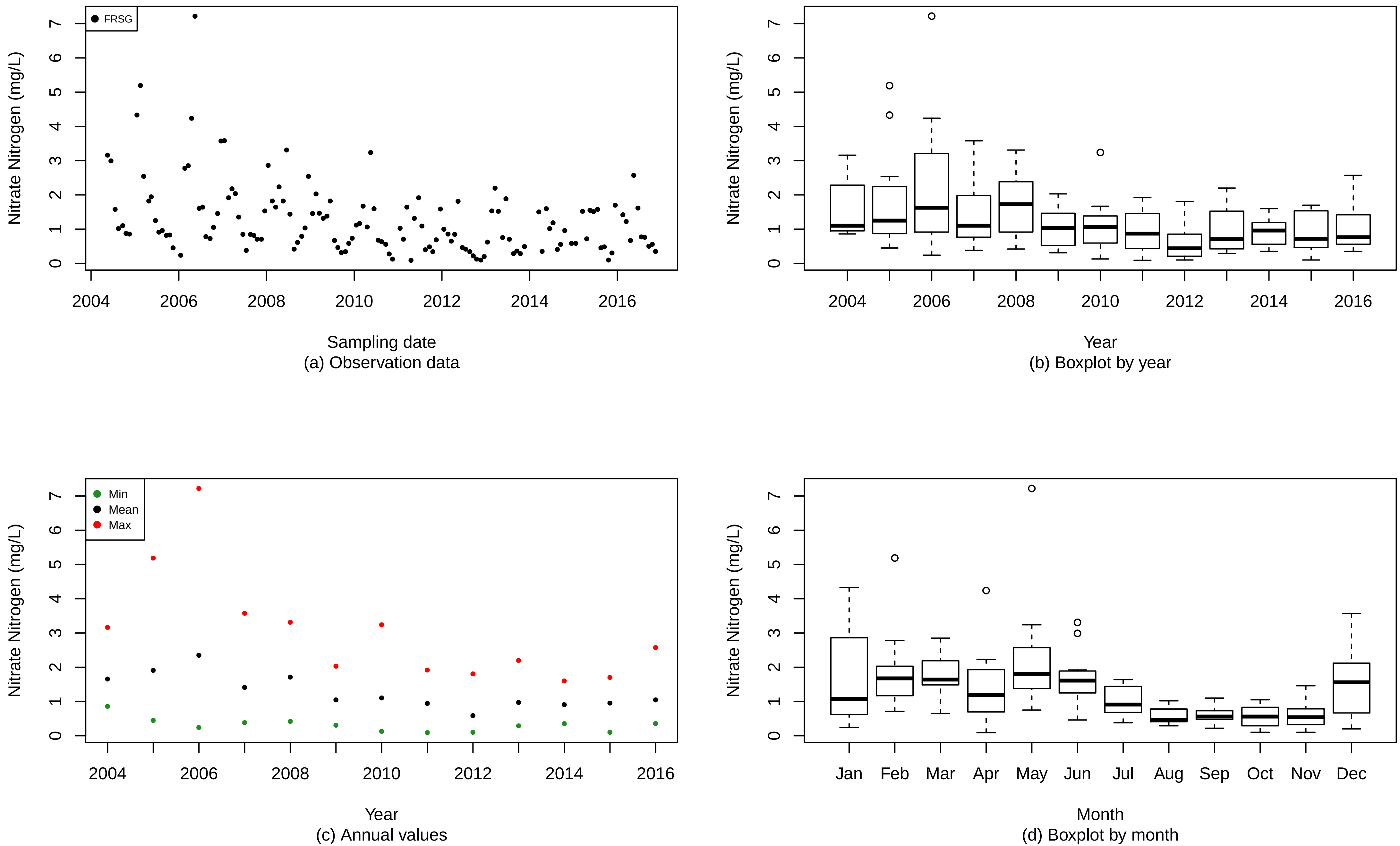


Blackberry Cr near Mouth (287): Organic Nitrogen (mg/L)
FRSG
Organic Nitrogen (mg/L)
Sampling date
(a) Observation data
Year
(b) Boxplot by year
Min
Mean
Max
Year
(c) Annual values
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
(d) Boxplot by month

Blackberry Cr near Mouth (287): Ammonia Nitrogen (mg/L)



Blackberry Cr near Mouth (287): Nitrate Nitrogen (mg/L)



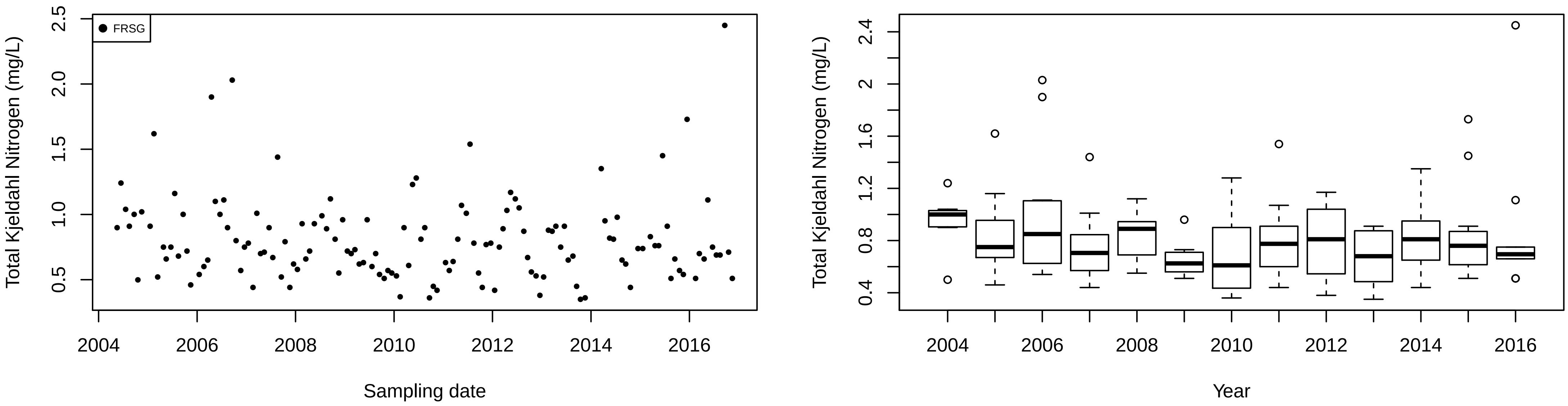
(a) Observation data

(b) Boxplot by year

(c) Annual values

(d) Boxplot by month

Blackberry Cr near Mouth (287): Total Kjeldahl Nitrogen (mg/L)



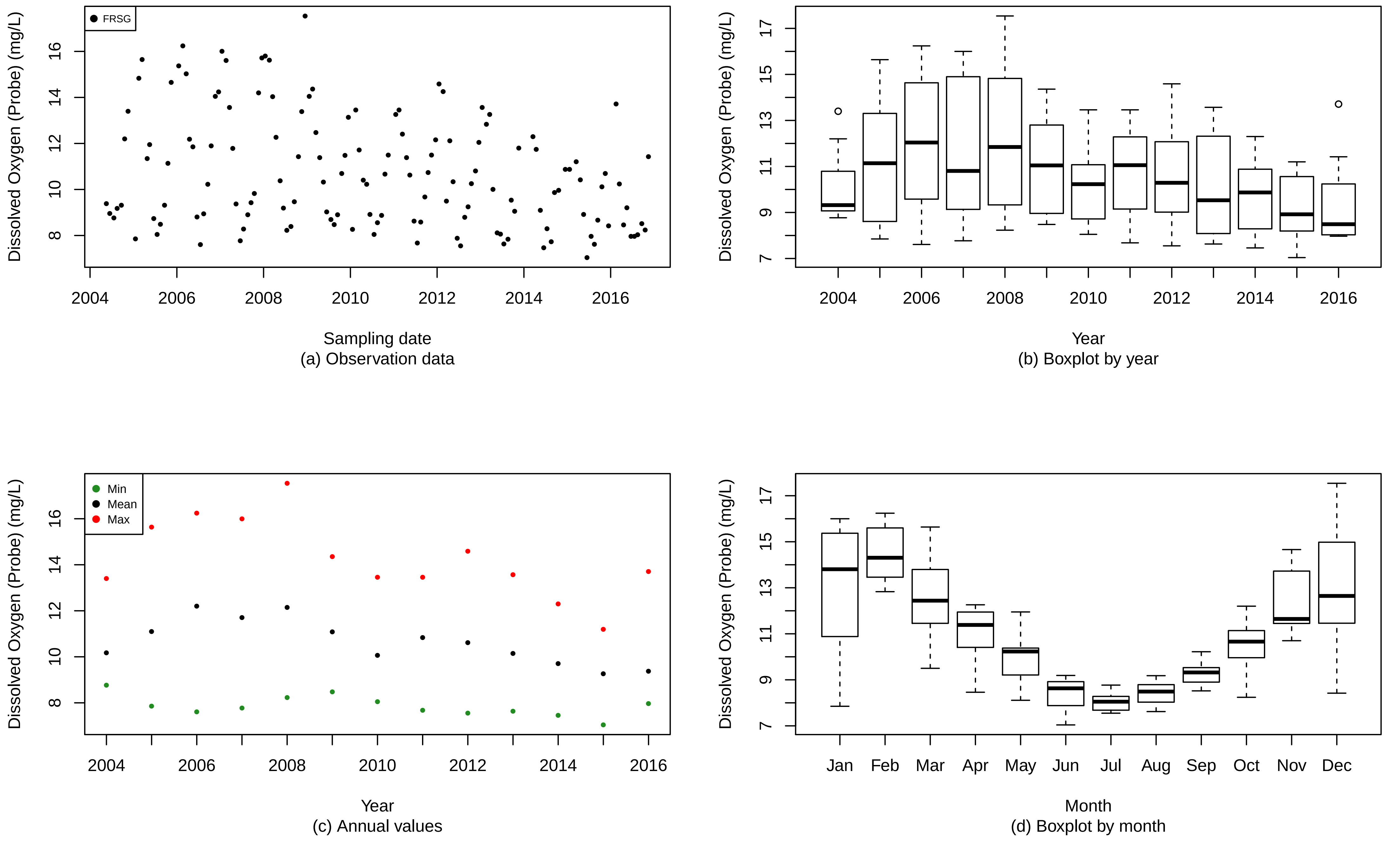
(a) Observation data

(b) Boxplot by year

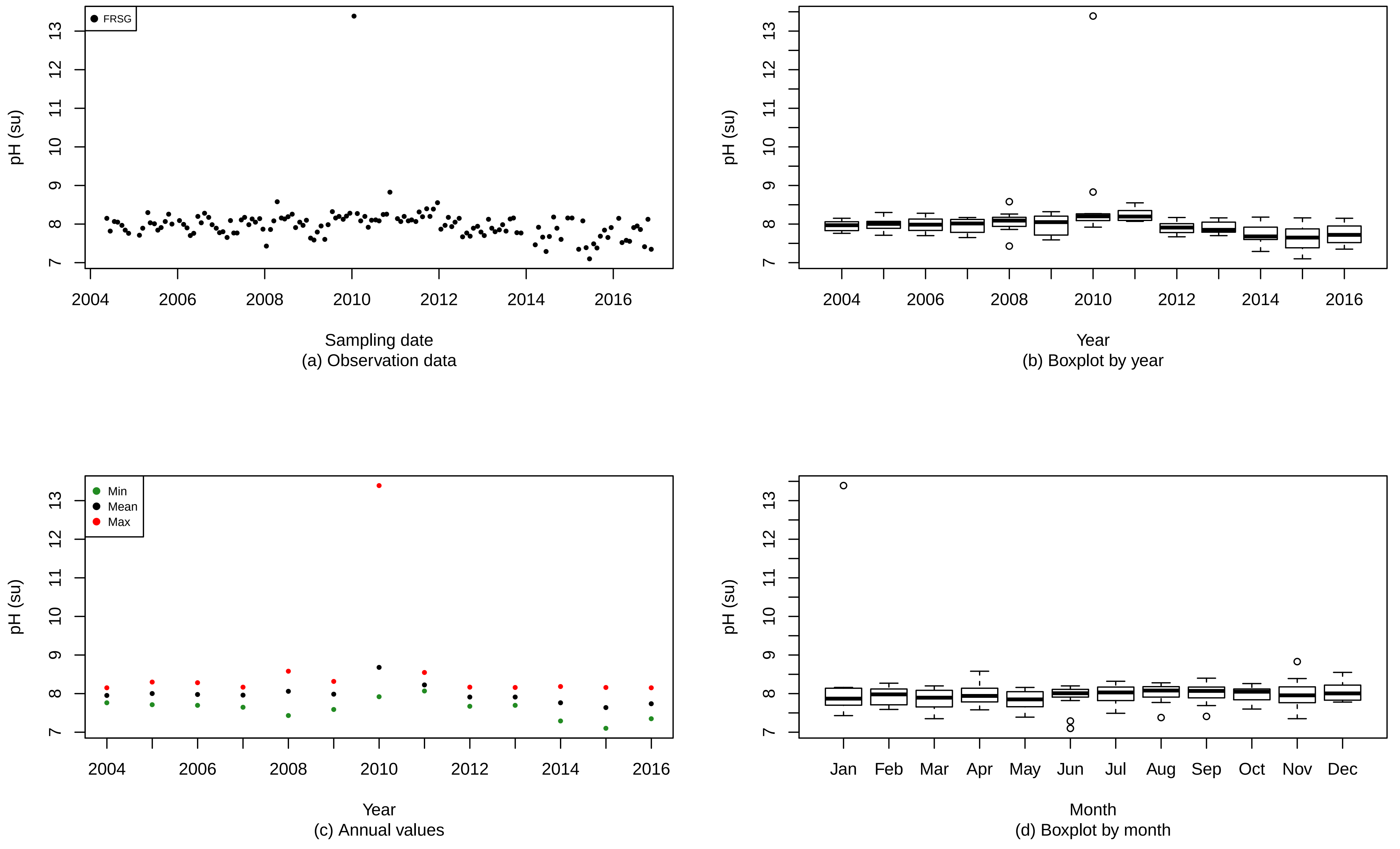
(c) Annual values

(d) Boxplot by month

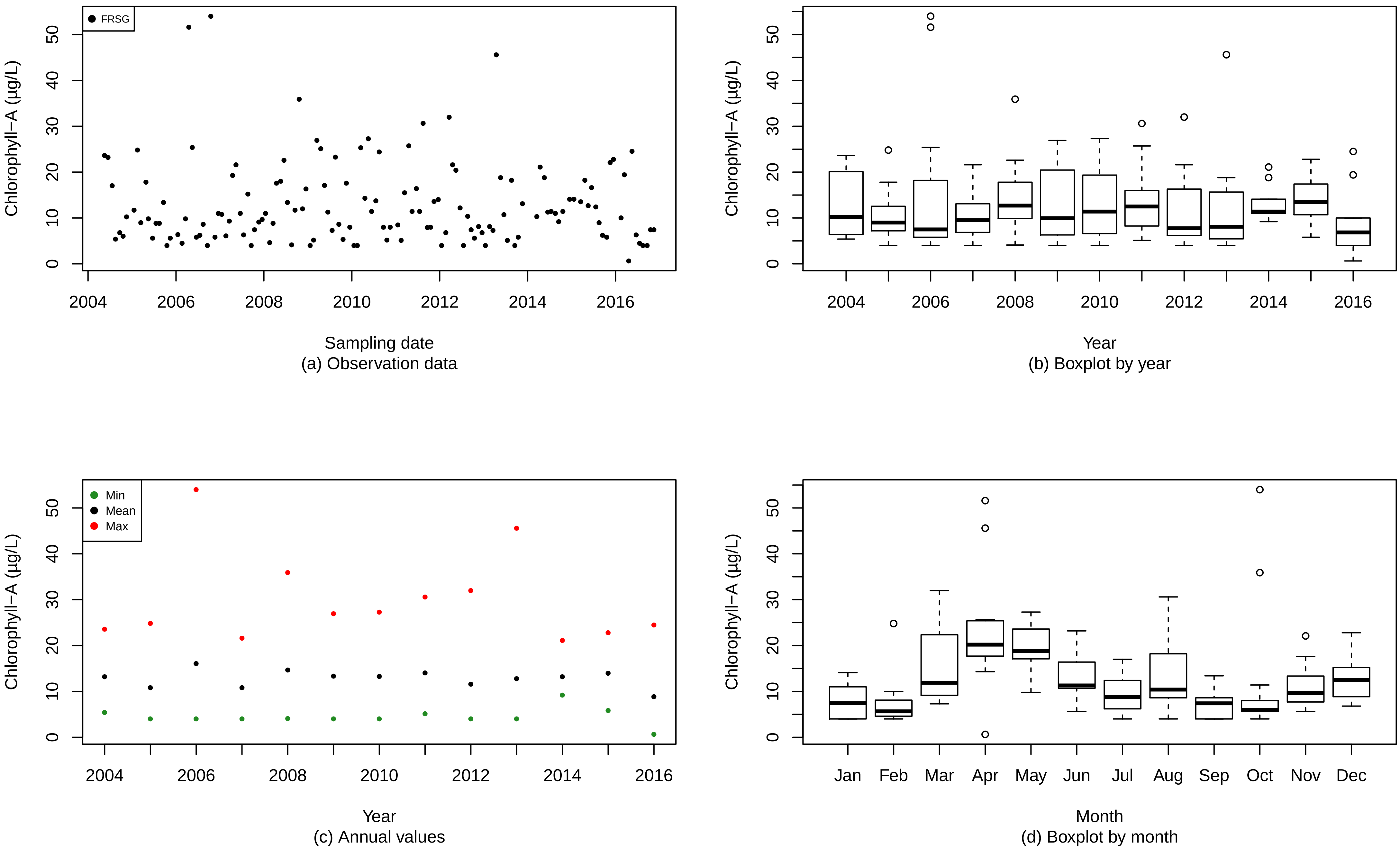
Blackberry Cr near Mouth (287): Dissolved Oxygen (Probe) (mg/L)



Blackberry Cr near Mouth (287): pH (su)



Blackberry Cr near Mouth (287): Chlorophyll−A (µg/L)



Appendix B - Summary Statistics of the Water Quality Parameters

List of Tables

Table B.1 Summary statistics of Total Phosphorus (TP) concentration (mg/L)

Station ID	Station Name	N	Mean	Median	Skewness	Minimum	Maximum	1st Quartile	3rd Quartile	StdDev
236	*Nipp-SpGrv*	96	0.039	0.030	2.611	0.004	0.230	0.018	0.043	0.037
1	*Nipp-abvWL*	49	0.047	0.034	1.884	0.007	0.188	0.016	0.051	0.045
184	**Fox-Jhnbg**	151	0.045	0.040	2.183	0.010	0.200	0.020	0.060	0.033
23	**Fox-Rt176**	197	0.034	0.023	6.566	0.002	0.498	0.010	0.043	0.044
258	**Fox-OHills**	88	0.049	0.040	3.616	0.010	0.270	0.030	0.060	0.033
4	*Flint-KesRd*	87	0.208	0.150	3.557	0.004	1.700	0.074	0.220	0.244
271	*Crys-Rt31*	117	0.427	0.250	1.517	0.010	2.330	0.110	0.630	0.418
24	**Fox-Algqn**	315	0.057	0.043	2.294	0.002	0.420	0.020	0.073	0.051
268	*Tyl-Rt31*	94	0.064	0.050	1.322	0.010	0.210	0.030	0.080	0.042
25	*Pop-Mouth*	176	0.026	0.020	1.732	0.002	0.130	0.010	0.037	0.023
26	**Fox-SElgn**	513	0.165	0.120	9.902	0.004	3.500	0.070	0.200	0.199
14	*Fers-Rt34*	86	0.055	0.048	1.136	0.004	0.200	0.004	0.074	0.049
79	*Fers-Mouth*	139	0.056	0.050	1.066	0.009	0.160	0.030	0.078	0.034
40	**Fox-Gnva**	247	0.163	0.130	1.741	0.004	0.680	0.077	0.210	0.128
27	**Fox-Mont**	458	0.159	0.130	1.693	0.004	0.740	0.074	0.200	0.118
34	**Fox-York**	196	0.302	0.250	1.136	0.050	1.030	0.150	0.420	0.198
28	*Black-Rt47*	219	0.042	0.030	2.767	0.004	0.340	0.010	0.051	0.044
287	*Black-Mouth*	142	0.123	0.110	2.018	0.010	0.510	0.060	0.150	0.081

Table B.2 Summary statistics of Dissolved Phosphorus (DP) concentration (mg/L)

Station ID	Station Name	N	Mean	Median	Skewness	Minimum	Maximum	1st Quartile	3rd Quartile	StdDev
236	*Nipp-SpGrv*	96	0.134	0.120	4.234	0.031	0.840	0.079	0.156	0.099
1	*Nipp-abvWL*	61	0.165	0.086	2.992	0.020	1.156	0.060	0.173	0.210
184	**Fox-Jhnbg**	159	0.157	0.144	1.099	0.040	0.410	0.100	0.190	0.072
23	**Fox-Rt176**	202	0.143	0.120	2.046	0.015	0.603	0.092	0.170	0.079
258	**Fox-OHills**	97	0.169	0.160	0.968	0.010	0.410	0.110	0.210	0.076
4	*Flint-KesRd*	89	0.287	0.240	2.123	0.120	1.100	0.166	0.330	0.184
271	*Crys-Rt31*	118	0.499	0.320	1.488	0.070	2.540	0.150	0.795	0.443
24	**Fox-Algqn**	323	0.182	0.160	1.057	0.015	0.540	0.110	0.230	0.091
268	*Tyl-Rt31*	126	0.136	0.110	1.669	0.020	0.540	0.070	0.178	0.090
25	*Pop-Mouth*	175	0.093	0.074	7.795	0.010	1.200	0.050	0.110	0.102
26	**Fox-SElgn**	543	0.290	0.230	6.646	0.054	3.590	0.170	0.335	0.227
14	*Fers-Rt34*	90	0.146	0.115	1.254	0.015	0.440	0.085	0.189	0.089
79	*Fers-Mouth*	137	0.112	0.100	2.128	0.020	0.500	0.060	0.140	0.073
40	**Fox-Gnva**	246	0.326	0.270	1.694	0.120	1.120	0.190	0.380	0.189
27	**Fox-Mont**	546	0.317	0.270	1.657	0.017	1.170	0.200	0.370	0.169
34	**Fox-York**	195	0.483	0.410	1.004	0.160	1.380	0.300	0.645	0.245
28	*Black-Rt47*	225	0.116	0.091	2.517	0.010	0.700	0.061	0.140	0.088
287	*Black-Mouth*	141	0.053	0.050	2.095	0.009	0.260	0.030	0.070	0.037

Table B.3 Summary statistics of Organic Nitrogen (Org-N) concentration (mg/L)

Station ID	Station Name	N	Mean	Median	Skewness	Minimum	Maximum	1st Quartile	3rd Quartile	StdDev
236	*Nipp-SpGrv*	-	-	-	-	-	-	-	-	-
1	*Nipp-abvWL*	-	-	-	-	-	-	-	-	-
184	**Fox-Jhnbg**	150	1.689	1.530	1.402	0.100	4.790	1.212	1.970	0.724
23	**Fox-Rt176**	-	-	-	-	-	-	-	-	-
258	**Fox-OHills**	90	1.760	1.615	1.568	0.100	5.070	1.240	2.068	0.850
4	*Flint-KesRd*	-	-	-	-	-	-	-	-	-
271	*Crys-Rt31*	120	0.937	0.815	6.215	0.180	6.480	0.688	1.040	0.641
24	**Fox-Algqn**	154	1.717	1.675	1.057	0.360	5.150	1.130	2.135	0.774
268	*Tyl-Rt31*	97	0.792	0.680	1.211	0.100	2.100	0.590	0.940	0.336
25	*Pop-Mouth*	-	-	-	-	-	-	-	-	-
26	**Fox-SElgn**	293	1.632	1.540	0.749	0.110	4.070	1.100	2.020	0.703
14	*Fers-Rt34*	-	-	-	-	-	-	-	-	-
79	*Fers-Mouth*	138	0.748	0.670	1.151	0.280	1.900	0.520	0.895	0.305
40	**Fox-Gnva**	168	1.660	1.520	1.126	0.250	4.270	1.098	1.980	0.766
27	**Fox-Mont**	256	1.585	1.460	1.603	0.240	5.406	1.048	1.876	0.759
34	**Fox-York**	194	1.619	1.455	1.073	0.030	4.790	1.072	2.068	0.776
28	*Black-Rt47*	-	-	-	-	-	-	-	-	-
287	*Black-Mouth*	141	0.749	0.690	1.715	0.030	2.420	0.540	0.880	0.336

Table B.4 Summary statistics of Ammonia Nitrogen (NH_3-N) concentration (mg/L)

Station ID	Station Name	N	Mean	Median	Skewness	Minimum	Maximum	1st Quartile	3rd Quartile	StdDev
236	*Nipp-SpGrv*	97	0.150	0.110	2.592	0.010	1.050	0.040	0.190	0.161
1	*Nipp-abvWL*	-	-	-	-	-	-	-	-	-
184	**Fox-Jhnbg**	159	0.077	0.060	2.014	0.010	0.390	0.030	0.100	0.061
23	**Fox-Rt176**	203	0.097	0.060	3.410	0.010	0.950	0.015	0.125	0.128
258	**Fox-OHills**	98	0.074	0.050	6.170	0.020	0.860	0.030	0.090	0.095
4	*Flint-KesRd*	88	0.113	0.067	2.052	0.015	0.640	0.031	0.140	0.124
271	*Crys-Rt31*	120	0.092	0.070	5.436	0.020	0.800	0.050	0.100	0.084
24	**Fox-Algqn**	324	0.104	0.060	5.393	0.010	1.580	0.030	0.130	0.152
268	*Tyl-Rt31*	132	0.069	0.060	5.502	0.010	0.570	0.040	0.080	0.057
25	*Pop-Mouth*	172	0.083	0.043	2.312	0.010	0.640	0.015	0.113	0.098
26	**Fox-SElgn**	531	0.111	0.060	4.313	0.010	1.300	0.030	0.140	0.148
14	*Fers-Rt34*	84	0.078	0.035	3.309	0.010	0.690	0.015	0.086	0.117
79	*Fers-Mouth*	138	0.061	0.050	1.263	0.010	0.180	0.030	0.078	0.035
40	**Fox-Gnva**	244	0.068	0.040	7.195	0.010	1.080	0.030	0.080	0.087
27	**Fox-Mont**	1335	0.082	0.041	3.560	0.005	1.010	0.026	0.100	0.105
34	**Fox-York**	288	0.089	0.048	4.257	0.010	1.160	0.030	0.100	0.116
28	*Black-Rt47*	190	0.097	0.054	5.721	0.010	1.500	0.015	0.130	0.141
287	*Black-Mouth*	142	0.068	0.050	3.208	0.010	0.430	0.030	0.080	0.053

Table B.5 Summary statistics of Nitrate Nitrogen (NO_3-N) concentration (mg/L)

Station ID	Station Name	N	Mean	Median	Skewness	Minimum	Maximum	1st Quartile	3rd Quartile	StdDev
236	*Nipp-SpGrv*	-	-	-	-	-	-	-	-	-
1	*Nipp-abvWL*	-	-	-	-	-	-	-	-	-
184	**Fox-Jhnbg**	159	1.038	0.760	1.167	0.028	4.010	0.490	1.490	0.786
23	**Fox-Rt176**	110	1.264	0.930	0.925	0.024	3.900	0.418	1.840	1.062
258	**Fox-OHills**	96	0.864	0.610	1.725	0.050	4.430	0.258	1.108	0.797
4	*Flint-KesRd*	-	-	-	-	-	-	-	-	-
271	*Crys-Rt31*	118	3.766	3.415	0.901	0.360	11.800	2.255	5.135	1.991
24	**Fox-Algqn**	231	1.285	1.010	0.804	0.010	4.500	0.495	1.930	0.952
268	*Tyl-Rt31*	99	2.391	1.780	2.004	0.400	10.420	1.035	2.835	1.922
25	*Pop-Mouth*	-	-	-	-	-	-	-	-	-
26	**Fox-SElgn**	380	1.720	1.505	0.797	0.064	4.880	1.098	2.232	0.898
14	*Fers-Rt34*	-	-	-	-	-	-	-	-	-
79	*Fers-Mouth*	139	1.148	0.860	1.511	0.090	4.300	0.505	1.510	0.897
40	**Fox-Gnva**	238	1.666	1.500	0.811	0.021	5.200	0.970	2.195	0.936
27	**Fox-Mont**	400	1.666	1.462	3.520	0.018	14.300	0.900	2.305	1.172
34	**Fox-York**	196	2.080	1.855	0.828	0.270	5.450	1.358	2.650	1.018
28	*Black-Rt47*	-	-	-	-	-	-	-	-	-
287	*Black-Mouth*	142	1.275	1.010	2.255	0.090	7.220	0.590	1.618	1.052

Table B.6 Summary statistics of Total Kjeldahl Nitrogen (TKN) (mg/L)

Station ID	Station Name	N	Mean	Median	Skewness	Minimum	Maximum	1st Quartile	3rd Quartile	StdDev
236	*Nipp-SpGrv*	75	0.978	0.870	1.753	0.100	3.200	0.710	1.090	0.498
1	*Nipp-abvWL*	-	-	-	-	-	-	-	-	-
184	**Fox-Jhnbg**	150	1.747	1.610	1.547	0.670	4.820	1.290	1.987	0.677
23	**Fox-Rt176**	186	1.645	1.600	1.085	0.100	4.600	1.100	2.000	0.771
258	**Fox-OHills**	90	1.839	1.675	1.777	0.650	5.100	1.355	2.095	0.807
4	*Flint-KesRd*	88	1.959	1.700	9.082	0.660	27.800	1.422	1.900	2.816
271	*Crys-Rt31*	120	1.000	0.900	7.180	0.250	6.660	0.740	1.100	0.604
24	**Fox-Algqn**	309	1.671	1.600	1.101	0.010	5.210	1.200	2.050	0.743
268	*Tyl-Rt31*	97	0.831	0.770	0.993	0.220	1.780	0.650	0.960	0.283
25	*Pop-Mouth*	167	1.096	1.000	5.489	0.100	9.400	0.625	1.300	0.991
26	**Fox-SElgn**	513	1.656	1.580	0.731	0.100	4.110	1.170	2.050	0.681
14	*Fers-Rt34*	87	1.418	1.200	3.638	0.250	6.850	0.975	1.600	0.927
79	*Fers-Mouth*	138	0.792	0.710	1.151	0.090	2.050	0.590	0.948	0.304
40	**Fox-Gnva**	244	1.732	1.600	1.009	0.270	4.300	1.320	2.030	0.671
27	**Fox-Mont**	538	1.604	1.520	1.231	0.150	5.430	1.100	1.938	0.702
34	**Fox-York**	194	1.673	1.510	1.145	0.230	4.820	1.160	2.085	0.721
28	*Black-Rt47*	201	1.013	0.830	8.309	0.100	14.650	0.440	1.300	1.163
287	*Black-Mouth*	141	0.806	0.750	1.887	0.350	2.450	0.580	0.930	0.329

