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Relative Linkages of Stream Dissolved Oxygen with the Environmental Drivers across the Gulf Coast of U.S.A

Aron Gebreslase

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Relative Linkages of Stream Dissolved Oxygen with the Environmental Drivers across the Gulf Coast of U.S.A.

Aron Gebreslase

Thesis Submitted

**to the Benjamin M. Statler College of Engineering and Mineral Resources
at West Virginia University**

in partial fulfillment of the requirements for the degree of

Master of Science in

Civil Engineering

Omar I. Abdul-Aziz, Ph.D., Chair

Kakan Dey, Ph.D.

P.V. Vijay, Ph.D, P.E.

Department of Civil and Environmental Engineering

Morgantown, West Virginia

2017

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Abstract

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Aron Gebreslase

Dynamics of coastal stream water quality and ecosystem health is influenced by a multitude of interacting environmental drivers. A systematic data analytics approach was employed to determine the relative environmental controls on stream dissolved oxygen (DO) dynamics across the Gulf Coast of U.S.A. Pearson's correlation, principal component, and factor analyses were utilized to examine the interrelations among DO, solar radiation, water temperature, atmospheric pressure, flow rate, nutrients, pH, and specific conductance (a surrogate of salinity) in 36 streams. Relative linkages of DO and the environmental drivers were then reliably estimated by resolving multicollinearity with power-law based partial least squares regression (Nash-Sutcliffe efficiency = 0.58-0.94). Based on the dominant controls of DO, streams were grouped into three regions across the U.S. Gulf Coast. In the northern part of Gulf Coast states (Texas, Louisiana, Mississippi, Alabama, and West Florida), water temperatures had the strongest and dictated control on stream DO. However, in the southern part of Texas and Florida coasts, pH showed the most dominant control on stream DO. Further, streams in between these two regions demonstrated notable controls of multiple drivers (water temperature, stream flow, and specific conductance) on DO. Four dynamic process components adequately described the system data variance in all three regions along the Gulf Coast. For example, the 'climate component' (temperature, solar radiation) in the northern part of Gulf Coast showed 2.7, 3.1, and 3.6 times stronger linkages with stream DO than that of the redox (pH, specific conductance), nutrient (total nitrogen, total phosphorus), and hydro-atmospheric (flow rate, atmospheric pressure) components, respectively. In contrast, in the southern part of Gulf Coast region, the redox components showed 1.6, 2.3, and 2.6 times stronger linkages with stream DO than that of the climate, nutrient, and hydro-atmospheric components, respectively. The identified environmental regimes and estimated linkages of stream DO provide important information into the dominant drivers and dynamic process components of water quality in urban/natural streams across the U.S. Gulf Coast. The knowledge and insights would help coastal managers and stakeholders to achieve a good stream water quality and ecosystem health.

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CHAPTER 1

INTRODUCTION

1.1 Background and Scope

Clean water is important in supporting a healthy stream ecosystem. Dissolved oxygen (DO) is a general indicator of stream water quality. Stream water quality is shaped by various interacting and dynamic environmental drivers in relation to climate, hydrology, and land use/cover. However, existing literature lacks large-scale data analytics and modeling investigations of stream water quality in relation to the dynamic environmental drivers, particularly in the context of urban-natural watersheds of U.S. Gulf coast representing a large geographical and longitudinal gradient. Stream water quality in the coastal environment of the Gulf of Mexico has been deteriorating rapidly by anthropogenic activities (Bricker et al., 2008). Rabalais et al. (1996) reported that human activity had increased the discharging of nutrient loading in the Gulf Coast. Previous studies of coastal stream water quality along the Gulf coast are mostly limited to the Mississippi River delta. Moreover, the previous studies focused only on the linkages of stream water quality with the land use activities (Basnyat et al. 1999). Further, existing studies often used regression-based modeling approaches to estimate the links of stream water quality with land uses without resolution of multicollinearity (mutual correlations) among the interacting drivers. Understanding and estimation of the relative linkages of stream DO with the dynamic environmental drivers by resolving multicollinearity can provide insights into the stream water quality dynamics, and help coastal managers to achieve clean water in the Gulf Coast and similar regions around the world.

1.2 Objective of the Study

The overall goal of this study is to determine the dominant environmental controls of stream DO dynamics across the Gulf Coast. The research involves processing and analyses of observed data

for DO, solar radiation, water temperature, atmospheric pressure, flow rate, nutrients, pH, and specific conductance (a surrogate of salinity) in 36 streams. The water quality data were gathered from the U.S. Geological Survey and the U.S. Environmental Protection Agency. Hourly climatic variables were obtained from the National Solar Radiation Data Base (NSRDB). The study employed systematic data analytic approach sequentially: Pearson's correlation matrix, principal component analysis (PCA), factor analysis (FA), and partial least squares regression (PLSR) to corroborate findings and reliably estimate the dominant controls of stream DO.

The specific research objectives of the study are as follows:

- Obtain and process long-term observations of stream water quality and dynamic environmental drivers along the Gulf Coast.
- Employ Pearson's correlation, principal component analysis, and factor analysis to examine the interrelations among DO and the dynamic environmental variables.
- Estimate the relative linkages of DO with the dynamic environmental drivers using power-law based partial least squares regression.

The research findings are expected to provide new information and insights into the dominant drivers and dynamic process components of stream DO. The knowledge would help coastal managers to achieve a healthy stream ecosystem along the U.S. Gulf Coast and around the world.

1.3 Organization of the Thesis

This thesis is comprised of four distinct chapters. The current chapter provides a brief introduction and scope along with the objectives and organization of the thesis. Chapter 2 describes the study area, data preparation for water quality and environmental variables, and detailed methodology

used for the research. Chapter 3 describes the results obtained from four systematic data analytics approach. Chapter 4 consists of a discussion of results and conclusion.

CHAPTER 2

LITERATURE REVIEW

On a global scale, human population is significantly increasing in the coastal urban areas (DiDonato et al., 2009). Population growth increases impervious land, which significantly alters surface water quality (Nagy et al., 2012). Many studies have been conducted in identifying the major drivers of stream water quality. Li et al. (2014) evaluated the temporal and spatial variations of stream water quality of the Xin'anjiang River, China. They used multivariate statistical techniques (correlation analysis, cluster analysis, discriminant analysis, and principal component analysis) and found that the soluble salts (reflected by EC, COD, permanganate index, ammonia-nitrogen, and E. coli) were the main drivers of water quality in Xin'anjiang River. Kuppusamy and Giridhar (2006) investigated the interrelationships among different water quality indicator variables and attempted to infer the likely sources or controls of coastal water quality in Chennai Ennore, India. The study reported that the eutrophication factor (i.e., pH, DO, and suspended solids) had explained most of the observed variance in water quality datasets.

The hydrological changes because of urban development can magnify the impact of non-point source pollutions in streams and rivers. The potential changes may include permanent alteration or transitional fluctuation in stream temperature, increased nutrient concentrations, and reduction in dissolved oxygen. Shrestha and Kazama (2007) identified variables that led to spatial and temporal changes in Fuji River Basin, Japan. The research used 13 water quality variables that were collected over 8 years on a monthly interval. The study found that climate (temperature) and the discharging nutrient were the main determinants of water quality in Fuji River.

In the Northern Gulf of Mexico, Turner et al. (2007) identified the major controls of stream water quality. They found that discharging total nitrogen and total phosphorus from the Mississippi

and Atchafalaya Rivers led to a major reduction in the quality of Gulf of Mexico. Nagy et al. (2012) investigated stream water quality by developing multiple regression models in the Apalachicola River Basin, Florida. They found that watershed with greatest impervious area exhibited higher in-stream pH, specific conductance, and temperature. Santhi et al. (2005) identified the major sources of pollutants in the Trinity River Basin, Texas using Soil Water Assessment Tool (SWAT). This study found that sediment erosion and nutrients were the major causes of pollution in the Trinity River basin.

Most previous studies in this area and around the world were conducted by focusing on a relatively small spatial scale, and statistical models were developed without resolving the multicollinearity (mutual correlations among the predictors) issue that can lead to biased and misleading results. Abdul-Aziz and Ahmed (2017) employed partial least squares regression (PLSR) modeling to resolve the multicollinearity issue among the predictors. They determined the relative linkages of land use and hydrologic drivers with stream water quality in the coastal-urban watersheds of southeast Florida. The research found that Everglades was the major source of total nitrogen in the coastal-urban streams, whereas stream total phosphorus (the limiting nutrient) was primarily contributed by the agricultural lands that represented a small portion (~3%) of the draining watersheds. The thesis builds on the study of Abdul-Aziz and Ahmed to identify the major drivers of dissolved oxygen (DO) dynamics and their dynamic environmental linkages of DO in the coastal/urban streams across the Gulf Coast of U.S.A.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area

This study was conducted in the coastal/urban streams across the U.S. Gulf Coast (Figure 1). Based on the availability of long-term observations, 36 water quality monitoring stations were considered in this study. The selected stations represented a good spatial coverage, and incorporated the geographic, latitudinal, and longitudinal gradients along the Gulf Coast, which extends 1631 miles and covers 13.5% of the U.S coastal area (Kennicutt, 2017). It includes 5 U.S. states (Texas, Louisiana, Mississippi, Alabama, and west Florida) and mostly humid/warm temperate; however, the southwestern part of Florida represents a subtropical climate (Mulholland et al., 1997).

Figure 1: Study area, Coastal watershed, and the location of water quality monitoring stations.

