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Database Analysis to Support Nutrient Criteria Development (Phase III)

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The intent of this publication of the Arkansas Water Resources Center is to provide a location whereby a final report on water research to a funding agency can be archived.

The Texas Commission on Environmental Quality (TCEQ) contracted with University of Arkansas researchers for a multiple year project titled "Database Analysis to Support Nutrient Criteria Development".

This publication covers the third of three phases of that project and has maintained the original format of the report as submitted to TCEQ. This report can be cited either as an AWRC publication (see below) or directly as the final report to TCEQ.

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DATABASE ANALYSIS TO SUPPORT NUTRIENT CRITERIA DEVELOPMENT

Final report submitted in fulfillment of
Contract number 582-14-40101 to:

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By

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Table of Contents

List of Tables

List of Figures

Section 1: Streams and Rivers

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EXECUTIVE SUMMARY

The Clean Water Action Plan, released in 1998 by the United States Environmental Protection Agency (USEPA), established a national set of nutrient targets for 14 aggregate ecoregions across the United States, directing states and tribes to adopt these targets or pursue development of scientifically defensible targets at the state level. For streams and rivers, the two main approaches for target development focus on the frequency distribution of median concentrations and statistical analysis of stressor-response relationships between nutrients and biological response variables. Predictive approaches have focused on establishing relationships between nutrient concentrations and algae, macroinvertebrates, and fish communities.

The objective of Section 1 was to provide statistical support to the Texas Commission on Environmental Quality (TCEQ) to assist in the development of numeric nutrient or biological response targets for Texas streams and rivers. The USEPA recommends that statistical approaches that evaluate stressor-response relationships in aquatic systems and frequency distribution analysis should be used in conjunction for developing numeric targets for streams and rivers. Further, questions remain regarding the legitimacy of promulgating a single numeric target for a parameter across areas that may contain multiple basins, ecoregions, and land uses. Analyses in Sections 1.1 – 1.3 provide analyses that aid in addressing these concerns through multiple lines of inquiry. These analyses were based upon data provided by the TCEQ for the period 2000 – 2010 and that were organized by the Arkansas Water Resources Center (AWRC) under a prior study (FY2012-2013). The data compiled water quality parameters from 2,273 stations spanning 23 basins across Texas and were collected under non-biased flow conditions.

In Section 1.1, prior changepoint analysis of stressor-response relationships in Texas streams and rivers were expanded by “flipping” the traditional configuration of the analysis to place the stressor and response parameters on the y-axis and x-axis, respectively. The study objective was to predict thresholds in biological variables. For these analyses, thresholds related to TP gradients were identified in spectrophotometric chlorophyll-a (chl-a spec) and Secchi transparency. The chl-a spec threshold= 3.5 ug/L exceeded chl-a targets recommended by the USEPA (2000), but was less than mean chl-a associated with low nutrient stations that had median TP and TN concentrations below threshold concentrations identified in the prior changepoint anlyses. In contrast, the Secchi transparency threshold = 0.42 m was close in range with mean transparency associated with high nutrient stations from previous analyses. “Flipped” changepoint analyses were generally statistically weak and should be used with caution for setting biological response targets.

Prior changepoint analysis of stressor-response relationships in Texas streams and rivers at the statewide level was refined in Section 1.2 by conducting these analyses on water quality data specific to major river basins and Omnerik Level III ecoregions. Potential geographic variability was further explored by conducting frequency distribution analysis of water quality parameters within stream and river segments in Section 1.3. The parameters of primary concern were total phosphorus (TP), ortho-phosphate (PO_4-P; SRP), total nitrogen (TN), nitrate plus nitrite N (NO_x-N), and sestonic chlorophyll-a (chl-a). Frequency distributions, including the minimum, 10th, 25th, 50th, 75th, and 90th percentiles, and maximum values of these parameters, were calculated within each segment. Both sets of regional analyses indicated significant variability in potential nutrient and biological response target values for different geographic areas, and model strength associated with nutrient thresholds was often much greater for basins or level III ecoregions than was observed for streams and rivers at the statewide-scale.

A subset of Texas streams and rivers has undergone more intensive biological and habitat sampling, in addition to water quality data collection. Prior changepoint analysis explored stressor-response relationships between biological communities and nutrients or habitat quality using multi-metric indices for fish and macroinvertebrates. In Section 1.4, these analyses were refined for macroinvertebrates, using both regression and changepoint analysis to explore relationships between community-level macrobenthic metrics and potential stressors. Regression relationships were identified for community metrics with both habitat quality (HBI) and chl-a concentrations, explaining ~ 10 – 20% of variability in these metrics. For changepoint analysis, thresholds in TN (1.0 mg/L), HQI (18 – 24), and chl-a (5.1 – 11 µg/L) were identified that explained up to 24% of variability in community metric response, but potential censored data effects were a concern for all analyses with chl-a as the explanatory variable. Preliminary exploration of stressor-response relationships and community metric data distribution at the level III ecoregion scale suggested natural geographic variability in these metrics and their relationship to nutrients, though more detailed analysis would be required to hash out these differences.

During 2011 – 2014, Texas was in extreme to exceptional drought, most notably in 2011. In Section 1.5, potential shifts in data distributions for groups of annual water quality medians during drought years were explored through comparisons with data collected during periods of normal to above average precipitation in Texas (2001 – 2004). Analyses were conducted at the statewide level and after targeting non-drought and drought conditions in 2004 and 2011, respectively, by removing data from geographical areas with precipitation regimes that were not representative of the rest of the state in those years. Stream and river stations were also divided into groups receiving low and high municipal discharge loads (< and ≥ 0.031 mgd/km^2, respectively). Among these subgroups of annual medians, differences between wet and dry years were typically small, though notably, means consistently exhibited the greatest differences and medians the smallest, supporting the idea that medians are a more robust choice for use in setting water quality targets. In contrast to other subgroups, for streams receiving high municipal discharges, both mean and median total and dissolved inorganic nutrient concentrations were up to 5x higher in 2011 than 2004. These findings indicated that nutrient concentrations in streams and rivers that already have a high proportion of in-stream flow represented by municipal discharges were most susceptible to drought effects and would likely be out of compliance with nutrient targets that were set without taking data from drought years into consideration.

INTRODUCTION

The Clean Water Action Plan, released in 1998 by the United States Environmental Protection Agency (USEPA), established a national set of water quality target standards for 14 regions across the United States aggregating geographically similar Omnerik Level III Ecoregions. These numeric values were a function of frequency distributions of national stream and river datasets, and targets were established for both causative variables, such as nutrients, and response variables, such as chlorophyll-a or transparency, that are associated with the prevention and assessment of eutrophic conditions in streams and rivers. In lieu of adopting USEPA recommended targets, states, tribes, and others were provided the option to establish scientifically defensible standards for streams and rivers at reduced spatial scales that are specific to an area of concern. States have overwhelmingly opted for this option, as the proposed USEPA targets did not account for local and regional influences that can affect water quality. Subsequent analysis has indicated that aggregate ecoregions likely represent too coarse a geographical scale for establishing nutrient targets, and the basin or individual ecoregion level may be more appropriate (Rohm et al. 2002). Variability in water quality metrics across geographical scales and locations has been shown to result in nutrient and biological data frequency distributions that deviate from nationwide datasets and therefore from USEPA recommendations (e.g., Ice et al., 2003; Smith et al. 2003; Binkley 2004, Longing and Haggard 2010; Evans-White et al. 2013).

Commonly accepted statistical approaches to developing water quality targets available to states, tribes, and others include percentile analysis of data frequency distributions and stressor-response relationships. The frequency distribution method does not require prior knowledge of individual stream conditions. Targets are instead developed relative to values observed for a specific population of water bodies. The USEPA (2000) suggested two statistical methods to identify nutrient targets based on percentile analysis of data frequency distributions. The first establishes the 75th percentile of a distribution of a reference or minimally impacted population as a target. The second focuses on the 25th percentile of the general population. The USEPA (2000) suggested that these approaches should result in similar target values (Figure 1.1); however, method comparisons indicate these values can differ greatly (Suplee et al. 2007 and Herlihy and Sifneos 2008). Generally, 75th percentile estimates of reference populations have been less conservative of water quality as potential targets than 25th percentile estimates of general populations (Evans-White, 2013). Furthermore, limited availability of water bodies representing true reference conditions often constrains the efficacy of the 75th percentile approach (Dodds and Oaks, 2004).

Stressor-response approaches, as recommended by the USEPA (2010), are commonly used to evaluate biological conditions over a range of environmental gradients, including nutrients and habitat quality. These approaches have also been used to explain the variance in nutrient concentrations of streams as a function of land use, ecoregion, and other watershed attributes (Herlihy and Sifneos 2008). Common techniques for analyzing stressor-response relationships include regression (linear and non-linear) and changepoint (threshold) analyses. Classification and regression tree (CART) analysis is an empirical modeling technique that is useful for identifying ecological thresholds and hierarchical structure in predictor variables (De'ath and Fabricius 2000). CART uses recursive partitioning to divide data into subsets that are increasingly homogeneous, invoking a tree-like classification that can explain relationships that may be difficult to reconcile with conventional linear models (Urban 2002). Categorical variables (e.g., station location, basin, ecoregion or land-use classifications) may also be used as independent variables in CART analysis. CART and other similar methods have been used to identify thresholds and hierarchical structure in environmental correlates of various biological processes in aquatic ecosystems (King et al. 2005, East and Sharfstein 2006). King et al. (2005) used CART specifically to identify thresholds in nutrient concentrations which resulted in shifts in ecological structure and function.

States currently in the process of developing regionally specific nutrient targets have considered the results of multiple statistical approaches before selecting control levels. Several states have adopted site-specific targets for streams and rivers, but only Wisconsin, Florida, New Jersey, and Vermont have statewide targets (Table 1.1, as summarized by Evans-White et al. (2013)).

The State of Texas and the Texas Commission on Environmental Quality (TCEQ) has contracted with the Arkansas Water Resources Center (AWRC) since 2011 to analyze the state's long-term water quality datasets. A median database (2000-2010) for streams and rivers was developed as part of a FY2012-2013 contract. This database is the foundation for both previous and the present analyses and is comprised of data provided by TCEQ that were collected from 1968 – 2012 from freshwater streams and rivers throughout Texas. Data were collected from 2,273 stream and river stations spanning 23 watersheds. The data described 116 stream characteristics and water quality parameters including nutrient and sediment concentrations, transparency, a range of physico-chemical parameters, and others. Data processing by AWRC was subject to quality control measures outlined in project QAPP's. After organization into a workable database, data were analyzed for frequency distributions and stressor-response relationships. This process is described in detail in the final report of the FY2012-2013 contract (AWRC 2013).

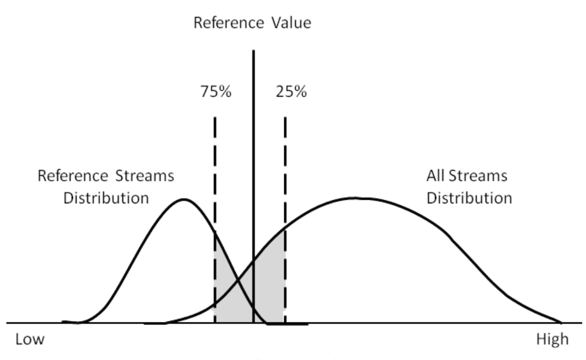


Figure 1.1. Distribution of data collected from reference condition streams and the general stream population and the associated percentile distribution used to develop nutrient criteria.

Table 1.1. Summary of numerical nutrient (i.e., total nitrogen; TN and total phosphorus; TP) criteria for streams and rivers in water quality standards (WQS) and the year they were publish across the 48 conterminous states (Evans-White et al., 2013).

State	Local	TN mg/L	Local	TP mg/L	WQS Year
Arizona	site-specific	0.50-1.00	site-specific	0.05-0.20	2010
California	site-specific	--	site-specific	--	--
Florida	statewide	0.67-1.87	statewide	0.06-0.49	2012
Georgia	--	--	site-specific	--	2012
Montana	site-specific	0.13-1.36	site-specific	0.01-0.12	2012
Nevada	site-specific	1.5-2.9 (2.4-4.0)	site-specific	0.10-0.33 (0.05-0.10)	2012
New Jersey	site-specific	2.0	statewide	0.10	2011
New Mexico	--	--	site-specific	0.10	2012
New York	site-specific	--	--	--	2002
Oklahoma	--	--	site-specific	0.04	2012
Oregon	--	--	site-specific	0.07	2012
Vermont	statewide	0.2-5.0	site-specific	0.01	2012
Washington	--	--	site-specific	0.03	2012
Wisconsin	--	--	statewide	0.07-0.10	2012

Present project tasks for analysis of Texas streams and rivers data refine and expand analytical goals set out in FY2012-2013. Stressor-response relationships were explored using changepoint analysis in a way that would result in potential chl-a or Secchi threshold values. Potential biological and nutrient target values relevant at the regional, or even segment-specific, scale were explored using frequency distribution and changepoint analysis of data collected specifically within these various geographic areas. Analyses of the Texas bioassessment database were refined from FY2012-2013 analyses on multimetric indices to explore relationships between community metrics and potential stressor variables, as well as regional variability among streams. Finally, because Texas experienced widespread severe to exceptional drought from 2011-2014 (United States Drought Monitor; droughtmonitor.unl.edu), potential drought-related trends in the values of key biological and nutrient parameters were explored, as these trends could affect nutrient target development.