Table B.7 Summary statistics of Dissolved Oxygen (DO) concentration (mg/L)

Station ID	Station Name	N	Mean	Median	Skewness	Minimum	Maximum	1st Quartile	3rd Quartile	StdDev
236	*Nipp-SpGrv*	130	10.480	10.180	-0.146	0.820	17.720	8.700	12.400	2.839
1	*Nipp-abvWL*	-	-	-	-	-	-	-	-	-
184	**Fox-Jhnbg**	138	10.840	10.500	1.075	3.600	27.600	8.150	13.100	3.655
23	**Fox-Rt176**	157	10.480	10.200	0.340	3.800	18.380	7.980	12.700	3.114
258	**Fox-OHills**	85	9.998	9.610	1.584	4.030	24.040	8.100	11.480	3.189
4	*Flint-KesRd*	-	-	-	-	-	-	-	-	-
271	*Crys-Rt31*	106	9.195	8.480	0.683	3.550	18.480	7.462	11.310	2.764
24	**Fox-Algqn**	295	10.050	9.930	0.446	1.880	20.640	7.405	12.140	3.416
268	*Tyl-Rt31*	132	11.490	11.150	0.382	7.200	17.800	9.200	13.580	2.649
25	*Pop-Mouth*	126	10.830	10.360	0.138	4.500	16.240	8.992	12.790	2.575
26	**Fox-SElgn**	664	10.220	9.630	0.547	3.380	19.440	7.698	12.490	2.974
14	*Fers-Rt34*	-	-	-	-	-	-	-	-	-
79	*Fers-Mouth*	139	9.928	9.430	1.242	3.760	26.520	7.530	11.930	3.564
40	**Fox-Gnva**	178	11.240	10.580	1.118	5.200	25.820	9.055	12.920	3.201
27	**Fox-Mont**	16450	9.449	9.290	1.599	4.800	23.200	8.470	10.190	1.440
34	**Fox-York**	276	10.240	9.895	0.221	2.670	17.540	7.990	12.830	2.966
28	*Black-Rt47*	170	10.030	9.735	0.458	5.160	18.440	7.620	12.180	2.777
287	*Black-Mouth*	142	10.720	10.240	0.663	7.040	17.540	8.708	12.200	2.441

Table B.8 Summary statistics of pH (su)

Station ID	Station Name	N	Mean	Median	Skewness	Minimum	Maximum	1st Quartile	3rd Quartile	StdDev
236	*Nipp-SpGrv*	97	8.117	8.120	3.872	7.190	11.190	7.940	8.250	0.423
1	*Nipp-abvWL*	-	-	-	-	-	-	-	-	-
184	**Fox-Jhnbg**	139	8.481	8.500	-0.242	7.200	9.500	8.300	8.700	0.318
23	**Fox-Rt176**	121	8.265	8.300	-0.919	7.000	8.940	8.110	8.470	0.346
258	**Fox-OHills**	75	8.264	8.420	-1.247	6.000	9.680	8.055	8.560	0.530
4	*Flint-KesRd*	-	-	-	-	-	-	-	-	-
271	*Crys-Rt31*	114	8.110	8.200	-0.956	6.800	8.900	7.922	8.400	0.423
24	**Fox-Algqn**	246	8.166	8.225	-0.673	6.660	9.100	7.900	8.522	0.486
268	*Tyl-Rt31*	94	8.198	8.200	-0.349	7.500	8.700	8.000	8.348	0.213
25	*Pop-Mouth*	90	7.852	7.850	-0.211	7.010	8.870	7.672	8.068	0.311
26	**Fox-SElgn**	330	8.349	8.385	-0.769	6.690	9.200	8.140	8.600	0.350
14	*Fers-Rt34*	-	-	-	-	-	-	-	-	-
79	*Fers-Mouth*	134	7.947	8.010	-0.530	6.970	8.660	7.770	8.130	0.301
40	**Fox-Gnva**	170	8.196	8.275	-0.298	6.810	9.350	7.875	8.478	0.430
27	**Fox-Mont**	1570	8.335	8.330	-0.346	6.325	10.600	8.130	8.550	0.372
34	**Fox-York**	294	8.327	8.295	0.366	7.290	9.350	8.120	8.518	0.332
28	*Black-Rt47*	134	7.919	7.970	0.251	6.950	9.140	7.680	8.100	0.314
287	*Black-Mouth*	141	7.992	7.980	7.436	7.100	13.390	7.790	8.150	0.533

Table B.9 Summary statistics of Total Suspended Solids (TSS) concentration (mg/L)

Station ID	Station Name	N	Mean	Median	Skewness	Minimum	Maximum	1st Quartile	3rd Quartile	StdDev
236	*Nipp-SpGrv*	54	29.820	25.000	3.023	3.000	154.000	16.000	36.000	23.400
1	*Nipp-abvWL*	-	-	-	-	-	-	-	-	-
184	**Fox-Jhnbg**	-	-	-	-	-	-	-	-	-
23	**Fox-Rt176**	51	27.010	25.000	0.388	4.000	59.000	18.000	38.000	14.660
258	**Fox-OHills**	-	-	-	-	-	-	-	-	-
4	*Flint-KesRd*	-	-	-	-	-	-	-	-	-
271	*Crys-Rt31*	-	-	-	-	-	-	-	-	-
24	**Fox-Algqn**	53	32.880	30.000	1.616	3.000	112.000	20.000	38.000	22.320
268	*Tyl-Rt31*	-	-	-	-	-	-	-	-	-
25	*Pop-Mouth*	45	12.180	8.000	2.971	2.000	70.000	4.000	14.000	11.830
26	**Fox-SElgn**	104	31.110	30.000	0.929	4.000	109.000	17.750	42.000	17.540
14	*Fers-Rt34*	-	-	-	-	-	-	-	-	-
79	*Fers-Mouth*	-	-	-	-	-	-	-	-	-
40	**Fox-Gnva**	-	-	-	-	-	-	-	-	-
27	**Fox-Mont**	104	34.120	33.000	1.454	4.000	130.000	20.750	43.000	21.520
34	**Fox-York**	-	-	-	-	-	-	-	-	-
28	*Black-Rt47*	100	28.230	20.000	3.285	1.000	203.000	12.380	31.000	29.300
287	*Black-Mouth*	-	-	-	-	-	-	-	-	-

Table B.10 Summary statistics of Chlorophyll A (CHL-A) concentration (µg/L)

Station ID	Station Name	N	Mean	Median	Skewness	Minimum	Maximum	1st Quartile	3rd Quartile	StdDev
236	*Nipp-SpGrv*	-	-	-	-	-	-	-	-	-
1	*Nipp-abvWL*	-	-	-	-	-	-	-	-	-
184	**Fox-Jhnbg**	151	81.630	70.200	1.637	1.070	343.000	37.800	105.500	63.230
23	**Fox-Rt176**	-	-	-	-	-	-	-	-	-
258	**Fox-OHills**	90	94.060	85.650	1.031	1.480	303.200	39.050	124.000	70.170
4	*Flint-KesRd*	-	-	-	-	-	-	-	-	-
271	*Crys-Rt31*	120	29.740	18.850	3.704	4.000	244.400	11.880	33.400	35.510
24	**Fox-Algqn**	155	92.560	86.200	0.827	4.000	314.000	40.300	127.300	67.780
268	*Tyl-Rt31*	96	9.694	8.600	2.706	1.900	45.400	5.600	11.420	6.284
25	*Pop-Mouth*	-	-	-	-	-	-	-	-	-
26	**Fox-SElgn**	195	86.680	78.800	1.094	1.970	333.000	24.650	124.500	71.510
14	*Fers-Rt34*	-	-	-	-	-	-	-	-	-
79	*Fers-Mouth*	139	13.260	10.700	3.229	0.630	84.500	7.000	17.000	9.946
40	**Fox-Gnva**	168	105.300	87.950	1.248	1.180	479.400	34.480	152.800	85.490
27	**Fox-Mont**	194	99.880	80.050	1.223	1.210	470.800	29.800	153.400	85.930
34	**Fox-York**	196	98.150	80.000	1.362	1.190	433.600	33.900	144.800	83.400
28	*Black-Rt47*	-	-	-	-	-	-	-	-	-
287	*Black-Mouth*	142	12.840	10.550	1.936	0.630	54.000	6.325	17.080	8.966

Appendix C – Annual and Seasonal Water Quality Trend Maps

List of Figures

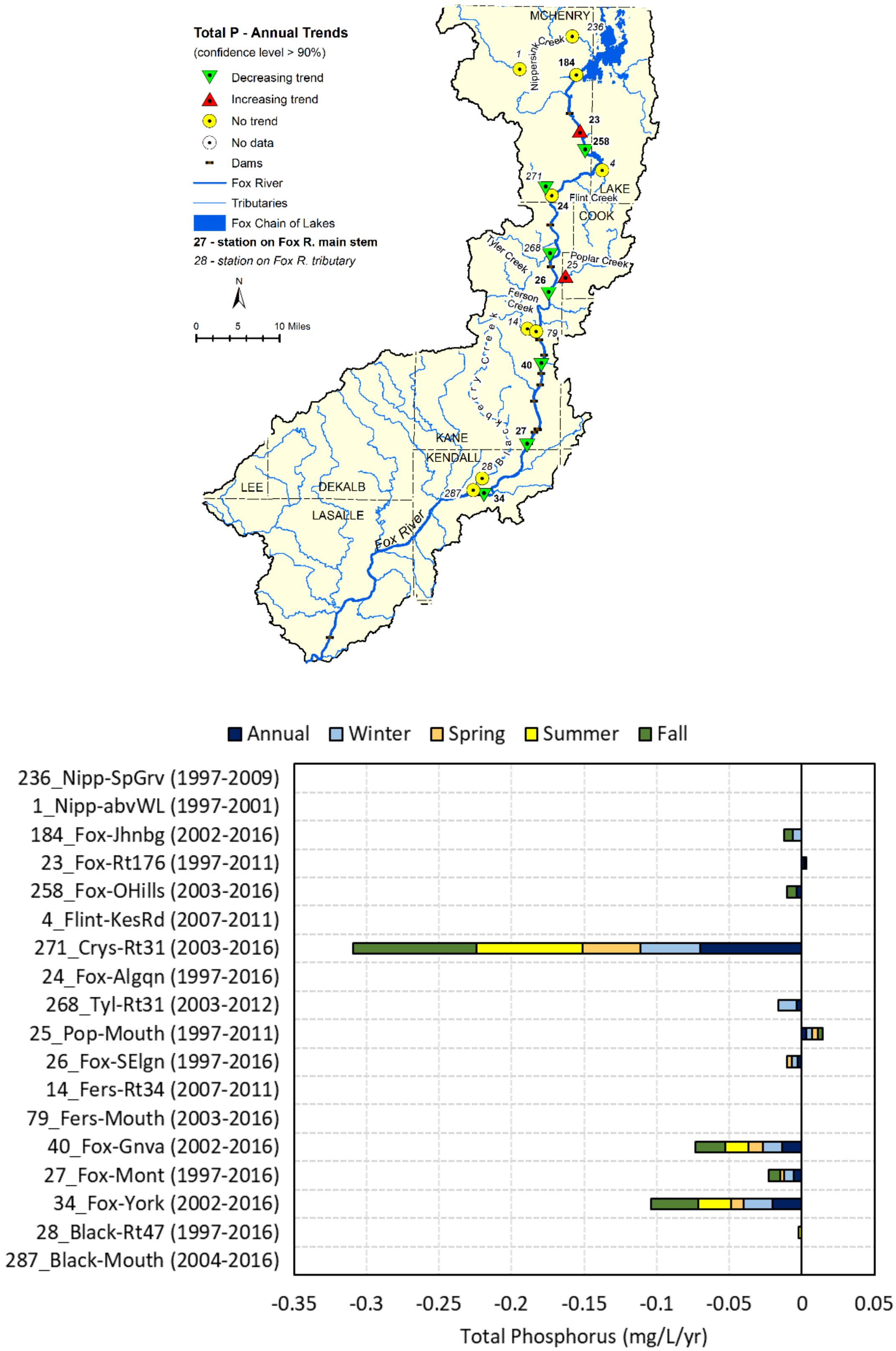


Figure C.1 Annual trends of total phosphorus (TP) in the Fox River watershed

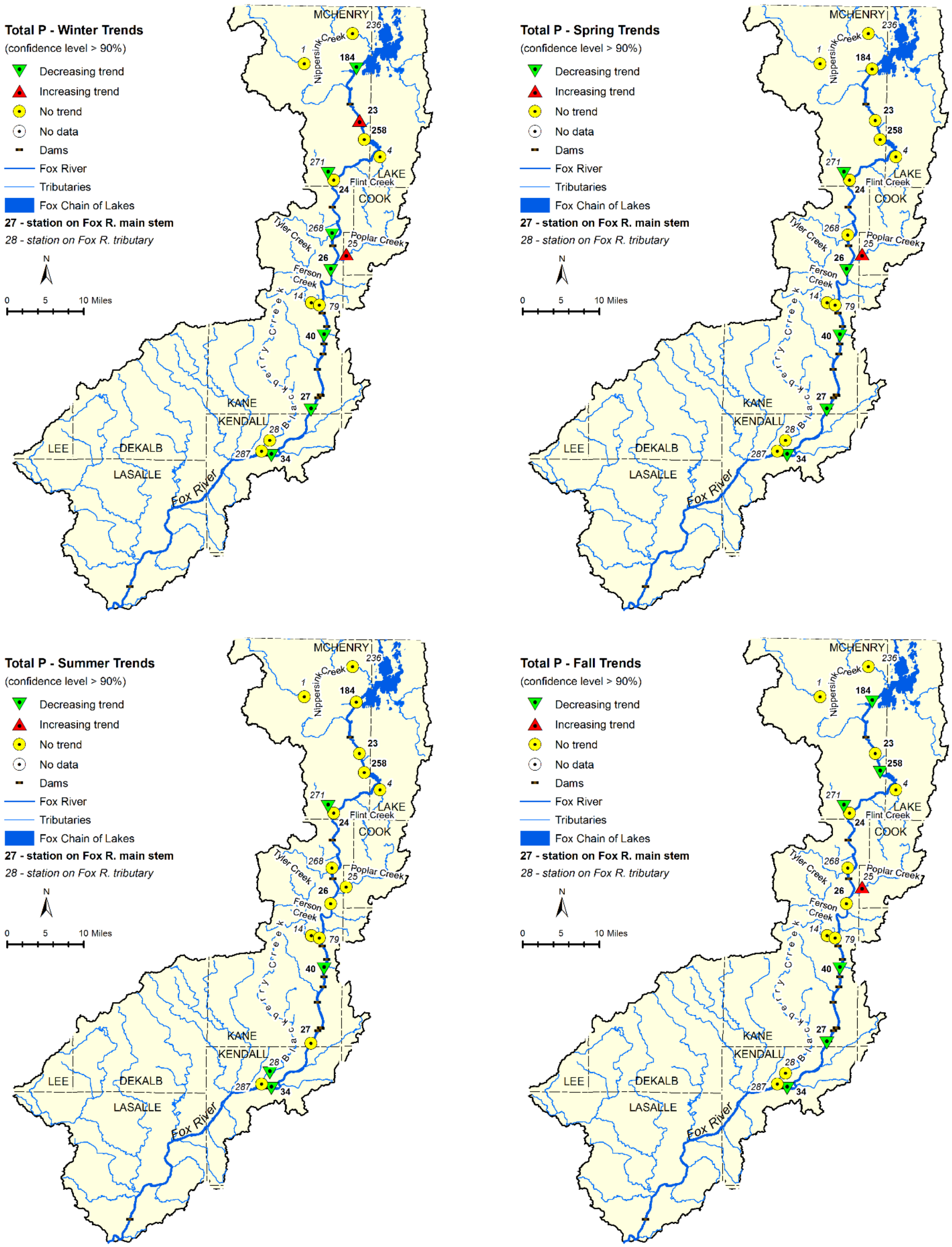
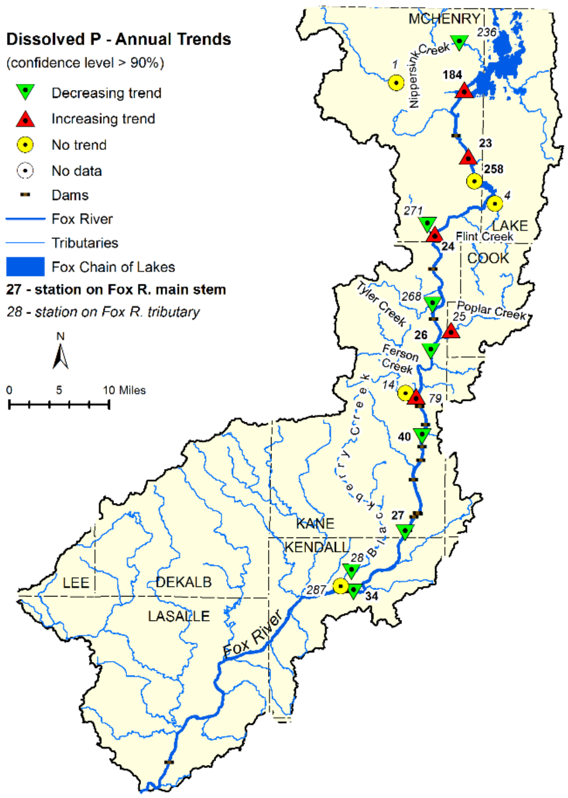


Figure C.2 Seasonal trends of total phosphorus (TP) in the Fox River watershed



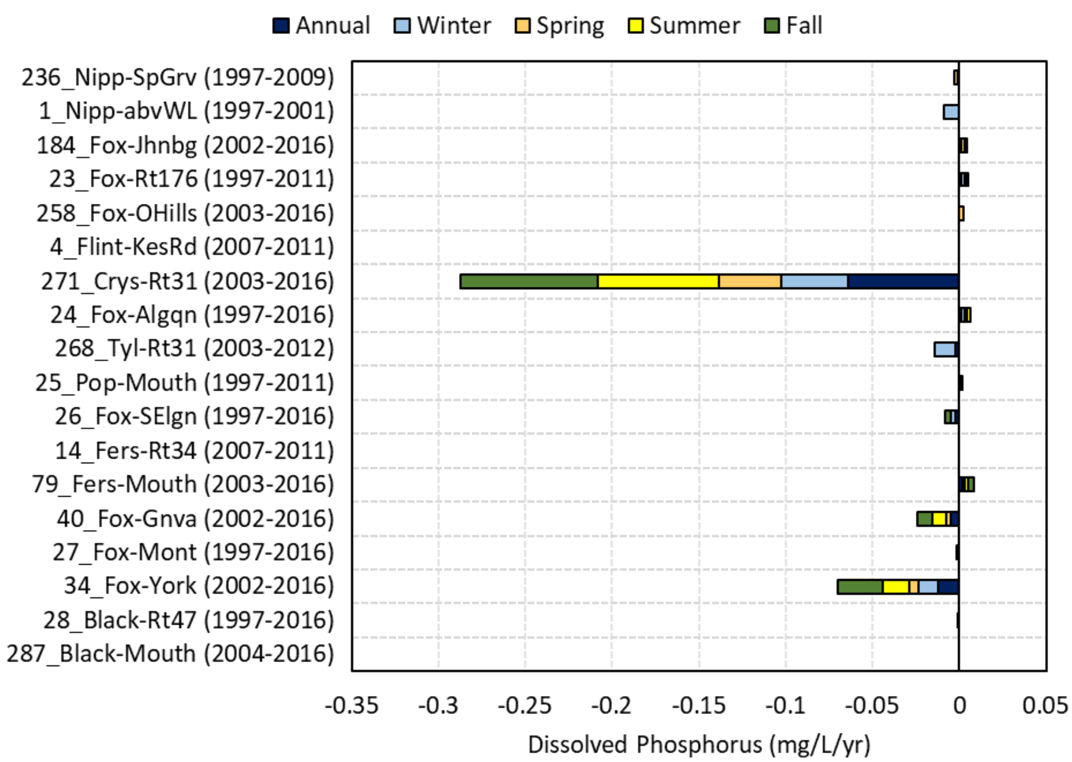


Figure C.3 Annual trends of dissolved phosphorus (DP) in the Fox River watershed

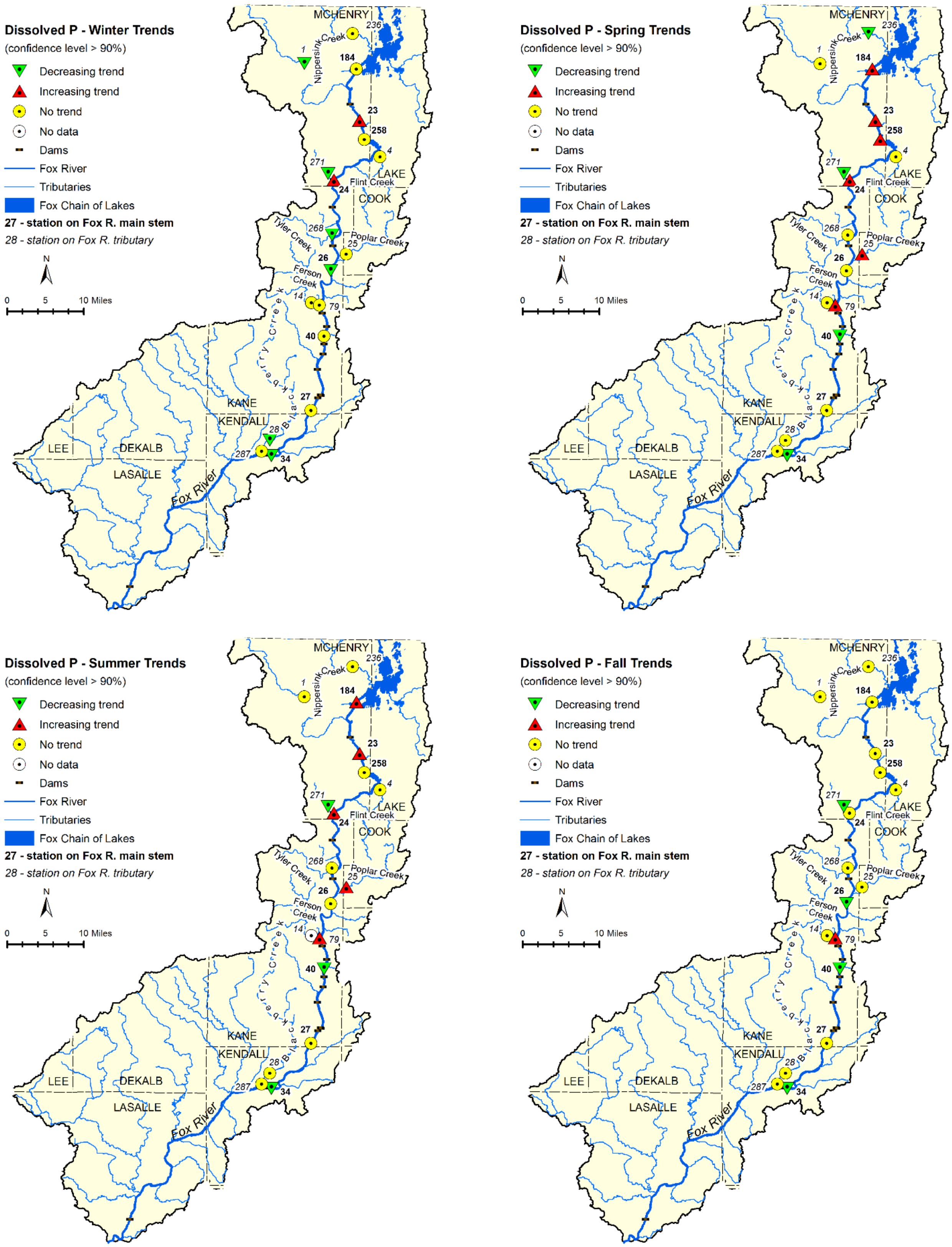
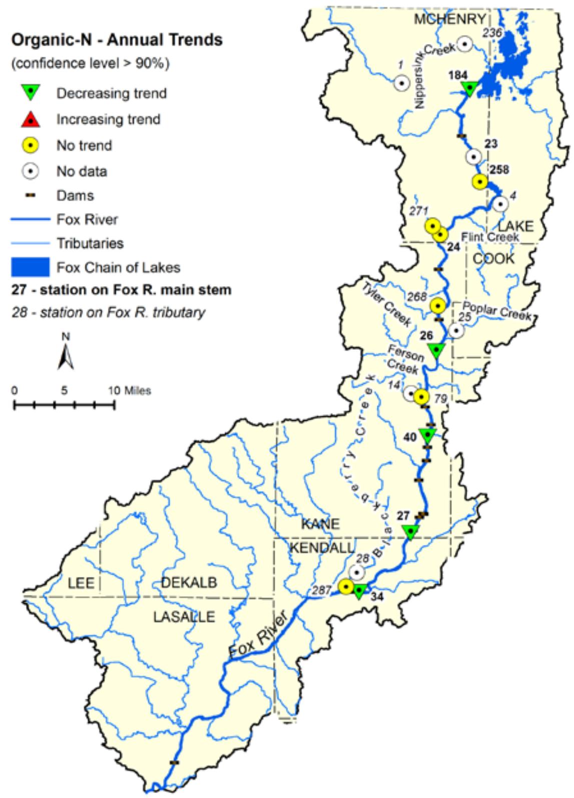


Figure C.4 Seasonal trends of dissolved phosphorus (DP) in the Fox River watershed



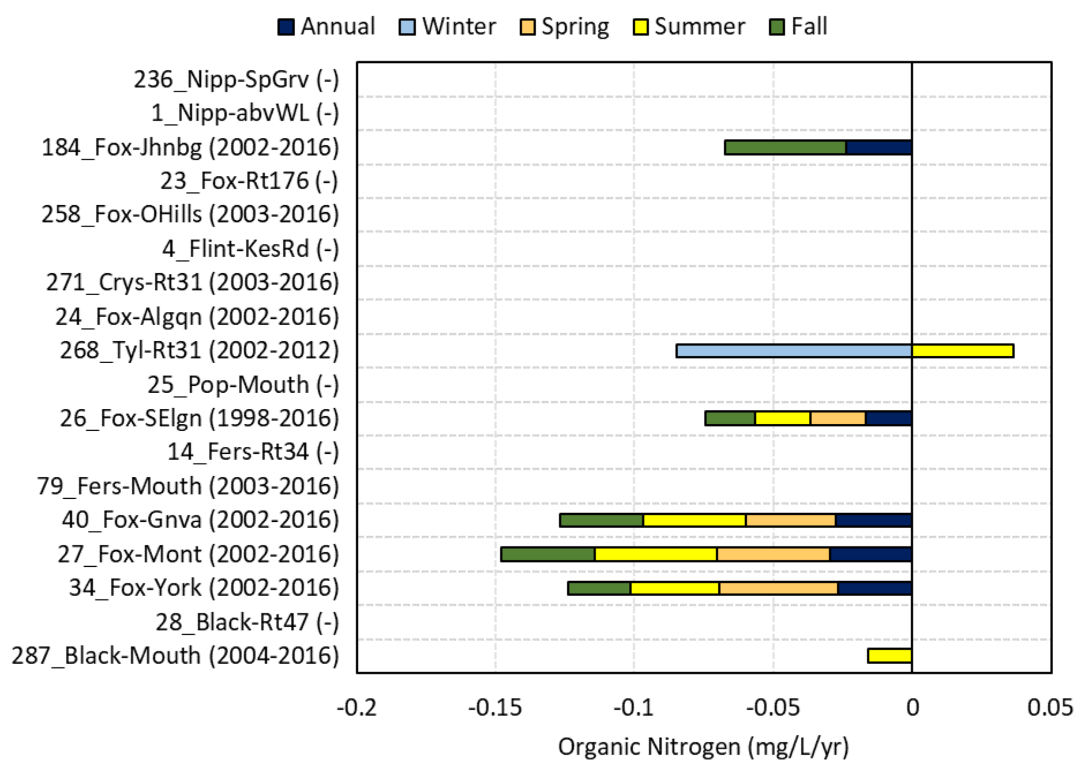


Figure C.5 Annual trends of organic nitrogen (Org-N) in the Fox River watershed

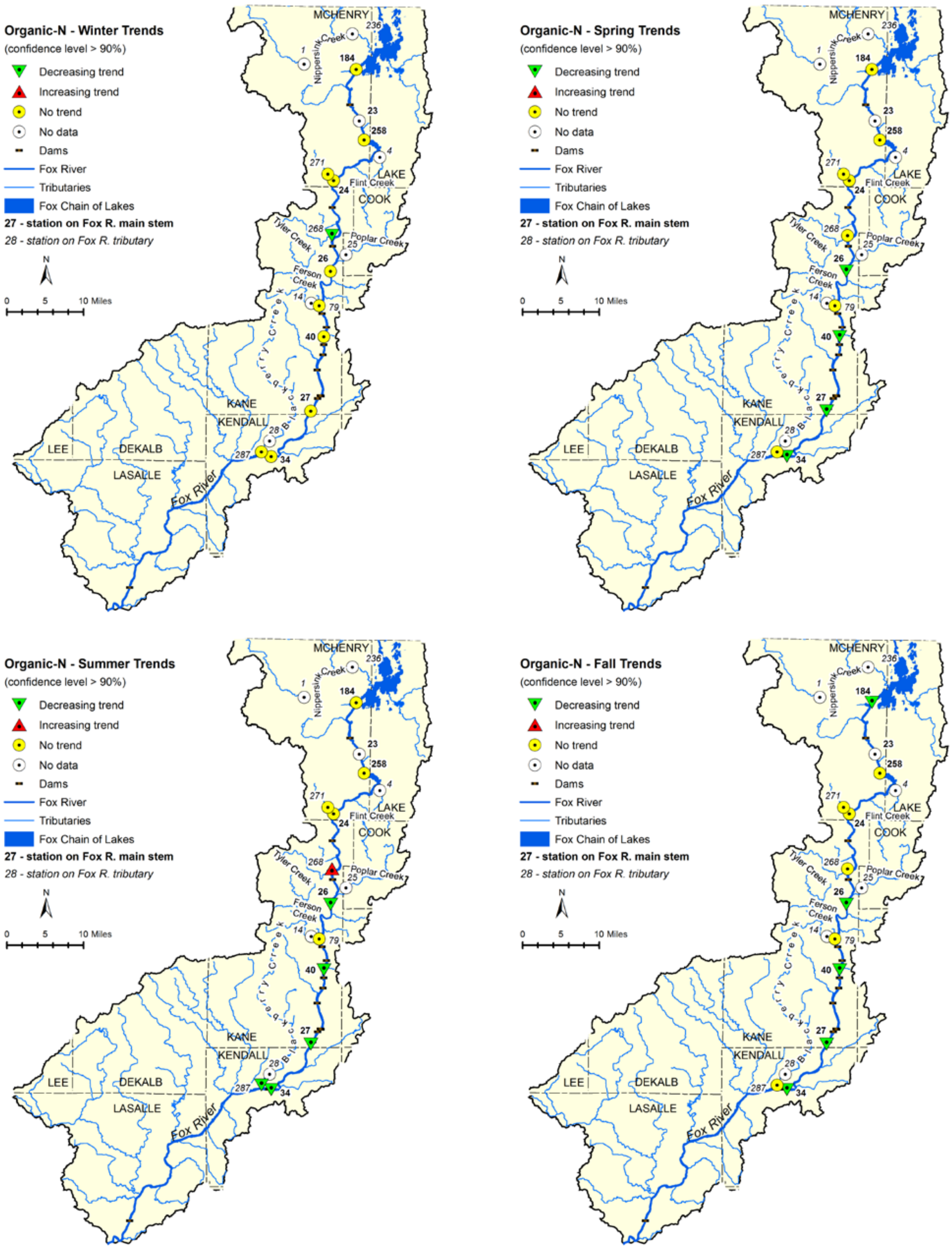


Figure C.6 Seasonal trends of organic nitrogen (Org-N) in the Fox River watershed