3.2 Datasets

The datasets of 36 stream water quality monitoring stations along the Gulf Coast States were gathered from the USGS NWIS and EPA STORET (NWQMC, 2017). The data often represented bimonthly samples between the years of 1998 and 2015. The selected water quality variables were: total nitrogen (TN), total phosphorus (TP), specific conductance (SC), potential of hydrogen (pH), flow rate (Q), water temperature (TW), and dissolved oxygen (DO). Further, to include the impact of climatic processes on stream DO, hourly averaged data of atmospheric pressure (AP) and solar radiation (SR) were obtained from the National Solar Radiation Data Base (NSRDB, 2017). The variables were selected based on preliminary data analysis and leveraging the current understanding of the temporal variation of stream dissolved oxygen in the coastal urban/natural streams (Chambers et al., 2006; Kannel et al., 2011; Bayram et al., 2015). TP was the summation of inorganic, organic, and dissolved forms of phosphorus; and TN was the summation of nitrate, nitrite (NO_2^-), ammonia (NH_3), and organic nitrogen. An interquartile range (IQR) criteria with a factor of two (i.e., $\text{median} \pm 2 \cdot \text{IQR}$) was used to remove outliers, which can distort the goodness of model fit (Aggarwal and Yu, 2001; Devarakonda et al., 2014). The sample size (n) of the temporal datasets ranged from 16 to 241 among the different sites (Table 1).

Table 1: Ensemble mean and standard deviations (in parenthesis) of the observed stream DO and the dynamic environmental drivers across the the Gulf Coast of U.S.A.

Station ID	I	Year	n	TN (mg/L)	TP (mg/L)	SC ($\mu\text{S}/\text{cm}$)	pH	Q (m^3/s)	AP (mbar)	TW ($^{\circ}\text{C}$)	SR (W/m^2)	DO (mg/L)
USGS-08475000	TX_1	2000-14	81	1.29(0.43)	0.20(0.07)	1354.27(246.95)	7.90(0.28)	9.52(6.16)	1013.39(4.13)	26.71(4.71)	522.23(253.40)	7.08(1.67)
USGS-08459200	TX_2	1999-07	57	1.36(0.40)	0.25(0.07)	950.81(151.74)	7.98(0.25)	46.68(28.49)	995.37(4.45)	24.36(5.50)	616.37(281.47)	7.57(1.36)
USGS-08042554	TX_3	2008-15	64	1.52(0.61)	0.28(0.13)	711.92(270.04)	8.05(0.23)	90.77(112.38)	1014.51(4.97)	24.44(7.01)	625.82(251.80)	8.18(1.76)
USGS-08042546	TX_4	1998-08	21	5.13(1.74)	1.34(0.56)	482.71(193.21)	7.58(0.31)	6.97(7.50)	1009.88(3.68)	24.47(5.12)	550.60(304.40)	6.34(1.35)
USGS-08116650	TX_5	1998-13	77	5.01(2.30)	1.02(0.50)	441.43(141.66)	7.63(0.48)	2.71(3.16)	1011.76(4.50)	22.54(6.19)	558.44(247.63)	8.86(2.09)
USGS-08070200	TX_6	1998-13	64	0.59(0.19)	0.09(0.03)	192.09(36.53)	7.02(0.21)	1.71(1.44)	1013.48(4.87)	21.30(6.14)	586.84(240.53)	8.00(1.58)
USGS-08012150	LA_1	1998-02	16	1.35(0.42)	0.23(0.08)	153.81(100.77)	7.25(0.43)	111.00(111.40)	1016.08(2.68)	19.50(6.11)	402.09(182.13)	4.24(1.71)
USGS-08014500	LA_2	1998-13	38	0.34(0.09)	0.04(0.01)	51.82(6.15)	6.75(0.49)	9.38(5.27)	1015.28(4.23)	20.01(5.14)	544.71(246.27)	8.46(1.21)
USGS-07381590	LA_3	1998-15	130	1.90(0.57)	0.22(0.06)	358.15(90.65)	7.76(0.25)	3539.87(1621.42)	1016.71(4.48)	20.13(7.38)	596.26(230.62)	7.69(2.04)
USGS-07381495	LA_4	1998-15	241	1.85(0.58)	0.22(0.06)	353.98(93.57)	7.76(0.26)	7040.87(3587.22)	1015.24(4.83)	18.68(7.99)	597.72(222.75)	8.43(2.02)
USGS-07381600	LA_5	1998-15	131	1.84(0.55)	0.21(0.06)	361.76(89.51)	7.75(0.25)	4260.84(2089.59)	1016.26(4.55)	20.12(7.61)	561.47(258.63)	7.55(2.26)
USGS-07373420	LA_6	1998-15	232	2.11(0.61)	0.23(0.07)	380.50(64.41)	7.79(0.25)	15946.17(7468.16)	1012.45(4.85)	17.87(8.27)	579.05(235.97)	8.80(2.04)
USGS-07374000	LA_7	2004-15	138	2.12(0.56)	0.23(0.06)	384.50(64.36)	7.89(0.18)	16294.50(7930.02)	1014.39(4.65)	17.41(8.16)	610.43(269.49)	8.92(2.11)
USGS-07374525	LA_8	2006-15	119	2.14(0.58)	0.25(0.07)	404.12(76.41)	7.82(0.20)	16949.42(7392.70)	1017.33(4.63)	18.26(8.10)	681.76(240.63)	8.53(2.16)
USGS-02470500	AL_1	2007-15	89	0.68(0.11)	0.10(0.04)	175.74(60.18)	7.37(0.33)	1744.38(1125.14)	1010.58(5.64)	18.65(7.17)	588.53(251.28)	9.33(1.58)
USGS-02469762	AL_2	1999-15	89	0.70(0.15)	0.10(0.05)	201.79(71.50)	7.47(0.27)	781.51(897.02)	1010.48(4.96)	20.54(7.67)	562.43(218.96)	9.66(1.63)
USGS-02429500	AL_3	1999-15	46	0.55(0.08)	0.07(0.01)	165.30(34.33)	7.52(0.24)	577.97(518.71)	1008.50(4.16)	21.39(6.60)	589.48(243.57)	9.15(1.75)
*21AWIC-7870	AL_4	2012-15	28	0.53(0.15)	0.02(0.01)	76.49(12.07)	7.13(0.24)	25.58(30.39)	1005.08(4.51)	20.98(6.98)	453.11(184.52)	7.68(2.06)

Note: (1) TX, LS, and AL, respectively, refer to stations in Texas, Louisiana, and Alabama. (2) “n” is the sample size. (3) TN, TP, SC, pH, Q, AP, SR, TW, and DO, respectively, refer to total nitrogen, total phosphorus, specific conductance, potential of hydrogen, flow rate, atmospheric pressure, solar radiation, water temperature, and dissolved oxygen. (4) * STORET water quality station. (5) “I” is station identifier.

Table1 (continued): Ensemble mean and standard deviations (in parenthesis) of the observed stream DO and the dynamic environmental drivers across the the Gulf Coast of U.S.A.

Note: (1) FL refers to stations in Florida. (2) “n” is the sample size. (3) TN, TP, SC, pH, Q, AP, SR, TW, and DO, respectively, refer to total nitrogen,

Station ID	I	Year	n	TN (mg/L)	TP (mg/L)	SC (μS/cm)	pH	Q (m ³ /s)	AP (mbar)	TW (°C)	SR (W/m ²)	DO (mg/L)
USGS-02359170	FL_1	2008-15	79	0.79(0.15)	0.04(0.01)	126.84(20.78)	6.73(0.57)	596.77(334.60)	1017.42(4.09)	20.92(6.68)	722.82(227.94)	7.99(1.91)
USGS-02312600	FL_2	1998-06	18	1.26(0.38)	0.07(0.03)	199.06(105.97)	6.87(0.94)	28.01(30.15)	1016.21(4.26)	20.40(5.77)	498.69(204.72)	4.21(2.43)
USGS-02312500	FL_3	1998-06	30	1.09(0.46)	0.08(0.03)	218.93(86.59)	6.94(0.81)	15.31(16.34)	1015.06(4.64)	21.70(5.39)	611.37(204.25)	5.45(1.60)
USGS-02310947	FL_4	2001-09	32	1.98(0.67)	0.11(0.04)	160.28(73.74)	6.27(0.47)	2.10(2.48)	1013.36(2.66)	22.73(2.95)	573.86(240.05)	4.06(1.31)
USGS-02310300	FL_5	1998-02	16	1.24(0.48)	0.05(0.02)	260.38(99.56)	6.61(0.58)	0.12(0.11)	1016.05(3.39)	21.26(3.43)	628.28(210.24)	4.70(1.03)
USGS-02303000	FL_6	1998-03	20	1.73(0.16)	0.24(0.14)	335.95(59.17)	7.23(0.56)	4.82(3.77)	1015.35(3.49)	23.50(2.76)	609.10(201.53)	6.12(0.86)
USGS-02309445	FL_7	2000-02	23	1.68(0.39)	0.11(0.04)	563.65(85.57)	7.00(0.68)	0.03(0.02)	1017.54(3.20)	23.79(3.13)	515.91(181.96)	6.50(0.72)
USGS-02309425	FL_8	1999-02	31	1.46(0.49)	0.23(0.05)	556.00(68.55)	7.09(0.81)	0.25(0.16)	1018.08(4.11)	22.61(4.75)	493.71(166.61)	7.24(1.11)
USGS-02307671	FL_9	1999-02	32	1.12(0.22)	0.11(0.05)	466.53(63.75)	7.13(0.74)	0.13(0.11)	1018.29(3.79)	22.85(4.51)	423.10(227.75)	5.67(1.29)
USGS-02307731	FL_10	1999-02	27	0.81(0.33)	0.19(0.07)	413.07(81.49)	7.07(0.75)	0.06(0.07)	1018.29(4.32)	22.22(5.00)	437.15(299.33)	5.91(1.16)
USGS-02301300	FL_11	1998-03	34	1.08(0.27)	0.74(0.23)	353.62(65.56)	7.35(0.72)	2.61(3.20)	1014.60(3.12)	22.43(5.01)	614.10(216.97)	7.05(2.17)
USGS-02300100	FL_12	1998-03	30	0.93(0.33)	0.51(0.16)	333.50(128.14)	7.04(0.78)	0.45(0.62)	1014.87(3.67)	21.34(4.36)	695.03(222.61)	7.09(1.37)
USGS-02295420	FL_13	1999-04	33	1.55(0.43)	0.80(0.12)	399.48(51.47)	7.45(0.64)	2.20(2.47)	1018.57(4.83)	22.26(4.63)	635.65(243.41)	7.17(1.29)
USGS-02296750	FL_14	1998-04	42	1.55(0.34)	0.95(0.23)	385.69(104.76)	7.48(0.50)	20.51(19.76)	1016.93(3.98)	23.90(5.40)	710.82(194.65)	7.05(1.40)
USGS-02298123	FL_15	1998-03	26	1.37(0.33)	0.09(0.06)	740.31(221.59)	7.29(0.70)	3.65(3.61)	1017.79(4.92)	23.58(5.28)	484.92(220.56)	6.20(1.69)
*WQX-10MIGR10	FL_16	2009-14	43	1.03(0.33)	0.03(0.01)	11297.21(12091.23)	7.44(0.08)	3.67(3.14)	1017.41(2.95)	25.93(3.40)	664.19(162.04)	5.27(1.04)
*WQX-10MIGR80	FL_17	2009-13	28	1.08(0.29)	0.02(0.01)	690.54(133.87)	7.55(0.23)	0.47(0.27)	1018.58(4.22)	24.03(4.89)	439.18(139.24)	5.86(2.48)
*WQX-46B-9GR	FL_18	2009-14	49	1.06(0.29)	0.02(0.01)	836.82(55.40)	7.37(0.17)	1.82(1.01)	1017.03(2.60)	24.97(2.37)	711.05(186.99)	4.91(1.86)