Therefore, for Texas streams and rivers, the objectives of this section are:

1) to explore whether changepoint analysis of stressor-response relationships can identify meaningful thresholds in median biological parameters (focusing on Secchi transparency and chlorophyll-a) relative to a gradient of median nutrient stressor values (focusing on TP and TN) by "flipping" traditional stressor and response variables;
2) to identify nutrient thresholds values associated with changes in the magnitude or variability of commonly measured biological parameters within Texas major river basins and Omnerik Level III Ecoregions;
3) to assess the frequency distribution of median nutrient concentrations and response variables at the segment scale for Texas streams and rivers, based on Segment ID's acquired from the TCEQ;

4) to identify nutrient and habitat threshold values associated with changes in the magnitude or variability of commonly measured bioassessment variables using community-specific metrics and examining relationships in streams with differing flow regimes;
5) and to calculate a time-series of annual station medians and determine if a shift in the median values of key water quality parameters occurred in tandem with drought onset and persistence.

1.1. CHANGEPOINT ANALYSIS TO IDENTIFY THRESHOLDS IN BIOLOGICAL PARAMETERS

Methods

We used a novel application of non-parametric changepoint analysis (nCPA; Qian et al. 2003, King and Richardson 2003), a stressor-response analysis related to CART, to identify thresholds in common biological response variables relative to gradients of nutrient stressor variables. This approach reverses the traditional stressor-response relationship, placing biological variables on the x-axis as the independent variable and nutrient variables on the y-axis as the dependent variable. These analyses were carried out on the median database for streams and rivers developed in FY2012 – 2013. The biological variables included in the analyses were median Secchi transparency (m; parameter code 00078C), median chlorophyll-a (chl-a) measured with spectrophotometry (chl-a spec; µg/L; 32211), and median chlorophyll-a measured with fluorometry (chl-a fluoro; µg/L 70953). The nutrient variables included in the analysis were total phosphorus (TP; mg/L; 00665) and total nitrogen (TN; mg/L; 00600C).

CART analysis is a means to reduce data, based on quantifying thresholds in independent variables that are correlated with shifts in the magnitude and/or variability of dependent variables. This statistical procedure can also provide hierarchical structure in independent variables, showing multiple thresholds from the same or different independent variables. CART analysis is very useful for resolving nonlinear, hierarchical, and high-order interactions among predictor variables (De'Ath and Fabricius 2000) and for detecting numerical values that lead to ecological changes (Qian and others 2003). CART models use recursive partitioning to separate data into subsets that are increasingly homogeneous; for example, subsets of data representing similar nutrient conditions. This iterative process invokes a tree-like classification that can reveal relationships that are often difficult to reconcile with conventional linear models (Urban 2002). We "pruned" CART models to generate final models that balanced accuracy within the available dataset with robustness to novel data (Urban 2002). CART models were cross-validated to determine "pruning size" (i.e., the number of predictor variables included in the model). Model cross-validations were conducted using 10 random and similarly sized subsets of our data according to the method detailed by De'ath and Fabricius (2000). The optimum tree size for each model was selected using the minimum cross-validated error rule (De'ath and Fabricius 2000).

CART and nCPA analyses were performed using the MVPART library in R 2.9.1 (http://www.r-project.org/). Non-parametric changepoint analysis was used to determine model statistical significance ($p_{perm}<0.05$) and 95% confidence interval about the threshold estimate (Qian et al. 2003, King and Richardson 2003).

This analysis uses random permutations to estimate a p value that can be used to determine Type I and II error associated with the threshold and simultaneously uses bootstrapping to calculate cumulative probability to estimate uncertainty and provide confidence estimates for the threshold. We required a minimum of 10 observations to be used in any single split in a model and that each terminal node in the model had a minimum of 5 observations. CART analysis is insensitive to missing data. Therefore, we did not remove observations from the data set due to missing values. We required that all calculated medians have a minimum of 10 observations used in calculating the median value.

A user's guide to interpreting CART and nCPA models and associated summary statistics is available in Appendix 1.1. In Appendix 1.2, the statistical code and raw output generated for each CART and nCPA analysis conducted for this study on stressor-response relationships in the Texas streams and rivers database has been compiled.

The chl-a and Secchi transparency thresholds identified through "flipped" changepoint analysis were compared to other potential biological response targets to determine whether this exploratory method yielded values that were relatively more or less conservative of water quality (Table 1.1.1). The sources of other potential targets available to TCEQ included recommendations by USEPA (2000) for streams and rivers within aggregate ecoregions, 25th percentiles of Texas stream and river station medians, and mean chl-a or transparency for station medians assigned to low and high nutrient groups. The latter two sources were derived from results of analyses carried out during FY2012-2013 contract (AWRC 2013). Low and high nutrient groups directly corresponded to changes in biological response and consisted of stations with median TP or TN concentration that was either less than a relevant TP or TN threshold for low nutrient groups, or exceeded a relevant TP or TN threshold for high nutrient groups. Characteristics of these low and high nutrient station groups, including the mean, maximum, minimum, and relevant threshold for TP or TN are summarized in Table 1.1.2.

Table 1.1.1. Summary of potential response variable targets for Secchi transparency and chlorophyll-a measured spectrophotometrically (chl-a spec) and fluorometrically (chl-a fluoro). Sources of potential response variable targets include the present "flipped" changepoint analysis and USEPA (2000), as well as values drawn from the FY2012 – 2013 contract, including 25th percentile estimates for Texas and the average value of the response variable associated with high and low TP and TN groups of streams and rivers determined using changepoint analysis of the cumulative median dataset. A dash indicates that a given estimate of a potential target was not available.

	Potential targets						
Parameter	CP Flip	USEPA	25thTILE	Low TP	High TP	Low TN	High TN
Chl-a Spec (ug/L)	3.5	0.93–3.0	-	6.6	11	7.9	11
Chl-a Fluoro (ug/L)	-	-	1.9–33	6.0	13	-	-
Secchi (m)	0.47	-	-	0.76	0.41	0.73	0.52

Results and Discussion

Sestonic Chlorophyll-a

For models relating TP and chl-a, a threshold in chl-a spec = 3.5 µg/L was identified for Texas streams and rivers (Fig. 1.1.1A). Suspended algal concentrations are generally positively related with total nutrient concentrations in streams and rivers (Royer et al. 2008; Haggard et al. 2013), and this relationship was consistent with ecological theory. On average, TP concentration was approximately 2x greater (0.15 vs. 0. 29 mg/L) when chl-a spec exceeded 3.5 µg/L.

This threshold was approximately 2x lower than the average chl-a spec concentration of station medians in low TP and TN groups (i.e. stations with median TP and/or TN less than threshold values; see Table 1.1.2). Therefore, this chl-a threshold represents a more conservative potential chl-a target than the mean chl-a spec representative of low-nutrient conditions in Texas rivers and streams (Table 1.1.1). In contrast, this threshold exceeded all chl-a targets recommended by the USEPA for aggregate ecoregions within Texas (0.93 – 3.0 µg/L; USEPA 2000). Therefore, this chl-a threshold represents a less conservative target than USEPA recommendations. Though significant, this model had very low explanatory power (r^2 = 0.02.), and should be used cautiously in setting chl-a targets for Texas streams. No statistically significant changepoint relationship was found between TN and chl-a spec or between TP or TN and chl-a fluoro (p>0.05; Fig. 1.1.1C-D).

Table 1.1.2. Nutrient concentration mean and range for stations categorized as “low” and “high” nutrient based on thresholds identified in changepooint analysis of stressor-response relationships as part of the FY2012-13 contract (AWRC 2013). The count of stations classified as “low” nutrient, or having a nutrient median below a nutrient threshold, or “high” nutrient, or having a nutrient median above a nutrient threshold are also provided for each stressor-response pair with a statistically significant threshold. For stressor-response pairs that did not have a statistically significant threshold, low and high nutrient groups could not be identified and no summary characteristics of groups were provided, as indicate by a dash.

			Total Nutrient Concentration (mg/L)			
Response parameter	Nutrient parameter	Threshold	Low Nutrient Mean (Count)	Low Nutrient Range	High Nutrient Mean	High Nutrient Range
Chl-a spec	TP	0.10	0.062 (298)	0.007 – 0.098	0.46 (297)	0.10 – 3.3
	TN	1.1	0.77 (166)	0.24 – 1.1	3.4 (233)	1.1 – 16
Chl-a fluoro	TP	0.069	0.058 (127)	0.050 – 0.067	0.49 (212)	0.070 – 7.4
	TN	-	-	-	-	-
Secchi	TP	0.063	0.057 (253)	0.002 – 0.063	0.51 (565)	0.064 – 7.4
	TN	0.70	0.51 (64)	0.24 – 0.70	2.9 (441)	0.70 - 83

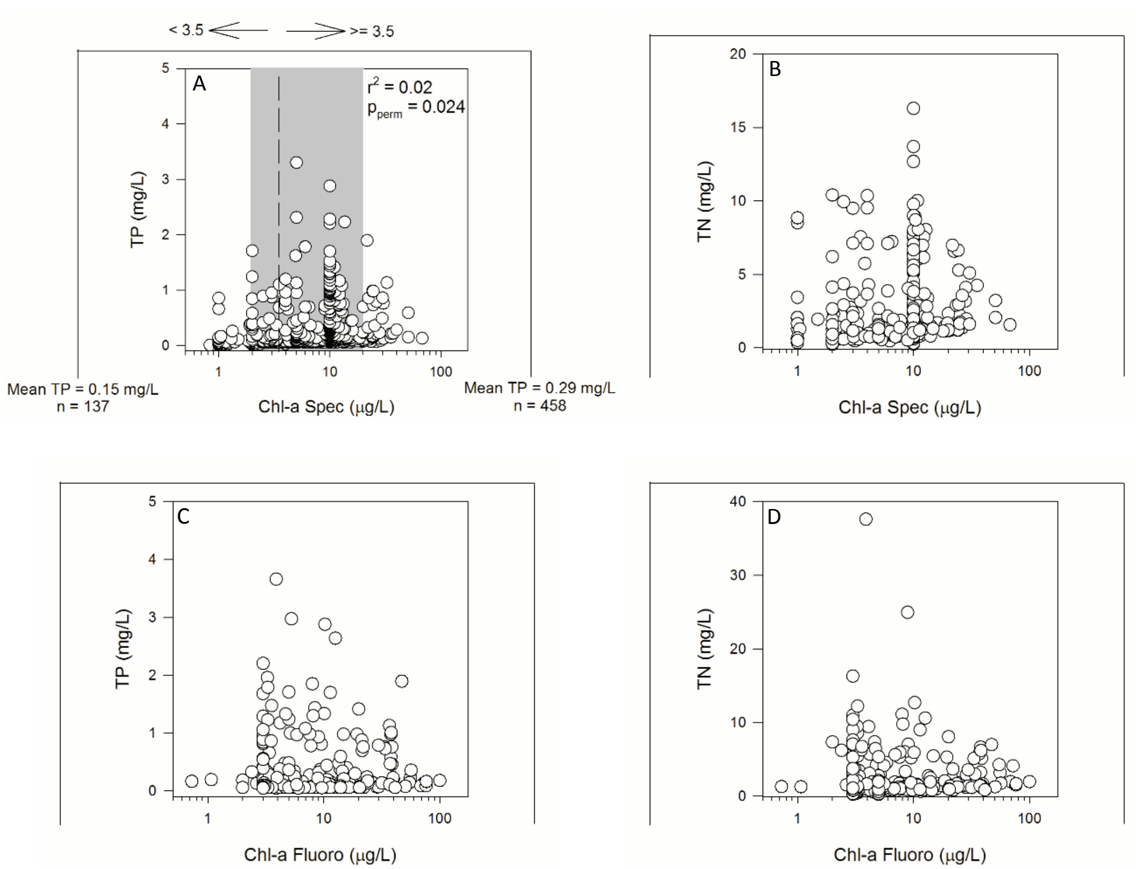


Figure 1.1.1. The "flipped" relationship between chlorophyll-a measured spectrophotometrically (chl-a spec; A-B) or fluorometrically (C-D) and total phosphorus (TP; A,C) and total nitrogen (TN; B,D). For statistically significant models (p<0.05), the chl-a threshold and confidence interval are shown as a dashed line and shaded area, respectively. For stressor-response pairs that did not yield a statistically significant threshold, only the scatterplot is shown.

Secchi transparency

For models relating TP and Secchi transparency, a threshold = 0.47 m was identified for Texas streams and rivers (Fig. 1.1.2A). On average, TP concentration was approximately 2x lower when transparency exceeded 0.47 m, a pattern consistent with ecological theory. Discussion in the scientific literature of water quality targets based on Secchi transparency is not common for streams and rivers, limiting availability of potential targets for comparison with the results of "flipped" analyses. However, comparisons can be made with the mean Secchi depth for low and high nutrient groups of station medians (i.e. stations with median TP and/or TN concentration either less than or exceeding threshold values for low and high groups, respectively; see Table 1.1.2). For these analyses, the Secchi threshold was in range with average transparency associated with stations with median TP and TN exceeding nutrient thresholds (Table 1.1.1). Therefore, "flipped" changepoint analysis yielded a relatively less conservative potential target than, for example, the mean transparency associated with low nutrient stations. Though significant, this model had very low explanatory power (r^2 = 0.05) and should be used cautiously in setting transparency targets. No statistically significant changepoint relationship was found between TN and Secchi transparency (p>0.05).