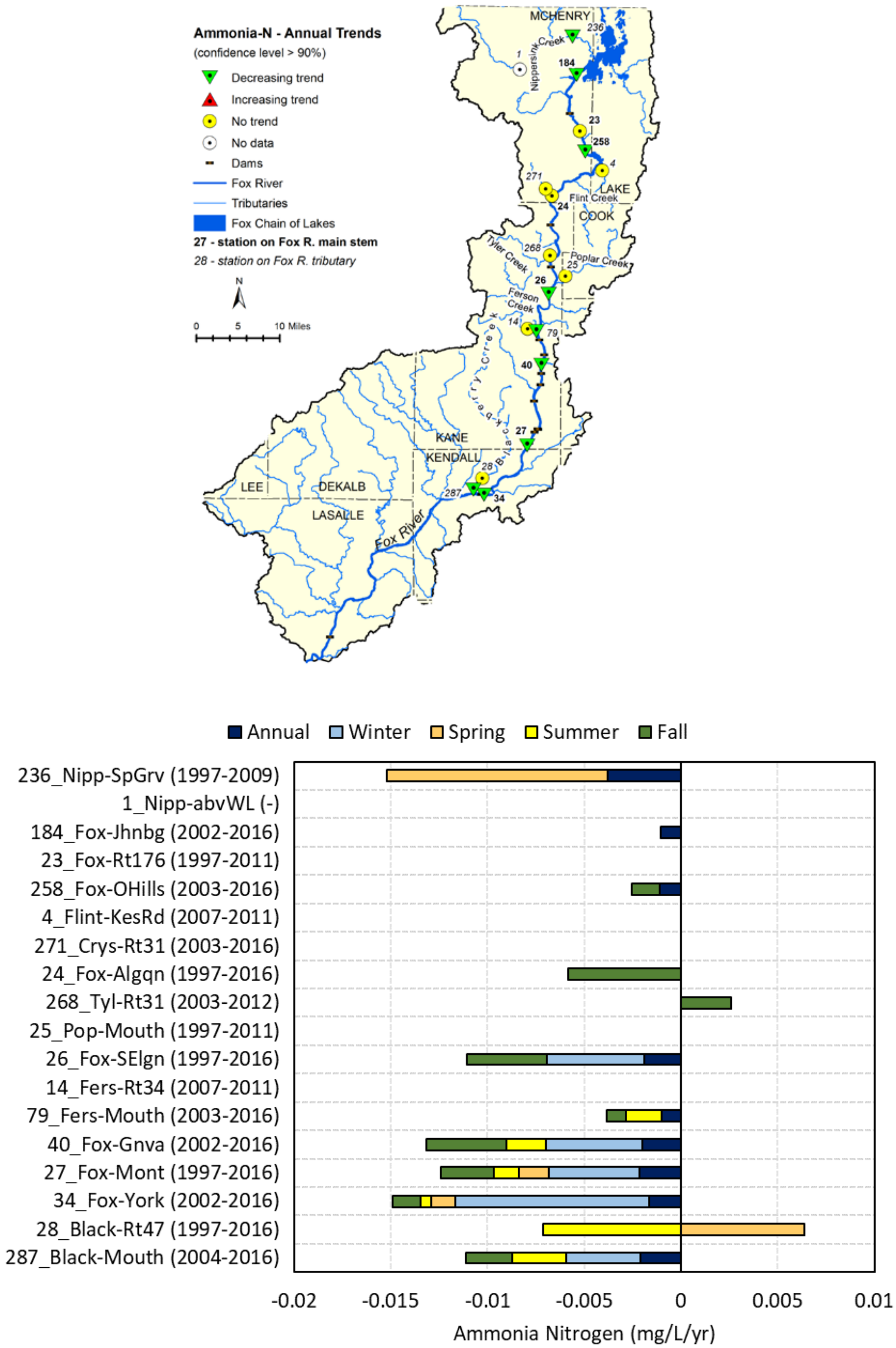


Figure C.7 Annual trends of ammonia nitrogen (NH_3-N) in the Fox River watershed

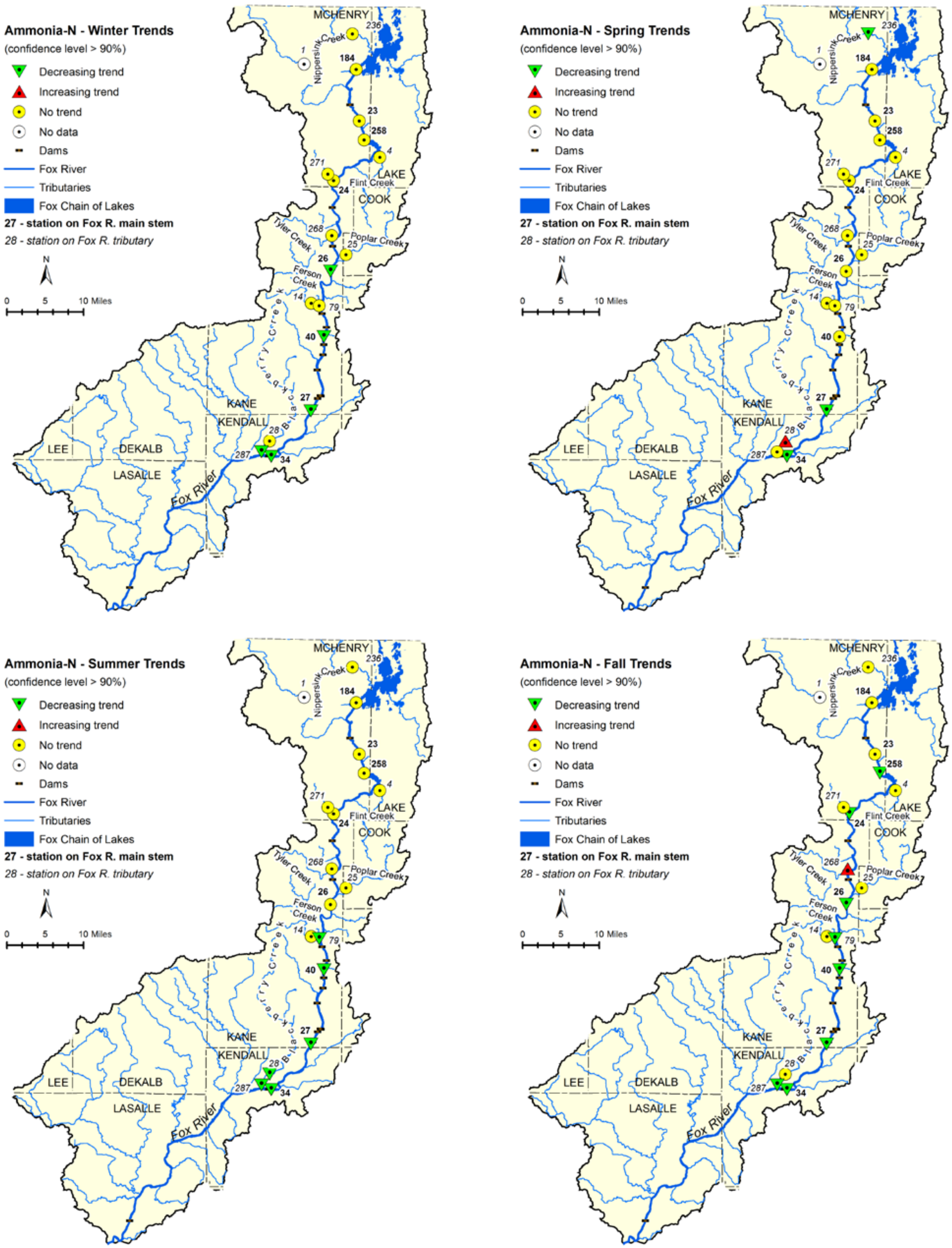
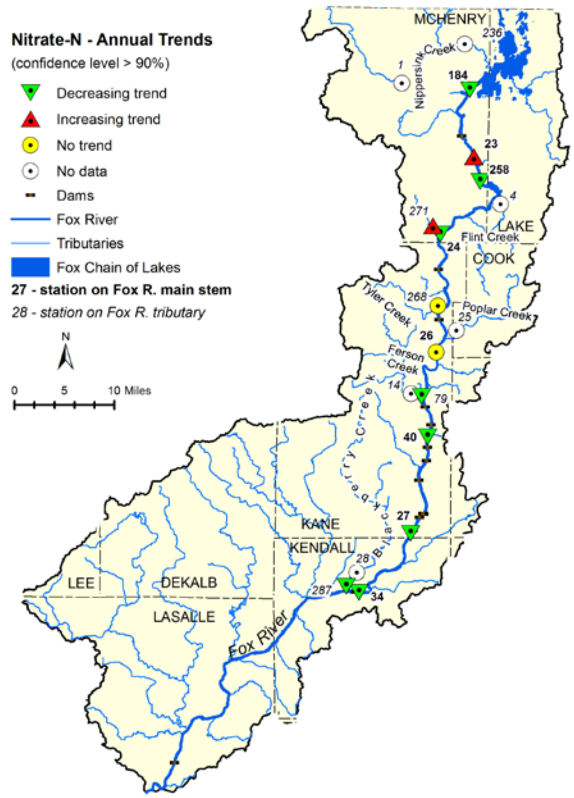


Figure C.8 Seasonal trends of ammonia nitrogen (NH_3-N) in the Fox River watershed



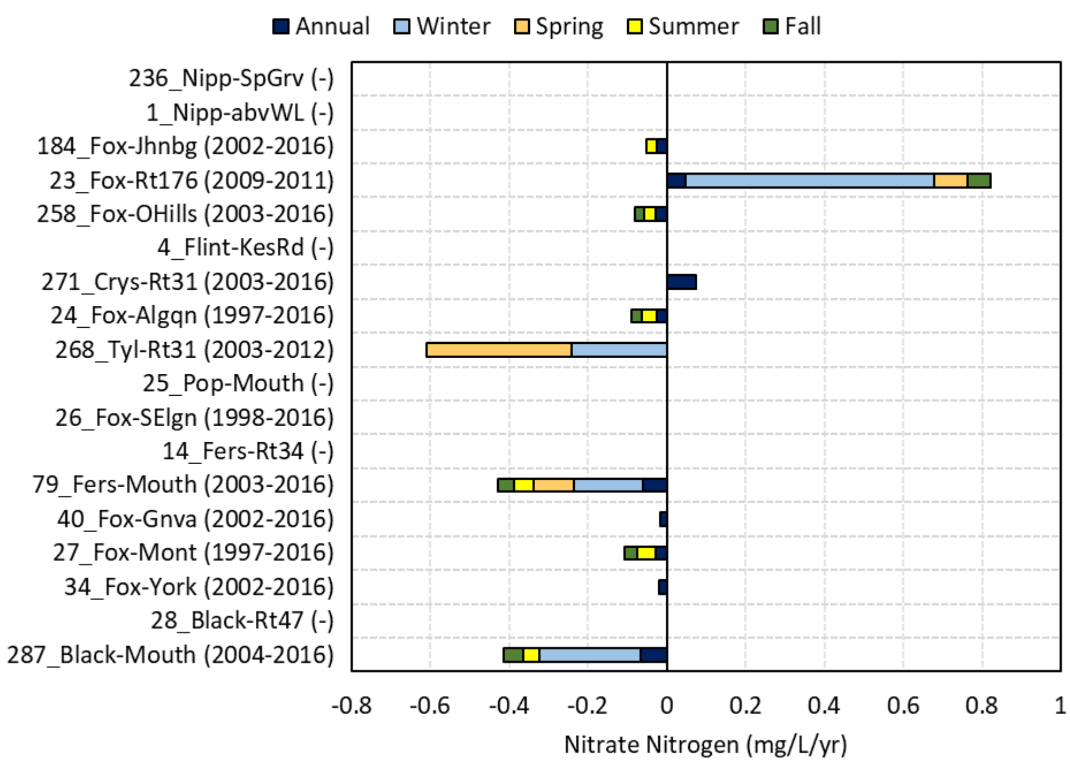


Figure C.9 Annual trends of nitrate nitrogen (NO3-N) in the Fox River watershed

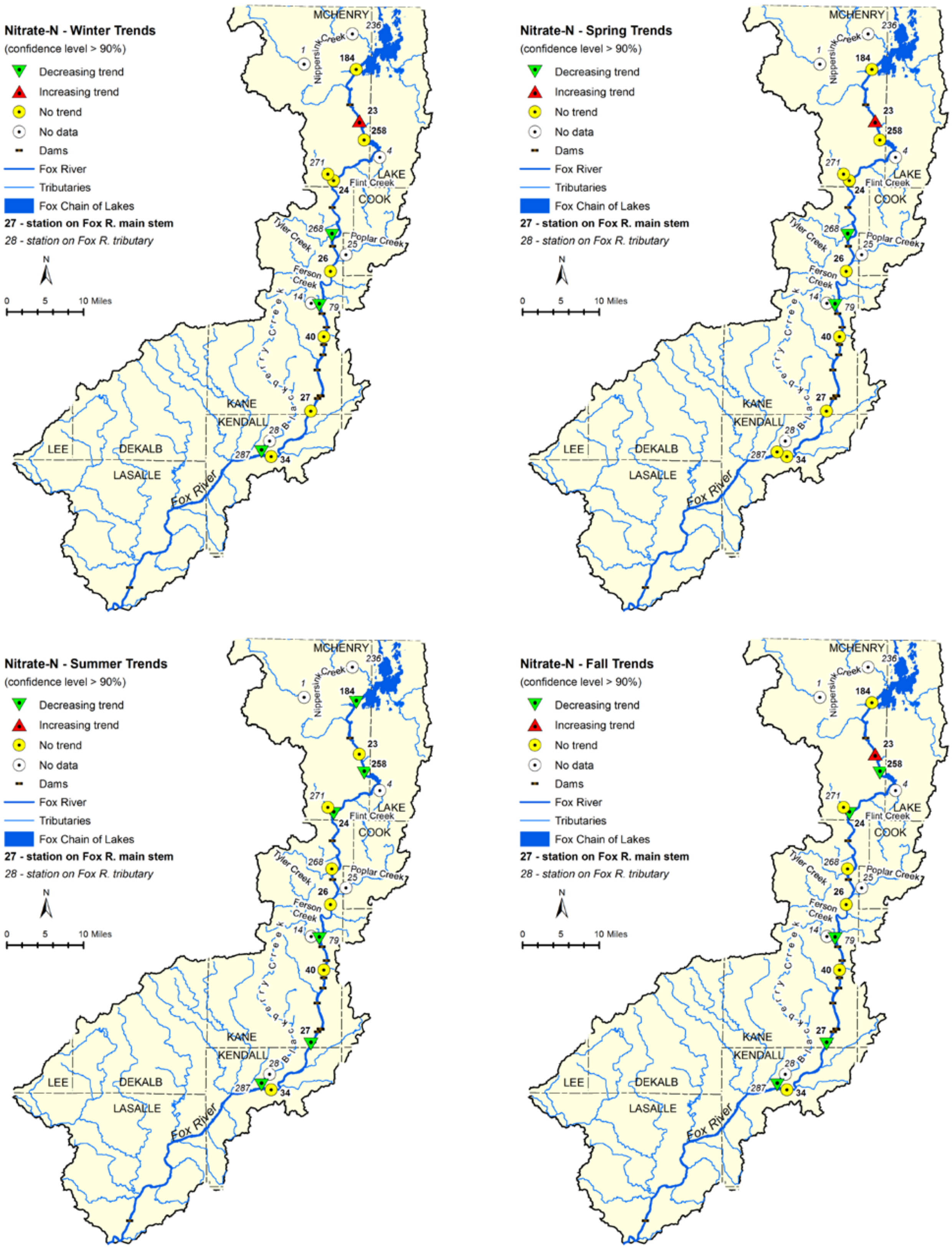


Figure C.10 Seasonal trends of nitrate nitrogen (NO3-N) in the Fox River watershed

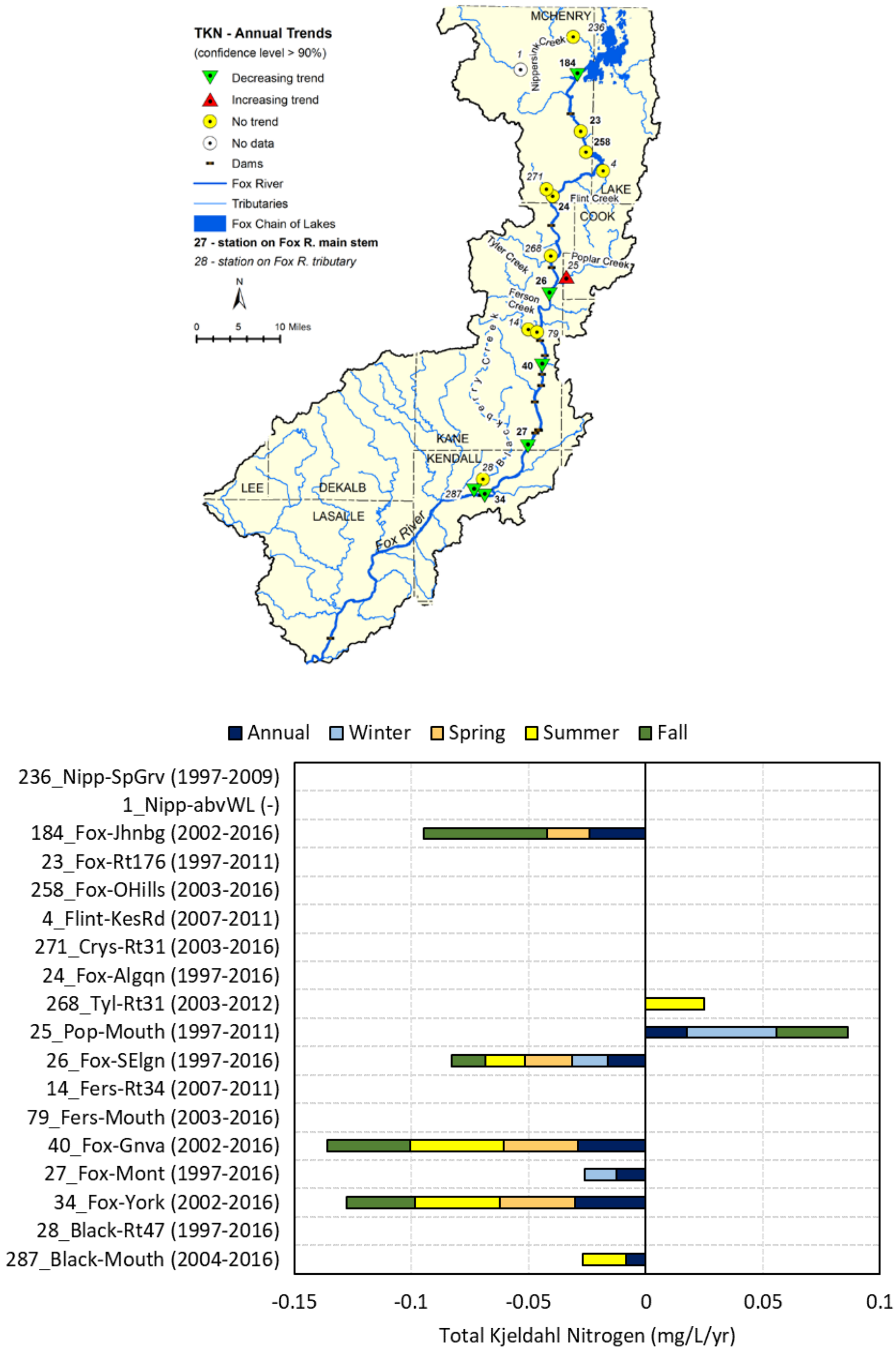


Figure C.11 Annual trends of total kjeldahl nitrogen (TKN) in the Fox River watershed

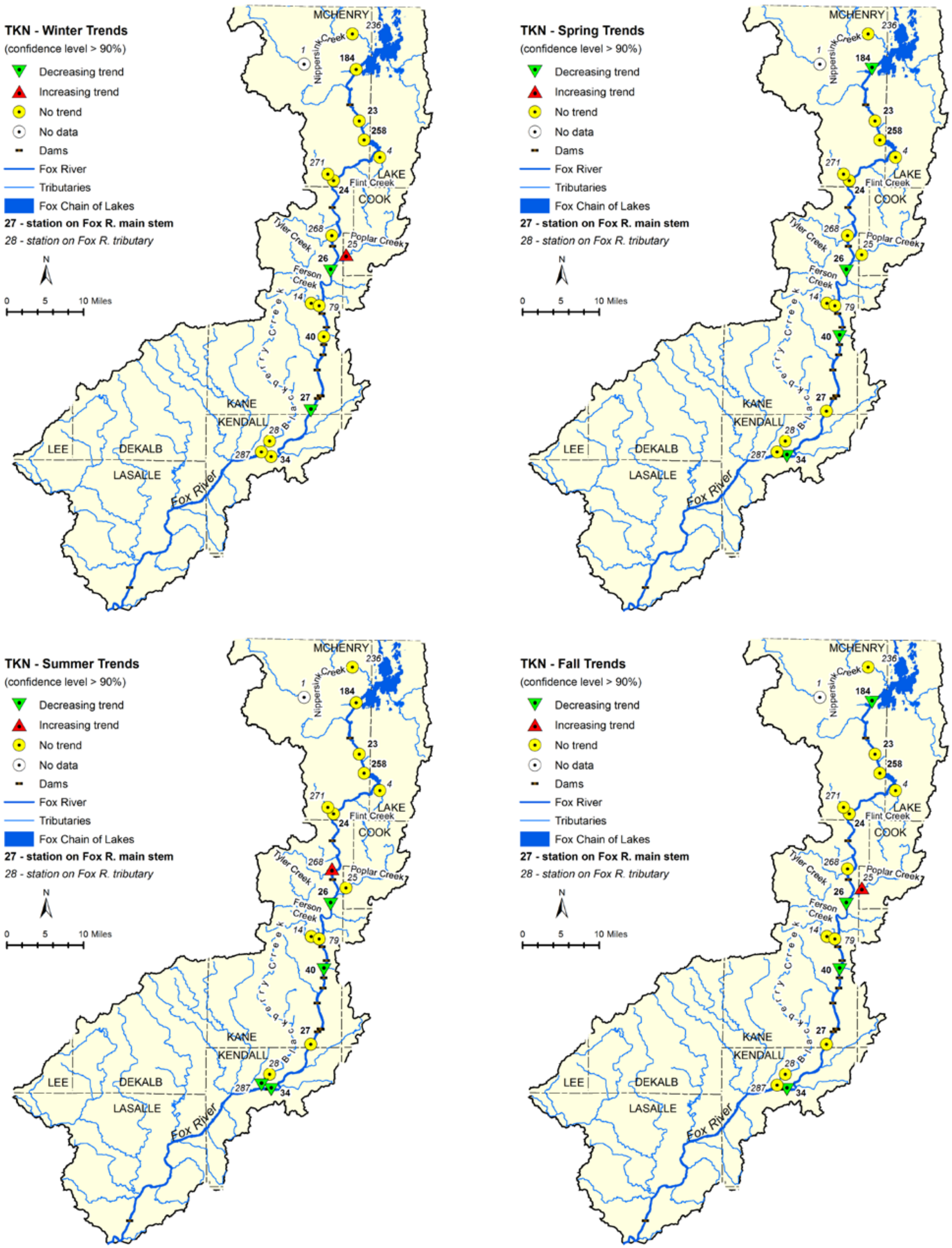


Figure C.12 Seasonal trends of total kjeldahl nitrogen (TKN) in the Fox River watershed