total phosphorus, specific conductance, potential of hydrogen, flow rate, atmospheric pressure, solar radiation, water temperature, and dissolved oxygen. (4) *21FLEECO STORET water quality station. (5) “I” is station identifier.

3.3 The Data Analytics Framework

A systematic data analytics approach (Figure 2) (Abdul-Aziz and Ahmed, 2017) was utilized to identify the dominant controls of stream DO in the Gulf Coast of U.S.A. Before applying data analytics, the data for all variables were log-transformed (log10) to incorporate any nonlinear correspondences and achieve a relatively constant variance of potential model residuals (i.e. homoscedasticity) (Box and Cox, 1964). The log-transformed data were standardized to compute the respective Z-scores (Abdul-Aziz and Ahmed, 2017) as follows: $Z = (X - \bar{X}) / S_x$, where X = log10-transformed variable, $\bar{X}$ = mean of X , S_x = standard deviation of X . The data centralization and normalization brought different values and units of variables to a common reference scale. First, Pearson's correlation analysis was applied to have a preliminary information on the nonlinear correspondences and multicollinear structure of the datasets. Second, principal component analysis (PCA) was conducted to reduce redundant dimensions, while retaining the variation present in the dataset (Jolliffe, 2002). Third, factor analysis (FA) was applied to reanalyze the standardized data and support findings from PCA by explaining the system data variances with fewer latent variables (factors) (Johnson and Wichern, 1992). Finally, partial least squares regression (PLSR) (Wold et al., 1993, 2001) was applied to estimate the relative linkages and dominant controls of stream DO by appropriately resolving any multicollinearity present in the data matrix. Each layer of data analytics was performed with the standardized data using MATLAB. Further details into the data analytics methods can be found in Abdul-Aziz and Ahmed (2017).

Figure 2: The data analytics framework to determine the relative linkages of stream dissolved oxygen with the dynamic environmental drivers.

PLSR models with a bootstrap Monte Carlo procedure (1000 iterations) were developed to obtain a robust estimation of the relative linkages of stream DO with the dynamic environmental drivers. The PLSR models were trained (i.e., fitted) and verified (i.e., tested) with the observed data using SIMPLS algorithm (de Jong, 1993) and a 10-fold cross-validation (Kuhn and Johnson, 2013). The optimality of the models was achieved by involving a minimum number of partial least squares (PLS) components, which was determined based on a synthesis of eigenvalue ≥ 1 , maximum Nash-Sutcliffe Efficiency (NSE), and minimum Akaike Information Criterion (AIC) (Akaike, 1974). The developed model's goodness-of-fit was measured by NSE, and the accuracy of predictions was evaluated by the ratio of root-mean-square error to the standard deviation of

observations (RSR). Each PLS component was a combination of all original environmental predictors of DO. The estimated, optimal PLSR models were therefore transformed back to the original (Z-scores) variable domain to compute the relative linkages (i.e., regression weights, β) of stream DO with the dynamic environmental drivers. The positive or negative sign of ' β ' indicated the direction of relationship (i.e., increasing or decreasing) between predictors and stream dissolved oxygen. Based on mechanistic understanding, the dynamic drivers of DO were grouped in four environmental process-components: (1) 'climate' (TW and SR), (2) 'hydroatmospheric' (Q and AP), (3) 'redox' (pH and SC), and (4) 'nutrients' (TN and TP). The aggregated linkages (β_C), (β_H), (β_R), and (β_N) for, respectively, the climatic, hydro-atmospheric, redox, and nutrient components were computed using the method of vector summation as follows:

$$\beta_C = \sqrt{\beta_{TW} + \beta_{SR}} \quad (1)$$

$$\beta_H = \sqrt{\beta_Q + \beta_{AP}} \quad (2)$$

$$\beta_R = \sqrt{\beta_{pH} + \beta_{SC}} \quad (3)$$

$$\beta_N = \sqrt{\beta_{TN} + \beta_{TP}} \quad (4)$$

CHAPTER 4

RESULTS

4.1 Mutual Correspondences of the Dynamic Environmental Drivers

The nonlinear correspondences of stream DO with the dynamic environmental drivers were first determined by computing the Pearson correlation coefficients (Table A1) with the $\log_{10}$ -transformed and standardized data. Three regions were identified based on dominant correlations of stream DO with the predictors. In the northern part of the Gulf Coast States (NGCS), 17 streams showed strong correlations between TW and DO. However, 3 streams in the southern part of the Gulf coast (SGCS) showed a notable correlation of TW and pH with stream DO. Further, 16 streams located between these two regions (i.e., in the “transition” region) demonstrated notable influence of multiple drivers (i.e., Q, SC, and TW) on stream DO. The results were further summarized by computing region-specific average correlation coefficients (Table 2).

In the northern part of the Gulf coast states, stream DO had a strong negative correspondence with TW ($r = -0.75$), representing a water temperature dominated environmental regime of stream DO. In contrast, in the southern part of the Gulf coast region (southern Texas and south-western Florida), DO had a strong positive correlation with pH ($r = 0.62$), whereas moderate correlation with TW ($r = -0.49$). Streams in the transition region were grouped into two environmental regimes: Q-dominated and SC-dominated. In the flow rate dominated regime, stream DO had strong correlations with Q ($r = -0.75$) and TP ($r = -0.60$), whereas moderate correlation with pH ($r = 0.49$), TW ($r = -0.48$), and SC (0.41). In specific conductance dominated regime, stream DO had a strong negative correlation with SC ($r = -0.73$), whereas moderate correlations with Q ($r = 0.58$), pH ($r = -0.49$), and TW ($r = -0.40$).

The correlation matrices (Table A2 to A5) showed strong mutual correspondences, indicating the presence of high multicollinearity among the dynamic environmental drivers. For example, flow rate had moderate to strong correlation with TP ($r = 0.50$) and SC ($r = -0.80$). The negative correspondence indicates that SC decreased with increasing flow rate (i.e. dilution effect). In contrast, flow rate had a positive correlation with total phosphorus, this indicates that the concentration of TP increases with increasing flow rate (i.e., hydrologic effect due to increased runoff and sediment load). These findings were corroborated using scatter-plotting of flow rate with total phosphorus (Figure A1). AP had a moderate to strong correlation with SR ($r = -0.46$) and TW ($r = -0.63$). The negative correspondences indicated that atmospheric pressure reduces with increasing atmospheric temperature. TW had moderate positive correspondence with TP ($r = 0.59$), indicating that TP increased with increasing metabolism as temperature of water increases.

Table 2: Ensemble mean Pearson correlation coefficients (r) of dissolved oxygen with dynamic environmental drivers of the three regions.

Region	Regimes	TN	TP	SC	pH	Q	AP	TW	SR
NGCS	TW dominated	-0.03	-0.23	0.06	0.17	-0.08	0.31	-0.75	-0.23
Transition	Q dominated	0.13	-0.60	0.41	0.49	-0.75	0.32	-0.48	-0.06
	SC dominated	-0.09	-0.25	-0.73	-0.49	0.58	0.33	-0.40	-0.12
SGCS	pH dominated	0.00	-0.16	0.14	0.62	-0.25	0.29	-0.49	-0.13

Note: (1) Data of all variables were log10-transformed to incorporate the non-linear interaction. (2) TN, TP, SC, pH, Q, AP, TW, and SR, respectively, refer to total nitrogen, total phosphorus, specific conductance, potential of hydrogen, flow rate, atmospheric pressure, water temperature, and solar radiation. (3) NGCS refers to Northern part of Gulf coast states. (4) SGCS refers to Southern part of Gulf coast states.