Summary of "flipped" stressor-response analysis for Texas streams and rivers

For all stressor-response pairs considered in these analyses, potential biological thresholds were statistically weak or non-significant, and this approach to using changepoint analysis has not been peer-reviewed or published. Therefore, these findings suggest that this novel application of non-parametric changepoint analysis to identify thresholds in traditional biological response variables may not be effective for numeric nutrient or biological response target development, particularly for the Texas streams and rivers dataset. The findings of these analyses should be used with caution in setting potential water quality targets.

"Flipped" changepoint models may have been statistically weak for Texas rivers and streams for several reasons. First, changepoint analysis of stressor-response pairs in the traditional configuration indicated that the relationships between sestonic chl-a and nutrients were not strong at the state-wide scale in this dataset (r^2 < 0.10). Therefore, it is not surprising that "flipping" this relationship did not result in statistically significant models with high explanatory power. The low explanatory power of sestonic chl-a concentrations in streams and rivers by gradients in TP and TN concentrations likely reflects the extreme variability present in this large dataset spanning a wide geographical range. Factors such as stream order, canopy cover, or climate likely also affect sestonic chl-a concentrations in Texas streams and rivers (Vannote et al. 1980; Smith et al. 2003), but were not accounted for in these analyses. Normalizing data for these factors could improve analysis.

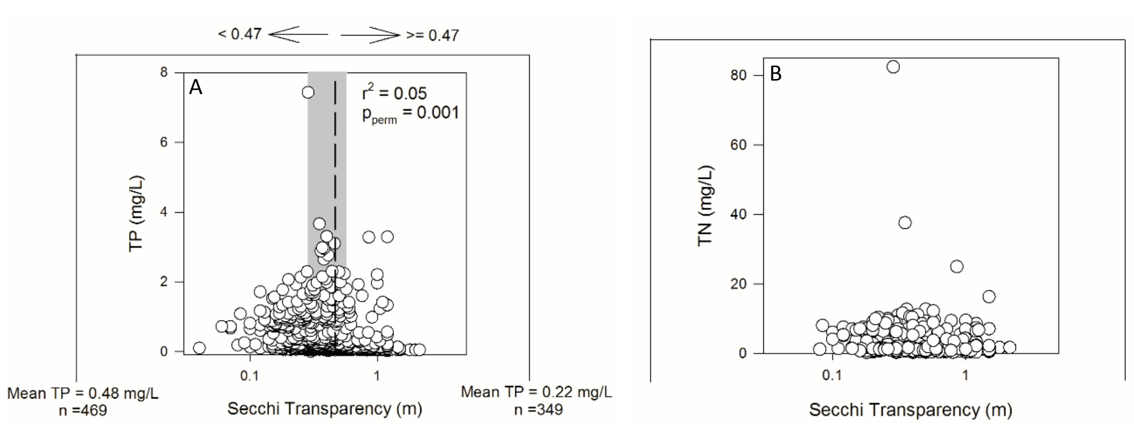


Figure 1.1.2. The "flipped" relationship between Secchi transparency and total phosphorus (TP; A) and total nitrogen (TN; B). For statistically significant models (p<0.05), the transparency threshold and confidence interval are shown as a dashed line and shaded area, respectively. For potential models that were not statistically significant, only the scatterplot is shown.

It is also possible that the prevalence of censored chl-a data affected analyses. The prevalence of censored data resulted in a large number of stations with median chl-a equal to the most common quantification limit (QL) for each method (chl-a spec QL = 10 µg/L, chl-a fluoro QL = 3 µg/L), indicating that these stations likely had ≥50% censored observations. As a result, a wide range of TP and TN values was associated with a single chl-a value for each method, which is exactly the type of signal that changepoint analysis is designed to detect, but which was introduced to this dataset spuriously by substituting the QL for censored observations. The potential effect of censored data is easily visualized in scatterplots (Fig. 1.1.1A-D), with vertical lines forming in the plot at the point on the x-axis that corresponds to the common QL. Despite this, the statistically significant threshold identified for the chl-a spec vs. TP relationship did not appear to be leveraged by stations with highly censored chl-a data (CP = 3.5 µg/L vs. QL = 10 µg/L), but the extreme variability in nutrient medians associated with a single chl-a value likely weakened the analysis and could have obscured real trends. However, advanced statistical analysis for censored datasets would be required to calculate stations medians in order to determine with greater certainty how censored data may have affected these analyses.

Finally, in light of the strong effects indicated by excluding high TP and TN values for analyses on Texas estuaries and reservoirs datasets (see Sections 2.1 and 3.1), it is also possible that changepoint analysis would yield a greater number of models with improved explanatory power for streams and rivers after removing potential nutrient outlier values.

Other statistical approaches are available for setting numeric targets for biological response variables that may be preferable to “flipping” changepoint analysis. These approaches include frequency distributions of a population of streams at a scale of interest and linear regression analysis. Frequency distributions directly yield potential response variable targets, assuming that a percentile has been identified that is considered protective of a desired use. Linear regression analyses do not yield specific numeric values for stressor or response variables, but allow potential targets to be calculated for the response variable, if the desired target for the nutrient stressor is known.

Changepoint analysis also provides potential numeric targets for response variables as the mean of the response variable values associated with stations that have stressor values either below or above the stressor threshold. CART and nCPA analyses automatically output the mean value of the response variable for these groups. For past changepoint analyses of Texas rivers and streams (AWRC 2013), chl-a and transparency means for stations in these low and high nutrient groups delineated by a nutrient threshold are summarized in Table 1.1.1.

1.2 NUTRIENT THRESHOLDS SPECIFIC TO TEXAS BASINS AND OMNERIK LEVEL III ECOREGIONS

Methods

We conducted CART analyses on the median database for streams and rivers to identify thresholds in nutrient concentrations that resulted in measurable changes in common biological response variables within Texas basins (Appendix 1.3) and Omnerik level III ecoregions (Appendix 1.4). The biological (dependent) variables included in the analyses were median Secchi transparency (m; parameter code 00078C), median chlorophyll-a measured with spectrophotometry (chl-a spec; 32211), and median chlorophyll-a measured with fluorometry (chl-a fluoro; 70953). The nutrient (independent) variables included in the analysis were total phosphorus (TP; 00665) and total nitrogen (TN; 00600C). We required a minimum of 20 paired medians within a basin or ecoregion for each analysis.

CART analysis is a means to reduce data, based on quantifying thresholds in independent variables that are correlated with shifts in the magnitude and/or variability of dependent variables. This statistical procedure can also reveal hierarchical structure in independent variables, showing multiple thresholds from the same or different independent variables. CART analysis is very useful for resolving nonlinear, hierarchical, and high-order interactions among predictor variables (De'Ath and Fabricius 2000) and for detecting numerical values that lead to ecological changes (Qian and others 2003). CART models use recursive partitioning to separate data into subsets that are increasingly homogeneous; for example, subsets of data representing similar nutrient conditions. This iterative process invokes a tree-like classification that can reveal relationships that are often difficult to reconcile with conventional linear models (Urban 2002). We "pruned" CART models to generate final models that balanced accuracy within the available dataset with robustness to novel data (Urban 2002). CART models were cross-validated to determine "pruning size" (i.e., the number of predictor variables included in the model). Model cross-validations were conducted using 10 random and similarly sized subsets of our data according to the method detailed by De'ath and Fabricius (2000). The optimum tree size for each model was selected using the minimum cross-validated error rule (De'ath and Fabricius 2000).

CART analyses were performed using the MVPART library in R 2.9.1 (http://www.r-project.org/). Non-parametric changepoint analysis was used to determine model statistical significance ($p_{perm}<0.05$) and 95% confidence interval about the threshold estimate (Qian et al. 2003, King and Richardson 2003). This analysis uses random permutations to estimate a p value that can be used to determine Type I and II error associated with the threshold and simultaneously uses bootstrapping to calculate cumulative probability to estimate uncertainty and provide confidence estimates for the threshold. We required a minimum of 10 observations to be used in any single split in the CART model and that each terminal node in the model had a minimum of 5 observations. CART analysis is insensitive to missing data. Therefore, we did not remove observations from the data set due to missing values. We required that all station medians have a minimum of 10 observations used in calculating the median value.

A user's guide to interpreting CART and nCPA models and associated summary statistics is available in Appendix 1.1. In Appendix 1.2, the statistical code and raw output generated for each CART and nCPA analysis conducted for this study on stressor-response relationships in the Texas streams and rivers bioassessment database has been compiled.

Results and Discussion

Nutrient thresholds by basin

For models relating Secchi transparency to TP, statistically significant TP thresholds were found for 50% of Texas basins, including Basins 2, 4, 5, 8, 10, 12, 14, 18, 19, 21, and 23 (Table 1.2.1). Consistent with ecological theory, these thresholds indicated that Secchi transparency decreased with increasing TP concentration and ranged from 0.060 – 0.16 mg/L. These values were typically in range with the TP threshold identified for Secchi transparency using combined data from all the basins (0.063 mg/L) in FY2012-2013, but sometimes exceeded this value by more than 2x. Model explanatory power (r^2) within basins typically was equal to or exceeded that of the combined data model (r^2 = 0.23). However, model explanatory power was less than 23% for Basins 10, 14, and 18. For some basins, the value of model TP thresholds was likely influenced by the high frequency of censored observations, as indicated by TP thresholds that were approximately equal to the most common quantification limit of 0.060 mg/L. These basins included Basins 2, 5, 12, and 18.

For models relating chl-a (both methods) and TP, statistically significant thresholds were less common than for Secchi transparency. Thresholds were identified for 17-25% Texas basins, including Basins 2, 8, 12, 14, 18, and 23. These thresholds indicated that chl-a concentration increased with increasing TP concentration and ranged from 0.058 – 0.21 mg/L. These values were typically in range with the TP thresholds identified for chl-a using combined data from all the basins (0.069 – 0.099 mg/L) in FY2012-2013, but sometimes exceeded these values by greater than 2x. Model explanatory power always exceeded that of the chl-a vs. TP models generated using combined data (r^2 = 0.09 and r^2 = 0.04 for chl-a spec and fluoro, respectively). The value of TP thresholds identified for chl-a appeared to be less strongly influenced by the prevalence of censored observations, with the exception of Basins 14 and 18, which had TP thresholds approximately equal to the most common quantification limit of 0.060 mg/L.

Fewer thresholds were identified for models relating biological variables to TN than to TP for Texas basins. Statistically significant TN thresholds for Secchi transparency were identified for 25% of Texas basins, including Basins 4, 5, 8, 14, 19, and 23. These thresholds varied by a factor of 10, ranging from 0.51 – 4.9 mg/L, and indicated that Secchi transparency decreased as TN concentration increased. Model explanatory power within basins always exceeded that of the Secchi transparency vs. TN model generated using combined data from all the basins (r^2 = 0.04).

For models relating chl-a (both methods) and TN, statistically significant thresholds were identified for less than 10% of Texas basins, including Basins 14 and 23. These thresholds indicated that chl-a concentration increased as TN concentration increased and ranged from 1.2 – 1.7 mg/L. These values were in range with, but slightly higher than the TN threshold (1.1 mg/L) identified for chl-a spec using the combined data for all basins. Model explanatory power for the chl-a vs. TN relationship was at least 5x greater for Basins 14 and 23 than for the cumulative dataset (r^2 = 0.04 for chl-a spec).

Several basins did not have sufficient data for changepoint analysis of any of the possible stressor-response combinations. These basins included Basins 1, 3, 6, 7, 9, 11, 13, 15, 16, 17, 20, 22, and 24. Many of the basins without sufficient data were tidal basins, and data from stations within these basins may largely be stored separately in the tidal streams median database.

Nutrient thresholds by level III ecoregion

For level III ecoregions within Texas, statistically significant models relating Secchi transparency and TP indicated that Secchi transparency decreased with increasing TP concentration (Table 1.2.2). Thresholds in TP were identified for 7 of 11 Texas level III ecoregions, including Ecoregion 24, 27, 31, 32, 33, 34, and 35 and ranged from 0.055 – 0.43 mg/L. These values were typically in range with the TP threshold identified for Secchi transparency using combined data from all the ecoregions (0.063 mg/L) in FY2012-2013, but sometimes exceed this value by more than 7x. Model explanatory power within ecoregions typically was equal to or exceeded that of the combined data model (r^2 = 0.23). However, model explanatory power was less than 23% for Ecoregions 32, 34, and 35. For some ecoregions, the value of model TP thresholds was likely influenced by the high frequency of censored observations, as indicated by TP thresholds that were approximately equal to the most common quantification limit of 0.060 mg/L. These ecoregions included Ecoregions 27 and 32.

For models relating sestonic chl-a (both methods) and TP, statistically significant thresholds were identified for 4 of 11 level III ecoregions, including Ecoregion 24, 29, 30, and 32. These thresholds indicated that chl-a increased with increasing TP. These thresholds were slightly lower or within the range of TP thresholds identified for chl-a using combined data from all the ecoregions (0.069 – 0.099 mg/L), but the TP threshold for Ecoregion 24 was more than 2x higher than this range. Model explanatory power within ecoregions typically was equal to or exceeded that of the combined data model (r^2 = 0.04 – 0.09). For Ecoregion 30, the value of model TP threshold was likely influenced by the high frequency of censored observations, as indicated by TP thresholds for both chl-a spec and fluoro that were approximately equal to the most common quantification limits of 0.050 mg/L and 0.060 mg/L.