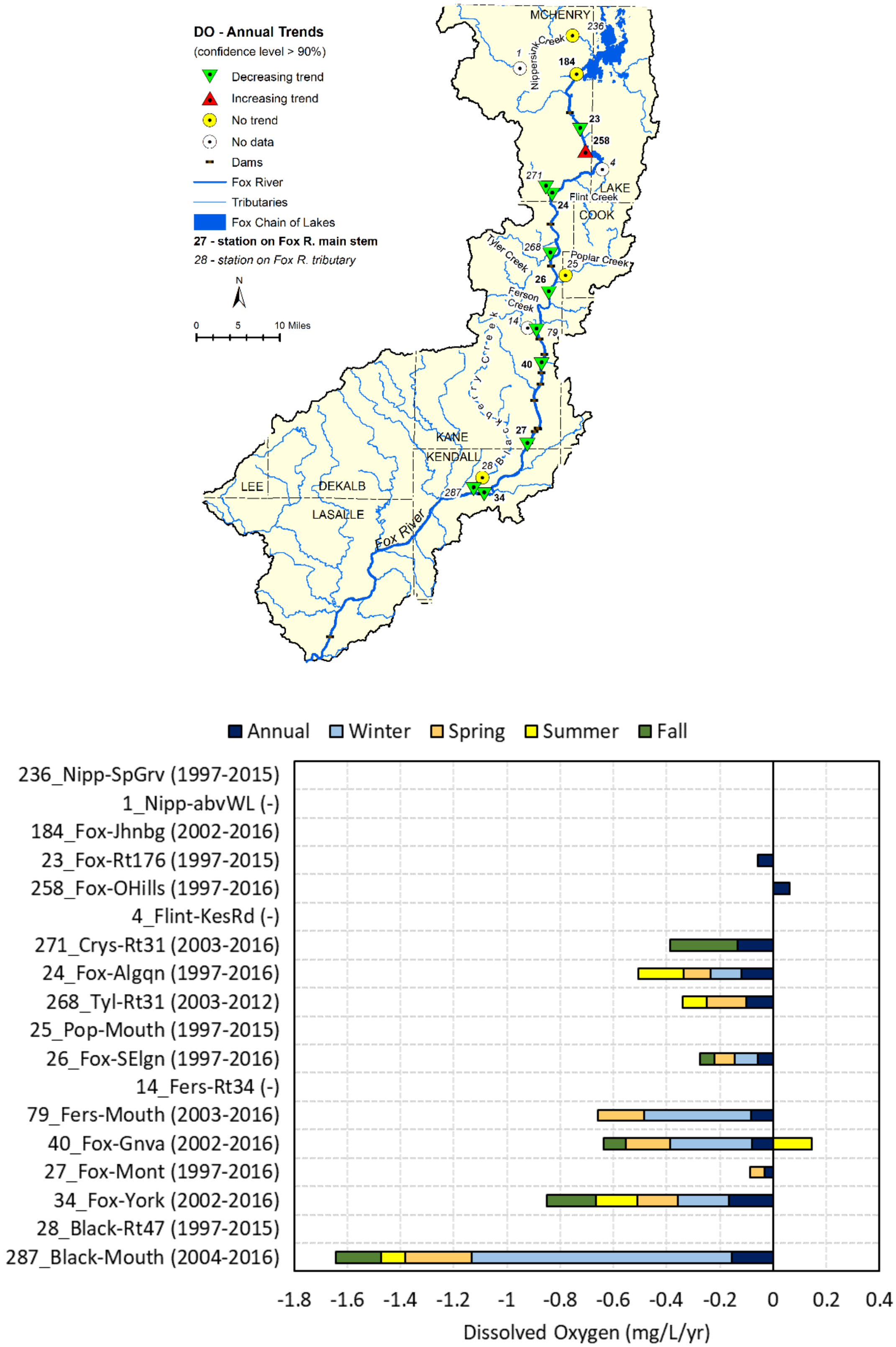


Figure C.13 Annual trends of dissolved oxygen (DO) in the Fox River watershed

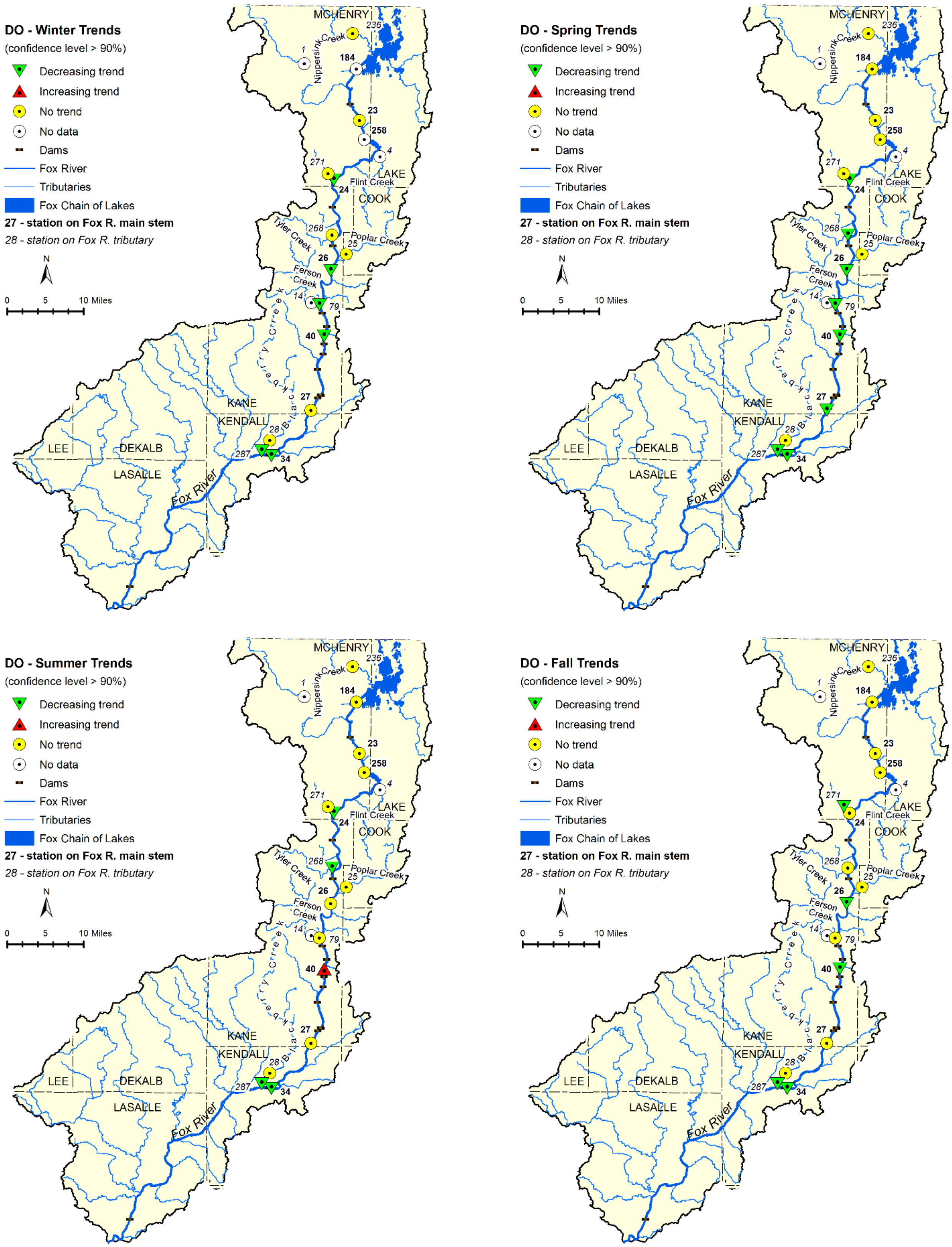


Figure C.14 Seasonal trends of dissolved oxygen (DO) in the Fox River watershed

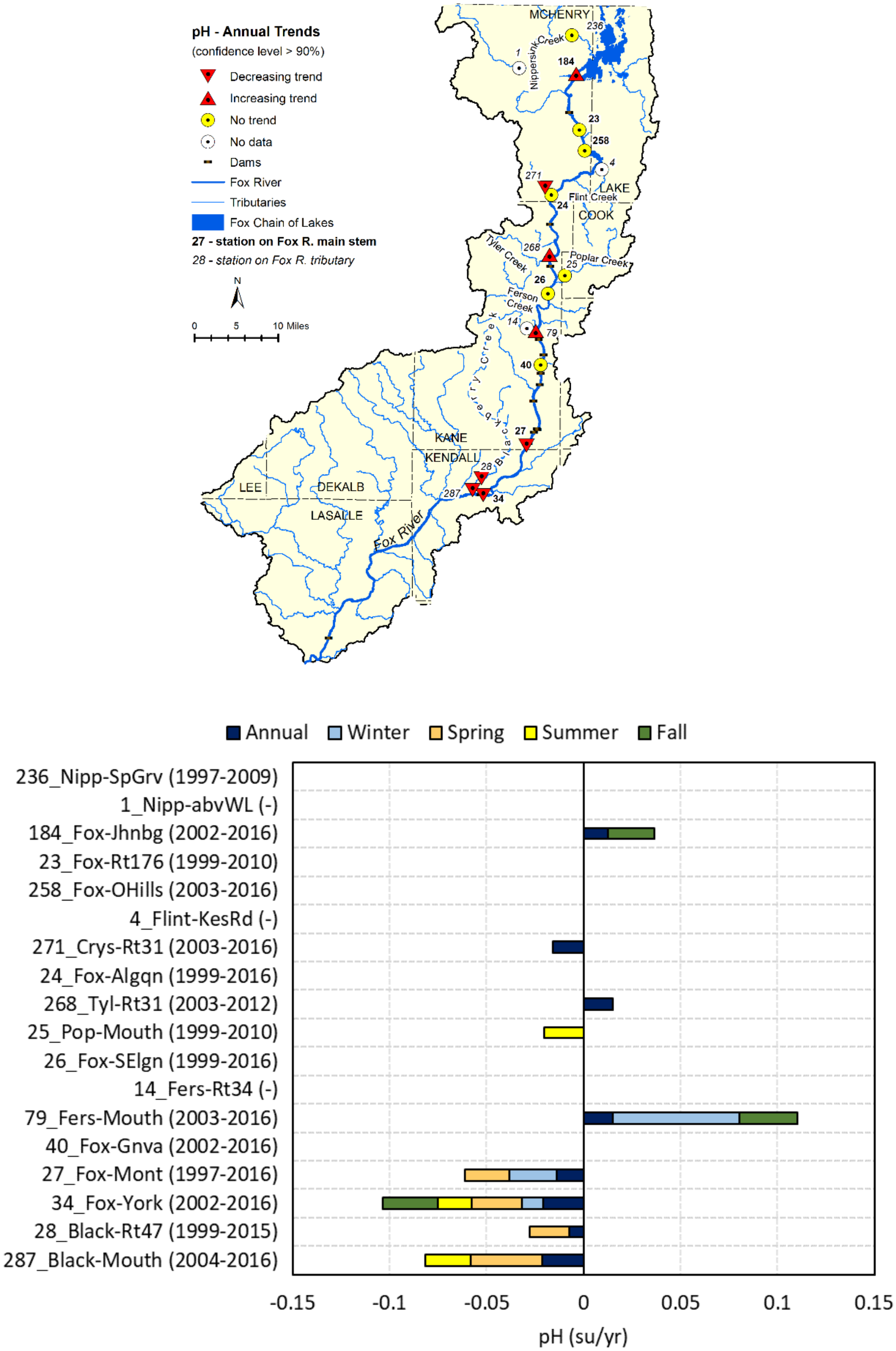


Figure C.15 Annual trends of pH in the Fox River watershed

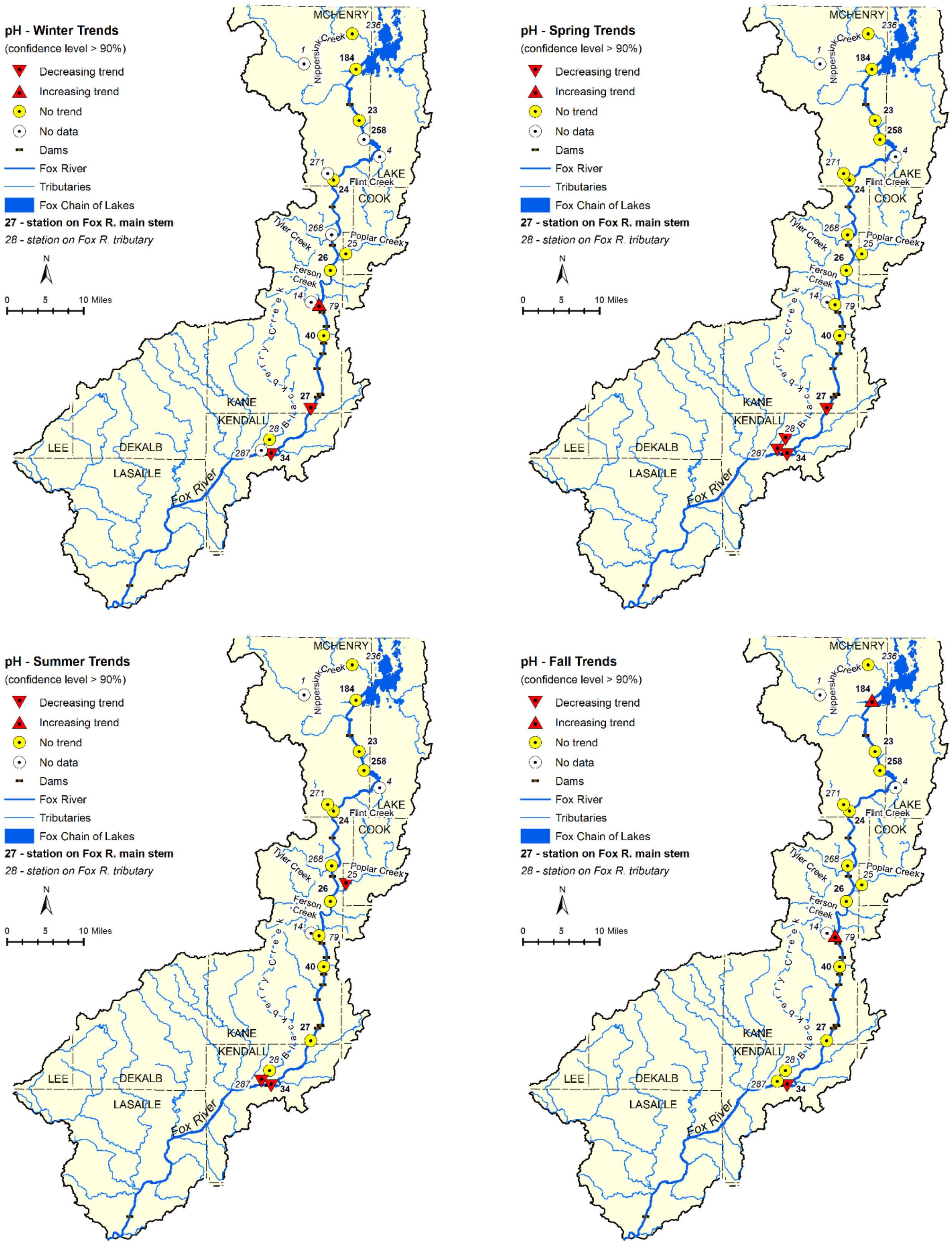
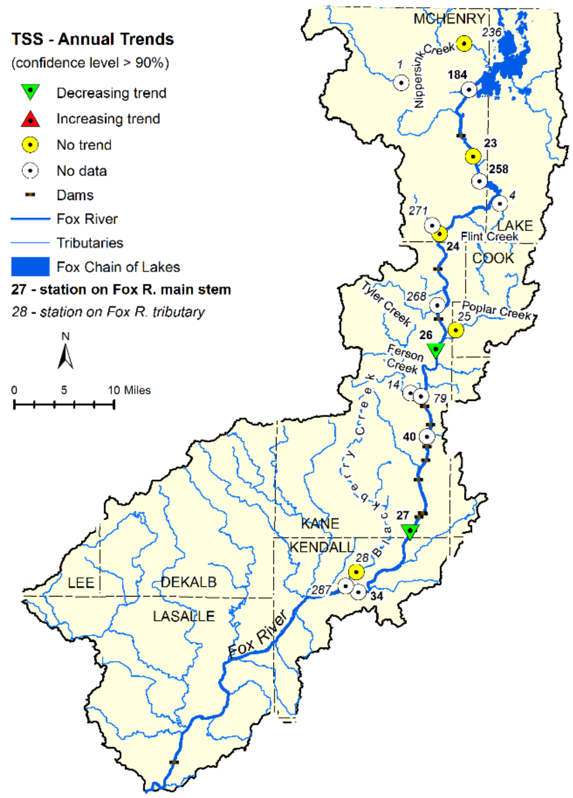


Figure C.16 Seasonal trends of pH in the Fox River watershed



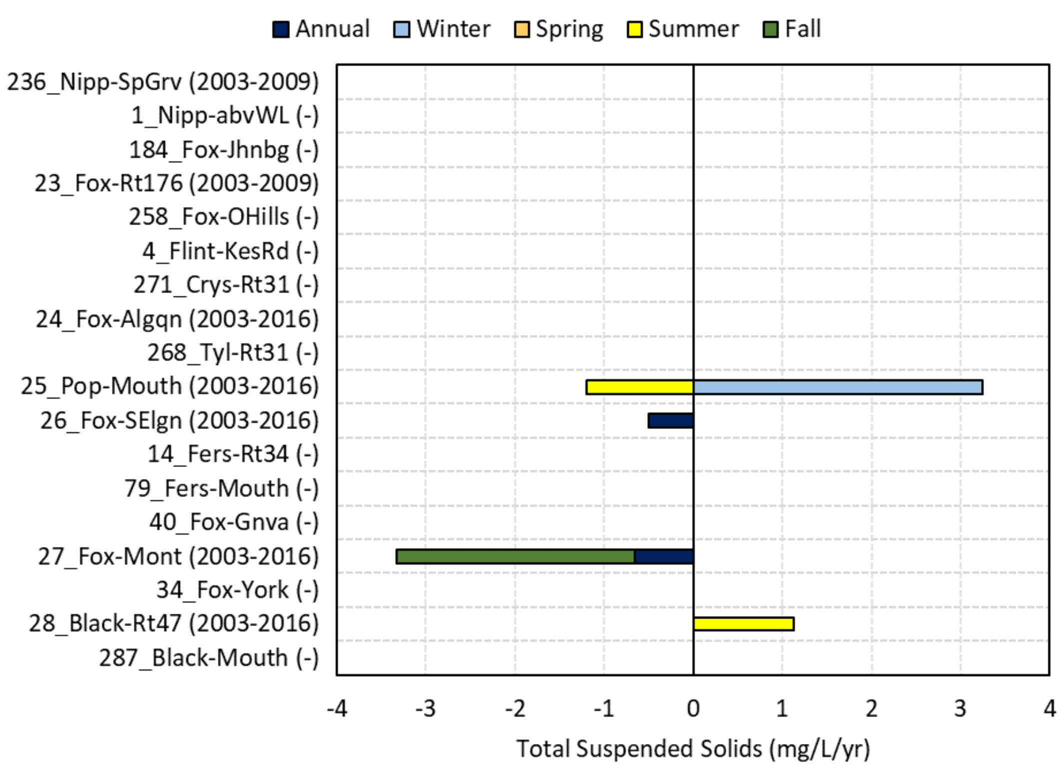


Figure C.17 Annual trends of total suspended solids (TSS) in the Fox River watershed

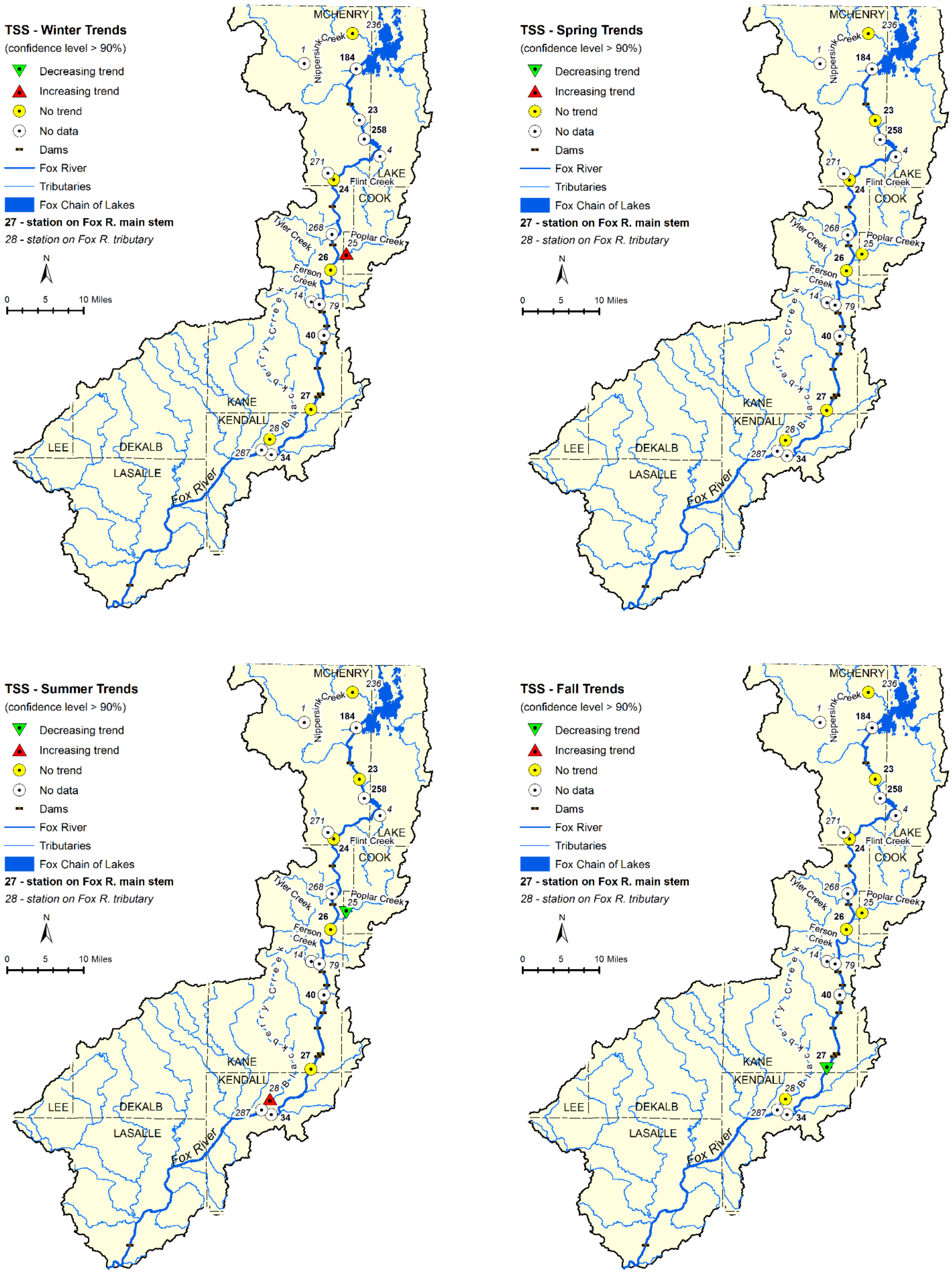
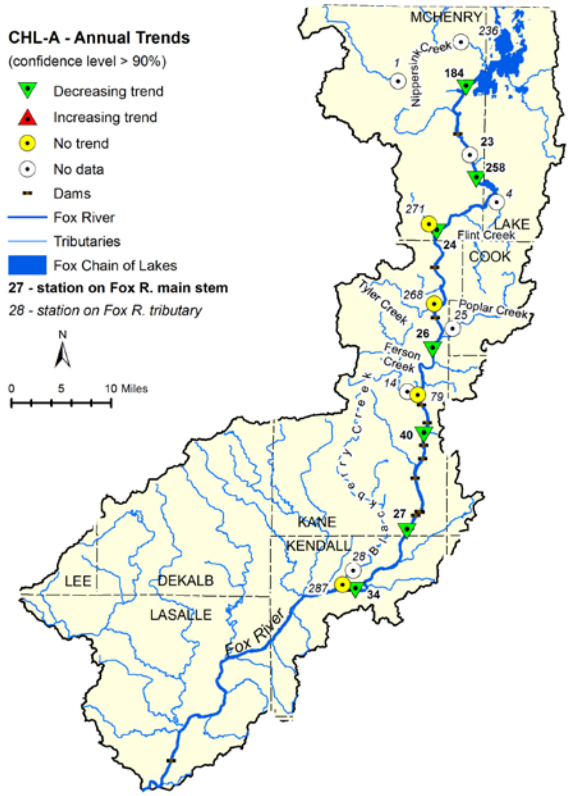


Figure C.18 Seasonal trends of total suspended solids (TSS) in the Fox River watershed



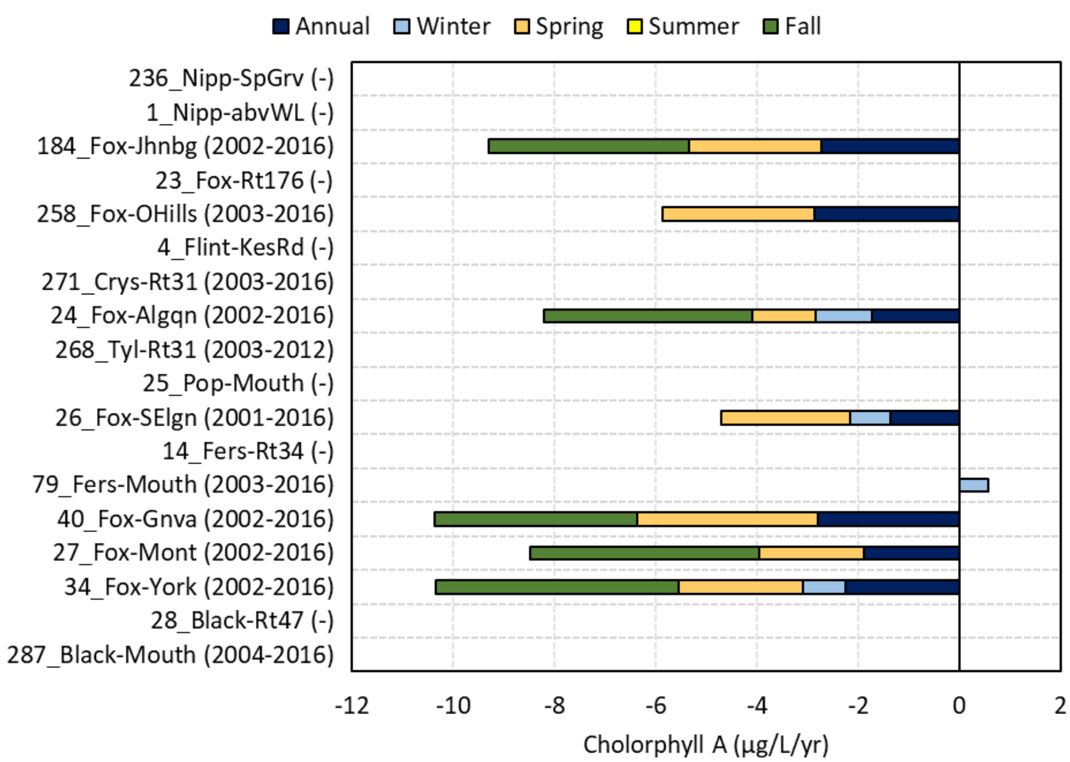


Figure C.19 Annual trends of chlorophyll-A (CHL-A) in the Fox River watershed

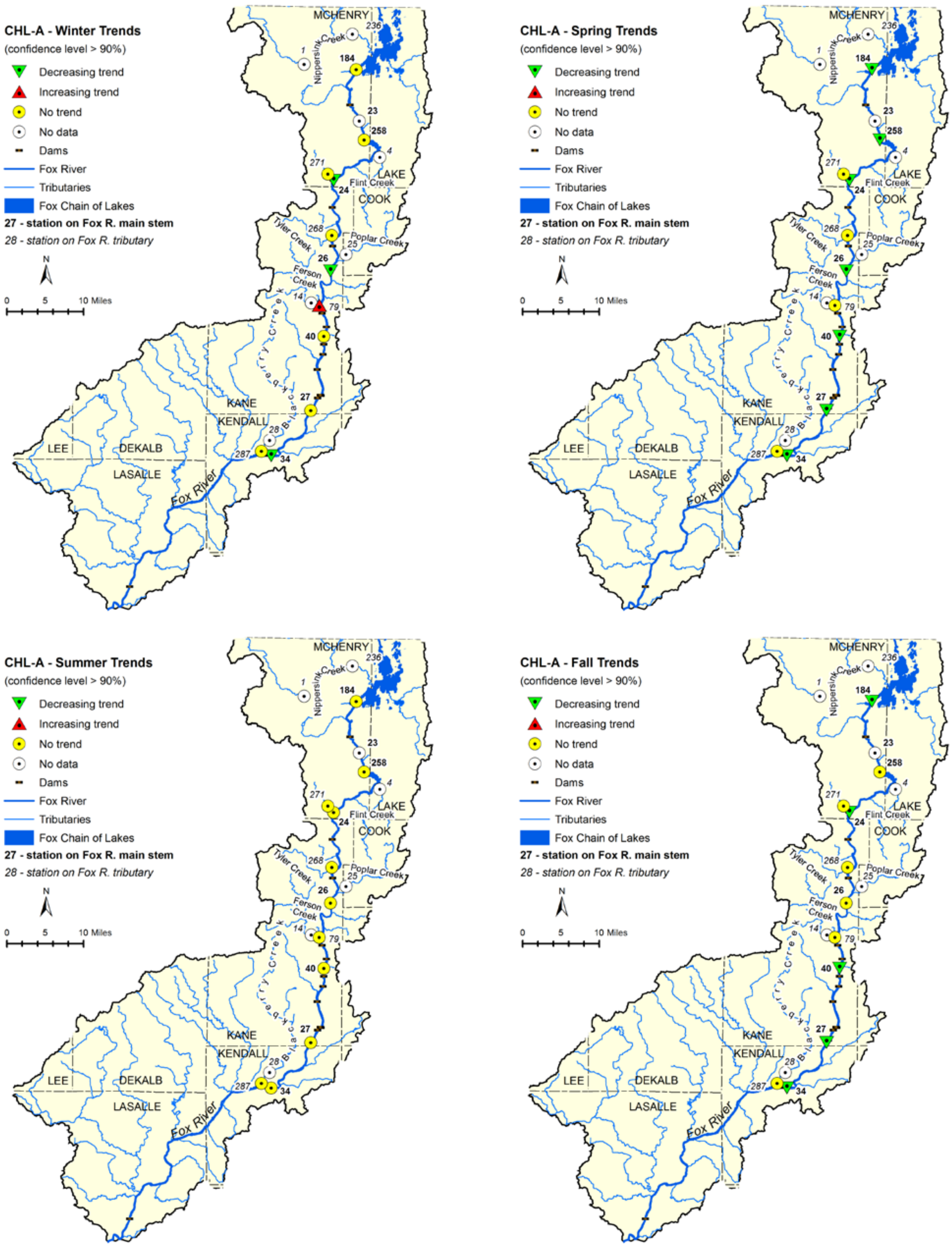


Figure C.20 Seasonal trends of chlorophyll-A (CHL-A) in the Fox River watershed

Appendix D – Annual and Seasonal Trends of Flow-normalized Concentrations and Fluxes

List of Figures

Annual Trends

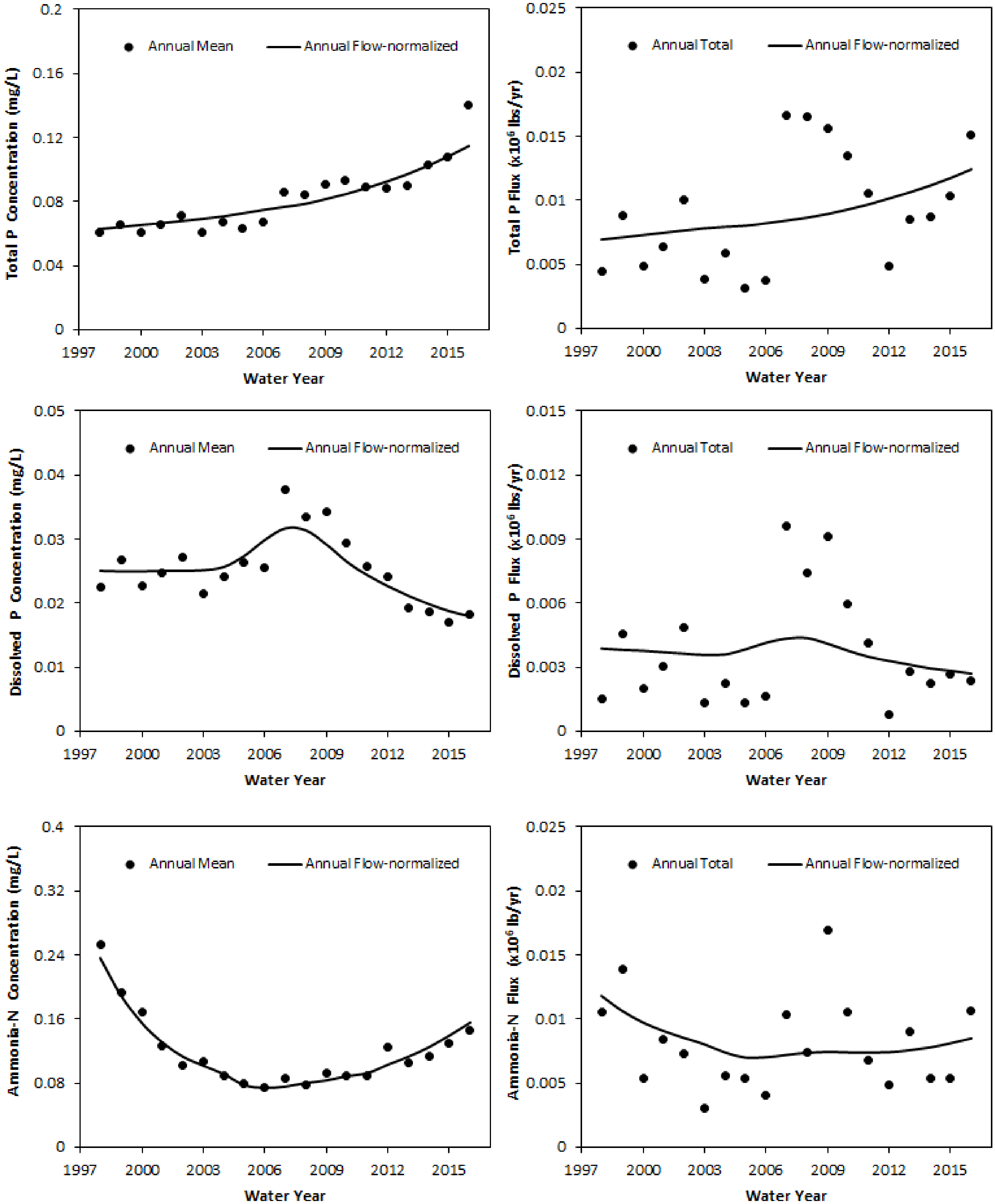


Figure D.1 Annual trends of TP, DP, and NH_3-N concentrations and fluxes for Poplar Cr near Mouth-Elgin

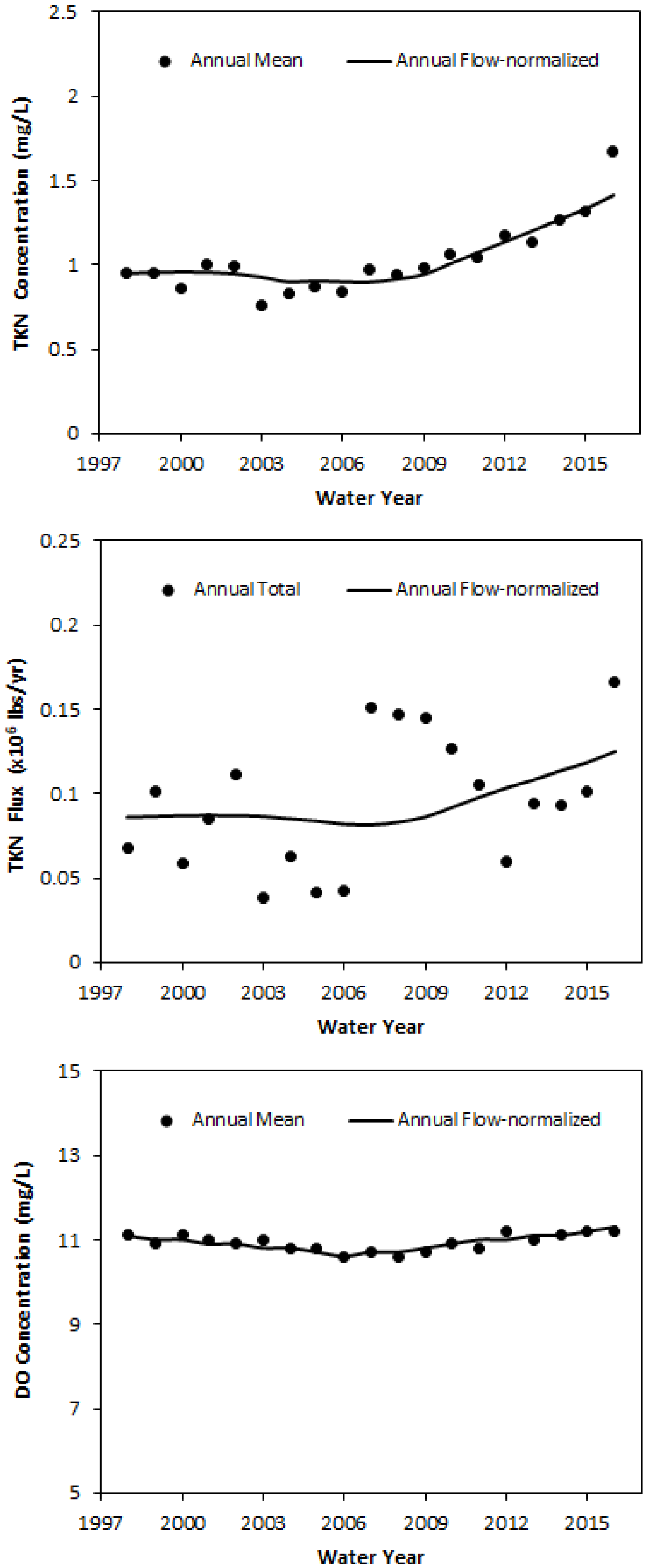


Figure D.2 Annual trends of TKN and DO concentrations and fluxes for Poplar Cr near Mouth-Elgin