4.2 Relative Orientations and Interrelations of Stream DO with the Dynamic Environmental Drivers

The nonlinear loadings of stream DO and various environmental drivers on the first two PCs are presented through biplots for four example streams, representing the four environmental regimes of stream DO across the U.S. Gulf Coast. The percentage variance explained by all individual PCs for each stream (Table A6) indicated that the first two PCs explained approximately 47% to 72% of the total data variance. Based on the orientation or linkages of dynamic environmental drivers with stream DO (Figure A2 to A5), stations were grouped into three regions, which were similar to that identified by the Pearson's correlation analyses.

In the northern part of the Gulf coast states, the first two PCs explained 48% to 72% of the total data variance. The orientations and lengths of TW and SR suggested their strong interrelationship, forming a negative linkage with DO (Figure 3a). Moreover, pH had a moderate negative linkage with DO. In contrast, AP, TN, and Q had moderate positive linkages with DO. Further, SC and TP had an orthogonal orientation with the response (DO), representing relatively weak or no linkage. In the southern part of the Gulf Coast region (southern Texas and southwestern Florida), the first two PCs explained 47% to 52% of the total data variance. The orientation and length of pH suggested its strong positive linkage with DO (Figure 3d). Moreover, AP had moderate positive linkage with DO. In contrast, Q, TW, and SC had moderate/strong negative linkages with DO.

Streams in in the “transition” region showed mixed dominance of Q, SC, and TW on DO. In flow rate dominated regime, the first two PCs explained 62% of the total data variance. The orientation and length of TP and Q suggest their strong interrelationship, forming a strong negative linkage with DO (Figure 3b). Moreover, TW and SR had strong interrelationship, forming a

moderate negative linkage with DO. In contrast, SC, AP, pH, and TN had moderate positive linkages with DO. In specific conductance dominated regime, the first two PCs explained 58% to 64% of the total data variance exhibited by the dynamic environmental drivers. The orientation and length of SC, pH, and TN suggest their strong interrelationships, forming a negative linkage with DO (Figure 3c). Moreover, DO had a moderate negative linkage with TW and a strong positive linkage with Q for streams located in this regime.

The biplots (Figure 3) also showed the strong interrelationships among the dynamic environmental drivers of stream DO, indicating the presence of multicollinearity in data. The orientations and lengths of Q, TP, and TN (Figure 3a) showed their strong interrelationships, indicating that flow rate brings in nitrogen and phosphorus from the agricultural area (i.e. hydrologic effect). The orientations and lengths of TW and SR (Figure 3b) suggested their strong interrelationships, given that SR is the primary source of energy that causes stream heating.

Figure 3: Representative biplots of the three regions obtained from principal component analysis, showing the interrelations of dissolved oxygen with dynamic environmental drivers: (a) TW dominated regime, (b) Q dominated regime, (c) SC dominated regime, and (d) pH dominated regime.

4.3 Major Water Quality Drivers Based on Independent Latent Factors

Three regions were identified based on streams that showed similar dominant controls of DO based on FA. The identified regions were consistent with the Pearson correlation analyses and PCA. FA results are shown for example stations to represent different environmental regimes within the three regions across the Gulf Coast (Table 3). Higher loadings of DO and the dynamic environmental drivers on the same factors indicates their strong interrelations.

In the northern part of the Gulf coast states, FA resulted in three to four independent latent factors to optimally demonstrate the hidden patterns in stream dissolved oxygen with the dynamic environmental drivers (Table 3). The 3 to 4 latent factors explained 61% to 88% of the total data variance. DO and TW typically loaded highly on factor 1 for most streams in this region (Table A7).. On average across the NGCS region, stream DO loaded very strongly on factor 1 (0.99), which had a high loading of water temperature (-0.93) and a notable loading of SR (-0.34) and pH (0.36) (Table 3); however, the loadings of DO on factor 2 and 3 were very weak.

In the southern part of the Gulf coast states (southern Texas and south-western Florida), FA resulted in 3 independent latent factors to optimally demonstrate the hidden patterns of stream dissolved oxygen with the dynamic environmental drivers (Table 3). The 3 latent factors explained 61% to 67% of the total data variance. Two streams in this region showed that DO moderately loaded on factor 1, whereas a single stream showed that stream DO loaded highly on factor 2 (Table A7). On average across the SGCS region, stream DO strongly loaded on factor 1 (0.73), which had a high loading of pH (0.96) and moderate loading of Q (-0.50) (Table 3).

Streams in in the “transition” region showed dominance of multiple drivers (i.e., Q, SC., and TW) on DO. In flow rate dominated regime, FA resulted in 3 independent latent factors to optimally demonstrate the hidden patterns of stream DO in relation to the dynamic environmental

drivers (Table 3). The 3 independent latent factors explained 72.54% of the total data variance. Dissolved oxygen highly loaded on factor 1 (0.87), which had a high loading of Q (-0.98) and moderate loading of TP (-0.55) and pH (0.63). Moreover, DO notably loaded on factor 3 (-0.45), which had a high loading of TW (0.72). In specific conductance dominated regime, FA resulted in 3 independent latent factors to optimally demonstrate the hidden patterns in data (Table 3). The 3 independent latent factors explained 73% to 81% of the total data variance. DO strongly loaded on factor 1 (-0.68), which had high loadings of SC (0.98) and Q (-0.84).

Table 3: Representative factors with their optimized loading on stream DO and corresponding dynamic environmental drivers of the identified three regions.

Regions	Regimes	F	TN	TP	SC	pH	Q	AP	TW	SR	DO
NGCS	TW dominated	1	-0.04	0.02	-0.17	0.36	0.03	0.24	-0.93	-0.34	0.99
		2	-0.01	-0.28	0.89	0.59	-0.88	0.07	0.24	0.06	0.09
		3	1.00	0.37	0.15	-0.07	0.19	-0.04	0.02	0.11	-0.04
Transition	Q dominated	1	0.34	-0.55	0.30	0.63	-0.98	0.07	-0.06	0.16	0.87
		2	-0.09	0.45	-0.26	0.10	-0.03	-0.92	0.56	0.45	-0.20
		3	0.41	0.07	-0.20	0.07	-0.20	-0.16	0.72	0.25	-0.45
	SC dominated	1	0.31	-0.18	0.98	0.52	-0.84	0.14	-0.05	0.00	-0.68
		2	-0.02	0.98	-0.20	-0.21	0.09	-0.46	0.57	0.16	-0.04
		3	-0.43	-0.12	0.05	-0.19	-0.13	0.75	-0.29	0.35	0.29
SGCS	pH dominated	1	-0.09	-0.06	-0.37	0.96	-0.50	0.18	-0.30	0.19	0.73
		2	0.23	0.00	-0.09	0.24	-0.03	0.98	-0.50	-0.24	0.05
		3	0.55	0.62	-0.14	-0.11	0.06	0.04	-0.34	-0.44	0.15

Note: (1) Bold value indicated variables having moderate to high loading on factor (F); F1-3 refers to three independent factors, (2) TN, TP, SC, pH, Q, AP, SR, and DO respectively refers to total nitrogen, total phosphorus, specific conductance, potential of hydrogen, flow rate, atmospheric pressure, water temperature, solar radiation, and dissolved oxygen. (3) NGCS refers to Northern part of Gulf coast states. (4) SGCS refers to Southern part of Gulf coast states.

4.4 Estimation of the Relative Linkages of Stream DO with the Predictors

The optimality of PLSR models was achieved based on the synthesis of the minimum AIC, maximum NSE, and eigenvalue ≥ 1 criteria, which suggested the first 3 to 4 PLS components (Figure 4). The models were robustly estimated with a 10-fold cross-validation method; the optimal models provided good predictions (Figure A8). The model intercept was “zero” for all stations since Z-score variables were used for model fitting. From PLSR results (Table A8), streams that have similar dominant drivers of stream DO were grouped into three regions and environmental regimes (Figure A6). The PLSR results were explained based on the mean of beta linkages for each region (Table 4).

Figure 4: Plot of cross-validated (a) normalized AIC, (b) Eigenvalue, and (c) Nash-Sutcliffe efficiency (NSE) with the number of incorporated partial least square components of all stations.

In the northern part of the Gulf coast states, DO had the strongest negative linkages with TW ($\beta_{TW} = -0.74$). Notable linkages of DO were also apparent with TP ($\beta_{TP} = -0.13$) and pH ($\beta_{pH} = 0.11$). Based on the aggregated linkages (Eqs. 3-6), the climate components showed 2.7, 3.1, and 3.6 times stronger linkages with dissolved oxygen than that of the redox, nutrient, and hydro-atmospheric components, respectively (Table 5). In contrast, for the southern part of the Gulf coast states (Southern Texas and south-west Florida), stream DO had strong positive linkages with pH ($\beta_{pH} = 0.56$). Notable linkages of DO were also apparent with TW ($\beta_{TW} = -0.35$) and SC ($\beta_{SC} = 0.16$) in this region. Based on the aggregated beta linkages, the redox components showed 1.6, 2.3, and 2.6 times stronger linkages with dissolved oxygen than that of the climate, nutrients, and hydroatmospheric components, respectively (Table 5).