Fewer thresholds were identified for models relating biological variables to TN than to TP for level III ecoregions within Texas. For models relating Secchi transparency and TN, statistically significant TN thresholds were identified for 3 of 11 ecoregions, including Ecoregions 33, 34, and 35. These thresholds indicated that Secchi transparency decreased with increasing TN concentration and ranged from 0.84 – 3.2 mg/L. For Ecoregions 34 and 35, these values were in range with the TN threshold (0.070 mg/L) identified for the data combined from all ecoregions in FY 2012-2013, but the TN thresholds for Ecoregion 33 was more than 4x greater than the cumulative dataset threshold. Model explanatory power was high for the Secchi transparency vs. TN relationship in these three ecoregions, up to 9x greater than for the cumulative dataset.

For models relating chl-a and TN, statistically significant thresholds were identified for chl-a spec only and for 3 of 11 ecoregions, including Ecoregions 27, 30, and 35. These threshold indicated that chl-a concentration increased with increasing TN concentration and ranged from 1.1 – 1.6 mg/L, which was slightly higher but close in range with the TN threshold identified from data combining all ecoregions in FY2012-2013. Model explanatory power was high for the chl-a spec vs. TN relationship in these three ecoregions, up to 10x greater than for the cumulative dataset.

Summary of regional stressor-response analysis for Texas streams and rivers

Regional analysis of stressor-response relationships indicated that significant differences in total nutrient thresholds existed between some Texas basins and level III ecoregions. The majoriy of the thresholds based on relationships between chl-a and nutrient ocncentrations in streams and rivers are bassed on benthic algal biomass, rather than sestonic chl-a. Targets that have been suggested for chl-a in streams and rivers based on a variety of methods including regression, regression tree, nCPA, and two-dimensional Kologrov Smironov tests range from 0.0127 – 0.043 mg/L for TP and 0.435 – 0.918 mg/L for TN (Dodds et al. 2002, 2006; Stevenson et al. 2008). Regionally-specific thresholds identified for Texas basins and level III ecoregions consistently exceeded this range for TP. For TN, regional thresholds were closer in value to this range, with the exception of Basins 8 and 19 and Ecoregion 33, as well as Basin 23 and Ecoregion 27, to a lesser extent.

For Texas basins and level III ecoregions, most TP and TN thresholds were in range with the thresholds identified using the cumulative dataset in FY2012 – 2013. However, for some regions, TP thresholds were approximately 30 – 40% lower than for the cumulative dataset and appeared to be strongly influenced by censored data. In contrast, some regionally specific TP thresholds were 2 – 7x higher than for the cumulative dataset. In some cases, TP thresholds relative to Secchi transparency or chl-a also diverged greatly within a single region, such as for Basin 2, where the TP threshold relative to transparency was among the lowest in the study (0.060 mg/L), while the TP threshold relative to chl-a was among the highest (0.21 mg/L). Regional TN thresholds could be up to 30% lower and up to 7x higher than the TN threshold identified using the cumulative dataset.

Model explanatory power almost always exceeded that of the cumulative dataset model for all stressor-response combinations, especially when chl-a was the response variable. These findings suggest that regional differences in the range of nutrient and biological response variable values and threshold interactions created noise in the cumulative dataset that weakened analysis, supporting the argument for examining stressor-response levels at regional scales for Texas streams and rivers. However, additional data are required before this objective can be achieved for all Texas basins or level III ecoregions.

Table 1.2.1 Summary of TP and TN thresholds (CP) with confidence intervals (CI) by major Texas river basin (1-24). Thresholds were identified using non-parametric changepoint analysis, where Secchi transparency and chl-a measured spectrophotometrically (chl-a spec) and fluorometrically (chl-a fluoro) were potential response variables. Model summary statistics, including r^2, p_{perm}, average value of the response variable above and below the nutrient threshold (M_R and M_L, respectively), and number of observations above and below the nutrient threshold (n_R and n_L, respectively) are included for all possible stressor-response models where n>20. All values for CP are in mg/L. Values for M_R and M_L are in meters or µg/L, where nutrient thresholds are relative to responses in Secchi transparency or chl-a, respectively. Models indicating relationships between nutrient stressors and response variables that were not congruent with ecological theory or not statistically significant (p>0.05) are shown in gray italics.

		vs. TP (mg/L)							vs. TN (mg/L)						
Basin	Variable	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L
All TX	Secchi	0.063↓ (0.062-0.085)	0.23	0.001	0.75	0.41	253	565	0.70↓ (0.56-3.5)	0.04	0.003	0.73	0.52	64	441
	Chl-a spec	0.099↑ (0.066-0.11)	0.09	0.001	6.6	11	298	297	1.1↑ (0.75-1.9)	0.04	0.01	7.9	11	155	244
	Chl-a fluoro	0.069↑ (0.068-0.12)	0.07	0.001	6.0	13	127	212	-	*0.05*	*0.059*	-	-	-	-
1	Secchi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Secchi	0.060↓ (0.060-0.28)	0.81	0.01	0.51	0.30	10	28	-	*0.20*	*0.16*	-	-	-	-
	Chl-a spec	0.21↑ (0.096-0.29)	0.27	0.012	8.4	20	28	10	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	Secchi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-

		vs. TP (mg/L)							vs. TN (mg/L)						
Basin	Variable	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L
4	Secchi	0.086↓ (0.085-0.12)	0.29	0.006	0.66	0.45	11	20	0.72↓ (0.66-0.93)	0.43	0.004	0.74	0.47	7	20
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	Secchi	0.066↓ (0.066-0.11)	0.46	0.001	0.67	0.36	5	17	0.85↓ (0.84-1.1)	0.64	0.001	0.80	0.39	5	17
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	Secchi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	Secchi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	Secchi	0.11↓ (0.063-0.13)	0.25	0.001	0.44	0.27	43	27	2.7↓ (0.79-2.99)	0.23	0.003	0.40	0.22	52	13
	Chl-a spec	0.078↑ (0.068-0.090)	0.34	0.001	5.9	11.6	44	47	-	*0.13*	*0.052*	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	Secchi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-

		vs. TP (mg/L)							vs. TN (mg/L)						
Basin	Variable	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L
10	Secchi	0.16↓ (0.15-1.6)	0.19	0.001	0.61	0.38	107	35	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	Secchi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	Secchi	0.063↓ (0.063-0.098)	0.23	0.001	0.84	0.46	40	78	-	*0.04*	*0.36*	-	-	-	-
	Chl-a spec	0.12↑ (0.12-0.49)	0.30	0.001	7.4	16	37	32	-	*0.09*	*0.26*	-	-	-	-
	Chl-a fluoro	0.11↑ (0.075-0.12)	0.14	0.008	6.7	16	54	47	-	*0.05*	*0.42*	-	-	-	-
13	Secchi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	Secchi	0.078↓ (0.063-0.093)	0.12	0.002	0.64	0.38	69	27	0.51↓ (0.43-1.5)	0.13	0.042	0.69	0.45	17	50
	Chl-a spec	0.063↑ (0.063-0.080)	0.18	0.012	6.8	16	44	28	1.2↑ (0.66-1.5)	0.15	0.040	6.4	14	49	14
	Chl-a fluoro	-	*0.14*	*0.074*	-	-	-	-	1.3↑ (0.93-2.0)	0.17	0.041	5.7	18	36	21
15	Secchi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-

		vs. TP (mg/L)							vs. TN (mg/L)						
Basin	Variable	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L
16	Secchi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	Secchi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	Secchi	0.060↓ (0.055-0.063)	0.11	0.039	1.2	0.61	29	33	-	-	-	-	-	-	-
	Chl-a spec	0.058↑ (0.055-0.058)	0.23	0.006	2.8	5.0	34	25	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	Secchi	0.16↓ (0.086-0.58)	0.48	0.001	0.98	0.42	33	36	4.9↓ (2.2-7.0)	0.40	0.001	0.86	0.33	44	22
	Chl-a spec	-	*0.06*	*0.48*	-	-	-	-	-	*0.07*	*0.56*	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	Secchi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	Secchi	0.065↓ (0.058-0.076)	0.55	0.001	0.99	0.26	17	16	-	-	-	-	-	-	-
	Chl-a spec	-	*0.18*	*0.12*	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	*0.19*	*0.073*	-	-	-	-	-	-	-	-	-	-	-

		vs. TP (mg/L)							vs. TN (mg/L)						
Basin	Variable	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L
22	Secchi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	Secchi	0.086↓ (0.080-0.095)	0.63	0.001	0.94	0.28	22	26	2.0↓ (1.1-2.2)	0.26	0.006	0.71	0.20	32	10
	Chl-a spec	0.13↑ (0.13-0.46)	0.18	0.047	8.5	15	34	21	1.7↑ (1.6-2.8)	0.20	0.032	9.3	16	27	16
	Chl-a fluoro	0.22↑ (0.14-0.33)	0.40	0.001	7.6	23	22	5	1.7↑ (1.2-2.0)	0.42	0.003	7.6	25	19	8
24	Secchi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-

↓ The value of the response variable decreases with increasing predictor variable values, and vice versa
↑The value of the response variable increases with increasing predictor variable values, and vice versa

Table 1.2.2. Summary of TP and TN thresholds (CP) with confidence intervals (CI) by EPA Level III Ecoregion (24-35, except 28). Thresholds were identified using non-parametric changepoint analysis, where Secchi transparency and chl-a measured spectrophotometrically (chl-a spec) and fluorometrically (chl-a fluoro) were potential response variables. Model summary statistics, including r^2, p_{perm}, average value of the response variable above and below the nutrient threshold (M_R and M_L, respectively), and number of observations above and below the nutrient threshold (n_R and n_L, respectively) are included for all possible models. All values for CP are in mg/L. Values for M_R and M_L are in meters or µg/L, where nutrient thresholds are relative to responses in Secchi transparency or chl-a, respectively. Models indicating relationships between nutrient stressors and response variables that were not congruent with ecological theory or that were not statistically significant (p>0.05) are shown in gray italics.

		vs. TP (mg/L)							vs. TN (mg/L)						
Ecoregion	Variable	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L
All TX	Secchi	0.063↓ (0.062-0.085)	0.23	0.001	0.75	0.41	253	565	0.070↓ (0.56-3.5)	0.04	0.003	0.73	0.52	64	441
	Chl-a spec	0.099↑ (0.066-0.11)	0.09	0.001	6.6	11	298	297	1.1↑ (0.75-1.9)	0.04	0.01	7.9	11	155	244
	Chl-a fluoro	0.069↑ (0.068-0.12)	0.07	0.001	6.0	13	127	212	1.2↑ (1.1-6.8)	0.05	0.059	6.5	15	118	179
24	Secchi	0.075↓ (0.075-0.10)	0.76	0.001	0.89	0.16	8	15	1.1↓ (1.0-1.5)	0.46	0.004	0.79	0.23	12	10
	Chl-a spec	0.23↑ (0.17-0.60)	0.39	0.005	10	17	14	10	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	Secchi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	Secchi	*-*	*0.07*	*0.56*	*-*	*-*	*-*	*-*	-	-	-	-	-	-	-
	Chl-a spec	*-*	*0.21*	*0.069*	*-*	*-*	*-*	*-*	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-

		vs. TP (mg/L)							vs. TN (mg/L)						
Ecoregion	Variable	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L
27	Secchi	0.066↓ (0.06-0.11)	0.28	0.001	0.53	0.33	19	25	-	*0.13*	*0.32*	-	-	-	-
	Chl-a spec	-	*0.22*	*0.054*	-	-	-	-	1.6↑ (1.4-1.8)	0.39	0.018	11	30	12	8
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	Secchi	-	*0.03*	*0.64*	-	-	-	-	-	*0.09*	*0.25*	-	-	-	-
	Chl-a spec	0.098↑ (0.075-0.49)	0.30	0.001	7.5	15	36	29	-	*0.14*	*0.11*	-	-	-	-
	Chl-a fluoro	0.085↑ (0.074-0.1)	0.17	0.017	7.0	14	32	25	-	*0.03*	*0.88*	-	-	-	-
30	Secchi	-	*0.07*	*0.071*	-	-	-	-	-	*0.13*	*0.083*	-	-	-	-
	Chl-a spec	0.045↑ (0.037-0.055)	0.23	0.002	1.4	7.0	12	51	1.1↑ (0.31-1.2)	0.22	0.01	6.7	11	34	10
	Chl-a fluoro	0.060↑ (0.058-0.060)	0.03	0.005	4.0	19	39	3	-	*0.10*	*0.22*	-	-	-	-
31	Secchi	0.083↓ (0.058-0.089)	0.45	0.001	0.92	0.30	21	19	-	*0.08*	*0.63*	-	-	-	-
	Chl-a spec	-	*0.15*	*0.11*	-	-	-	-	-	-	-	-	-	-	-
	Chl-a fluoro	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32	Secchi	0.055↓ (0.055-0.15)	0.17	0.001	1.1	0.58	14	130	-	*0.03*	*0.51*	-	-	-	-
	Chl-a spec	0.079↑ (0.073-0.085)	0.08	0.005	5.3	7.9	80	67	-	*0.05*	*0.23*	-	-	-	-
	Chl-a fluoro	-	*0.07*	*0.27*	-	-	-	-	-	*0.06*	*0.50*	-	-	-	-

		vs. TP (mg/L)							vs. TN (mg/L)						
Ecoregion	Variable	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L
33	Secchi	0.43↓ (0.091-0.52)	0.33	0.002	0.43	0.24	28	26	3.2↓ (2.9-4.7)	0.35	0.001	0.43	0.24	27	25
	Chl-a spec	-	*0.09*	*0.30*	-	-	-	-	-	*0.13*	*0.16*	-	-	-	-
	Chl-a fluoro	-	*0.11*	*0.29*	-	-	-	-	-	*0.09*	*0.42*	-	-	-	-
34	Secchi	0.16↓ (0.095-0.24)	0.18	0.001	0.55	0.33	44	138	0.91↓ (0.91-2.6)	0.30	0.006	0.53	0.29	5	44
	Chl-a spec	-	*0.09*	*0.18*	-	-	-	-	-	*0.16*	*0.08*	-	-	-	-
	Chl-a fluoro	-	*0.05*	*0.61*	-	-	-	-	-	*0.06*	*0.59*	-	-	-	-
35	Secchi	0.088↓ (0.062-1.4)	0.10	0.003	0.56	0.43	58	107	0.84↓ (0.79-0.93)	0.28	0.001	0.63	0.41	26	48
	Chl-a spec	-	*0.10*	*0.09*	-	-	-	-	1.2↑ (0.70-1.2)	0.17	0.026	8.7	13	41	6
	Chl-a fluoro	-	*0.08*	*0.36*	-	-	-	-	-	*0.11*	*0.33*	-	-	-	-