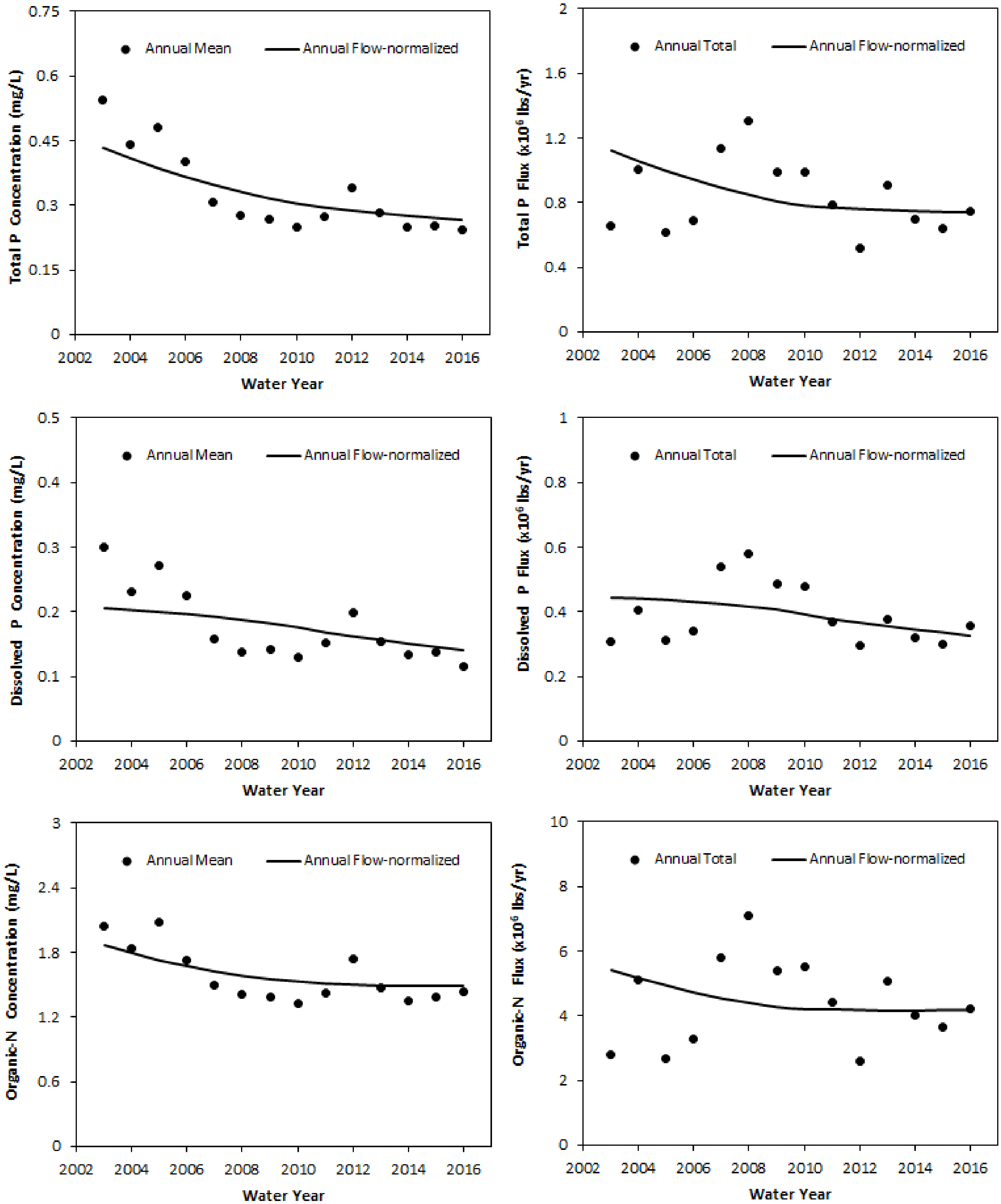


Figure D.3 Annual trends of TP, DP and Org-N concentrations and fluxes for Fox River at Montgomery

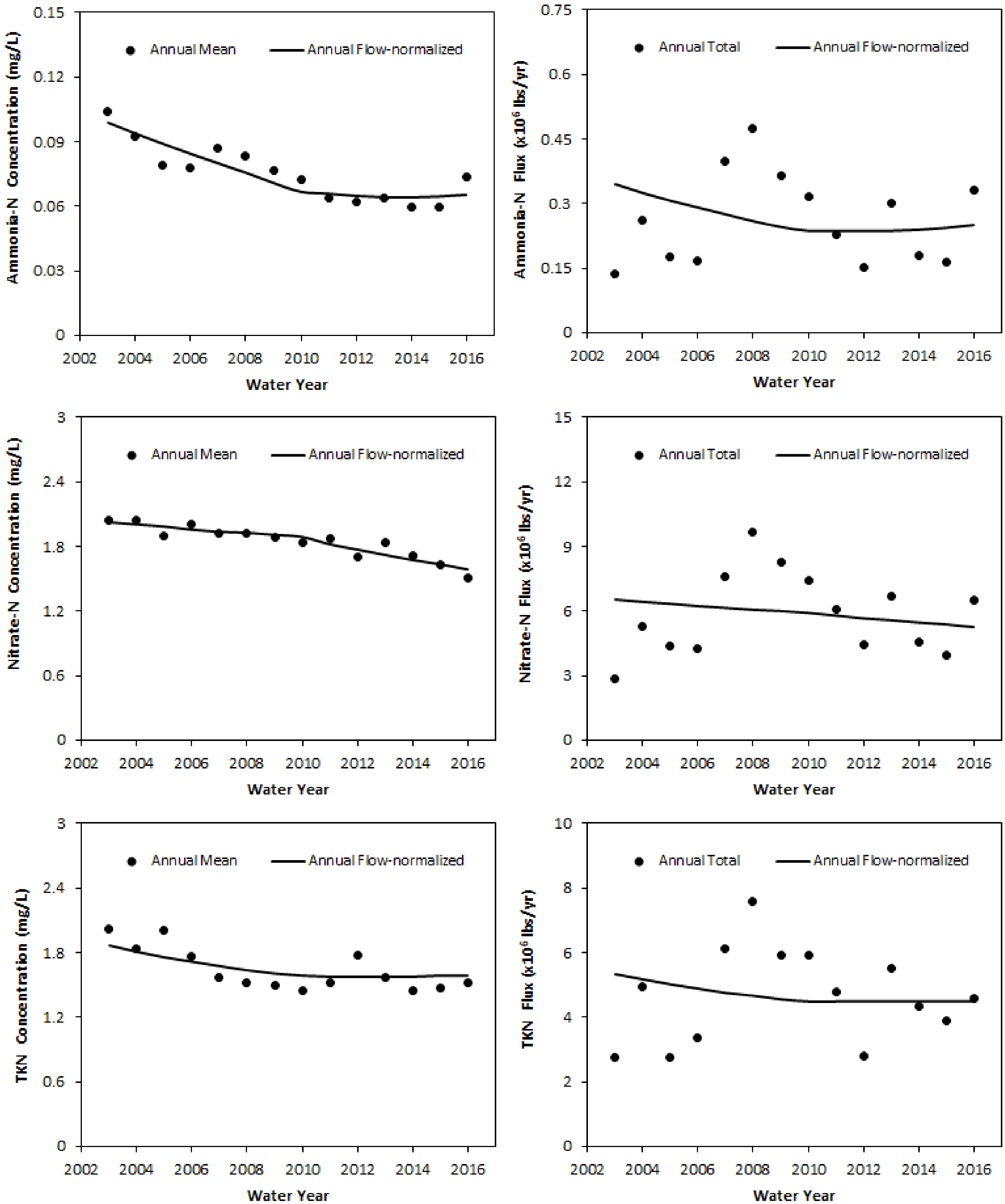


Figure D.4 Annual trends of NH_3-N, NO_3-N and TKN concentrations and fluxes for Fox River at Montgomery

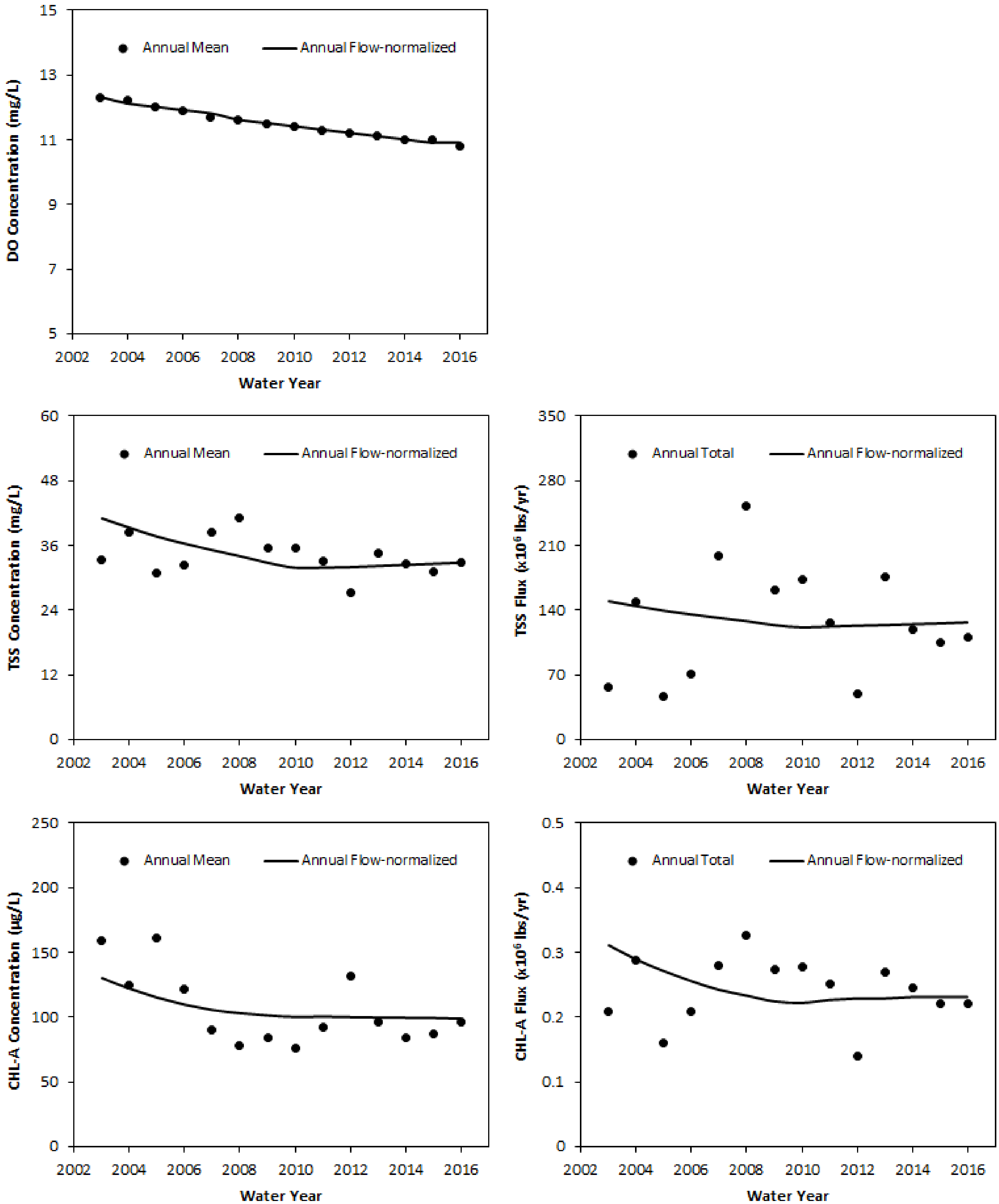


Figure D.5 Annual trends of DO, TSS and CHL-A concentrations and fluxes for Fox River at Montgomery

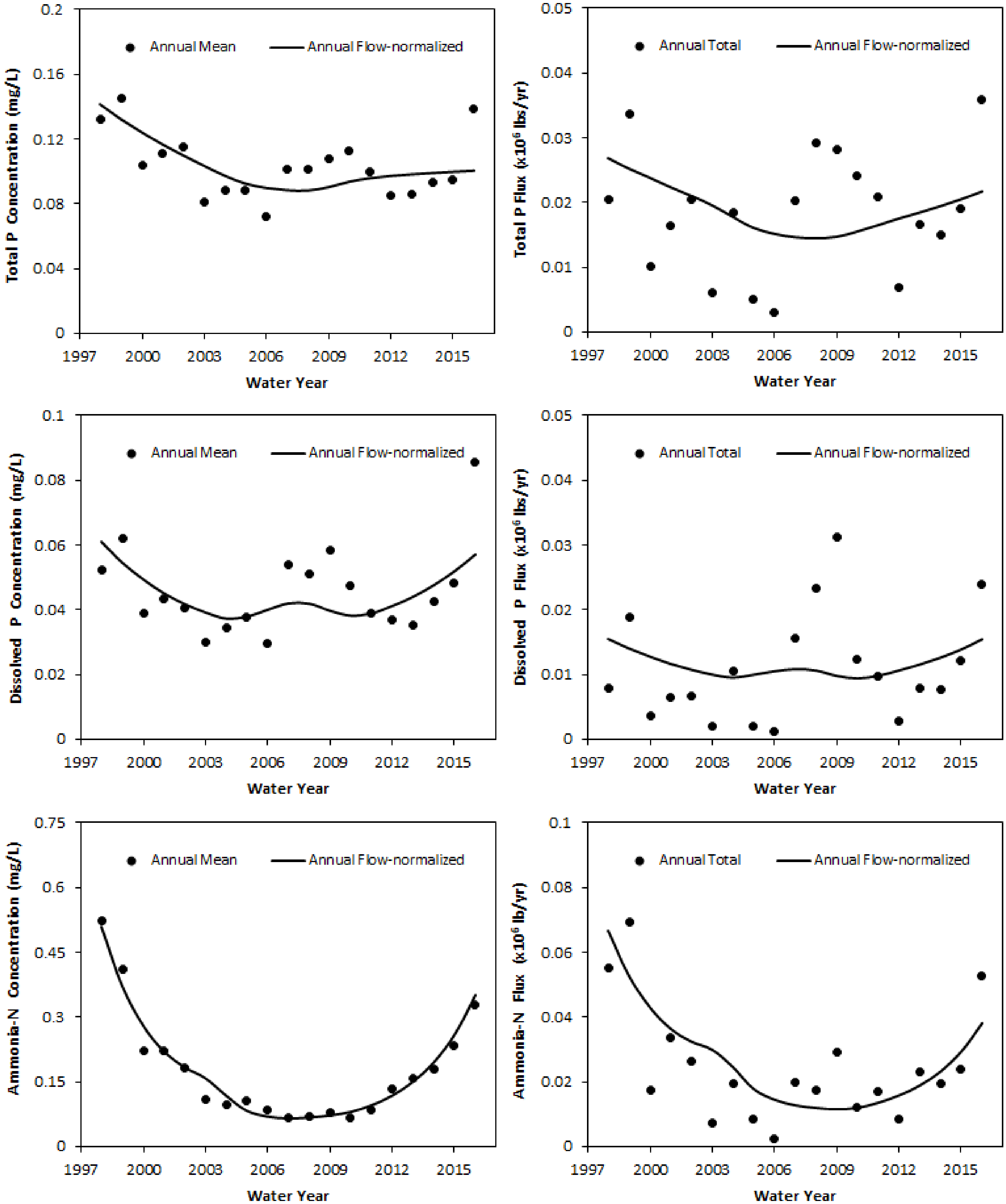


Figure D.6 Annual trends of TP, DP, and NH_3-N concentrations and fluxes for Blackberry Cr at Rt 47

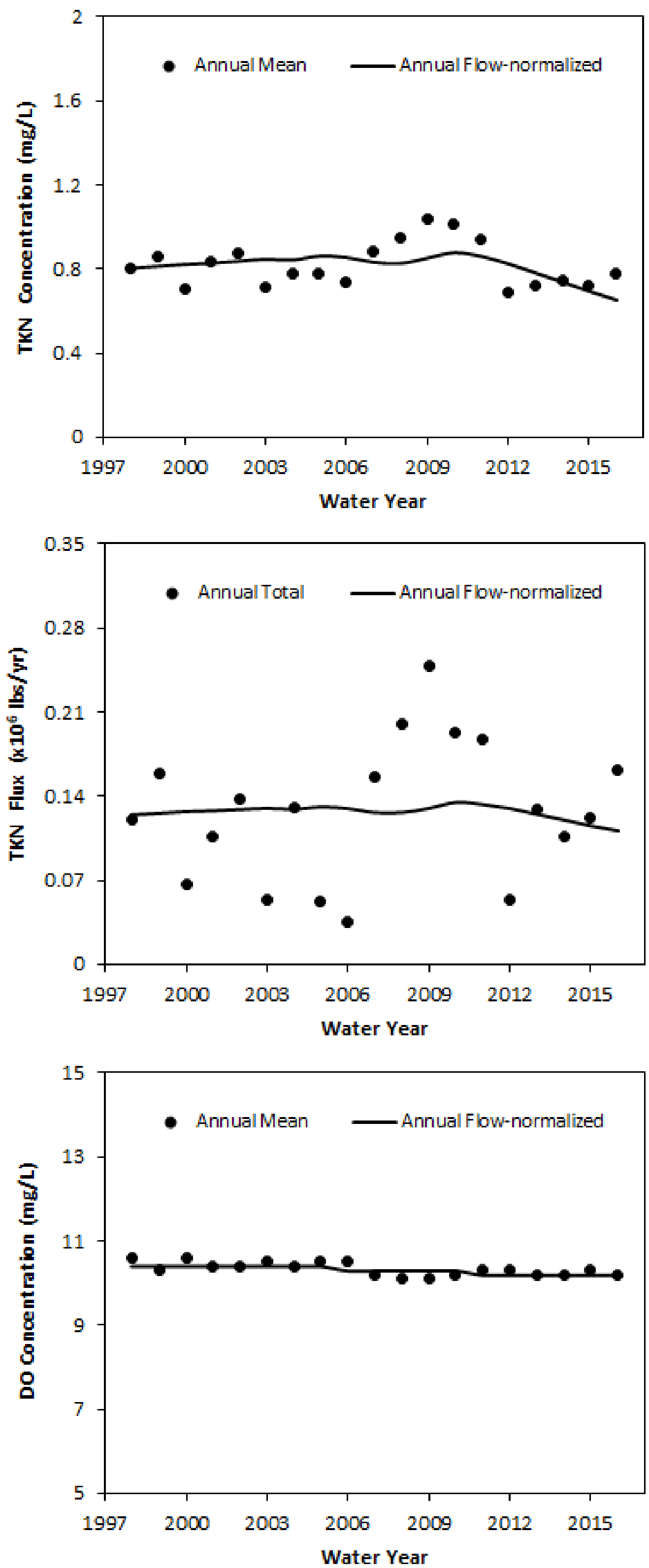


Figure D.7 Annual trends of TKN and DO concentrations and fluxes for Blackberry Cr at Rt 47

Winter Trends

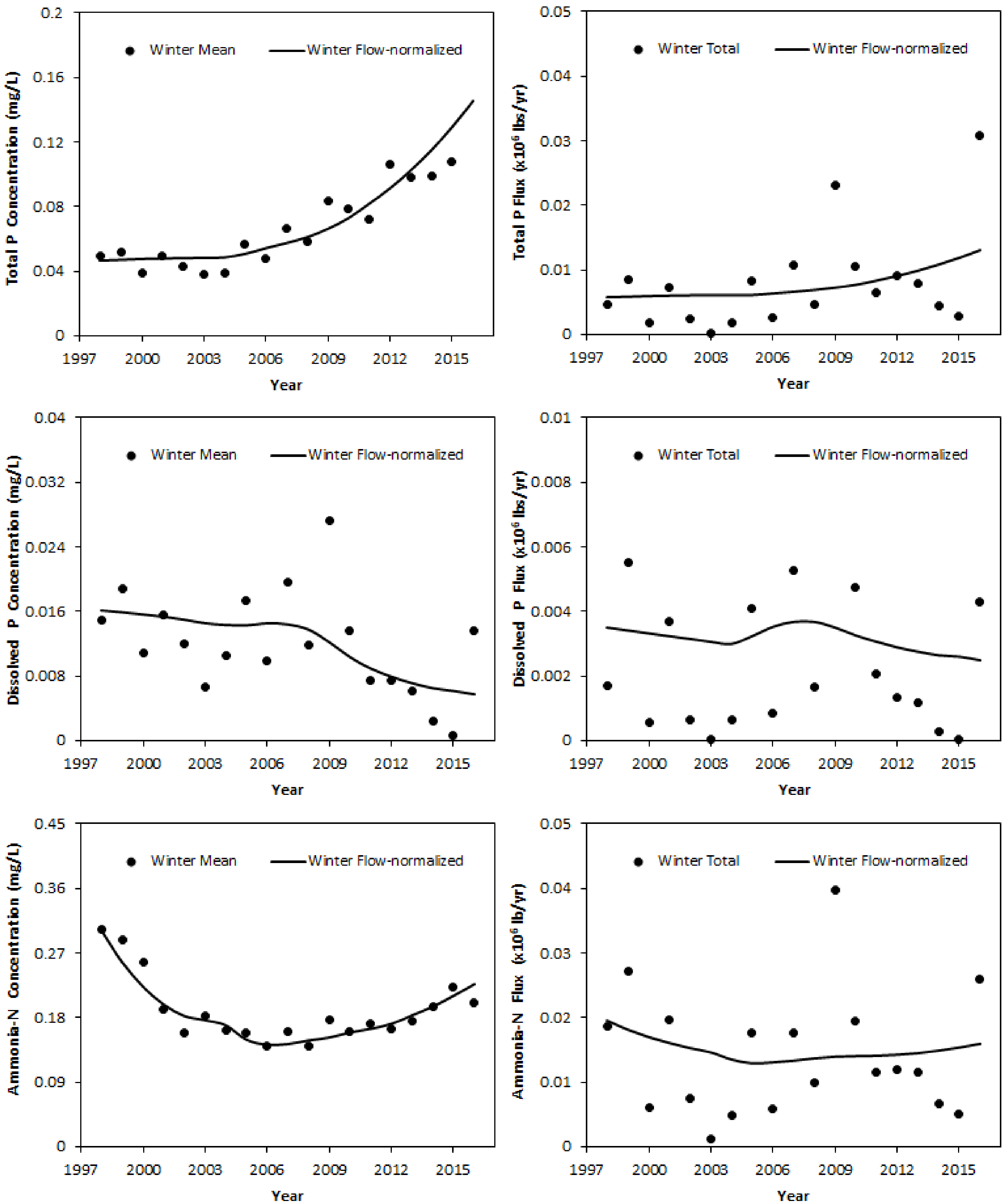


Figure D.8 Winter trends of TP, DP, and NH_3-N concentrations and fluxes for Poplar Cr near Mouth-Elgin

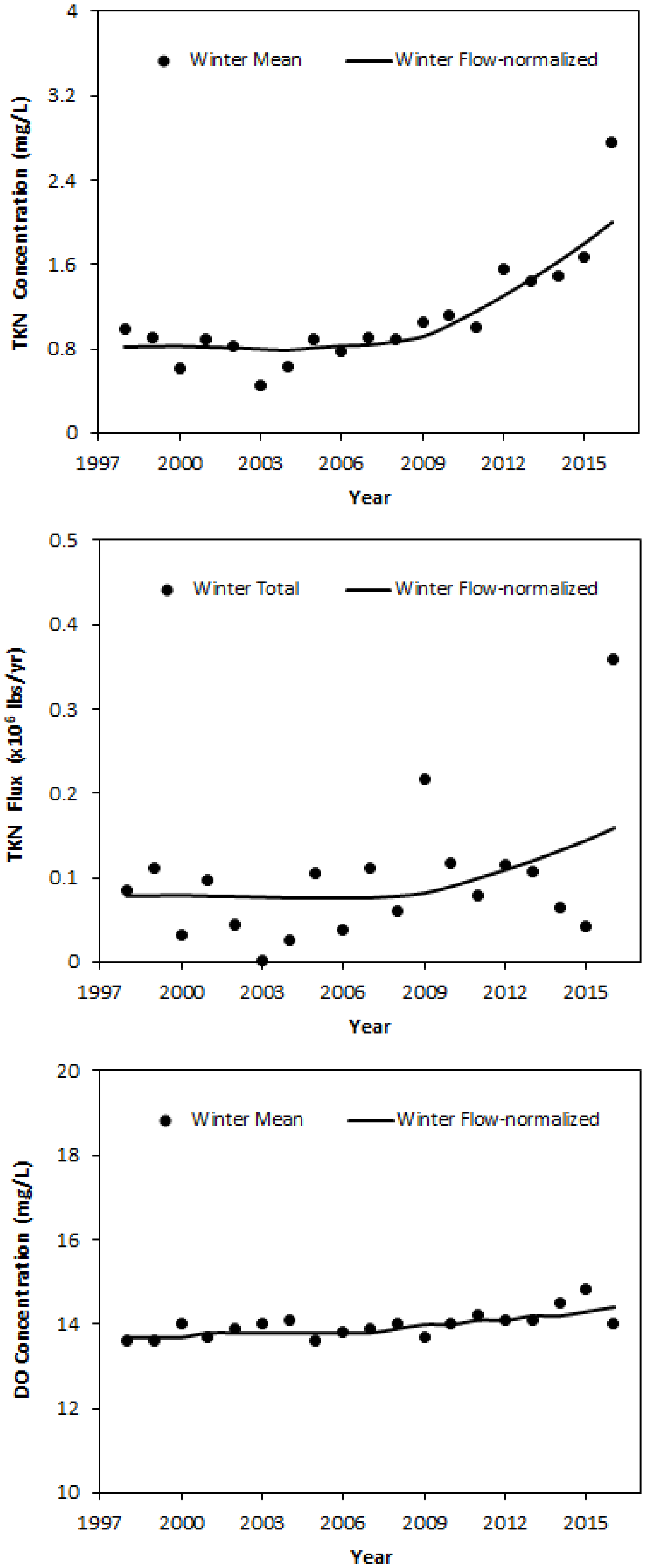


Figure D.9 Winter trends of TKN and DO concentrations and fluxes for Poplar Cr near Mouth-Elgin

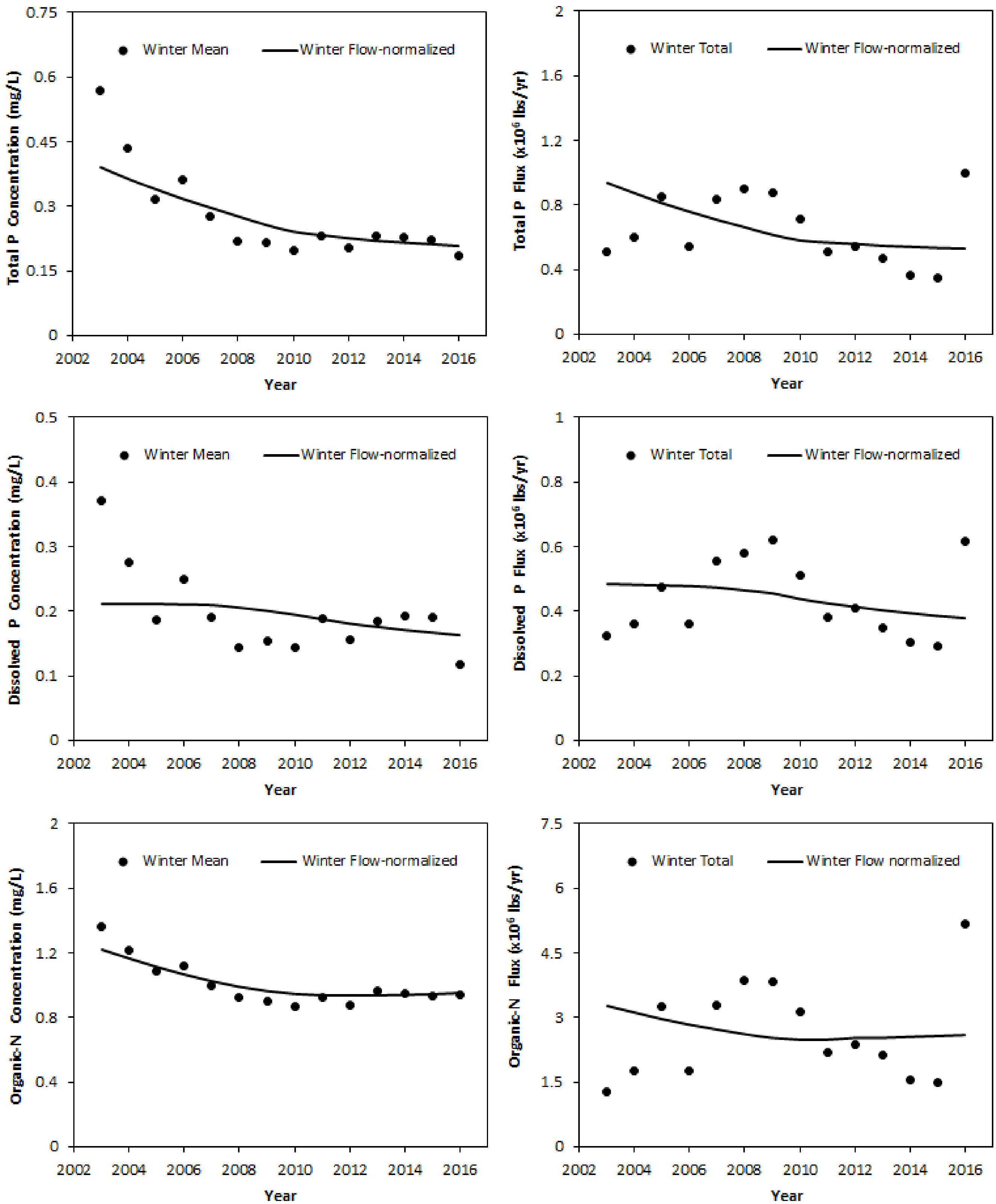


Figure D.10 Winter trends of TP, DP, and Org-N concentrations and fluxes for Fox River at Montgomery