Streams in the transition region showed multiple dominant drivers (i.e., Q and SC) of DO along with water temperature. The transition region was divided into two environmental regimes. In the flow rate dominated regime, DO had strong linkages with TW ($\beta_{TW} = -0.49$) and Q ($\beta_Q = -0.58$). Notable linkages of DO were also apparent with SC ($\beta_{SC} = 0.20$), pH ($\beta_{pH} = 0.20$), and TN ($\beta_{TN} = -0.11$). Based on the aggregated linkages, the hydro-atmospheric components showed 1.2, 2.0, and 3.4 times stronger linkages with dissolved oxygen than that of the climate, redox, and nutrient components, respectively (Table 5). In specific conductance dominated regime, DO had the strongest linkages with SC ($\beta_{SC} = -0.43$). Notable linkages of DO were also apparent with TW ($\beta_{TW} = -0.23$) and Q ($\beta_Q = 0.21$). Based on the aggregated linkages, the redox components showed 1.3, 1.4, and 1.6 times stronger linkages with dissolved oxygen than that of the hydroatmospheric, climate, and nutrient components, respectively (Table 5).

Table 4: Ensemble mean and standard deviation (in parenthesis) of the beta linkages after 1000 Monte Carlo simulations for the identified regions.

Regions	NGCS		Transition		SGCS
	TW dominated	Q dominated	SC dominated		pH dominated
TN	0.01 (0.11)	-0.11 (0.09)	-0.01 (0.21)		-0.08 (0.13)
TP	-0.13 (0.11)	-0.09 (0.10)	-0.06 (0.16)		-0.07 (0.12)
SC	0.03 (0.10)	0.20 (0.09)	-0.43 (0.13)		0.16 (0.11)
pH	0.11 (0.12)	0.20 (0.11)	-0.02 (0.15)		0.56 (0.11)
Q	-0.03 (0.11)	-0.58 (0.13)	0.21 (0.16)		0.03 (0.12)
AP	0.01 (0.11)	-0.06 (0.10)	0.11 (0.21)		-0.02 (0.12)
TW	-0.74 (0.12)	-0.49 (0.13)	-0.23 (0.20)		-0.35 (0.12)
SR	-0.02 (0.11)	0.04 (0.12)	-0.01 (0.14)		0.04 (0.13)
Model Statistics					
*OPC	3-4	3	3		3
NSE	0.80	0.90	0.80		0.68
RSR	0.43	0.28	0.41		0.56

Note: (1) *OPC refers to the number of optimum partial least square components. (2) TN, TP, SC, pH, Q, AP, TW, and SR respectively, refer to total nitrogen, total phosphorus, specific conductance, potential of hydrogen, flow rate, atmospheric pressure, water temperature, and solar radiation. (3) NGCS refers to Northern part of Gulf coast states. (4) SGCS refers to Southern part of Gulf coast states.

Table 5: Aggregated relative linkages of the process components for the four regimes after 1000 Monte Carlo simulation with mean and standard deviation (in parenthesis).

Aggregated components	TW dominated	Q dominated	SC dominated	pH dominated
β_C	0.77 (0.12)	0.51 (0.10)	0.33 (0.15)	0.38 (0.12)
β_H	0.21 (0.09)	0.59 (0.13)	0.34 (0.14)	0.23 (0.10)
β_R	0.28 (0.10)	0.30 (0.09)	0.46 (0.13)	0.59 (0.11)
β_N	0.25 (0.09)	0.18 (0.08)	0.28 (0.14)	0.26 (0.09)
Ratio to the Strongest β				
	$\beta_C/\beta_H=3.6$	$\beta_H/\beta_C=1.2$	$\beta_R/\beta_C=1.3$	$\beta_R/\beta_C=1.6$
	$\beta_C/\beta_R=2.7$	$\beta_H/\beta_R=2.0$	$\beta_R/\beta_H=1.4$	$\beta_R/\beta_H=2.6$
	$\beta_C/\beta_N=3.1$	$\beta_H/\beta_N=3.4$	$\beta_R/\beta_N=1.6$	$\beta_R/\beta_N=2.3$

Note: (1) The aggregated relative linkages of the ‘climate components’ (β_C), ‘hydroatmospheric components’ (β_H), ‘redox components’ (β_R), and the ‘nutrient components’ (β_N) were calculated, respectively, by using Eqs. 1-4.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

5.1 Discussion

Based on the finding from the systematic data analytics approach, streams were grouped into three regions along the U.S. Gulf Coast (Figure 7A). In the Northern part of Gulf Coast states (Texas, Louisiana, Mississippi, Alabama, and West Florida), water temperature (and the climate process component) had the strongest control on stream DO. However, in the southern part of Texas and Florida, clear dominance of pH and the redox component on stream DO were found. Further, streams in between this two regions (i.e., in the “transition” region) showed mixed dominance of multiple drivers (e.g., water temperature, TW; flow rate, Q; specific conductivity, SC) on the DO.

The strong negative linkages of stream dissolved oxygen with water temperature in the northern part of Gulf Coast states can be attributed to the reduction of solubility of DO at higher temperature. As water temperature increases, the solubility of dissolved oxygen reduces; warm water becomes more easily saturated with oxygen, and the oxygen holding capacity reduces (Schaefer and Hollibaugh, 2017). Further, low DO in warm streams can also be contributed by high microbial activities (e.g., respiration) and degradation of organic matter (Mulholland et al., 1997; Hsiao et al., 2014). In this study, most streams did not show any notable linkage between solar radiation (SR) and stream DO. However, the effect of SR may be indirectly reflected by water temperature (TW), because SR is the principal energy source that causes stream heating. Further, the effect of SR is typically more clearly reflected in the diurnal cycle of stream DO (Abdul-Aziz and Ishtiaq, 2014), whereas datasets in this study represented monthly and seasonal samples. The impact of atmospheric pressure on stream DO was also not notable in this analysis, because data of AP did include much variation during the multi-year study period. Further, there was also a weak linkage of stream DO with nutrients in this region. Especially, TN had a very

linkage with stream DO. Instead, TP had a noteworthy negative linkage with stream DO. This may be linked to the role of TP as the limiting nutrient in coastal streams (Dodds, 2006). High TP could potentially stimulate phytoplankton growth, which typically leads to higher organic matter, increased microbial respiration and decomposition, and a reduction in stream DO (Ice, 2008; Wang et al., 2014).

Streams located in the southern part of Texas and Florida showed a dominant pH control on stream DO. In this region, temperature of water were always high and relative less variable, and therefore the impact of TW was not as strong as that of the northern Gulf states. The reduced linkage of TW and DO could also be caused by excessive sunlight (i.e., photo inhibition; see Demmig-Adams and Adams lii, 1992) in this region. Instead, the notable positive linkages of pH with DO might have shown the effect of aquatic plant's photosynthesis on stream DO. During photosynthesis, stream plants absorb carbon dioxide and release oxygen, ultimately increasing the pH (i.e., decreasing CO₂) of the stream (Bowmer and Muirhead, 1987; Petersen et al., 2001; Haag and Westrich, 2002). Moreover, warm water can have a high pH due to the conversion of CO₂ to organic carbon by plant photosynthesis (King, 1970). The notable positive linkages of stream specific conductivity (SC) with DO indicated that a high salinity (represented by SC) can hinder the proliferation of algal blooms and eutrophication in coastal streams.

Streams in the transition region of the Gulf Coast showed controls of multiple drivers (i.e., stream flow, water temperature, and specific conductance) on stream DO. This region is located between 27°00'00"N and 29°00'00"N latitudes, which represents cold winters similar to the upper part of U.S.A and hot summer similar to the equatorial area. The two contrasting climate patterns, in concert with a complex mix of developed (e.g., urban, agriculture) and undeveloped (wetlands, open spaces) land uses, might have led to the mixed controls of stream DO in this "transitional"

region. Flow rate (Q) had a strong negative linkage with DO. Factor analysis (Table 3) showed that flow rate (Q) and total phosphorus (TP) loaded highly on factor 1, suggesting that flow rate might have brought total phosphorus from agriculture area or urban sewage (Petersen et al., 2001; Banner et al., 2009). The maximum extent of hypoxia in the Gulf of Mexico is due to the high flow rate, which increases the density of stratification and eutrophication (Mulholland et al., 1997). Drewry et al. (2009) also found a positive correlation between discharging stream flow and TP of an estuary in Australia. Higher algal growth with increasing TP and a subsequent decomposition of organic matter might have consumed the available stream DO. In addition, Kennicutt (2017) found a high concentration of dissolved inorganic phosphorus in Tampa Bay due to the natural occurrence of phosphate rocks and anthropogenic activities in the draining watershed. Some streams in the “transition” region showed a strong negative linkage of specific conductance and DO. As salinity (SC) increases, the solubility of DO reduces, and stress for plant’s photosynthesis increases (Pezeshki et al., 1989; Rietz and Haynes, 2003; Timpano et al., 2015). Datta and Sharma (1990) found that chlorophyll a content of leaves reduces under saline condition. The remaining streams in this region showed that water temperature had moderate to strong negative linkage with stream DO.

The estimated relative linkages can be used in identifying of management plans and targets to achieve a health stream ecosystem along the U.S. Gulf Coast and beyond. Since the climate components are the most dominant driver of DO in most streams (Figure 7A), restoration strategies and management activities should be designed to counteract the rapid change in atmospheric temperature. For example, riparian vegetation should be preserved or planted along the streams to increase shading and mitigate excessive warming of streams through solar radiation. Moreover, stream temperature is also affected by urban heat island effect, which could be mitigated by

decreasing imperviousness and increasing green developments in the draining watersheds. The flow rate is the main contributor of in-stream nutrients, a major reduction of nutrients can be achieved by adding engineering solutions (e.g., detention ponds) and implementing best management practices.