↓ The value of the response variable decreases with increasing predictor variable values, and vice versa
↑The value of the response variable increases with increasing predictor variable values, and vice versa

1.3 FREQUENCY DISTRIBUTION ANALYSIS FOR TEXAS STREAM AND RIVER SEGMENTS

Methods

Frequency distribution analyses were conducted on station medians located within TCEQ designated stream and river segments (https://gisweb.tceq.texas.gov/segments/default.htm). Because each stream and river reach within a segment was not equally represented in the raw water quality dataset, frequency distributions were calculated using medians to remove potential site-specific bias for sites that were over- or under-represented in the data.

Frequency distributions (minimum value, 10th, 25th, 50th, 75th, 90th percentiles and maximum value) were calculated using Microsoft Excel for the water quality parameters total phosphorus (TP; TCEQ parameter code 00665), total nitrogen (TN; calculated parameter code 00600C; TCEQ parameter code 00625 + 00630, 00625 + 00593 or 00625 + 00615 + 00620), nitrate+nitrite-nitrogen (NO_x-N; calculated parameter 00630C; TCEQ parameter code 00630, 00593 or 00615 + 00620), orthophosphate-phosphorus (PO_4-P; TCEQ calculated parameter code 00671C; TCEQ parameter codes 00671 or 70507), and sestonic chlorophyll-a measured fluorometrically (chl-a fluoro; TCEQ parameter code 70953). For this study, a parameter combining chl-a measured spectrophotometrically and fluorometrically measured chlorophyll-a was not created due differences between the methods (Laurie Eng, personal communication). Because data were more complete and censorship was less of a concern than for spectrophotometric chl-a, frequency distributions for sestonic chl-a were only calculated for the fluorometric method.

Results and Discussion

For Texas streams and rivers, 769 unique segment codes were identified from the data that TCEQ provided for building the streams and rivers median database during FY2012-2013. For all parameters of interest, the majority of these stream and river segments contained fewer than 4 station medians and were therefore not eligible for calculation of 25th percentile estimates. None of the segments contained 30 or more stations medians, which is the minimum number of data points recommended by the EPA for frequency distribution analysis as a means for developing water quality standards.

Significant variability in 25th percentiles among segments with n ≥4 station medians was observed, for Texas streams and rivers (Table A1.5.1; Appendix 1.5). For TP, 75 segments had ≥4 medians, and 25th percentiles ranged from 0.020 – 1.2 mg/L. For TN, 34 segments had ≥4 medians, and 25th percentiles ranged from 0.29 – 7.5 mg/L. For NO_x-N, 73 segments had ≥4 medians, and 25th percentiles ranged from 0.02 – 6.2 mg/L. For PO_4-P, 81 segments had ≥4 medians, and 25th percentiles ranged from 0.005-1.2 mg/L. For chl-a fluoro, 15 segments had ≥4 medians, and 25th percentiles ranged from 1.1 – 21.9 µg/L.

Summary of frequency distributions by segment for Texas streams and rivers

Significant variability in 25th percentiles among segments with n ≥4 station medians was observed in these analyses. While no Texas stream or river segments included 30 or more station medians, these percentile estimates may be a useful tool for identifying stream and river segments that would be in or out of compliance with proposed nutrient and biological response target or as part of a weight of evidence approach to setting targets. Furthermore, we recommend that TCEQ review whether combining segments with overlapping designations, such as 1233A and 1233B, would be appropriate for calculating segment-specific frequency distributions. If appropriate, combining segments with potentially overlapping designations would increase the number of medians per segment for many Texas stream and river segments.

1.4 NUTRIENT, HABITAT, AND CHLOROPHYLL-A THRESHOLDS FOR MACROINVERTEBRATE COMMUNITY RESPONSE

Methods

Data acquisition and compilation of macrobenthic community metrics database

Previous stressor-response analyses were conducted using multimetric rapid bioassessment index of biotic integrity (RBIBI) scores. These analyses identified thresholds that were consistently weak or not statistically valid as predictors of RBIBI (AWRC 2013). However, habitat quality (HQI) was consistently a strong predictor variable. To expand these analyses, TCEQ provided bioassessment data for parameters describing individual components of macroinvertebrate communities in select Texas streams and rivers. These metrics describe the macrobenthic community at a finer scale than the RBIBI and may yield stronger relationships to nutrients than RBIBI scores. These metrics included Hilsenhoff Biotic Index (HBI; parameter 90007); the percentage of individuals in functional feeding groups, such as gatherers (90025), filterers (90030), shredders (90035), and predators (90036); the percentage of individuals belonging to the dominant taxon (90042); the ratio of intolerant to tolerant benthic taxa (90050); total taxa richness (90055); total number of intolerant taxa (90058); the percentage of individuals belonging to the orders Ephemeroptera, Plecoptera, and Tricoptera (EPT; 90060); the percentage of individuals belonging to tolerant taxa (90066); and the percentage of individuals in the dominant 3 taxa (90067). For the parameters taxa richness and number of intolerant taxa, individuals belonging to the order Chironomidae were classified both to the family and genus level. Because the dataset was more complete, the iteration of the data for which Chironomidae were classified to the family level was selected for inclusion in the community metrics bioassessment median database and for subsequent analysis.

The raw community metric data were provided from two sources: the Surface Water Quality Monitoring Information System (SWQMIS) and a more comprehensive database stored in-house by TCEQ personnel. Both databases were initially sorted, and any data collected before calendar year 2000 or after 2010 were removed to constrain the community metric data within the same timeframe as water quality medians from the FY2012-2013 streams and rivers database. Data from the SWQMIS were received in a single column format and were therefore reorganized using a pivot table so that data for each unique parameter were stored in a separate column. The in-house database was already organized with separate columns by parameter. After achieving an identical format for the raw databases, data from the two sources were merged for each Station ID. Many station and sample date combinations were redundant between the two sources, but the values of redundant data were often not identical, potentially due to transcription error (Jill Csekitz, personal communication). For station and sample date combinations appearing in both raw databases, TCEQ prioritized the values stored in the in-house database. Therefore, if multiple values for a parameter were available for the same station on the same sample date, where at least one value each originated from the SWQMIS and the in-house database, only data from the in-house database were retained. In other cases, multiple values were available for a station on a single date within the in-house database. These were interpreted as replicates and were averaged for each date.

Following these data reduction steps to remove conflicting or redundant information, long-term medians for each community metric were calculated for each station. Previous work with Texas bioassessment data indicated that relationships between bioindicator (Fish IBI and RBIBI) scores and potential stressor variables were most apparent when the raw data were aggregated into summary statistics over long time scales (AWRC 2013). Therefore, medians were calculated for the cumulative period of record (2000 – 2010) of this study. The medians for each Station ID were then compiled into a community metrics database.

Station medians for community metrics were linked to other identifying geographic classifications, including basin, Omnerik Level III Ecoregion, and Segment ID, by cross referencing with stations in the FY2012 – 2013 water quality median database and bioassessment database for Texas streams and rivers. Habitat quality index (HQI) scores were also integrated in this way. In tandem with community metric raw data, TCEQ providedflow designations (e.g. perennial, intermittent, intermittent with pools) and projected aquatic life use (ALU) scores for stations and segments. These were linked to station medians for community metrics by cross referencing with Segment ID. Finally, community metric medians were linked to water quality medians calculated for the years 2000 – 2010 from the FY2012 – 2013 Texas streams and rivers water quality median database. For these analyses, the minimum number of observations required for a water quality median to be included in analysis was 10 per station.

Statistical analyses of macrobenthic community metrics database

We conducted both regression and changepoint analyses on the community metrics bioassessment median database for streams and rivers. Analyses focused on three priority community metrics, as defined by TCEQ: HBI, the ratio of intolerant vs. tolerant taxa, and total taxa richness. Potential explanatory variables in the analyses were total nitrogen and phosphorus (TN and TP; mg/L); parameter codes 00600C and 00665, respectively), habitat quality index (HQI), sestonic chlorophyll-a measured with spectrophotometry (chl-a spec; 32211), and sestonic chlorophyll-a measured with fluorometry (chl-a fluoro; 70953).

Regional factors, including flow regime, were expected to give rise to naturally occurring variability in stream biological communities. In this study, analyses of community metrics vs. total nutrients (TN and TP) were carried out both for all Texas streams and rivers represented in the bioassessment database and also for perennial streams only. Data from intermittent, intermittent with pools, and tidal streams, were insufficient for separate analysis. In this study, distributions of macrobenthic community metrics and relationships with TP and TN within Omnerik Level III ecoregions were examined for potential broad regional differences, as has been shown for fish communities in Texas (Pease et al. 2015).

Regression analyses relating community metrics and potential explanatory variables were conducted in SigmaPlot 12.5. Relationships between these types of variables can vary relative to one another both linearly or over orders of magnitude for one or both variables. Therefore, simple linear regression, as well as non-linear exponential, logarithmic, and power models were considered.

CART analyses were performed using the MVPART library in R 2.9.1 (http://www.r-project.org/). CART analysis is a means to reduce data, based on quantifying thresholds in independent variables that are correlated with shifts in the magnitude and/or variability of dependent variables. This statistical procedure can also provide hierarchical structure in independent variables, showing multiple thresholds from the same or different independent variables. CART analysis is very useful for resolving nonlinear, hierarchical, and high-order interactions among predictor variables (De'Ath and Fabricius 2000) and for detecting numerical values that lead to ecological changes (Qian and others 2003). CART models use recursive partitioning to separate data into subsets that are increasingly homogeneous; for example, subsets of data representing similar nutrient conditions. This iterative process invokes a tree-like classification that can reveal relationships that are often difficult to reconcile with conventional linear models (Urban 2002). We "pruned" CART models to generate final models that balanced accuracy within the available dataset with robustness to novel data (Urban 2002). CART models were cross-validated to determine "pruning size" (i.e., the number of predictor variables included in the model). Model cross-validations were conducted using 10 random and similarly sized subsets of our data according to the method detailed by De'ath and Fabricius (2000). The optimum tree size for each model was selected using the minimum cross-validated error rule (De'ath and Fabricius 2000).

Following CART analysis, non-parametric changepoint analysis was used to determine model statistical significance (p_{perm}<0.05) and 95% confidence interval about the threshold estimate (Qian et al. 2003, King and Richardson 2003). This analysis uses random permutations to estimate a p value that can be used to determine Type I and II error associated with the threshold and simultaneously uses bootstrapping to calculate cumulative probability to estimate uncertainty and provide confidence estimates for the threshold. We required a minimum of 10 observations to be used in any single split in the CART model and that each terminal node in the model had a minimum of 5 observations.

A user's guide to interpreting CART and nCPA models and associated summary statistics is available in Appendix 1.1. In Appendix 1.2, the statistical code and raw output generated for each CART and nCPA analysis conducted for this study on stressor-response relationships in the Texas streams and rivers bioassessment database has been compiled.

Results and Discussion

Nutrients

A number of relationships between macrobenthic community response and stressor variables were identified in the Texas streams and rivers bioassessment median database in both regression and changepoint analyses. However, with the exception of taxa richness vs. TN, total nutrients were consistently not statistically significant predictor variables ($p<0.05$) for the focus community metrics. These findings were consistent with previous analysis of multimetric bioassessment indices (Fish IBI and RBIBI) for Texas streams and rivers indicating that total nutrient concentrations were weak or not statistically significant predictors of macrobenthic biotic integrity (AWRC 2013).

For both the all streams and perennial streams groups, no regression relationships were identified for any stressor-response pair. For total taxa richness vs. TN in both all streams and perennial streams groups, changepoint analysis indicated a TN threshold = 1.0 mg/L (Fig. 1.4.1A-B). This threshold explained approximately 14-16% of variability in richness (r^2 = 0.14-0.16) and was in range with TN thresholds identified in previous analyses of the FY2012-2013 water quality median database (Table 1.1.1). Results were similar between the all streams and perennial streams groups. The difference between low and high richness station groups above and below the TN threshold were somewhat greater in the perennial streams group. For all streams, macrobenthic richness was approximately 20% lower when TN exceeded 1.0 mg/L, but was 30 – 40% lower on average above the threshold in perennial streams. The number of taxa was reduced by 4 in the all streams group and by 6 in the perennial streams group.