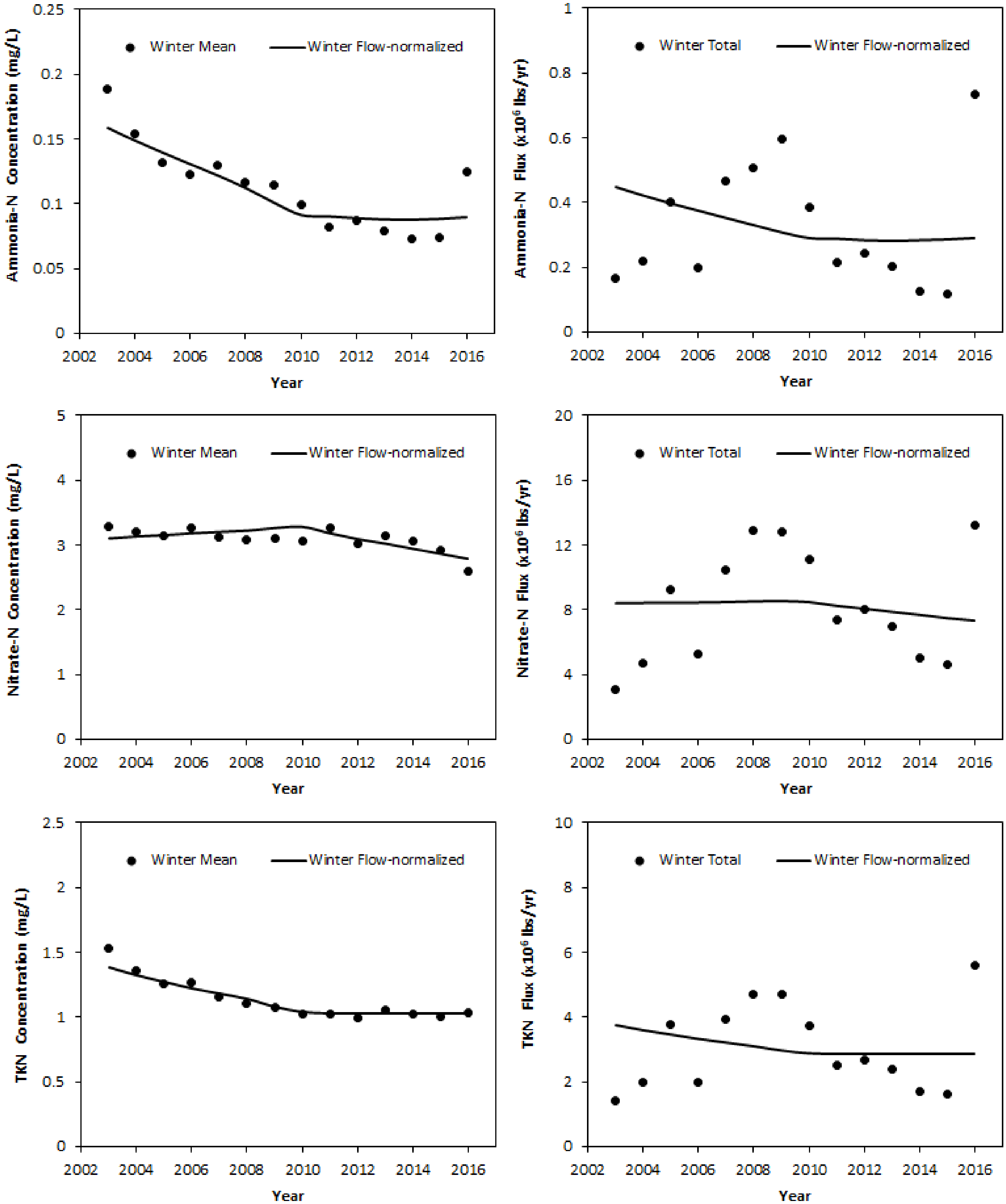


Figure D.11 Winter trends of NH_3-N, NO_3-N and TKN concentrations and fluxes for Fox River at Montgomery

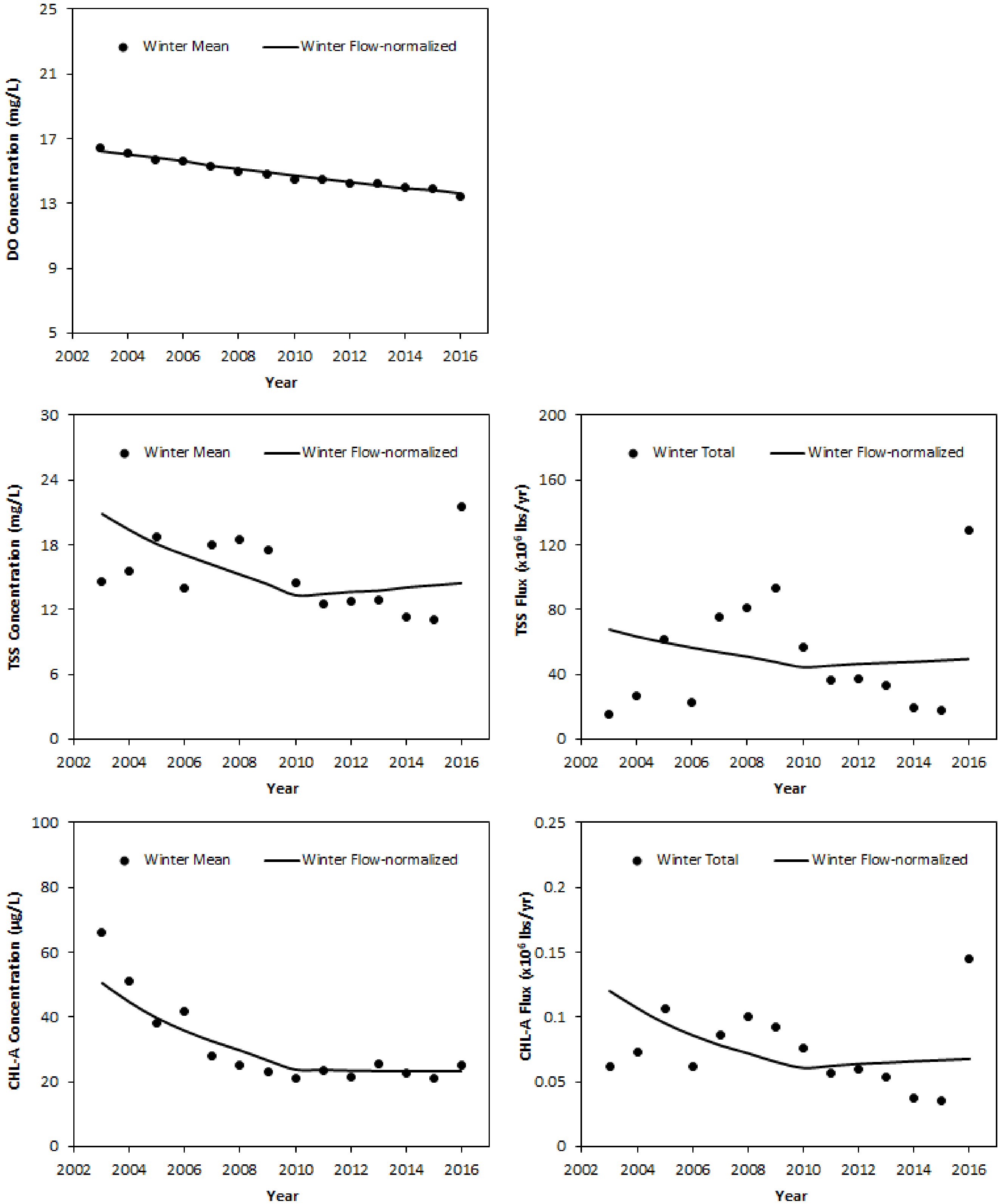


Figure D.12 Winter trends of DO, TSS and CHL-A concentrations and fluxes for Fox River at Montgomery

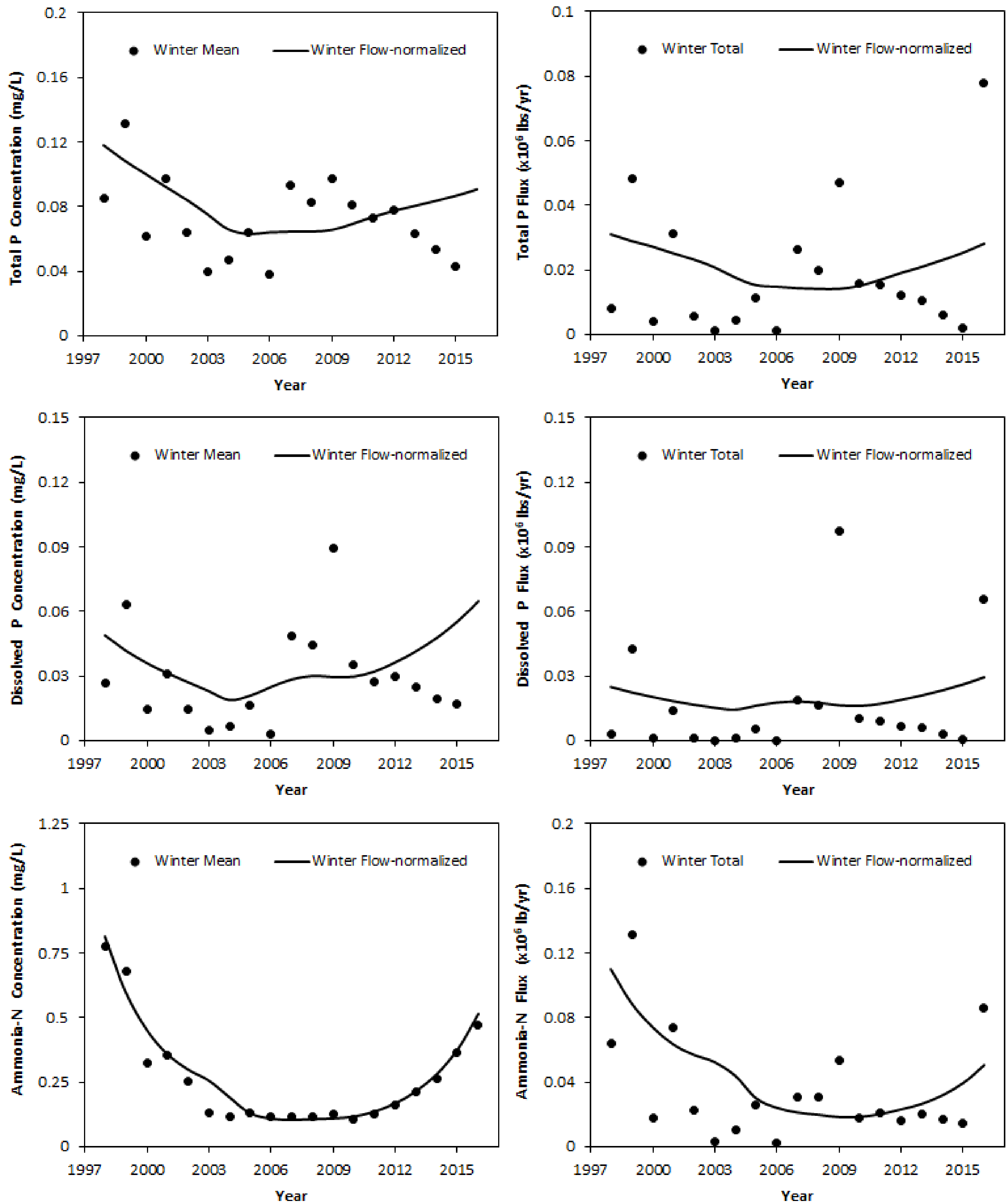


Figure D.13 Winter trends of TP, DP, and NH_3-N concentrations and fluxes for Blackberry Cr at Rt 47

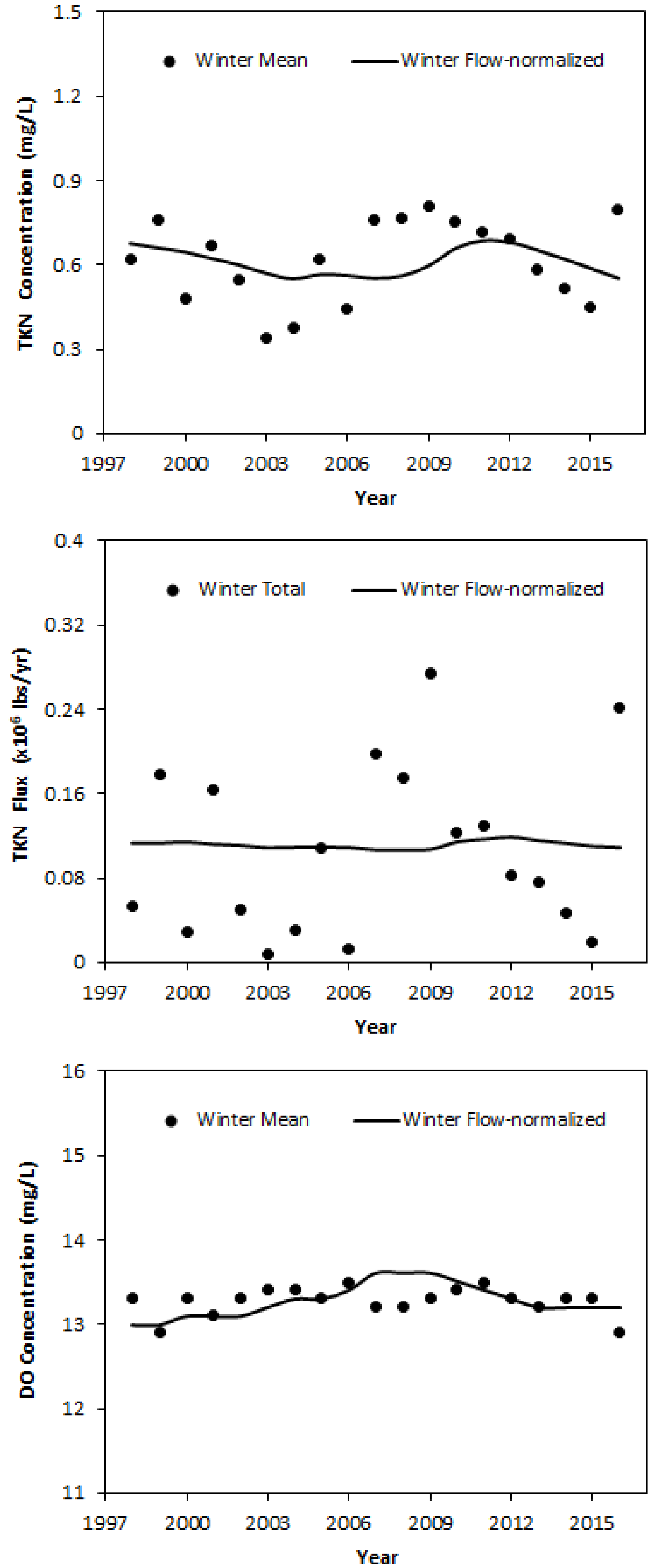


Figure D.14 Winter trends of TKN and DO concentrations and fluxes for Blackberry Cr at Rt 47

Spring Trends

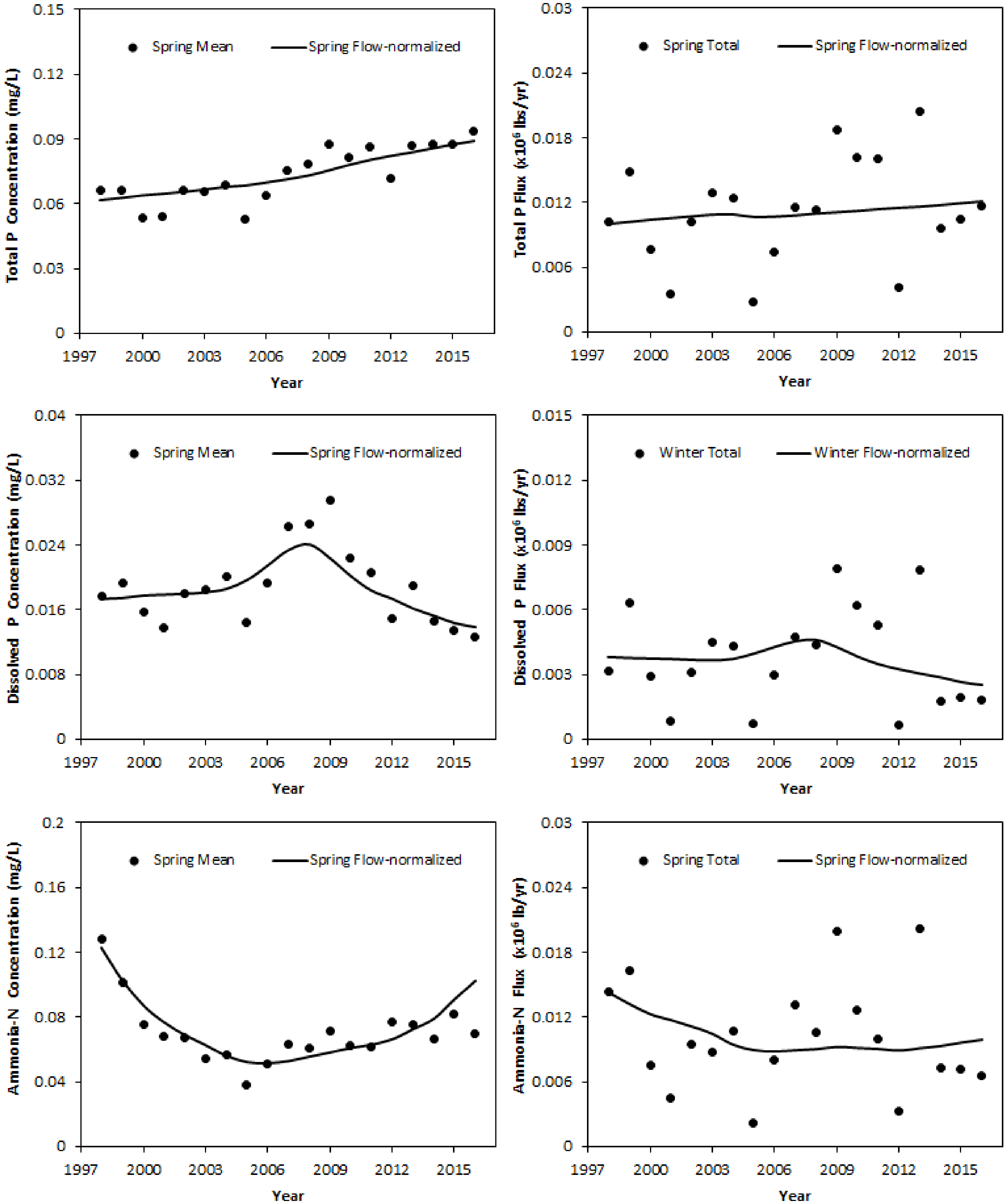


Figure D.15 Spring trends of TP, DP, and NH_3-N concentrations and fluxes for Poplar Cr near Mouth-Elgin

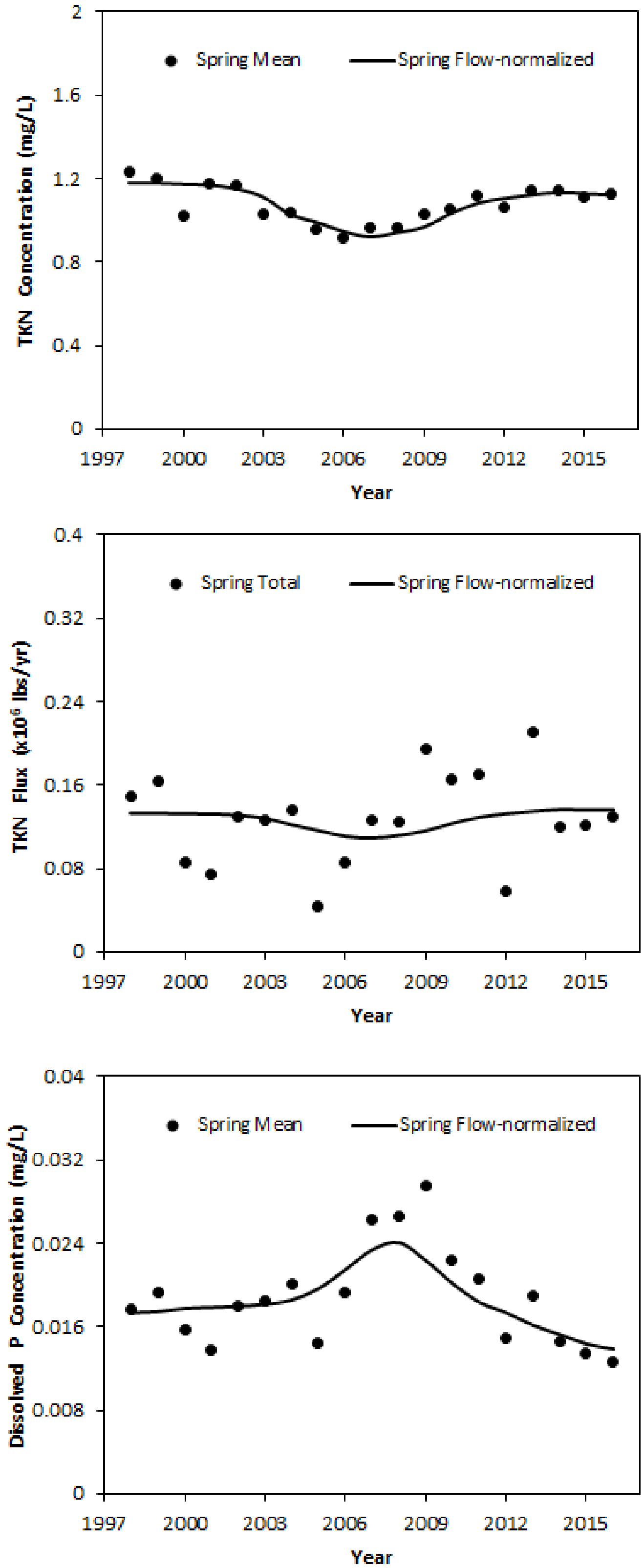


Figure D.16 Spring trends of TKN and DO concentrations and fluxes for Poplar Cr near Mouth-Elgin

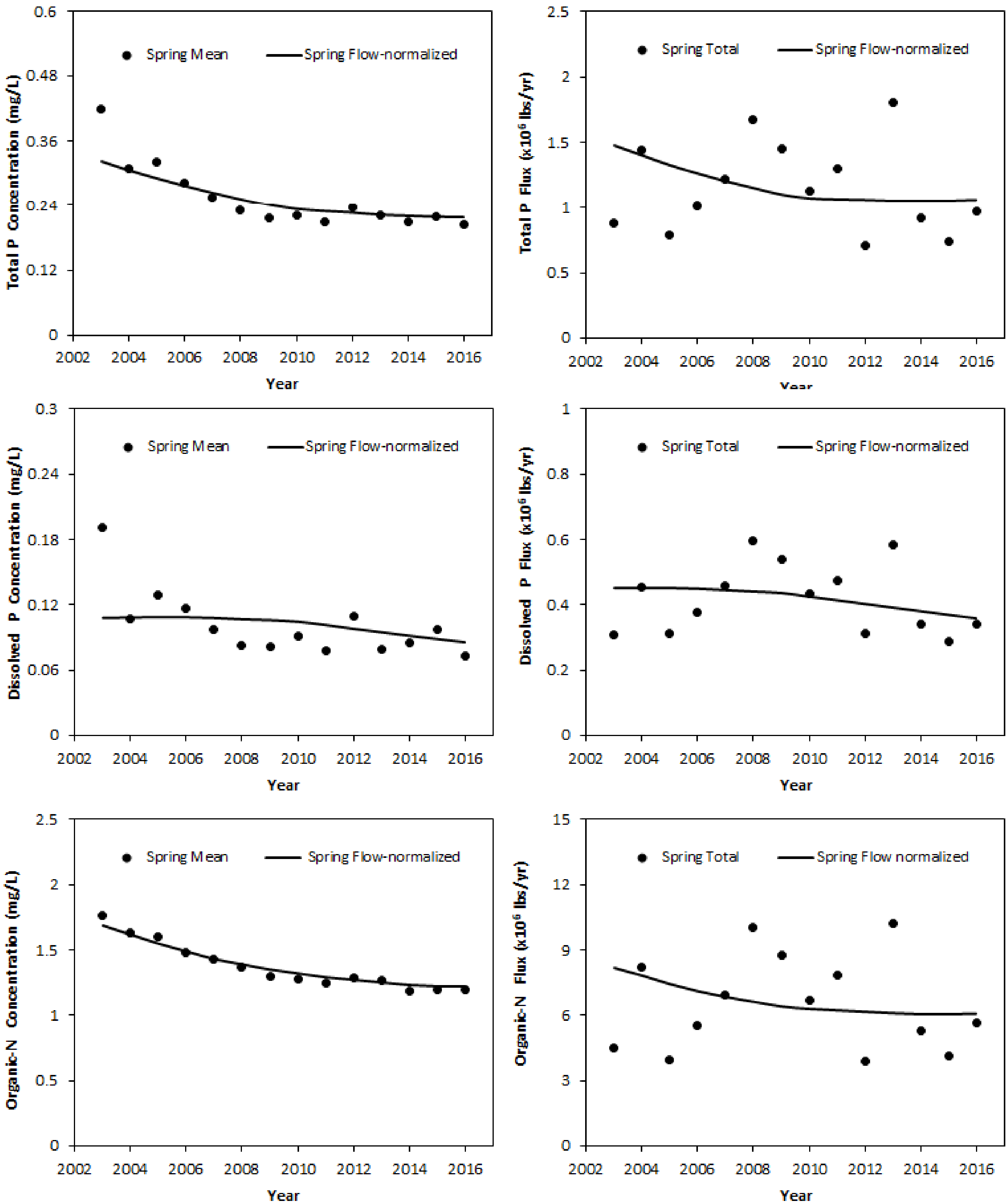


Figure D.17 Spring trends of TP, DP, and Org-N concentrations and fluxes for Fox River at Montgomery

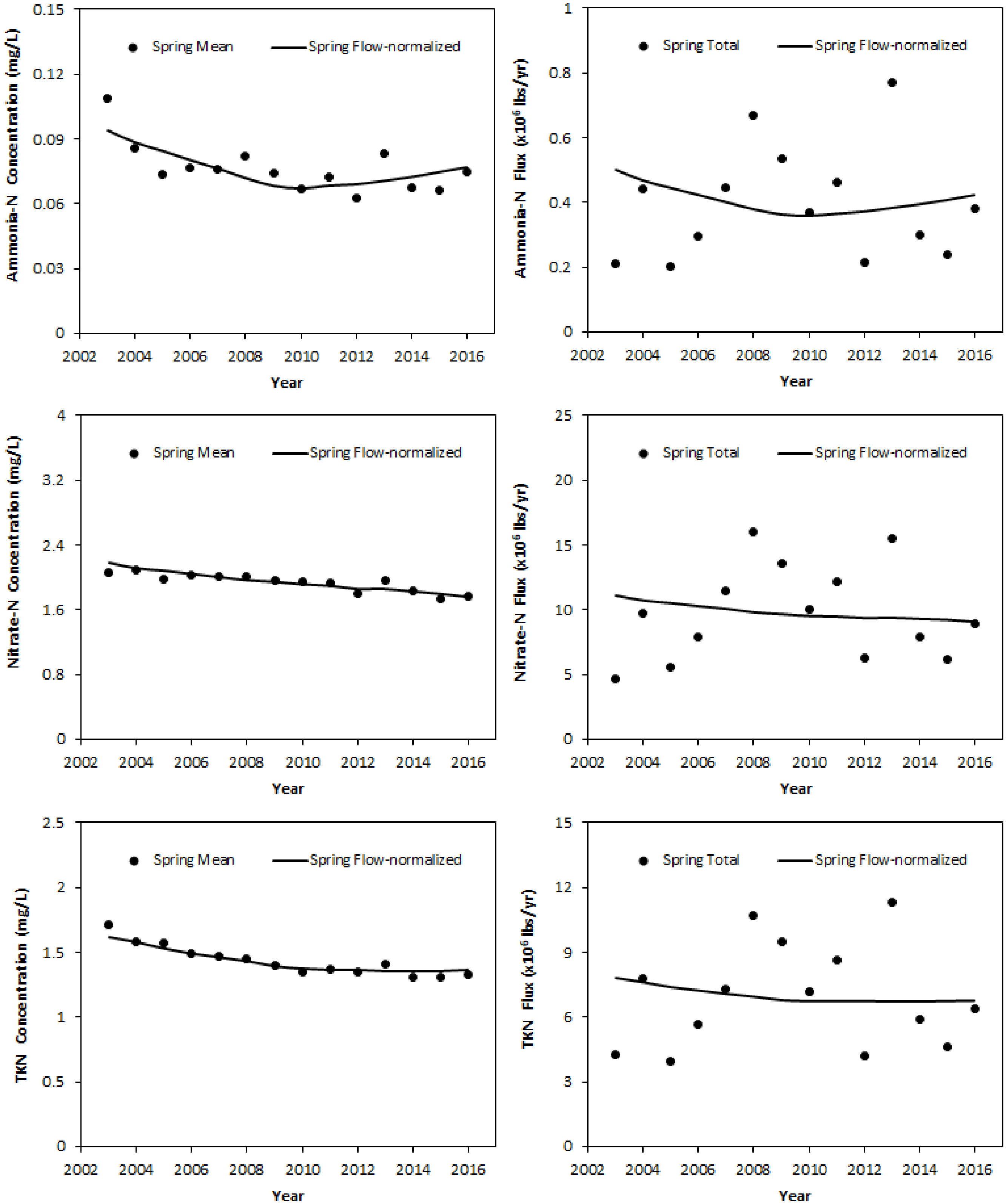


Figure D.18 Spring trends of NH_3-N, NO_3-N and TKN concentrations and fluxes for Fox River at Montgomery