5.2 Conclusions

The temporal relative linkages of stream dissolved oxygen with the dynamic environmental drivers were reliably estimated across the U.S. Gulf Coast by resolving multicollinearity through a systematic data analytics approach. Based on findings, streams were grouped into three regions across the U.S. Gulf Coast. In the northern part of Gulf Coast states (Texas, Louisiana, Mississippi, Alabama, and West Florida), water temperatures had the strongest and dictated control on stream DO. However, in the southern part of Texas and Florida coasts, pH showed the most dominant control on stream DO. Further, streams in between these two regions demonstrated notable controls of multiple drivers (water temperature, stream flow, and specific conductance) on DO. Four dynamic process components adequately described the system data variance in all three regions along the Gulf Coast. For example, the ‘climate component’ (temperature, solar radiation) in the northern part of Gulf Coast showed 2.7, 3.1, and 3.6 times stronger linkages with stream DO than that of the redox (pH, specific conductance), nutrient (total nitrogen, total phosphorus), and hydro-atmospheric (flow rate, atmospheric pressure) components, respectively. In contrast, in the southern part of Gulf Coast region, the redox components showed 1.6, 2.3, and 2.6 times stronger linkages with stream DO than that of the climate, nutrient, and hydro-atmospheric components, respectively. The identified environmental regimes and estimated linkages of stream DO provided important information into the dominant drivers and dynamic process components of water quality

in urban/natural streams across the U.S. Gulf Coast. The knowledge and insights would help coastal managers and stakeholders to achieve a good stream water quality and ecosystem health.

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APPENDIX A

Table A1: Correlation coefficients of stream DO with the dynamic environmental predictors for the selected water quality monitoring stations along the U.S. Gulf Coast.

Station	I	TN	TP	SC	pH	Q	AP	TW	SR
USGS-08475000	TX_1	0.17	-0.06	0.26	0.51	-0.11	0.10	-0.54	-0.13
USGS-08459200	TX_2	0.20	0.05	0.29	0.36	-0.13	0.22	-0.76	-0.35
USGS-08042554	TX_3	0.22	-0.28	0.19	0.64	-0.13	0.37	-0.79	-0.24
USGS-08042546	TX_4	0.27	0.03	0.12	0.07	0.01	-0.11	-0.76	-0.36
USGS-08116650	TX_5	0.18	0.11	0.26	0.25	-0.21	0.16	-0.49	-0.01
USGS-08070200	TX_6	-0.21	-0.42	0.07	0.10	0.31	0.42	-0.90	-0.28
USGS-08012150	LS_1	-0.22	-0.18	-0.46	-0.25	0.32	0.14	-0.71	0.07
USGS-08014500	LS_2	0.00	-0.34	0.01	0.06	-0.01	0.36	-0.68	-0.26
USGS-07381590	LS_3	0.01	-0.10	-0.09	0.33	-0.15	0.34	-0.85	-0.35
USGS-07381495	LS_4	-0.12	-0.08	-0.15	0.18	-0.09	0.38	-0.84	-0.32
USGS-07381600	LS_5	0.06	-0.08	-0.01	0.38	-0.23	0.35	-0.82	-0.36
USGS-07373420	LS_6	-0.20	-0.07	-0.09	0.15	-0.09	0.32	-0.87	-0.41
USGS-07374000	LS_7	-0.08	-0.02	-0.10	0.42	-0.05	0.24	-0.90	-0.34
USGS-07374525	LS_8	-0.03	0.11	-0.11	0.33	-0.03	0.45	-0.91	-0.21
USGS-02470500	AL_1	0.05	-0.14	0.12	0.38	-0.12	0.26	-0.62	-0.16
USGS-02469762	AL_2	0.33	0.29	-0.21	-0.23	0.27	0.38	-0.86	-0.39
USGS-02429500	AL_3	0.23	-0.09	-0.03	-0.33	0.21	0.15	-0.85	-0.32
21AWIC-7870	AL_4	-0.18	-0.17	-0.06	0.50	-0.15	0.27	-0.94	-0.19

Note: (1) TX, LS, and AL, respectively, refers to stations in Texas, Louisiana, and Alabama. (2) * STORET water quality station. (3) Bold value indicates moderate to strong correlation. (4) “I” is station identifier.

Table A1 (continued): Correlation result of predictors with stream DO for each water quality monitoring stations across the Gulf Coast.

Station	I	TN	TP	SC	pH	Q	AP	TW	SR
USGS-02359170	FL_1	0.28	-0.29	0.02	-0.23	0.06	0.30	-0.66	-0.36
USGS-02312600	FL_2	-0.43	-0.57	0.19	0.04	-0.09	0.33	-0.67	-0.32
USGS-02312500	FL_3	-0.57	-0.65	0.63	0.54	-0.51	0.56	-0.61	-0.05
USGS-02310947	FL_4	-0.34	0.05	-0.64	-0.35	0.48	0.13	-0.11	0.09
USGS-02310300	FL_5	0.13	-0.60	0.41	0.49	-0.75	0.32	-0.48	-0.06
USGS-02303000	FL_6	0.43	-0.76	0.68	0.10	-0.62	0.68	-0.87	-0.36
USGS-02309445	FL_7	-0.42	-0.41	0.19	-0.12	-0.08	0.13	-0.54	0.05
USGS-02309425	FL_8	0.25	-0.34	0.40	0.00	-0.23	0.35	-0.71	-0.28
USGS-02307671	FL_9	-0.28	-0.35	-0.12	0.06	0.20	0.10	-0.59	-0.07
USGS-02307731	FL_10	-0.07	-0.44	0.11	-0.03	0.05	0.21	-0.76	-0.10
USGS-02301300	FL_11	0.16	-0.55	-0.82	-0.63	0.69	0.53	-0.69	-0.33
USGS-02300100	FL_12	-0.37	-0.41	-0.11	0.08	-0.37	0.42	-0.80	0.02
USGS-02295420	FL_13	-0.20	-0.11	0.23	0.43	-0.24	0.57	-0.88	0.00
USGS-02296750	FL_14	-0.32	-0.18	0.25	0.36	-0.29	0.29	-0.54	-0.34
USGS-02298123	FL_15	-0.26	-0.71	0.10	0.22	-0.42	0.50	-0.86	-0.38
21FLEECO_WQX	FL_16	-0.22	-0.42	0.29	0.64	-0.33	0.59	-0.53	-0.34
21FLEECO_WQX	FL_17	0.41	-0.30	-0.47	0.43	0.26	0.21	-0.51	-0.20
21FLEECO_WQX	FL_18	0.05	0.00	-0.14	0.70	-0.31	0.19	-0.41	0.08

Note: (1) FL refers stations in Florida. (2) *21FLEECO STORET water quality station. (3) Bold value indicates moderate to strong correlation. (4) “I” is station identifier.

Table A2: Ensemble mean triangular matrices and mutual correlation of the dynamic environmental drivers for the TW dominated regime.

	TN	TP	TW	SC	pH	Q	AP	SR	DO
TN	1.00	0.35	-0.03	0.00	-0.10	0.13	-0.03	-0.02	-0.03
TP	0.35	1.00	0.14	-0.14	-0.13	0.22	-0.07	0.07	-0.23
TW	-0.03	0.14	1.00	0.08	0.00	-0.06	-0.45	0.28	-0.75
SC	0.00	-0.14	0.08	1.00	0.39	-0.57	0.11	0.02	0.06
pH	-0.10	-0.13	0.00	0.39	1.00	-0.34	0.12	0.00	0.17
Q	0.13	0.22	-0.06	-0.57	-0.34	1.00	-0.14	-0.01	-0.08
AP	-0.03	-0.07	-0.45	0.11	0.12	-0.14	1.00	-0.05	0.31
SR	-0.02	0.07	0.28	0.02	0.00	-0.01	-0.05	1.00	-0.23
DO	-0.03	-0.23	-0.75	0.06	0.17	-0.08	0.31	-0.23	1.00

Note: (1) TN, TP, SC, pH, Q, AP, TW, SR and DO respectively, refer to total nitrogen, total phosphorus, specific conductance, potential of hydrogen, stream flow, atmospheric pressure, water temperature, solar radiation, dissolved oxygen.

Table A3: Triangular matrices and mutual correlation of the dynamic environmental drivers for the Q dominated regime.

	TN	TP	TW	SC	pH	Q	AP	SR	DO
TN	1.00	-0.26	0.12	-0.21	0.31	-0.41	0.03	0.18	0.13
TP	-0.26	1.00	0.35	-0.20	-0.38	0.50	-0.46	0.13	-0.60
TW	0.12	0.35	1.00	-0.23	0.10	-0.11	-0.63	0.36	-0.48
SC	-0.21	-0.20	-0.23	1.00	-0.09	-0.25	0.32	-0.26	0.41
pH	0.31	-0.38	0.10	-0.09	1.00	-0.63	-0.05	0.30	0.49
Q	-0.41	0.50	-0.11	-0.25	-0.63	1.00	-0.01	-0.23	-0.75
AP	0.03	-0.46	-0.63	0.32	-0.05	-0.01	1.00	-0.46	0.32
SR	0.18	0.13	0.36	-0.26	0.30	-0.23	-0.46	1.00	-0.06
DO	0.13	-0.60	-0.48	0.41	0.49	-0.75	0.32	-0.06	1.00

Note: (1) TN, TP, SC, pH, Q, AP, TW, SR and DO respectively, refer to total nitrogen, total phosphorus, specific conductance, potential of hydrogen, stream flow, atmospheric pressure, water temperature, solar radiation, dissolved oxygen.

Table A4: Ensemble mean triangular matrices and mutual correlation of the dynamic environmental drivers for the SC dominated regime.