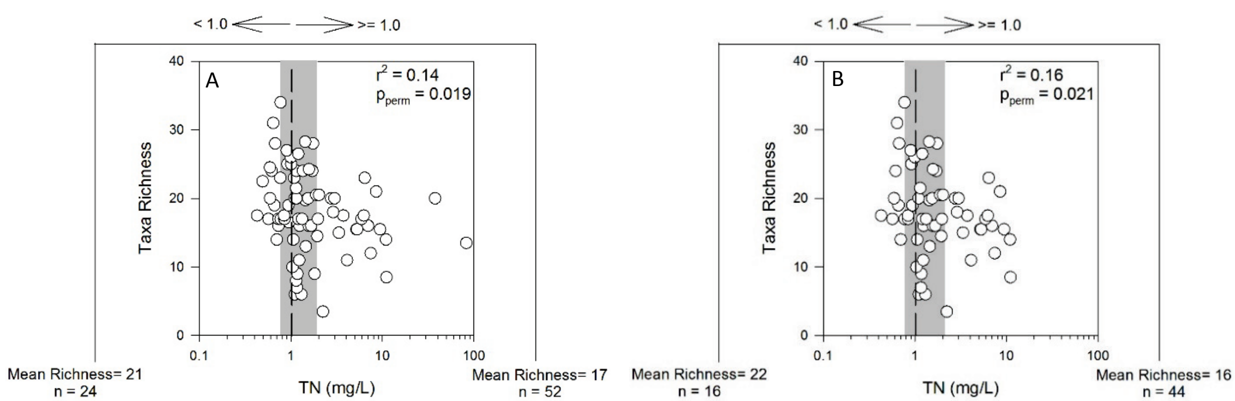


Figure 1.4.1. Analysis of the relationship between total taxa richness and total nitrogen (TN) using changepoint analysis in the A) all Texas streams and rivers and B) perennial streams only groups. The TN threshold and confidence interval are shown as a dashed line and shaded area, respectively.

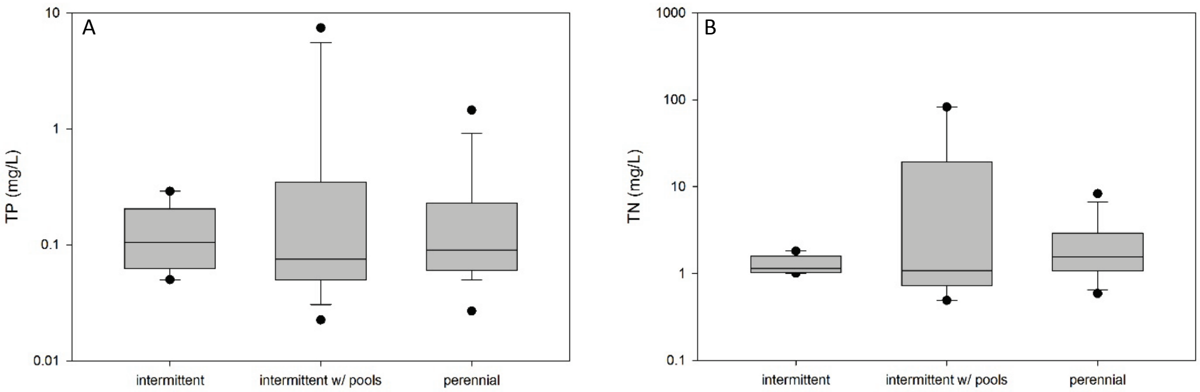


Figure 1.4.2. Distributions of A) total phosphorus (TP) and B) total nitrogen (TN) medians by stream flow type in the community metrics bioassessment database shown on the log10 scale. The shaded area represents data falling between the 25th and 75th percentiles, while error bars indicate the 10th and 90th percentiles and outlier icons represent 5th and 95th percentiles.

No clear differences were observed in analytical outcomes when all stream types were considered together vs. perennial streams only. This finding reflects the fact that approximately 80% of the eligible stations were designated as perennial streams. Therefore, due to the limited availability of data for other stream types, it was not possible to determine if biological community composition and stressor-response relationships were affected by flow regime.

Differences in nutrient concentrations between streams of different flow regimes was observed, however. Nutrient data from each stream type were fitted to boxplots to explore whether frequency distributions differed by flow type (Fig. 4.1.2A-B). Intermittent streams with pools were associated with the highest nutrient concentrations, with upper percentiles that were up to an order of magnitude higher than for perennial streams. Intermittent streams, by contrast exhibited a narrow range of values compared to both perennial and intermittent with pools streams, though the sample size for this flow type was low $n < 5$. High nutrient outliers have the potential to strongly skew or reduce analysis strength for both regression and changepoint analyses. Therefore, in subsequent stressor-response analyses (habitat and sestonic chl-a), these effects were avoided by including data from perennial streams only. However, all stream types were considered together for subsequent regional analyses of community metric frequency distributions since the dataset was predominantly comprised of biological samples from perennial streams, and broad regional analysis was performed for exploratory purposes only.

Omnerik Level III Ecoregion

Potential regional differences in target macrobenthic community metrics among all Texas stream types were explored by organizing data frequency distributions into boxplots by Omnerik Level III Ecoregions (Fig. 1.4.3A-C). Boxplots indicated potential regional differences in the target community metrics, revealing variability both in medians and in the spread of data distributions. These differences could indicate naturally occurring gradients in macrobenthic community composition and biotic integrity, but could also reflect local flow regime or anthropogenically derived differences between ecoregions, such as the percentage of land use in urban or agricultural development, or other factors. Further analyses would also be required to determine whether ecoregion-specific datasets represent statistically different populations, and several ecoregions would likely require additional data for such analyses (i.e. Ecoregions 24, 27, and 31).

Based on regional HBI distributions (Fig. 1.4.3.A), Omnerik Level III ecoregions within Texas could be divided into three groups (low, mid-range, and high HBI). Low and high range groups would consist of ecoregions where medians, but also other percentiles, differed most from each other, while a mid-range group would consist of ecoregions with mid-range medians and largely overlapping spread in distributions. Ecoregions 27, 30, and 31 exhibited the largest differences in distributions. For Ecoregion 27, HBI scores were consistently high relative to other regions, indicating low biotic integrity in benthic communities. For Ecoregions 30 and 31, HBI medians were most often the lowest in the study, indicating high biotic integrity. The shape of data distributions for Ecoregions 27, 30, and 31 were potentially different enough from each other and other ecoregions with mid-range medians that advanced analysis might substantiate that these were statistically significant differences. However, it should be noted that Ecoregions 27 and 31 had very limited sample size (n = 4 – 6), and therefore the available data may not adequately represent biological communities in these ecoregions. Ecoregion 24 had the highest median HBI in the study, but also the largest spread (HBI ~ 2 – 8), making it difficult to place this ecoregion in one of the low, mid, or high HBI groups. Median HBI scores for the remaining ecoregions (Ecoregions 29, 32, 33, 34, and 35), which comprised a mid-range HBI group, were approximately = 5.

Similar regional trends were observed in the ratio of intolerant: tolerant taxa (Fig. 1.4.3.B). Ecoregion 27 again comprised a low biotic integrity group with the lowest ratios in the study (ratio <1), indicating low representation of intolerant taxa in the biological community in this region. Ecoregions 30 and 31 again comprised a high biotic integrity group with highest ratios in the study and median ratios an order of magnitude higher than for Ecoregion 27. For ecoregion 31, ratios were always >1, and only the lowest percentiles were <1 for ecoregion 30. Ecoregion 24 had the lowest median ratio (ratio ~ 0.1) and the greatest spread in the value of the metric of interest, with ratios ranging from approximately 0.01 – 10 across the 5^{th} – 95^{th} percentile range, across just 5 sites. Median ratios for the remaining ecoregions (Ecoregions 29, 32, 33, 34, and 35), which comprised a mid-range group, were approximately = 1.

For taxa richness, potential regional trends were less clear (Fig. 1.4.3C). Median richness ranged from approximately 8 – 20 taxa across ecoregions, but low, mid, and high richness groups could not be established with confidence because the spread of the distributions was similar for most of the ecoregions. Distributions of data from Ecoregions 27 and 31 exhibited smaller spread, but data from these regions was all mid-range within data from other ecoregions with a wider spread of taxa richness. As with HBI and intolerant:tolerant, median taxa richness was among the lowest for Ecoregion 27 and highest for Ecoregion 30, but higher and lower percentiles for both ecoregions fell within the range of the distributions of the remaining ecoregions.

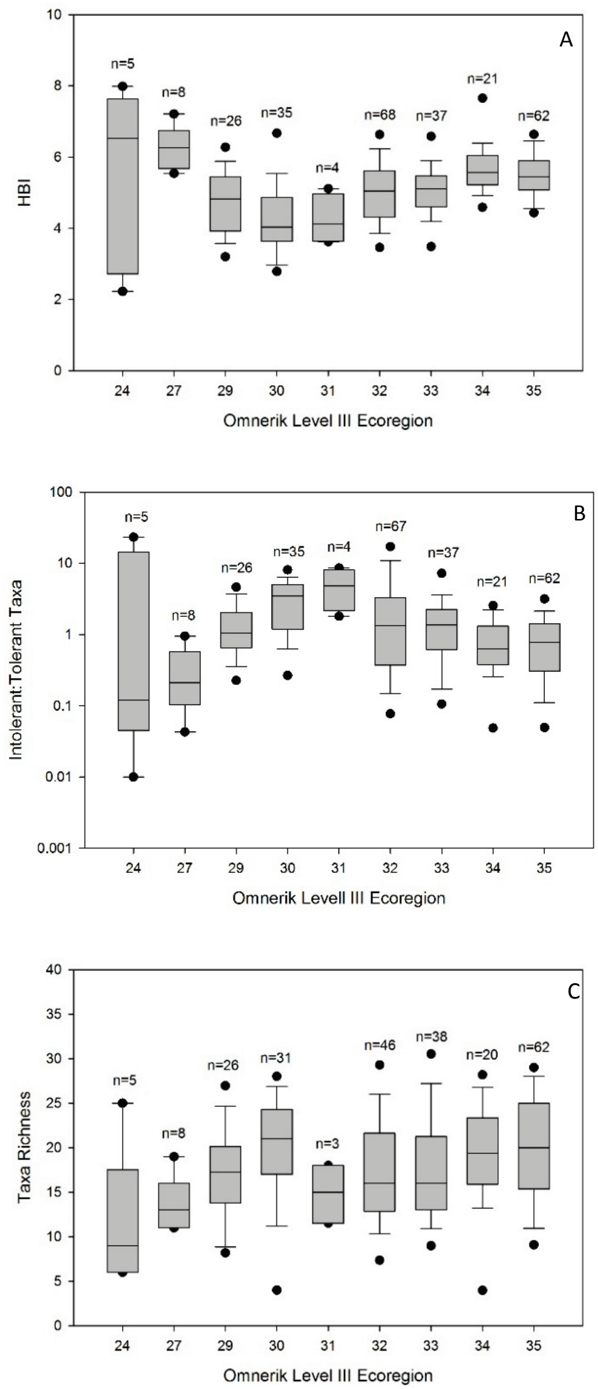


Figure 1.4.3. Distributions of A) Hilsenhoff biotic index (HBI) scores, B) ratios of intolerant:tolerant taxa, and C) taxa richness within Omnerik Level III ecoregions within Texas and with available stream and river bioassessment data. The shaded area represents data falling between the 25th and 75th percentiles, while error bars indicate the 10th and 90th percentiles and outlier icons represent 5th and 95th percentiles.