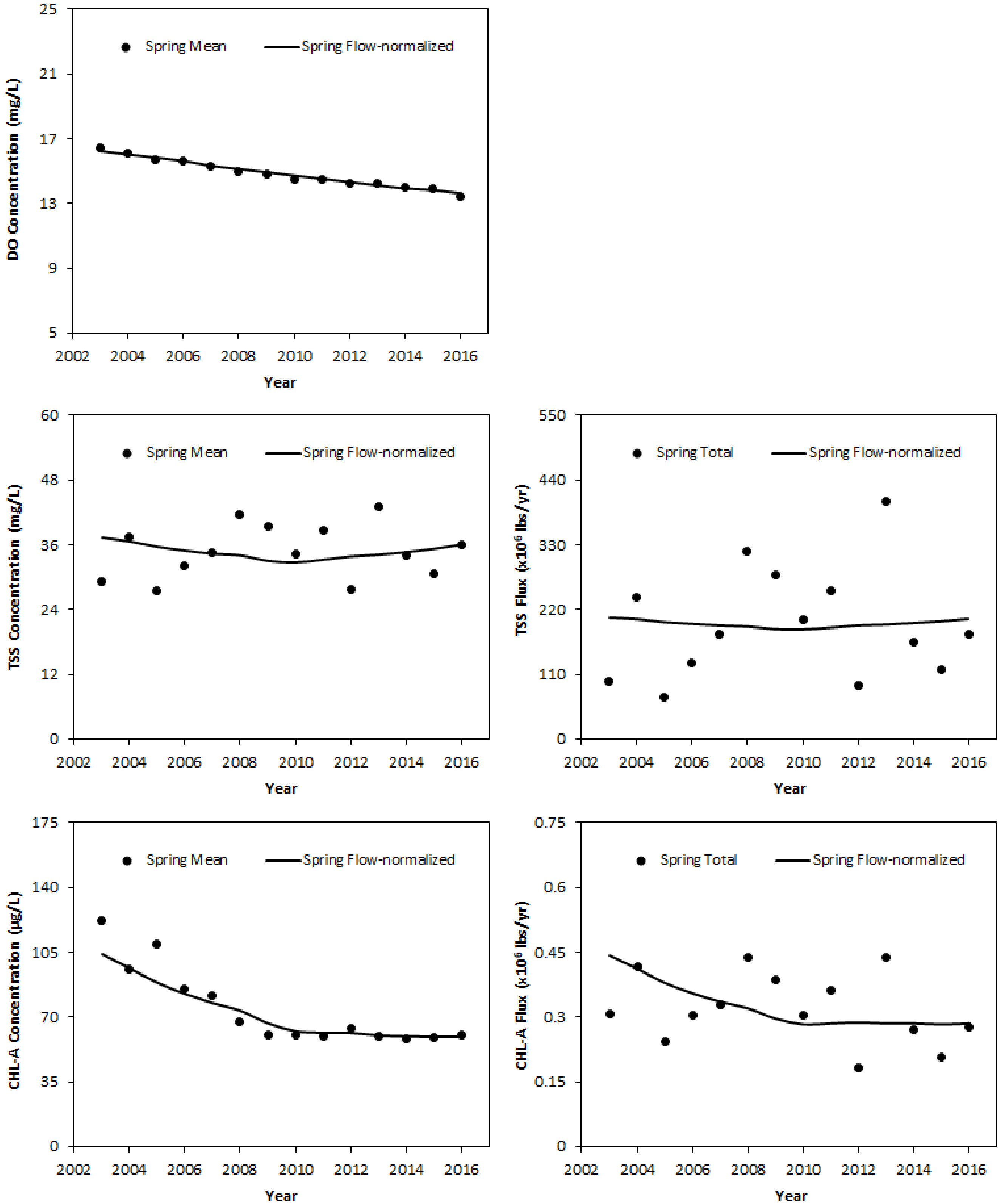


Figure D.19 Spring trends of DO, TSS and CHL-A concentrations and fluxes for Fox River at Montgomery

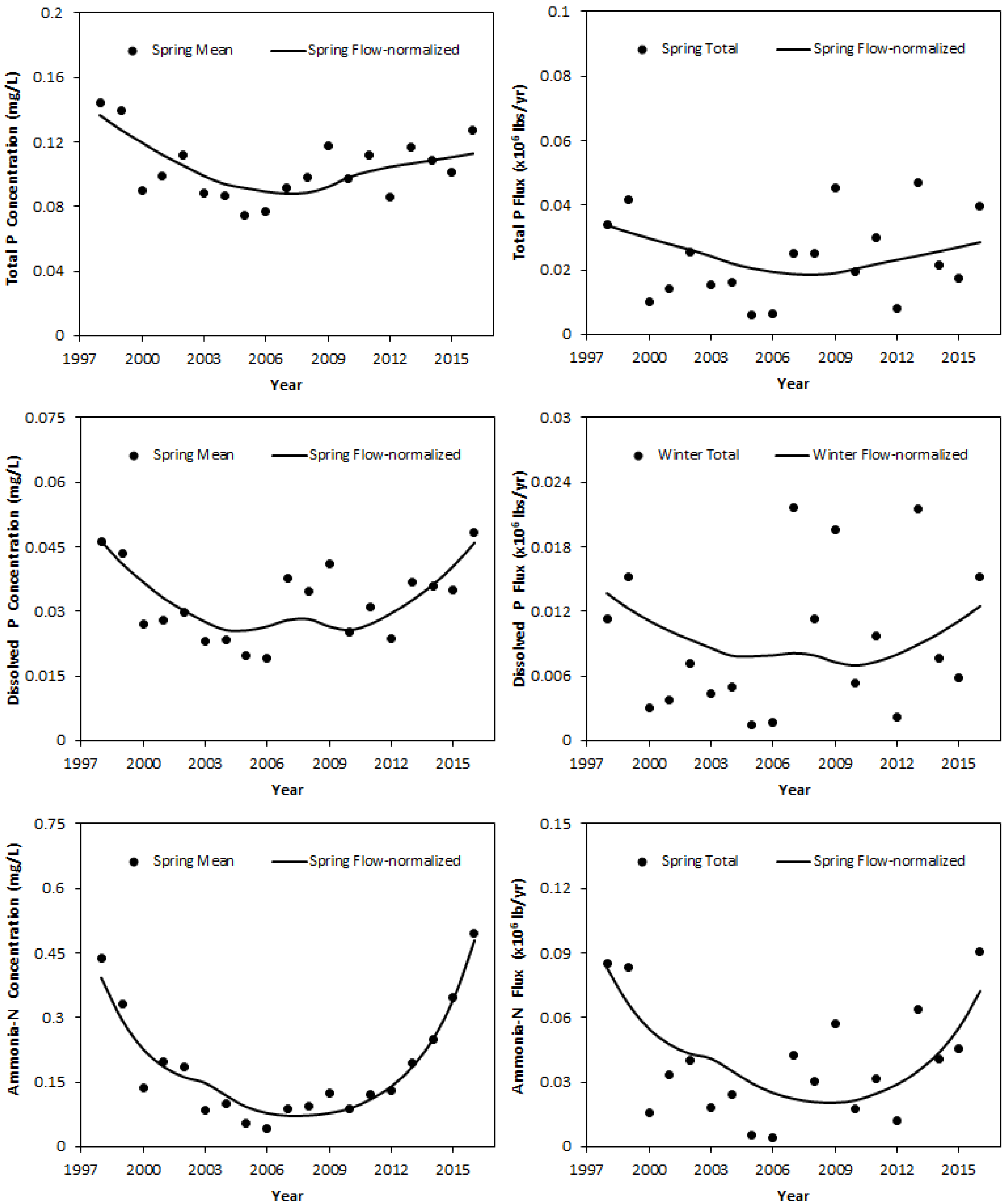


Figure D.20 Spring trends of TP, DP, and NH_3-N concentrations and fluxes for Blackberry Cr at Rt 47

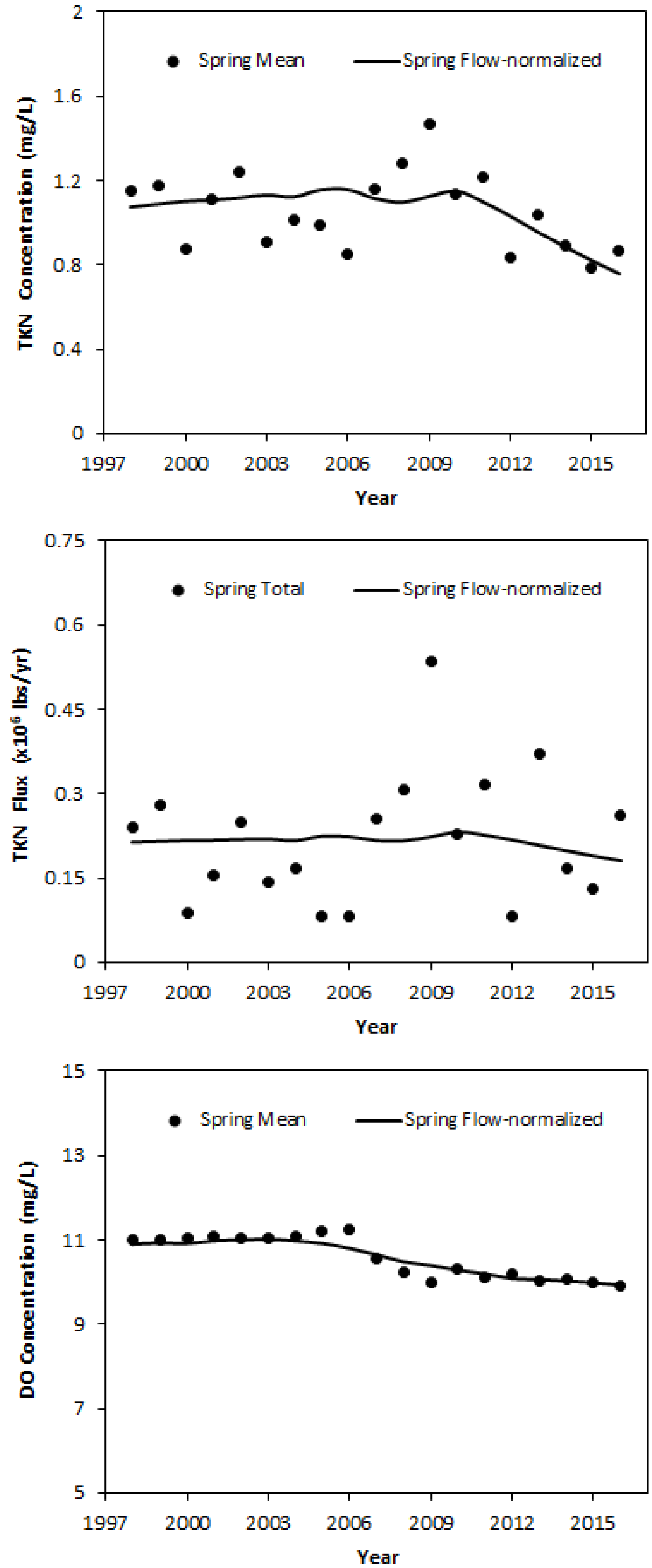


Figure D.21 Spring trends of TKN and DO concentrations and fluxes for Blackberry Cr at Rt 47

Summer Trends

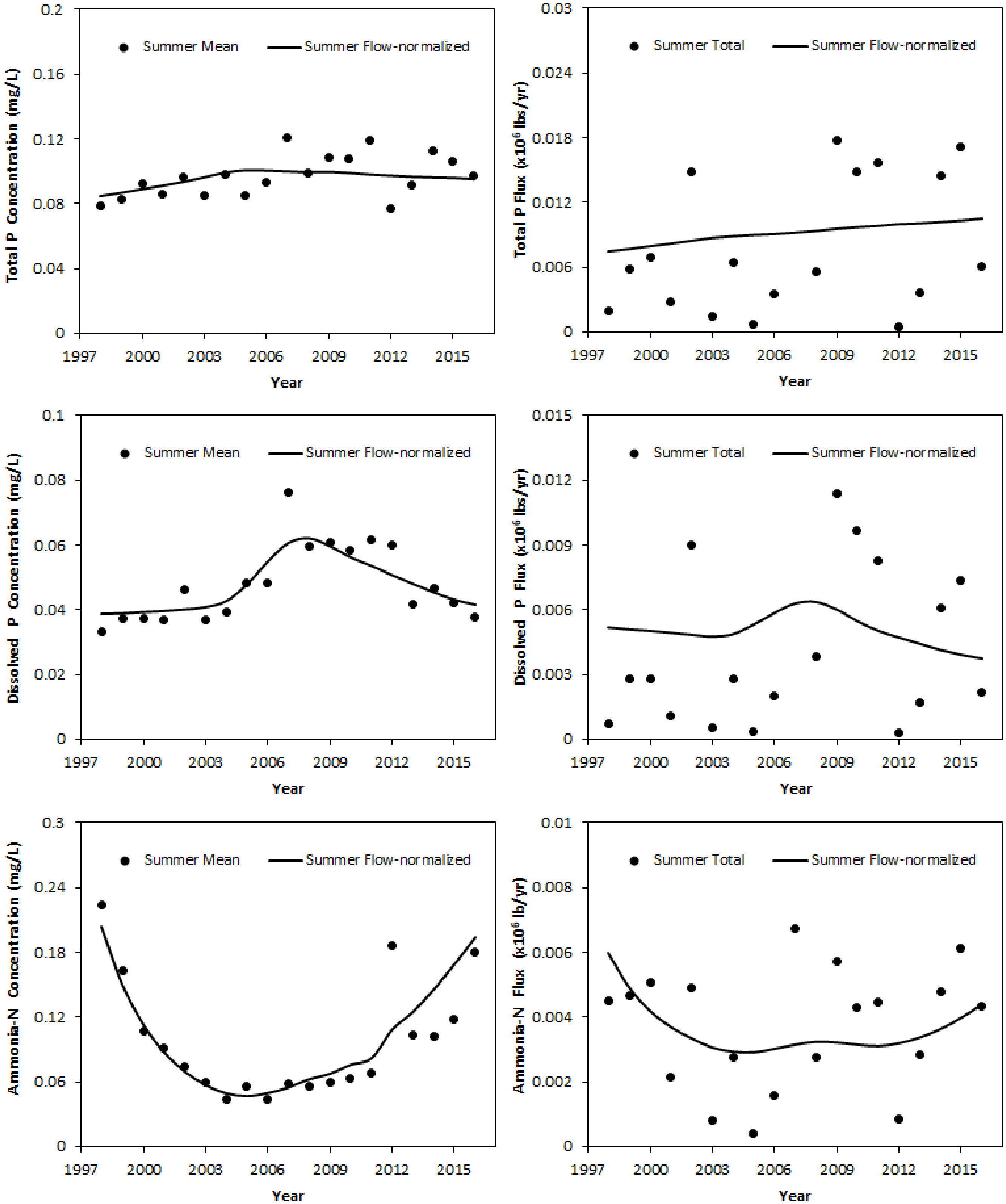


Figure D.22 Summer trends of TP, DP, and NH_3-N concentrations and fluxes for Poplar Cr near Mouth-Elgin

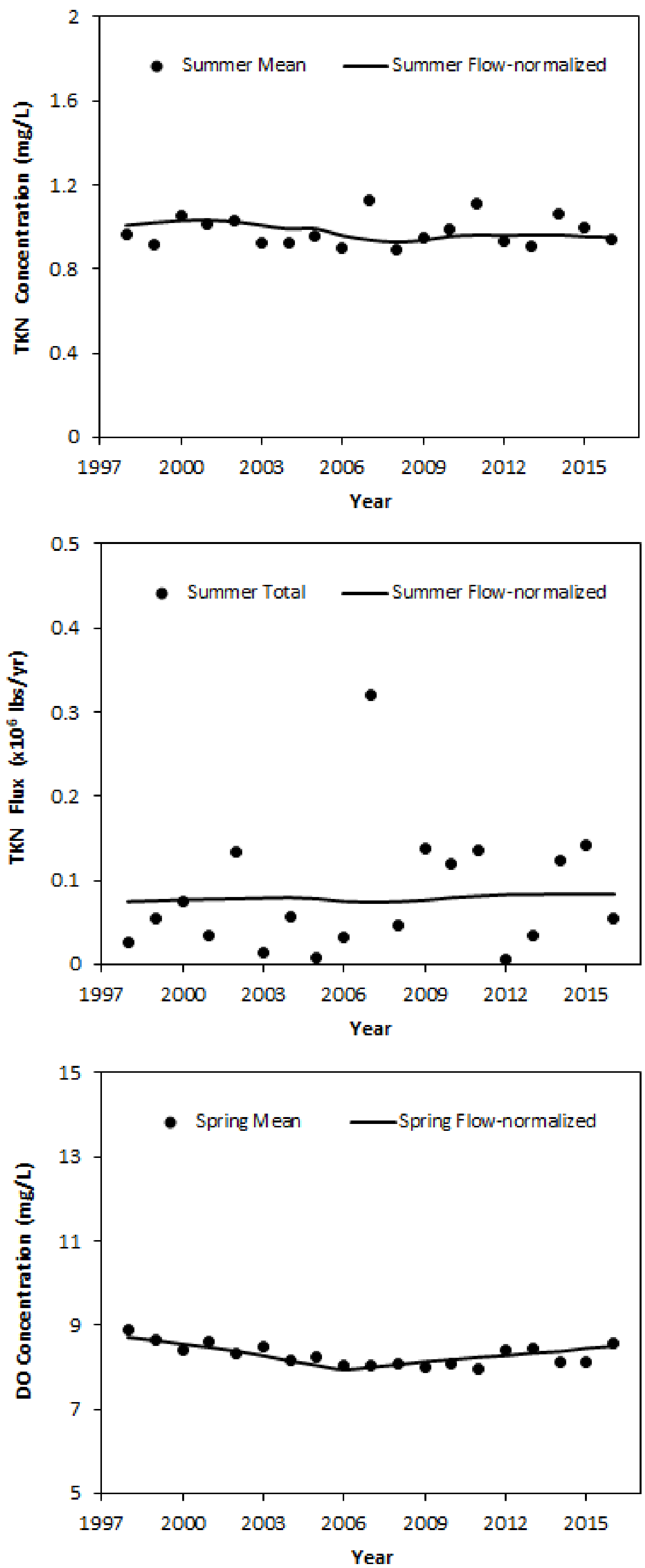


Figure D.23 Summer trends of TKN and DO concentrations and fluxes for Poplar Cr near Mouth-Elgin

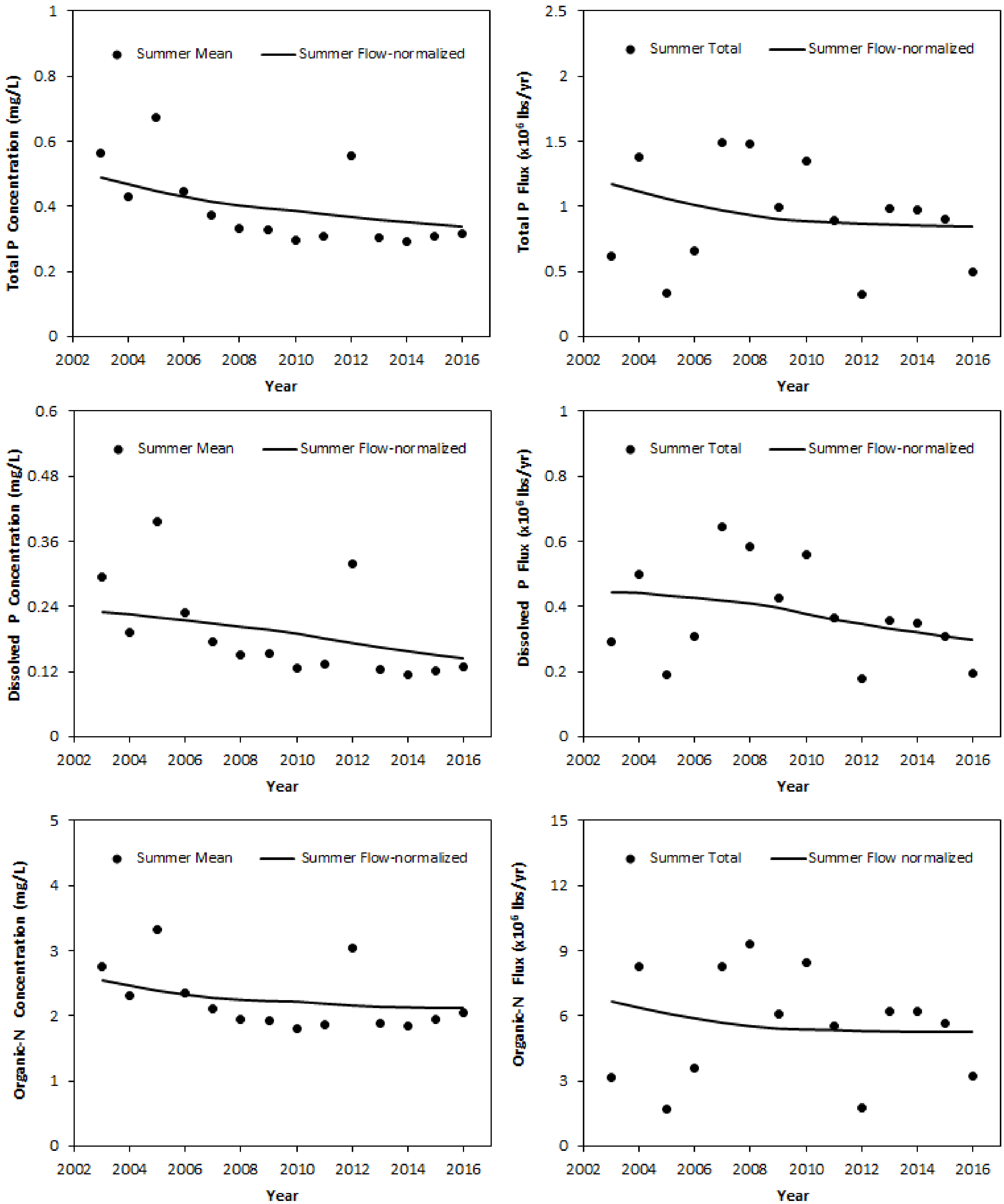


Figure D.24 Summer trends of TP, DP, and Org-N concentrations and fluxes for Fox River at Montgomery

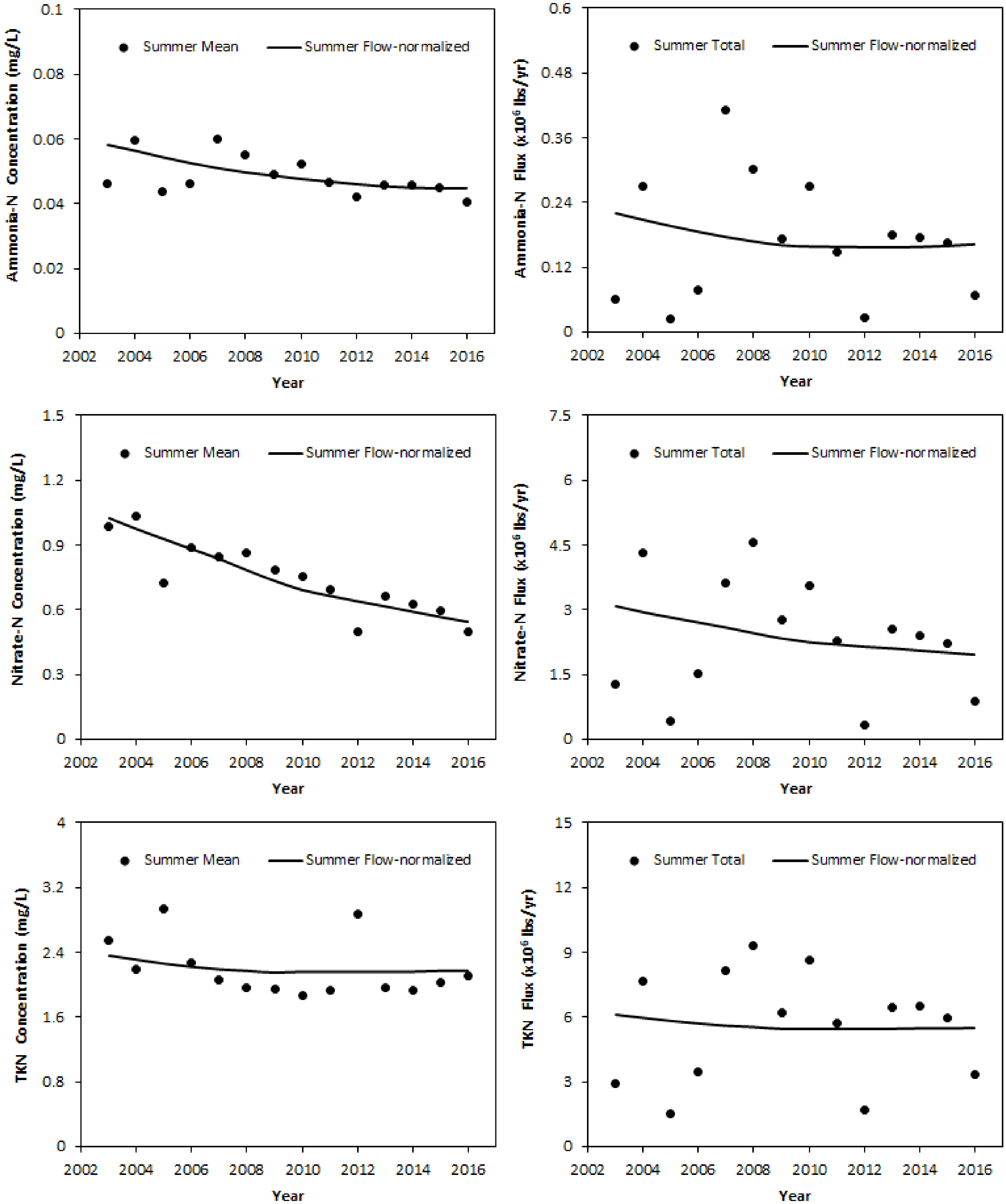


Figure D.25 Summer trends of NH_3-N, NO_3-N and TKN concentrations and fluxes for Fox River at Montgomery

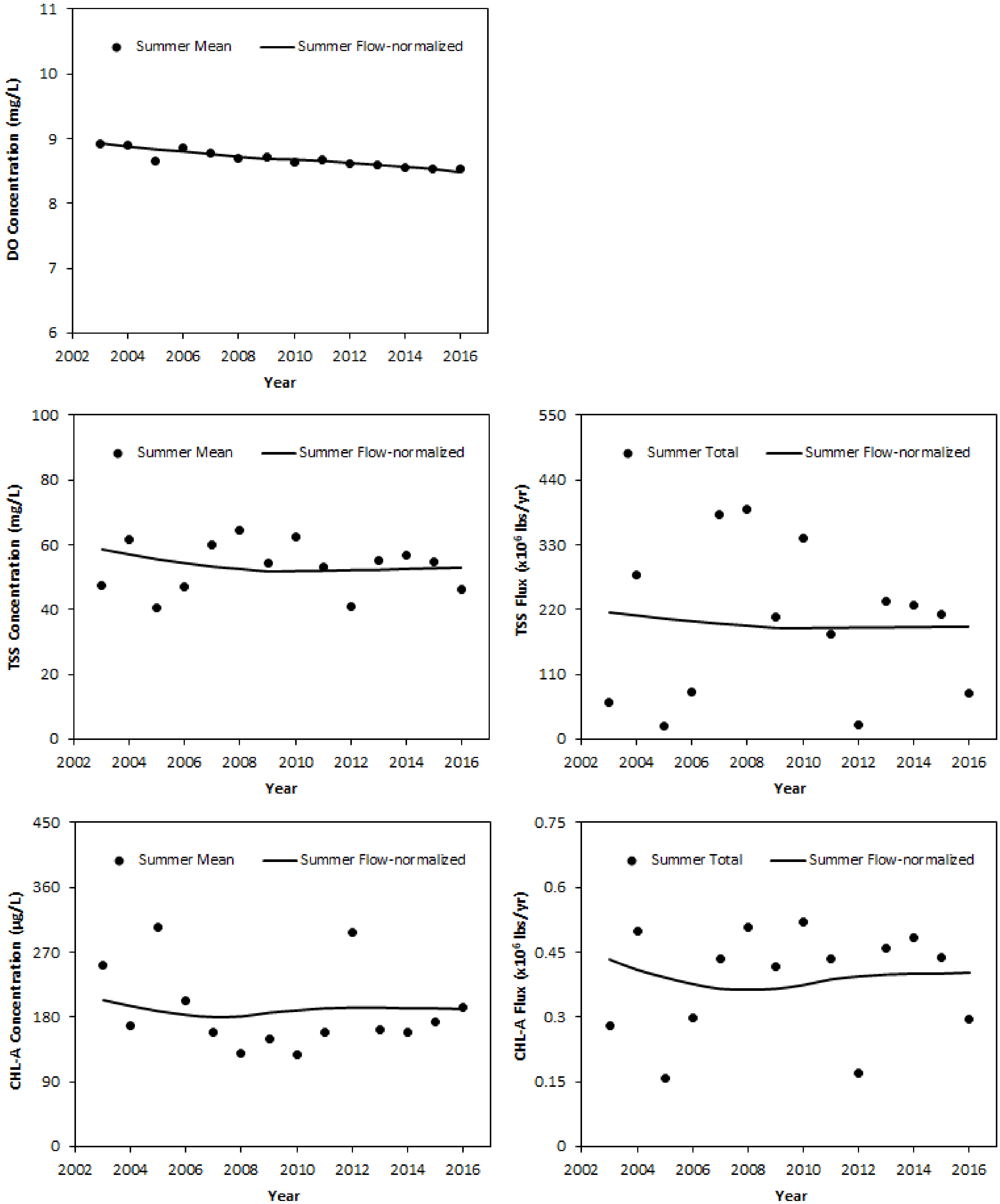


Figure D.26 Summer trends of DO, TSS and CHL-A concentrations and fluxes for Fox River at Montgomery

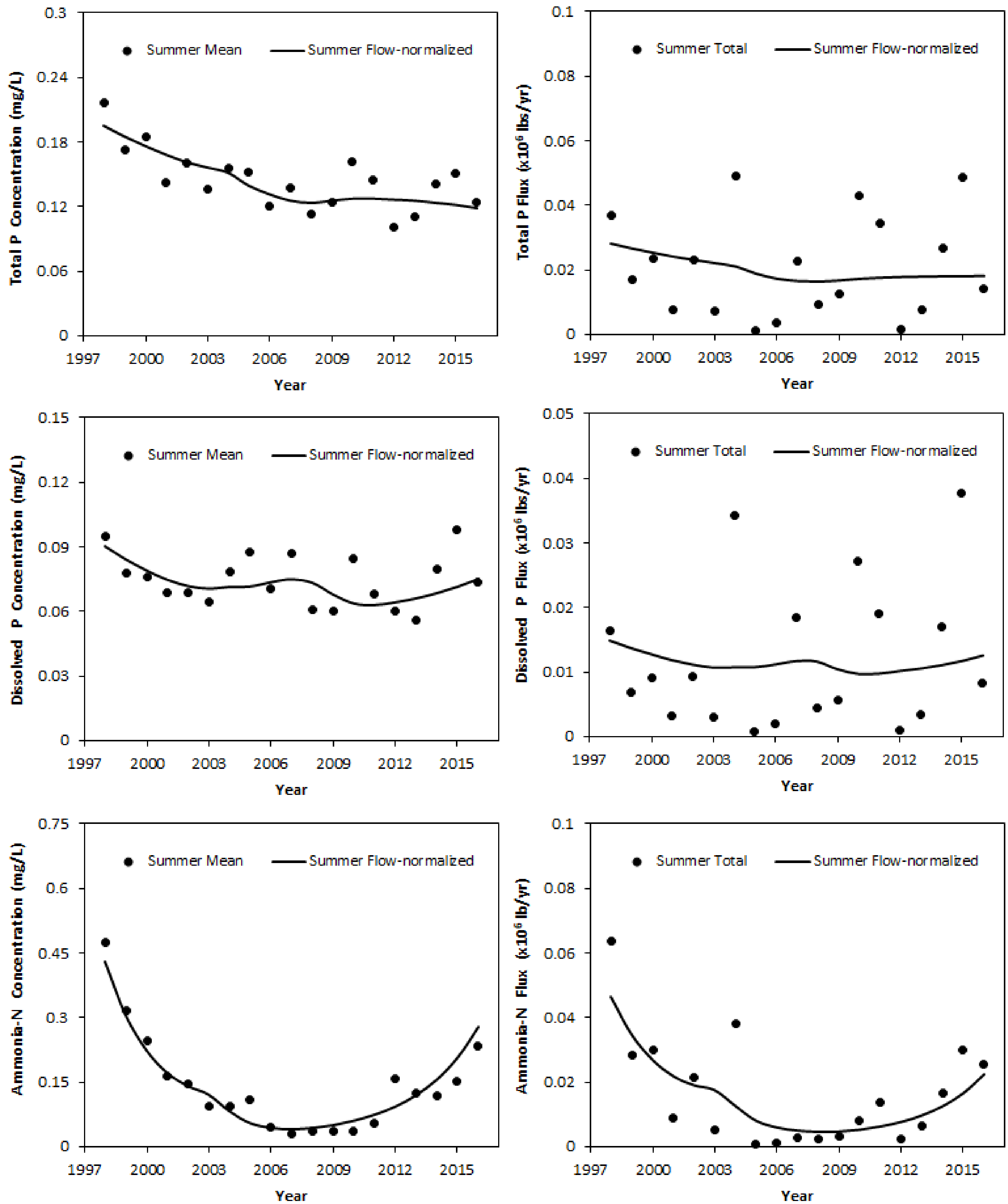


Figure D.27 Summer trends of TP, DP, and NH_3-N concentrations and fluxes for Blackberry Cr at Rt 47