	TN	TP	TW	SC	pH	Q	AP	SR	DO
TN	1.00	-0.05	0.10	0.14	0.32	0.03	0.06	-0.23	-0.09
TP	-0.05	1.00	0.59	-0.01	0.02	-0.02	-0.33	0.41	-0.25
TW	0.10	0.59	1.00	0.20	0.35	0.05	-0.43	0.22	-0.40
SC	0.14	-0.01	0.20	1.00	0.58	-0.80	-0.07	-0.01	-0.73
pH	0.32	0.02	0.35	0.58	1.00	-0.38	-0.25	0.14	-0.49
Q	0.03	-0.02	0.05	-0.80	-0.38	1.00	0.11	-0.05	0.58
AP	0.06	-0.33	-0.43	-0.07	-0.25	0.11	1.00	-0.01	0.33
SR	-0.23	0.41	0.22	-0.01	0.14	-0.05	-0.01	1.00	-0.12
DO	-0.09	-0.25	-0.40	-0.73	-0.49	0.58	0.33	-0.12	1.00

Note: (1) TN, TP, SC, pH, Q, AP, TW, SR and DO respectively, refer to total nitrogen, total phosphorus, specific conductance, potential of hydrogen, stream flow, atmospheric pressure, water temperature, solar radiation, dissolved oxygen.

Table A5: Ensemble mean triangular matrices and mutual correlation of the dynamic environmental drivers for the pH dominated regime.

	TN	TP	TW	SC	pH	Q	AP	SR	DO
TN	1.00	0.23	-0.34	0.04	-0.03	0.10	0.09	-0.12	0.00
TP	0.23	1.00	-0.06	-0.09	-0.19	0.19	-0.10	-0.18	-0.16
TW	-0.34	-0.06	1.00	-0.04	-0.25	0.17	-0.53	0.36	-0.49
SC	0.04	-0.09	-0.04	1.00	-0.04	-0.07	-0.01	-0.07	0.14
pH	-0.03	-0.19	-0.25	-0.04	1.00	-0.33	0.20	-0.08	0.62
Q	0.10	0.19	0.17	-0.07	-0.33	1.00	-0.21	0.03	-0.25
AP	0.09	-0.10	-0.53	-0.01	0.20	-0.21	1.00	-0.29	0.29
SR	-0.12	-0.18	0.36	-0.07	-0.08	0.03	-0.29	1.00	-0.13
DO	0.00	-0.16	-0.49	0.14	0.62	-0.25	0.29	-0.13	1.00

Note: (1) TN, TP, SC, pH, Q, AP, TW, SR and DO respectively, refer to total nitrogen, total phosphorus, specific conductance, potential of hydrogen, stream flow, atmospheric pressure, water temperature, solar radiation, dissolved oxygen.

Table A6: Percent variance explained by each principal components (PC) for each water quality monitoring stations along the Gulf Coast states.

Stations	I	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
USGS-08475000	TX_1	26.51	20.08	13.65	11.84	8.43	6.66	5.72	4.64
USGS-08459200	TX_2	30.27	24.05	11.60	10.42	8.24	6.32	5.45	2.00
USGS-08042554	TX_3	35.28	29.64	9.59	8.45	5.62	4.62	4.28	1.73
USGS-08042546	TX_4	48.69	23.00	14.85	5.12	4.57	1.55	1.26	0.75
USGS-08116650	TX_5	42.42	20.59	12.88	10.59	7.77	3.04	1.64	0.72
USGS-08070200	TX_6	32.62	18.70	15.95	10.92	7.38	6.08	4.67	2.69
USGS-08012150	LA_1	40.84	16.83	16.20	10.75	7.30	3.87	2.18	1.68
USGS-08014500	LA_2	36.07	22.40	14.96	10.16	6.14	5.13	2.76	1.63
USGS-07381590	LA_3	28.61	25.81	14.33	9.48	8.62	5.86	4.12	2.62
USGS-07381495	LA_4	28.82	23.59	14.84	9.74	7.45	7.01	5.35	2.35
USGS-07381600	LA_5	27.24	26.68	15.37	9.32	8.20	5.17	4.36	3.00
USGS-07373420	LA_6	27.95	23.40	13.79	10.98	8.65	7.01	5.67	1.76
USGS-07374000	LA_7	27.07	25.86	14.75	10.68	8.82	5.91	4.86	1.59
USGS-07374525	LA_8	30.47	26.72	12.93	10.51	7.41	5.86	4.21	1.48
USGS-02470500	AL_1	37.32	22.06	12.55	10.94	7.25	3.89	3.34	1.74
USGS-02469762	AL_2	45.09	20.90	10.32	6.98	6.00	5.39	3.01	1.45
USGS-02429500	AL_3	37.42	20.52	14.15	10.80	6.73	4.15	3.46	2.13
*21AWIC-7870	AL_4	32.78	18.19	15.20	12.30	7.18	6.39	5.99	1.55

Note: (1) TX, LS, and AL, respectively, refers to stations in Texas, Louisiana, and Alabama. (2) * STORET water quality station. (3) “I” is station identifier.

Table A6 (continued): Percent variance explained by each principal components (PC) for each water quality monitoring stations along the Gulf Coast states.

Stations	I	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
USGS-02359170	FL_1	34.90	24.31	11.20	10.02	7.40	5.74	3.66	1.81
USGS-02312600	FL_2	40.77	20.55	15.52	7.69	6.54	4.76	2.58	1.19
USGS-02312500	FL_3	50.29	18.90	11.63	8.19	4.03	3.27	1.88	1.09
USGS-02310947	FL_4	34.60	23.00	13.25	8.90	6.78	5.27	4.29	2.84
USGS-02301300	FL_5	34.88	26.61	11.87	8.19	6.27	4.95	4.18	2.65
USGS-02303000	FL_6	49.57	15.99	12.06	7.75	7.31	3.41	2.15	1.31
USGS-02309445	FL_7	32.47	21.37	16.26	11.90	7.02	4.86	3.34	1.72
USGS-02309425	FL_8	37.72	14.58	12.21	10.26	7.81	6.69	5.24	3.53
USGS-02307671	FL_9	29.03	19.40	16.40	10.49	8.87	6.47	4.42	2.75
USGS-02307731	FL_10	31.02	21.19	14.67	13.11	7.29	5.15	3.91	2.48
USGS-02310300	FL_11	46.89	17.46	16.98	9.64	3.98	2.21	1.45	0.95
USGS-02300100	FL_12	33.73	20.64	13.17	8.95	8.42	6.83	4.23	2.93
USGS-02295420	FL_13	34.96	23.37	15.05	8.35	6.69	4.83	3.24	2.77
USGS-02296750	FL_14	36.18	24.44	14.52	9.62	6.90	3.70	2.55	1.57
USGS-02298123	FL_15	43.82	21.66	12.65	8.02	6.30	3.12	2.04	1.72
*WQX-10MIGR10	FL_16	27.47	21.46	14.43	11.31	8.58	7.08	5.12	3.77
*WQX-10MIGR80	FL_17	36.60	16.18	13.65	10.80	8.41	7.81	3.33	1.84
*WQX-46B-9GR	FL_18	30.26	21.54	12.12	9.20	8.46	6.78	5.21	4.67

Note: (1) FL refers stations in Florida. (2) *21FLEECO STORET water quality station. (3) “I” is station identifier.

Table A7: Representative factor analysis extracted from data matrices the four environmental regimes based on which DO loaded on different factor.

Regimes	F	TN	TP	TW	SC	pH	Q	BP	SR	DO
Northern Gulf Coast State (NGCS)										
<i>Temperature dominated stations</i>										
Type I	1	0.35	-0.02	-0.95	-0.04	-0.24	0.27	0.20	-0.43	0.91
	2	-0.35	-0.09	0.16	0.88	0.45	-0.69	0.32	-0.16	-0.02
	3	0.70	0.81	-0.24	-0.10	0.05	0.46	-0.30	-0.24	-0.11
Type II	1	0.27	0.66	-0.05	-0.92	-0.69	0.99	-0.19	0.11	-0.09
	2	0.40	0.55	0.75	-0.11	-0.04	-0.01	-0.38	0.22	-0.98
	3	0.11	-0.20	-0.42	-0.02	0.38	0.09	0.42	0.60	-0.16
Type III	1	0.61	0.95	-0.26	-0.36	-0.21	0.60	0.09	0.01	-0.11
	2	-0.02	-0.28	0.22	0.63	0.92	-0.59	0.07	0.01	0.36
	3	0.20	0.08	-0.94	-0.02	0.01	0.24	0.36	-0.33	0.78
Transition Region of the U.S. Gulf Coast										
<i>Flow rate dominated stations</i>										
	1	0.34	-0.55	-0.06	0.30	0.63	-0.98	0.07	0.16	0.87
	2	-0.09	0.45	0.56	-0.26	0.10	-0.03	-0.92	0.45	-0.20
	3	0.41	0.07	0.72	-0.20	0.07	-0.20	-0.16	0.25	-0.45
<i>Specific conductance dominated stations</i>										
	1	0.31	-0.18	-0.05	0.98	0.52	-0.84	0.14	0.00	-0.68
	2	-0.02	0.98	0.57	-0.20	-0.21	0.09	-0.46	0.16	-0.04
	3	-0.43	-0.12	-0.29	0.05	-0.19	-0.13	0.75	0.35	0.29
Southern Gulf Coast State (SGCS)										
<i>pH dominated stations</i>										
Type I	1	-0.09	-0.06	-0.30	-0.37	0.96	-0.50	0.18	0.19	0.73
	2	0.23	0.00	-0.50	-0.09	0.24	-0.03	0.98	-0.24	0.05
	3	0.55	0.62	-0.34	-0.14	-0.11	0.06	0.04	-0.44	0.15
Type II	1	-0.03	0.14	0.82	0.09	-0.13	0.26	-0.89	0.57	-0.46
	2	-0.07	-0.46	-0.24	0.41	0.70	-0.28	0.20	-0.10	0.82
	3	0.99	-0.18	-0.26	-0.02	0.04	-0.06	-0.09	0.03	-0.18

Note: (1) Bold values indicated variables having moderate to high loadings on factors (F); F1-3 refers to three independent factors. (2) TN, TP, SC, pH, Q, AP, TW, SR and DO respectively, refer to total nitrogen, total phosphorus, specific conductance, potential of hydrogen, stream flow, atmospheric pressure, water temperature, solar radiation, dissolved oxygen.