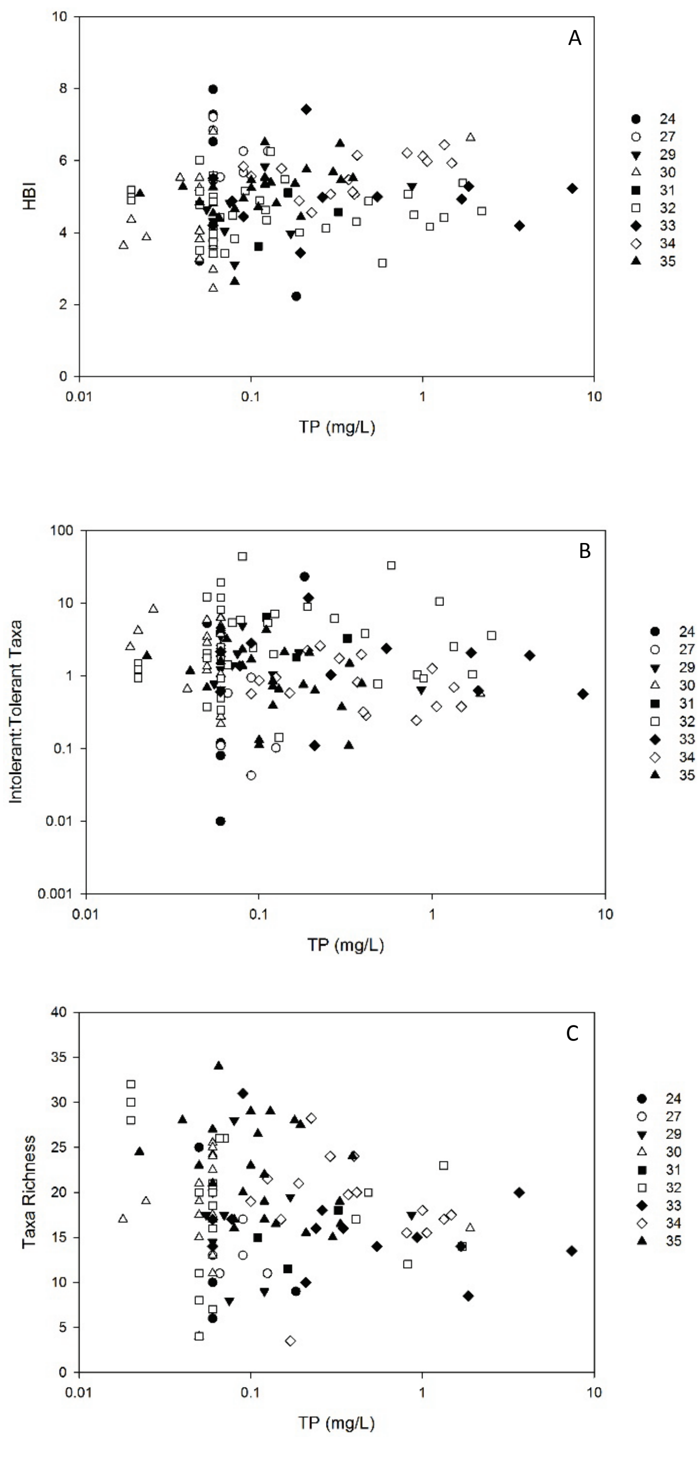


Figure 1.4.4. The relationship between A) Hilsenhoff biotic index (HBI), B) intolerant:tolerant taxa, and C) taxa richness and total phosphorus (TP) by Level III Omnerik ecoregion in Texas streams and rivers represented in the bioassessment database.

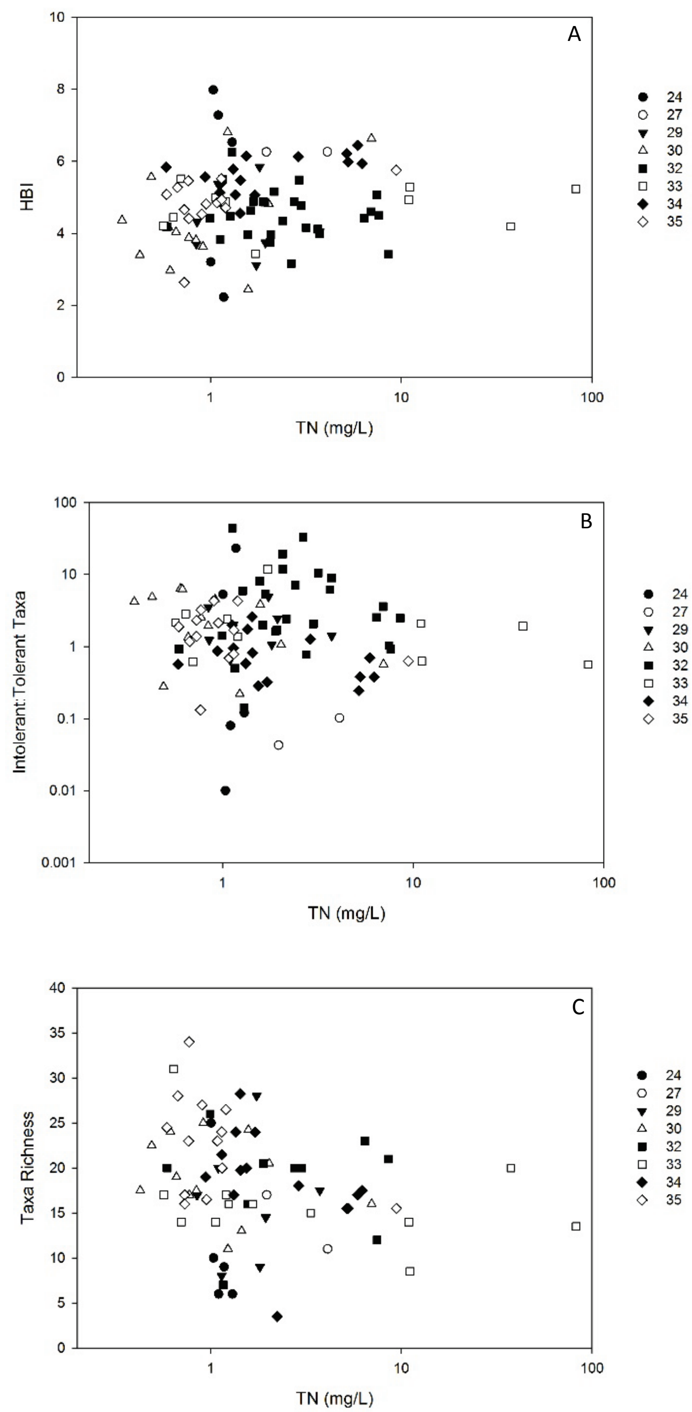


Figure 1.4.5. The relationship between A) Hilsenhoff biotic index (HBI), B) intolerant:tolerant taxa, and C) taxa richness and total nitrogen (TN) by Level III Omnerik ecoregion in Texas streams and rivers represented in the bioassessment database.

No clear differences were observed in the way that the target community metrics responded to TP (Fig. 1.4.4A-C) or TN gradients (1.4.5.A-C) between Omnerik Level III Ecoregions. Across ecoregions, stressor-response pairs were found within a wide range of nutrient values for each of the three target community metrics. No clusters of stressor-response pairs widely deviated from other data points or obscured the expected trend of decreasing biotic integrity with increasing nutrient concentrations. As with frequency distribution analysis, sample size was also limiting for some ecoregions in these comparisons. Just a few stressor-response pairs were available for Ecoregions 24, 27, and 31, and no community metric and TN concentration data were paired for Ecoregion 31.

A noteworthy trend that emerged from these comparisons ties the highest outlier nutrient concentrations observed in intermittent streams with perennial pools to a specific ecoregion. At the highest nutrient values (TP > 5.0 mg/L and TN > 10 mg/L), only stations within Ecoregion 33 were represented in the paired data. Removing these data points did not alter the outcome of the regression or changepoint analyses of community metric vs. nutrient relationships in perennial streams compared to all streams, but these high nutrient stations did exhibit lower HBI and higher intolerant:tolerant taxa and taxa richness (i.e. higher biotic integrity) than would be expected based on potential statistical models, especially regression relationships. Possible interpretations for this trend include high naturally occurring nutrient conditions for Ecoregion 33 that have led to a macrobenthic community with high resilience to nutrient enrichment. However, flow permanence is an important factor in macrobenthic community resilience (Shriever et al. 2015), making this finding unexpected for intermittent streams, even with perennial pools. Biological response to nutrient enrichment may also exhibit a plateau, where biotic integrity is not reduced after initial reductions related to enrichment, which may be the case for these streams.

Habitat

Habitat quality has consistently emerged as an important explanatory variable for biological community response in Texas streams and rivers. In the present and previous studies, models with HQI as an explanatory variable were among the most successful. Statistically significant relationships between the focus community metrics and HQI were found using both regression and changepoint analyses for each of the three response variables. Findings were consistent both with expectations based on ecological theory and with analyses of the multimetric index of biotic integrity scores for both fish and macroinvertebrates in Texas streams and rivers (AWRC 2013).

Hilsenhoff biotic index was inversely related to HQI (Fig. 1.4.6A-B). As habitat quality increased (increasing HQI), HBI decreased, reflecting improved biotic integrity. A linear regression model best described the rate at which HBI decreased with increasing HQI and explained approximately 20% of variability in HBI (Fig. 1.4.6A; $r^2 = 0.20$). A changepoint model, with a threshold in HQI = 21, also explained approximately 20% of variability in HBI (Fig. 1.4.6B; $r^2 = 0.20$). This threshold was in range with habitat thresholds identified for fish and macroinvertebrate IBI response (HQI = 17 – 21; AWRC 2013). However, the difference between HBI in low and high quality habitat groups was not substantial (HBI = 5.2 vs. 4.3).

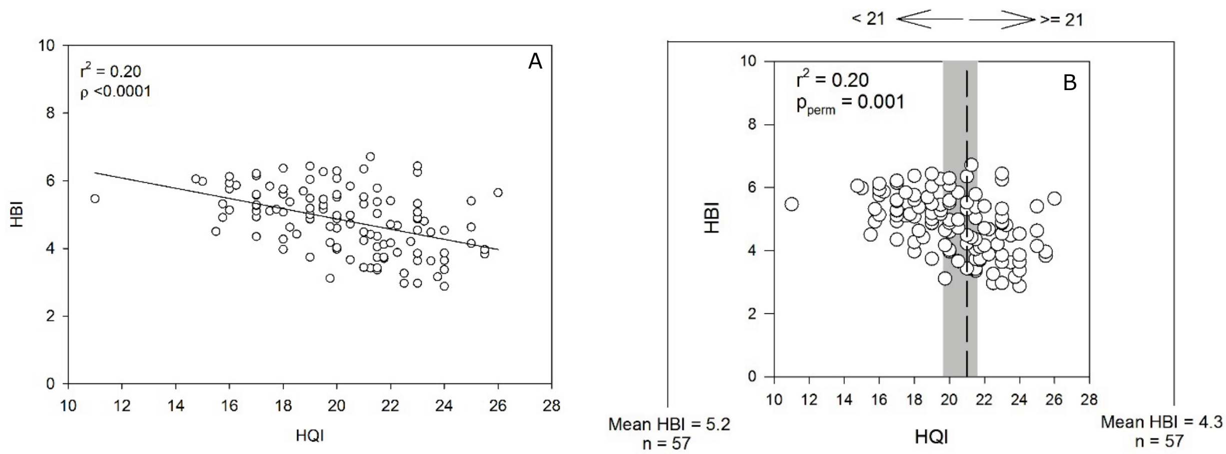


Figure 1.4.6. Analysis of the relationship between Hilsenhoff Biotic Index (HBI) and habitat quality (HQI) using A) simple linear regression analysis and B) changepoint anlysis in Texas streams and rivers. For statistically significant models (p<0.05), the best fit line in regression analysis is shown as a solid line. For changepoint analysis results, the habitat threshold and confidence interval are shown as a dashed line and shaded area, respectively.

Intolerant:tolerant taxa was positively related to HQI (Fig. 1.4.7A-B). As habitat quality increased (increasing HQI), ratios also increased, reflecting greater representation of species that are intolerant to disturbance in the community. Ratios ranged over four orders of magnitude in the dataset, compared to a relatively small range of variability in HQI (approximately 10 – 30). Therefore, a simple linear regression model was not a suitable fit for the intolerant:tolerant taxa vs. HQI relationship. An exponential growth model best described the rate at which ratios increased with increasing HQI and explained approximately 14% of variability in ratios (Fig. 1.4.7A; r^2 = 0.14).

A changepoint model, with a threshold in HQI = 24, was also statistically significant and explained a similar level of variability in ratios (Fig. 1.4.7B; r^2 = 0.18). This threshold was higher than the range of other habitat thresholds in this study and those identified previously for fish and macroinvertebrate IBI response (HQI = 17 – 21; AWRC 2013). The relationship may have been driven by a few high ratios observed at sites with the highest quality habitat, but could also indicate that the intolerant:tolerant taxa was a more sensitive metric for detecting changes in the macrobenthic due to physical disturbance than multimetric indices or the other two community metrics analyzed in this study. Intolerant to tolerant taxa ratios were approximately 4x greater on average for stations grouped by the analysis for high habitat quality vs. low habitat quality (10 and 2.3, respectively). However, ratios in the two groups were within the same order of magnitude. Since ratios varied over four orders of magnitude in the dataset, the observed differences between the groups may not be substantial, on average.

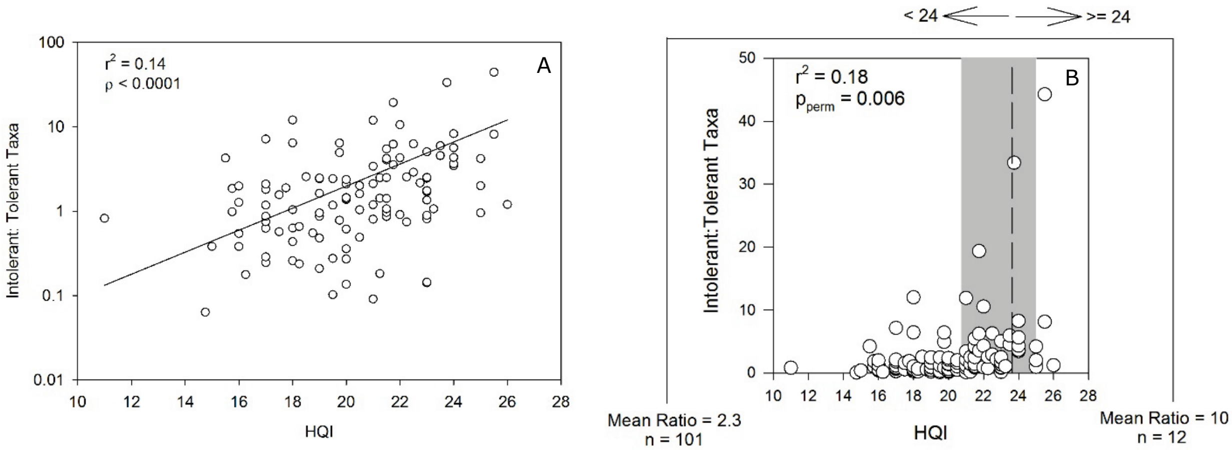


Figure 1.4.7. Analysis of the relationship between the ratio of intolerant to tolerant taxa and habitat quality (HQI) using A) logistic regression analysis and B) changepoint analysis in Texas streams and rivers. For statistically significant models (p<0.05), the best fit line in regression analysis is shown as a solid line. Note that ratios are shown on the log-scale for the panel illustrating results of regression analysis. For changepoint analysis results, the habitat threshold and confidence interval are shown as a dashed line and shaded area, respectively.