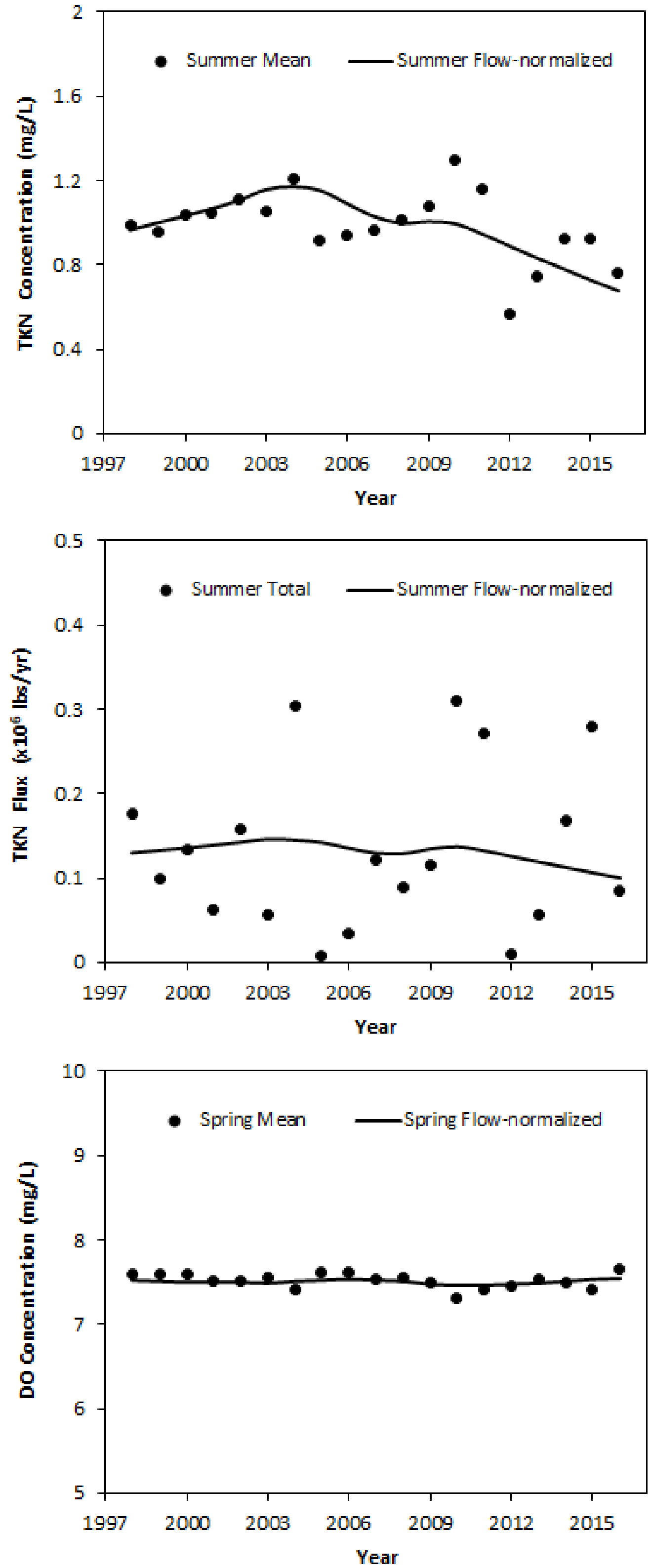


Figure D.28 Summer trends of TKN and DO concentrations and fluxes for Blackberry Cr at Rt 47

Fall Trends

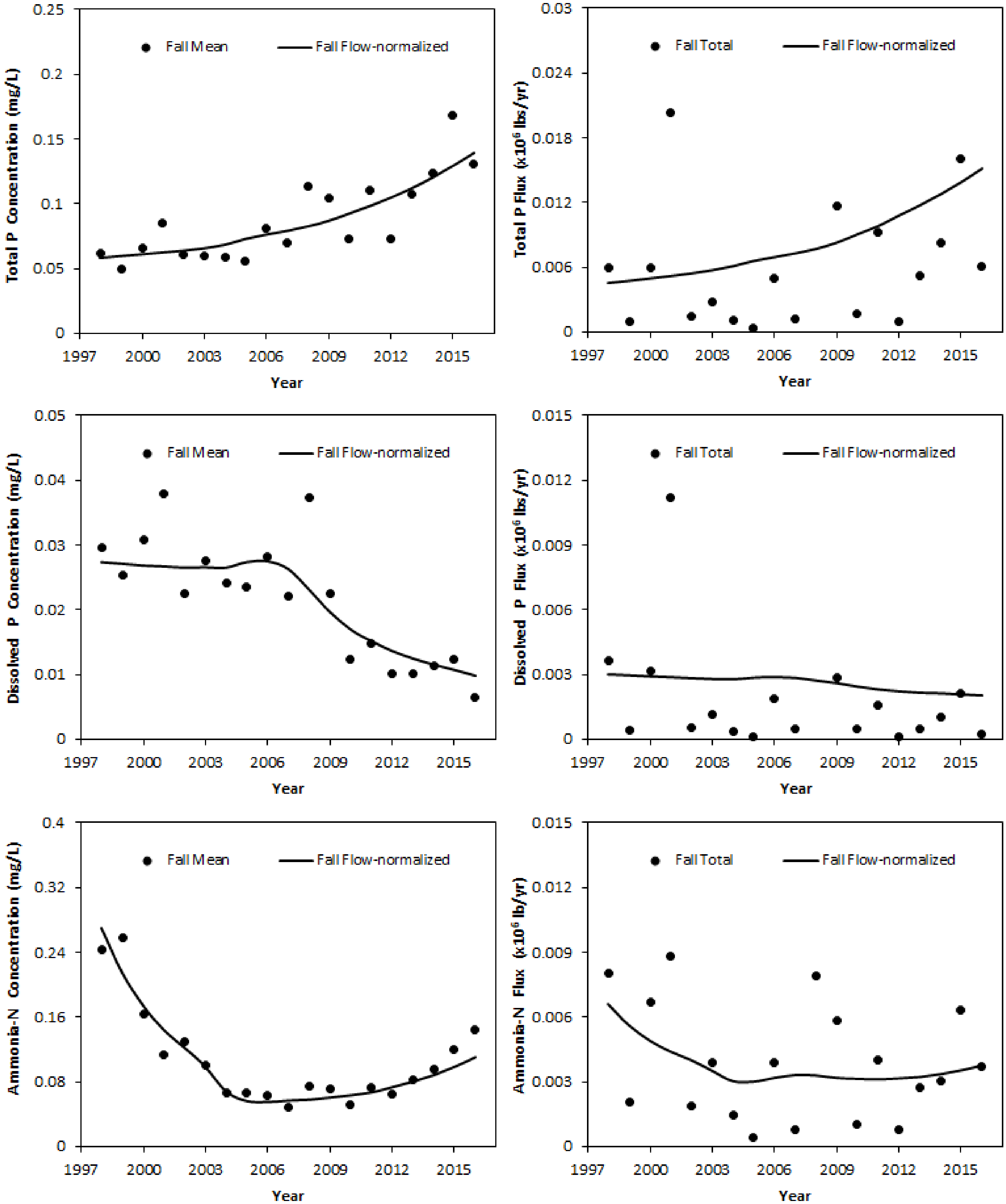
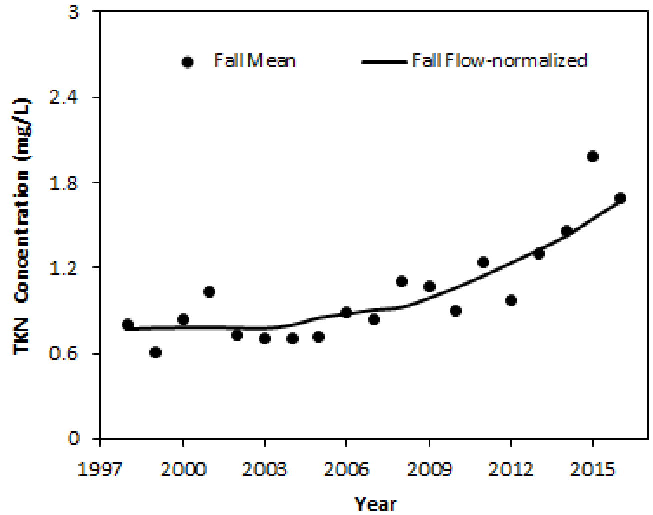
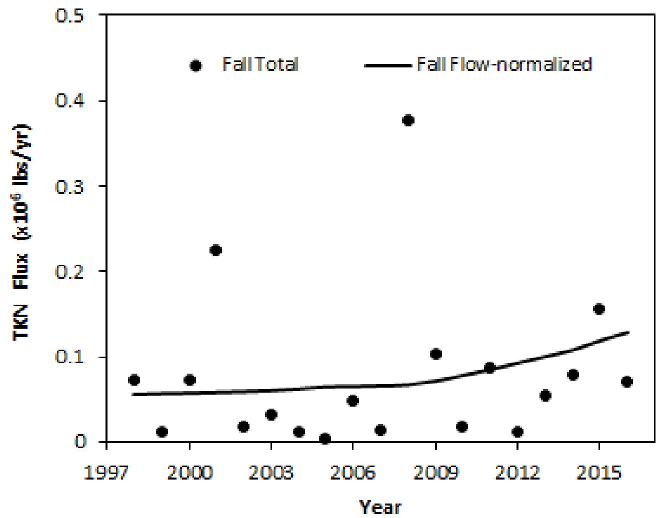


Figure D.29 Fall trends of TP, DP, and NH_3-N concentrations and fluxes for Poplar Cr near Mouth-Elgin





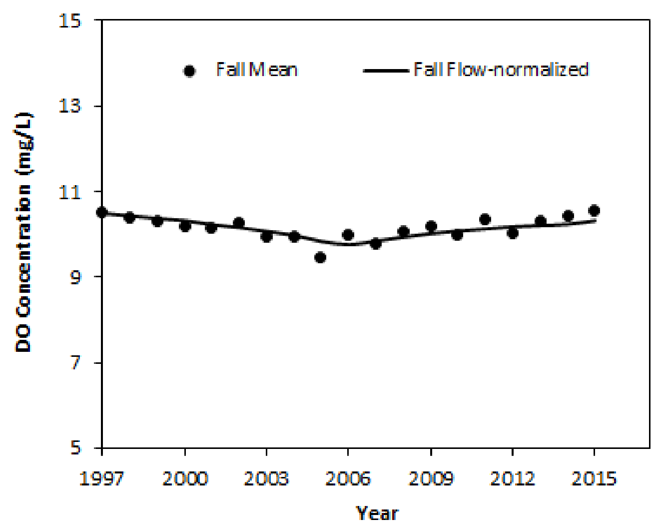


Figure D.30 Fall trends of TKN and DO concentrations and fluxes for Poplar Cr near Mouth-Elgin

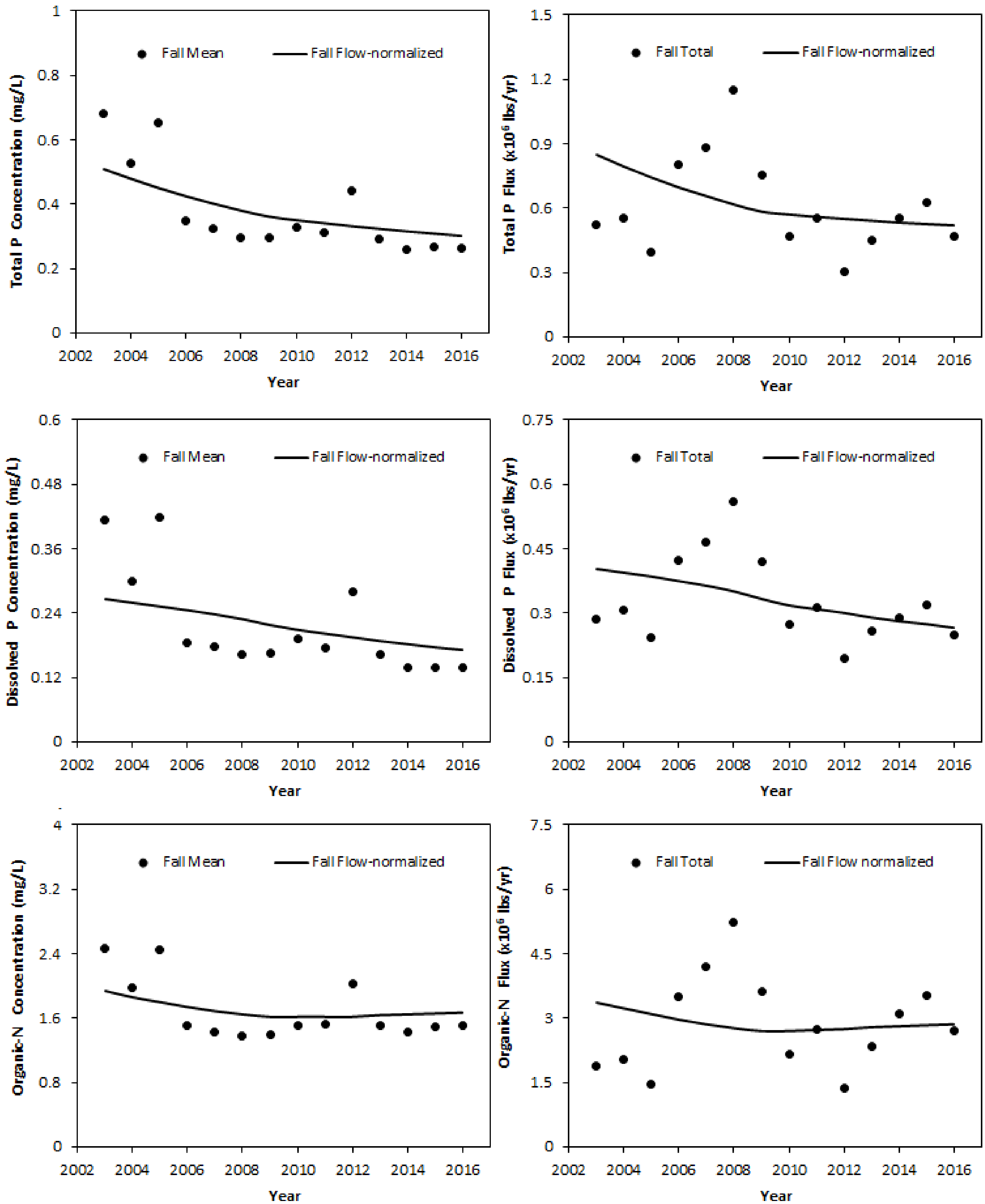


Figure D.31 Fall trends of TP, DP, and Org-N concentrations and fluxes for Fox River at Montgomery

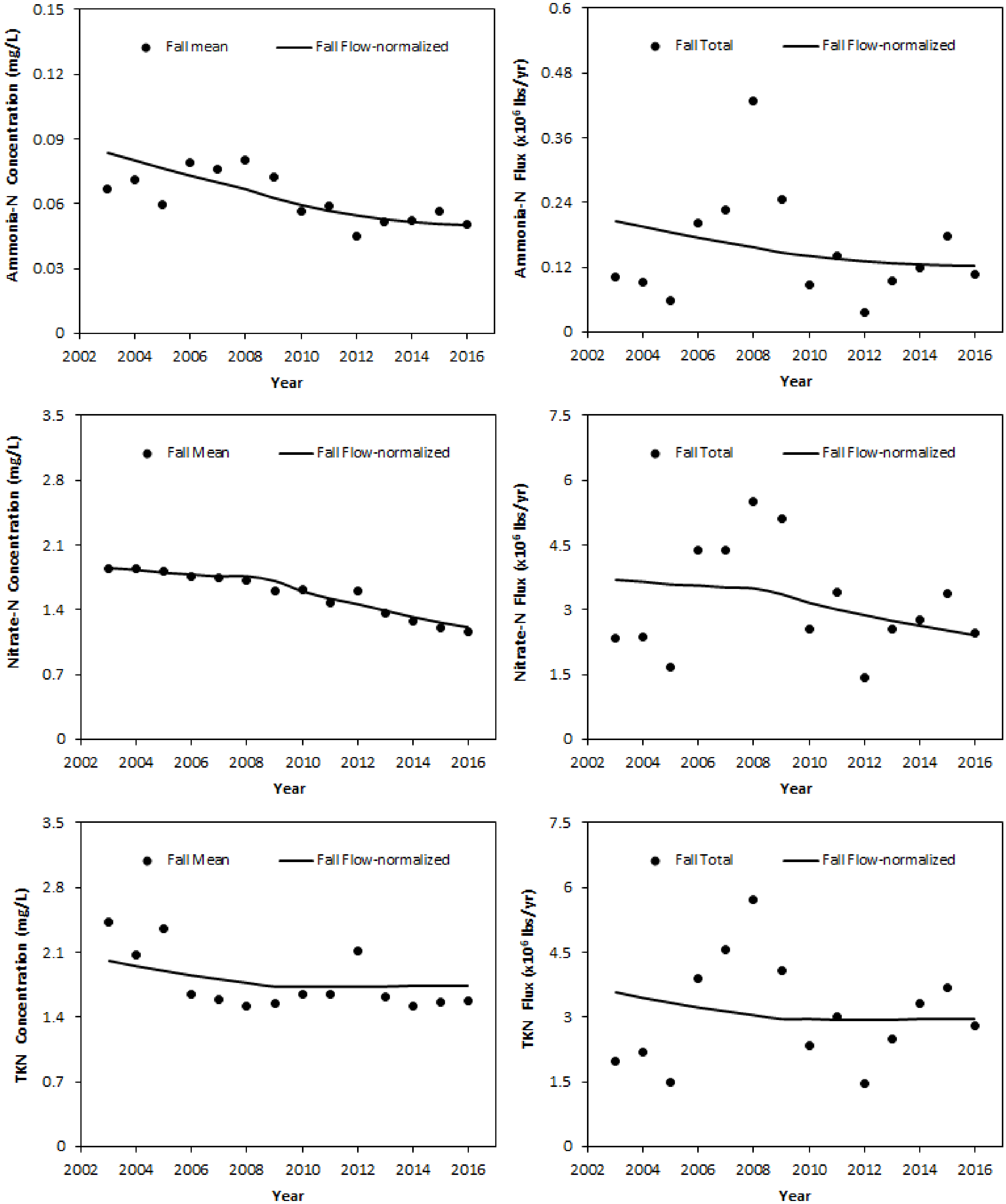


Figure D.32 Fall trends of NH_3-N, NO_3-N and TKN concentrations and fluxes for Fox River at Montgomery

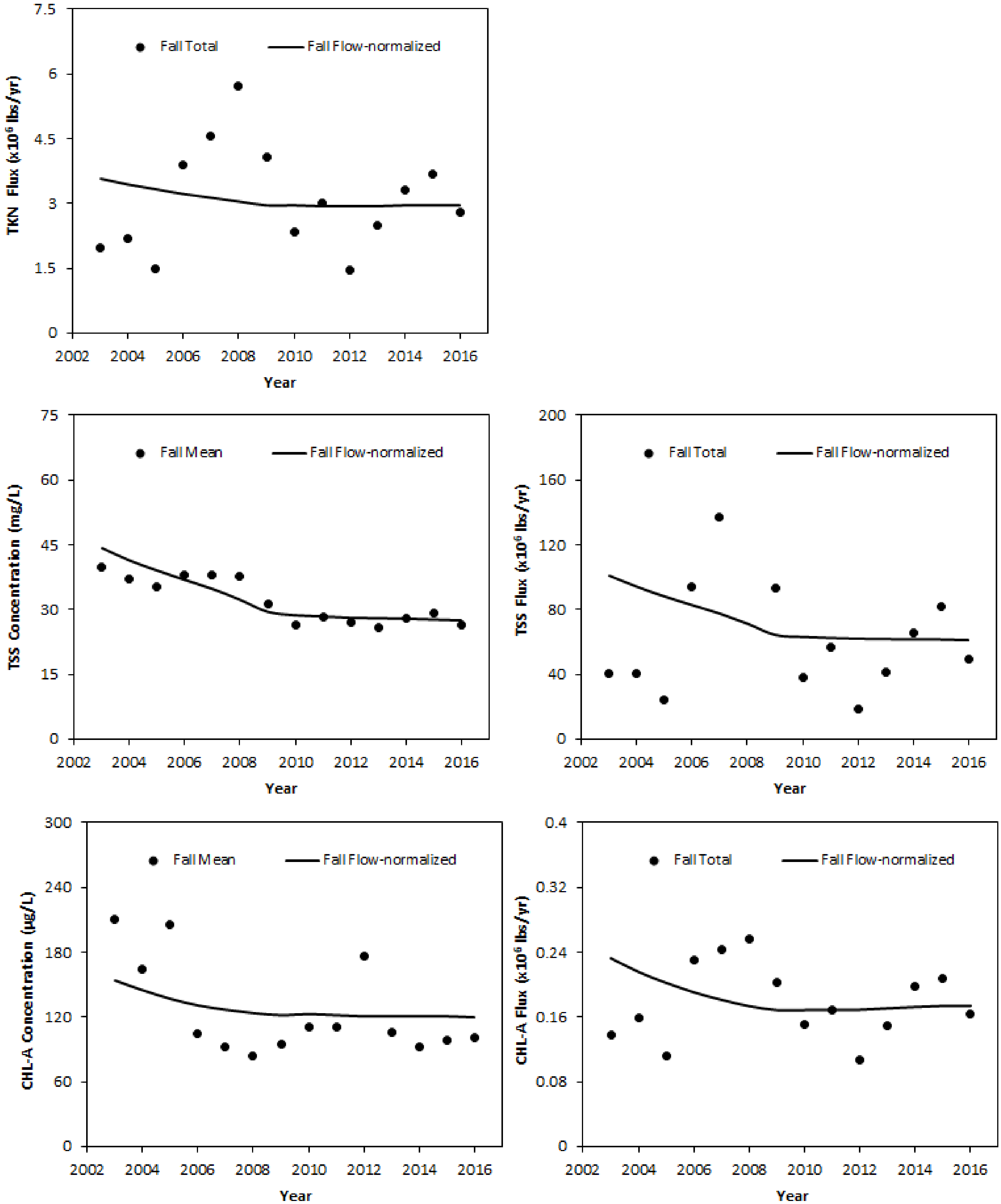


Figure D.33 Fall trends of DO, TSS and CHL-A concentrations and fluxes for Fox River at Montgomery

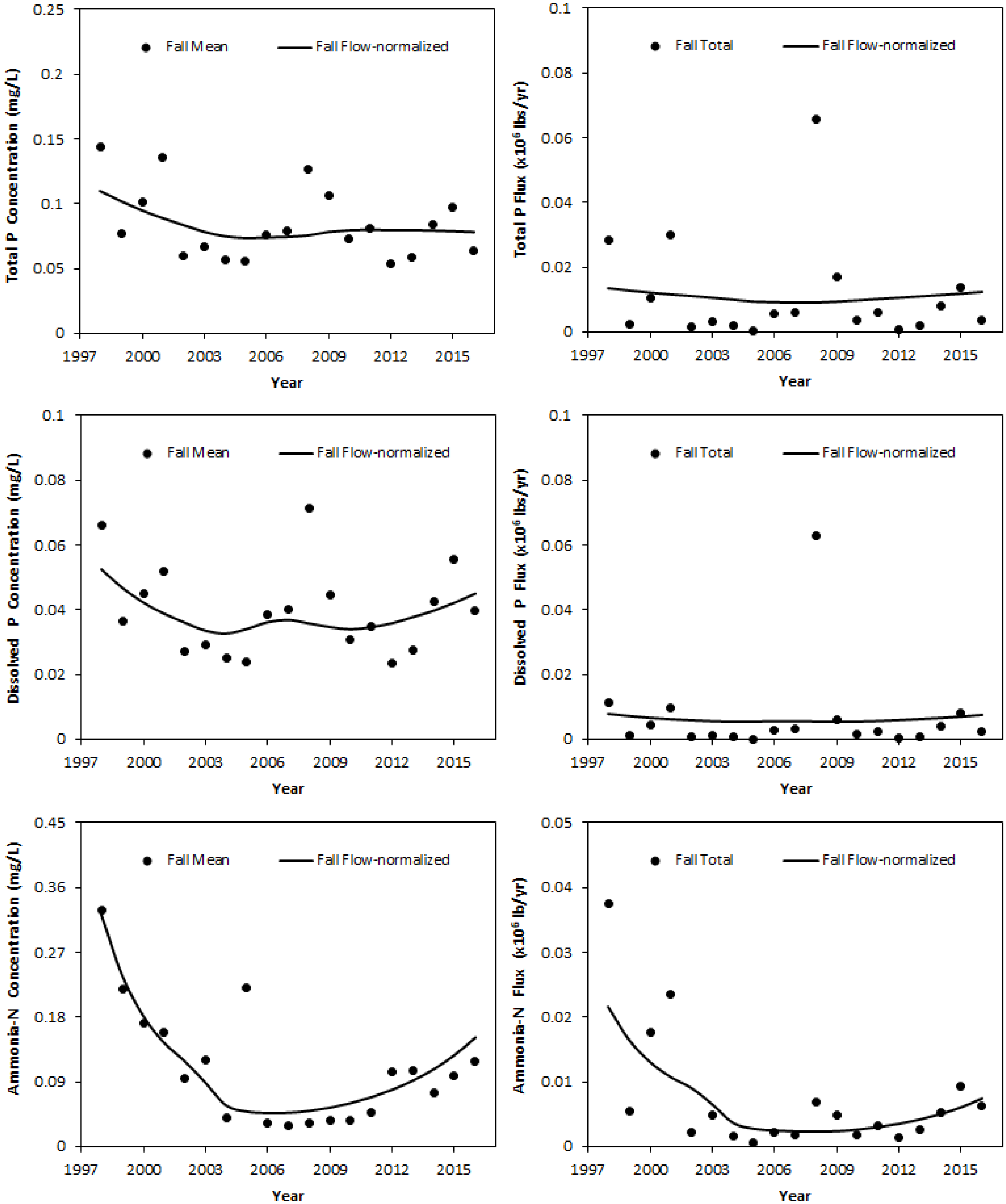
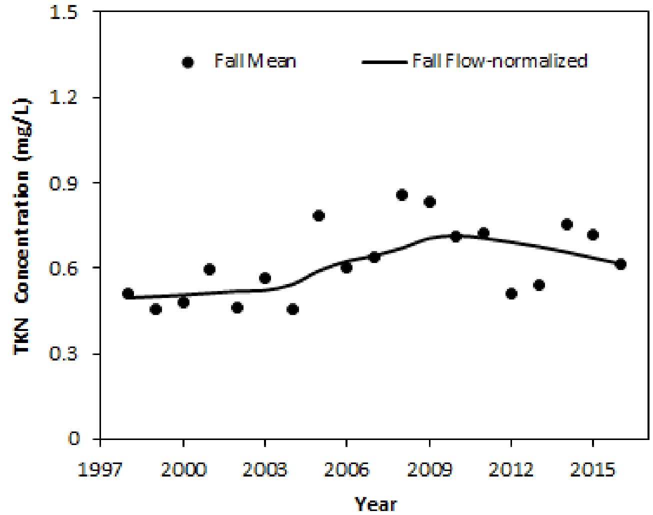
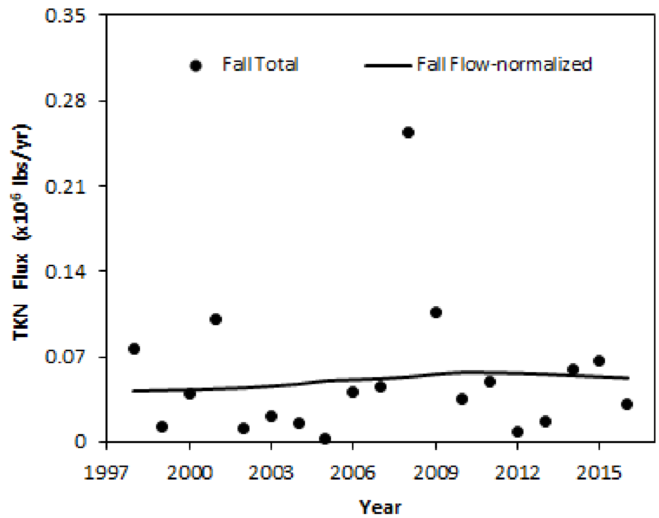


Figure D.34 Fall trends of TP, DP, and NH_3-N concentrations and fluxes for Blackberry Cr at Rt 47





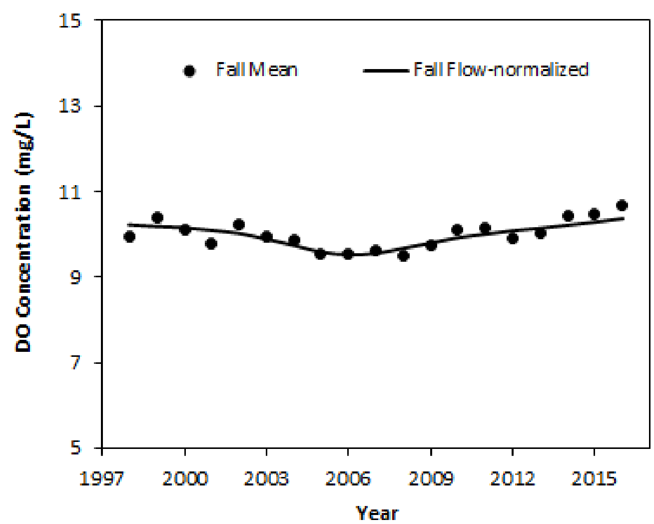


Figure D.35 Fall trends of TKN and DO concentrations and fluxes for Blackberry Cr at Rt 47