Table A8: Coefficient (β) of the normalized (dimensionless) PLSR models of stream dissolved oxygen with the dynamic environmental drives after 1000 Monte Carlo simulation of the Gulf Coast water quality monitoring stations.

Stations ID	I	OPC	TN	TP	SC	pH	Q	BP	TW	SR	NSE	RSR
USGS-08475000	TX_1	3	-0.07	-0.10	0.18	0.48	0.06	-0.05	-0.50	0.06	0.59	0.64
USGS-08459200	TX_2	3	0.04	0.04	0.10	0.22	-0.01	-0.03	-0.75	0.16	0.67	0.56
USGS-08042554	TX_3	3	0.19	-0.20	0.05	0.38	-0.06	0.05	-0.63	0.09	0.88	0.35
USGS-08042546	TX_4	3	0.21	-0.05	0.05	0.23	0.15	-0.05	-0.76	-0.23	0.81	0.42
USGS-08116650	TX_5	3	-0.04	-0.15	0.17	0.53	-0.15	-0.12	-0.77	0.19	0.58	0.64
USGS-08070200	TX_6	3	-0.06	-0.08	0.02	-0.02	0.07	0.04	-0.82	0.07	0.83	0.40
USGS-08012150	LA_1	3	0.01	-0.04	-0.07	-0.04	0.03	-0.14	-0.58	-0.04	0.77	0.45
USGS-08014500	LA_2	3	0.14	-0.13	0.17	0.17	-0.16	0.10	-0.67	-0.09	0.64	0.59
USGS-07381590	LA_3	3	0.23	-0.09	0.02	0.20	-0.20	-0.01	-0.90	-0.06	0.89	0.33
USGS-07381495	LA_4	3	0.15	-0.12	0.05	0.18	-0.15	0.00	-0.96	0.05	0.83	0.42
USGS-07381600	LA_5	3	0.20	-0.10	0.03	0.20	-0.19	-0.02	-0.88	-0.03	0.88	0.35
USGS-07373420	LA_6	3	0.04	-0.05	0.09	0.12	-0.15	-0.02	-0.94	-0.02	0.85	0.39
USGS-07374000	LA_7	3	0.06	-0.08	0.02	0.27	-0.08	-0.01	-0.89	0.01	0.92	0.28
USGS-07374525	LA_8	3	0.12	0.00	0.04	0.23	-0.11	0.04	-0.90	-0.01	0.92	0.28
USGS-02470500	AL_1	3	-0.06	-0.20	-0.18	0.48	-0.18	0.00	-0.89	0.05	0.78	0.46
USGS-02469762	AL_2	3	0.08	-0.24	0.00	0.01	-0.05	-0.01	-0.96	-0.03	0.80	0.45
USGS-02429500	AL_3	3	-0.10	-0.18	0.11	-0.24	-0.04	0.07	-0.88	0.00	0.83	0.40
*21AWIC-7870	AL_4	3	0.01	0.10	-0.04	0.29	0.01	-0.09	-0.82	-0.06	0.94	0.25

Note: (1) TX, LS, and AL, respectively, refers to stations in Texas, Louisiana, and Alabama. (2) OPC refers to number of optimum partial least square components. (3) NSE refers to Nash-Sutcliffe efficiency. (4) RSR refers to ratio of root-mean-square error to the standard deviation of observations. (5) TN, TP, SC, pH, Q, AP, TW, and SR respectively, refer to total nitrogen, total phosphorus, specific conductance, potential of hydrogen, stream flow, atmospheric pressure, water temperature, and solar radiation. (6) * STORET water quality station. (7) "I" is station identifier.

Table A8 (continued): Coefficient (β) of the normalized (dimensionless) PLSR models of stream dissolved oxygen with the environmental drives after 1000 Monte Carlo simulation of the Gulf Coast water quality monitoring station.

Stations ID	I	OPC	TN	TP	SC	pH	Q	BP	TW	SR	NSE	RSR
USGS-02359170	FL_1	3	0.11	-0.18	0.09	-0.08	-0.09	-0.03	-0.62	-0.12	0.60	0.62
USGS-02312600	FL_2	3	-0.21	-0.42	-0.03	-0.25	0.06	0.08	-0.46	-0.29	0.86	0.36
USGS-02312500	FL_3	3	-0.28	-0.09	0.24	0.18	0.03	0.02	-0.46	-0.15	0.84	0.39
USGS-02310947	FL_4	3	-0.15	0.01	-0.54	0.06	0.16	0.15	-0.18	0.06	0.68	0.53
USGS-02301300	FL_5	3	-0.11	-0.09	0.20	0.20	-0.58	-0.06	-0.49	0.05	0.92	0.28
USGS-02303000	FL_6	3	0.08	-0.11	0.23	0.08	-0.03	0.20	-0.46	-0.08	0.91	0.29
USGS-02309445	FL_7	4	-0.20	-0.35	-0.08	-0.02	0.19	-0.15	-0.75	0.20	0.73	0.50
USGS-02309425	FL_8	3	-0.06	-0.18	0.27	-0.17	0.18	-0.01	-0.62	-0.03	0.67	0.55
USGS-02307671	FL_9	3	-0.07	-0.27	-0.14	0.13	0.38	0.01	-0.61	0.00	0.71	0.52
USGS-02307731	FL_10	3	0.10	-0.23	-0.09	-0.07	0.20	0.14	-0.76	0.18	0.78	0.45
USGS-02310300	FL_11	3	0.11	-0.13	-0.33	-0.08	0.27	0.05	-0.30	-0.07	0.92	0.26
USGS-02300100	FL_12	3	-0.01	-0.05	0.08	-0.02	-0.33	-0.07	-0.75	0.01	0.80	0.42
USGS-02295420	FL_13	3	-0.18	-0.01	0.00	-0.06	-0.11	0.08	-0.77	-0.03	0.84	0.39
USGS-02296750	FL_14	4	-0.37	0.06	0.27	0.16	-0.03	-0.06	-0.74	-0.26	0.76	0.48
USGS-02298123	FL_15	3	-0.04	-0.30	-0.06	-0.18	-0.32	-0.03	-0.62	-0.03	0.89	0.32
*WQX-10MIGR10	FL_16	3	0.18	-0.05	-0.49	0.26	0.17	0.14	-0.62	-0.02	0.86	0.37
*WQX-10MIGR80	FL_17	3	-0.29	-0.21	0.09	0.46	-0.01	0.22	-0.24	0.01	0.80	0.44
*WQX-46B-9GR	FL_18	3	0.10	0.09	0.19	0.74	0.02	-0.23	-0.29	0.06	0.65	0.58

Note: (1) FL refers stations in Florida. (2) OPC refers to number of optimum partial least square components. (3) NSE refers to Nash-Sutcliffe efficiency. (4) RSR refers to ratio of root-mean-square error to the standard deviation of observations. (5) TN, TP, SC, pH, Q, AP, TW, and SR respectively, refer to total nitrogen, total phosphorus, specific conductance, potential of hydrogen, stream flow, atmospheric pressure, water temperature, and solar radiation. (6) * 21FLEECO. (7) "I" is station identifier.

Figure A1: Scatter plot of flow rate (Q , ft^3/s) with total phosphorus (TP, mg/L).

Figure A2: Biplot of TW dominated regime obtained from principal component analysis showing interrelation of DO with dynamic environmental driver.

Figure A2 (continued): Biplot of TW dominated regime obtained from principal component analysis showing interrelation of DO with dynamic environmental driver.

Figure A2 (continued): Biplot of TW dominated regime obtained from principal component analysis showing interrelation of DO with dynamic environmental driver.

Figure A2 (continued): Biplot of TW dominated regime obtained from principal component analysis showing interrelation of DO with dynamic environmental driver.

Figure A2 (continued): Biplot of TW dominated regime obtained from principal component analysis showing interrelation of DO with dynamic environmental driver.

Figure A3: Biplot of Q dominated regime obtained from principal component analysis showing interrelation of DO with the dynamic environmental drivers.

Figure A4: Biplot of SC dominated regime obtained from principal component analysis showing interrelation of DO with the dynamic environmental drivers.

Figure A5: Biplot of pH dominated regime obtained from principal component analysis showing interrelation of DO with the dynamic environmental drivers.

Figure A6: Box plot of Beta coefficient after 1000 Monte Carlo for each environmental regime: (a) TW dominated regime, (b) Q dominated regime, (c) SC dominated regime, and (d) pH dominated regime. The magenta color shows the zero-zero line.

Figure A7: Map of the study area and the dominant process components for each station.

Figure A8: Observed vs. predicted Z-score of dissolved oxygen.

Figure A8 (continued): Observed vs. predicted Z-score of dissolved oxygen.

Figure A8 (continued): Observed vs. predicted Z-score of dissolved oxygen.