In Texas streams and rivers, taxa richness was positively related to HQI (Fig. 1.4.8A-B). As habitat quality increased (increasing HQI), taxa richness also increased, reflecting improved biotic integrity. Of the three focus community metric variables, relationships between taxa richness and habitat quality were the weakest, explaining the least amount of variability (< 12%), though both linear regression and changepoint models were statistically significant. A linear regression model best described the rate at which taxa richness increased with increasing HQI and explained approximately 8% of variability in taxa richness (Fig. 1.4.8A; r^2 = 0.08).

A changepoint model, with a threshold in HQI = 18, explained approximately 12% of variability in taxa richness (Fig. 1.4.8B; r^2 = 0.12). This threshold was in the lower range of habitat thresholds identified in this study or in previous studies of fish and macroinvertebrate IBI response (HQI = 17 – 21; AWRC 2013). This findings indicates that taxa richness may be a relatively insensitive metric for detecting changes in the macrobenthic community due to physical disturbance. The difference between taxa richness in low and high quality habitat groups was not substantial (Richness = 16 and 20, respectively).

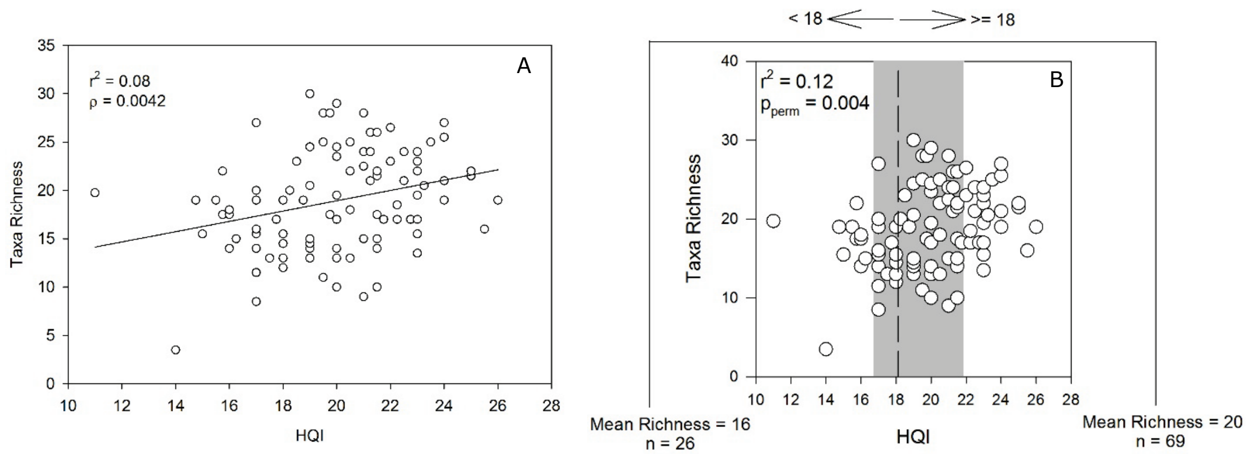


Figure 1.4.8. Analysis of the relationship between total taxa richness and habitat quality (HQI) using A) simple linear regression analysis and B) changepoint analysis in Texas streams and rivers. For statistically significant models (p<0.05), the best fit line in regression analysis is shown as a solid line. For changepoint analysis results, the habitat threshold and confidence interval are shown as a dashed line and shaded area, respectively.

Sestonic chlorophyll-a

In Texas streams and rivers, sestonic chl-a was also a potential predictor variable for community metrics. Statistically significant relationships between the focus community metrics and chl-a were found using both regression and changepoint analyses for each of the three response variables, and findings were consistent with expectations based on ecological theory. However, for the Texas streams and rivers datasets, sestonic chl-a data are also highly censored, and potential effects on analytical outcomes due to censored data were apparent for both chl-a spec and chl-a fluoro. These potential effects are discussed in detail for each community metric.

Hilsenhoff biotic index was positively related to sestonic chl-a concentration (Fig. 1.4.9A-D). As chl-a concentrations increased, HBI increased, reflecting reduced biotic integrity. This trend was observed for chl-a measured both spectrophotometrically and fluorometrically. A linear regression model best described the rate at which HBI increased with increasing chl-a spec and chl-a fluoro concentrations (Fig. 1.4.9A-B). When chl-a spec was the predictor variable, linear regression explained approximately 20% of variability in HBI (Fig. 1.4.9A; r^2 = 0.20), but chl-a fluoro was a weaker predictor for HBI (Fig. 1.4.9B; r^2 = 0.06). Differences in model strength between chl-a spec and fluoro likely reflect the elevated variability in HBI at low chl-a fluoro concentrations, paired with just a few high chl-a fluoro data points that may have driven the analysis. Therefore, the linear regression model relating HBI and chl-a fluoro should be applied with caution for setting targets for macrobenthic communities.

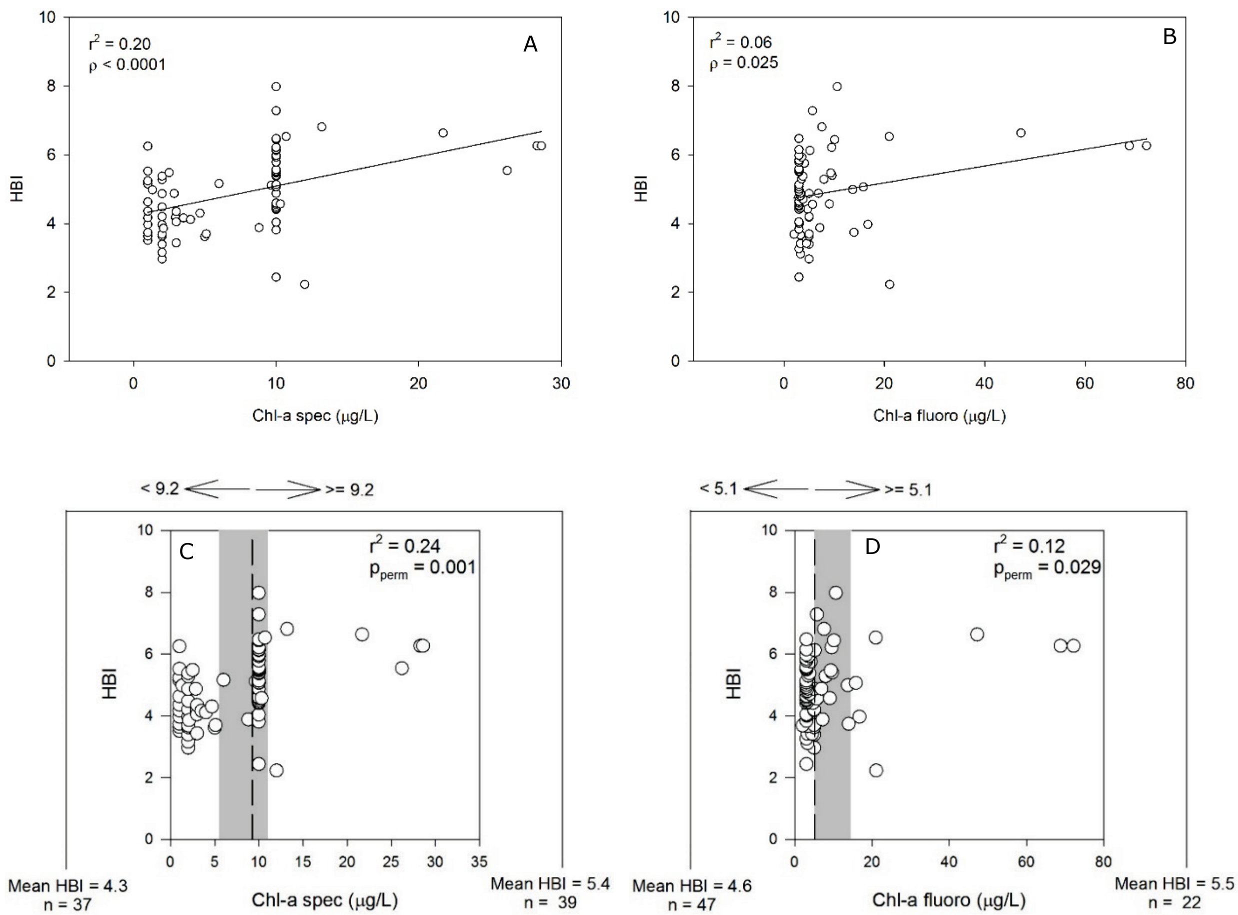


Figure 1.4.9. Analysis of the relationship between Hilsenhoff Biotic Index (HBI) and chlorophyll-a measured spectrophotometrically or fluorometrically (chl-a spec and fluoro, respectively) using A-B) simple linear regression analysis and C-D) changepoint anlysis in Texas streams and rivers. For statistically significant models (p<0.05), the best fit line in regression analysis is shown as a solid line. For changepoint analysis results, the habitat threshold and confidence interval are shown as a dashed line and shaded area, respectively.

For the HBI vs. chl-a relationship, changepoint models were a somewhat better fit than regression models. For chl-a spec, a threshold = 9.2 µg/L was identified and accounted for approximately 24% of variability in HBI (Fig. 1.4.9C; $r^2 = 0.24$). This threshold was in range with average chl-a concentrations associated with high nutrient stream groups identified previously in analyses of the FY2012-2013 streams and rivers water quality median database (Table 1.1.1). A lower threshold for chl-a fluoro concentration (5.1 µg/L) was identified that explained approximately 12% of variability in HBI (Fig. 1.4.9D). For both chl-a spec and fluoro, the difference in HBI between streams with low and high sestonic chl-la concentrations was not substantial (HBI = 4.3 – 4.6 and 5.4 – 5.5., respectively).

For HBI-chl-a pairs, 30 of 76 chl-a spec station medians and 25 of 69 chl-a fluoro station medians were equal to the value of the most common QL's for the methods (QL = 10 µg/L and 3 µg/L, respectively). Because the value of the QL was substituted for unknown censored values, this indicated that these stations likely had a high proportion of censored data (≥50%), and the signal created by making this assumption is visible in plots of HBI vs. chl-a (Fig. 1.4.9A-D) where vertical lines form at the value of chl-a QL's on the x-axis. This signal introduced high variability in the response variable associated with just one stressor value. For regression analyses, it is difficult to determine the potential effects of censored data, though the effects may be small relative to changepoint analysis. Depending on how HBI scores related to the true value of chl-a observations, the observed linear or log-linear trends could be strengthened, or completely erased, if these values were known. For chl-a fluoro, high variability in HBI at low-range concentrations was a confounding trend in the dataset as a whole, and the prevalence of station medians equal to the QL undoubtedly exacerbated this trend.

The effects of censored data on changepoint analysis can be discussed with greater clarity because the analysis is designed to detect changes in variability or magnitude in the response variable over a relatively narrow range of stressor values. This is exactly the type of trend that was introduced spuriously to these datasets when a substantial number of chl-a medians were set equal to the single value of the QL and were then associated with a wide range of HBI scores. These effects were most apparent for the HBI vs. chl-a spec relationship, for which the changepoint was approximately equal to the most common QL (CP = 9.2 µg/L vs. QL = 10 µg/L). For chl-a fluoro, these effects were not as clearly evident, though still possible. Other real trends in the data may have more greatly influenced analysis. The identified threshold of 5.1 µg/L was close in range with the QL, but, in contrast to chl-a spec, a number of uncensored chl-a fluoro observations fell between the values of the QL and threshold, making it more likely that the analysis identified a real trend. Nevertheless, it is possible that the variability in HBI could have been better explained by chl-a fluoro if values < 3 µg/L could have been consistently measured. Conversely, it is also possible that the identified trend could be erased and no threshold found.

The ratio of intolerant to tolerant taxa was inversely related to sestonic chl-a concentration (Fig. 1.4.10A-C). As chl-a concentrations increased, ratios decreased, reflecting reduced representation of species that are intolerant to disturbance. This trend was observed for chl-a measured both spectrophotometrically and fluorometrically. Ratios ranged over four orders of magnitude, compared to just two orders of magnitude for chl-a. Therefore, a simple linear regression model was not a suitable fit for the intolerant:tolerant taxa vs. chl-a relationship. An exponential decay model best described the rate at which ratios decreased with increasing chl-a concentration. These models explained 10 – 12% of variability in ratios (Fig. 1.4.10A-B; $r^2 = 0.10 – 0.12$). For intolerant:tolerant vs. chl-a fluoro, variability in ratios was high at low chl-a concentration, and high chl-a concentration sites were underrepresented. Visual examination of plotted relationship between ratios and chl-a fluoro shows that, though statistically significant, the regression model relating these variables would not generate predictions of intolerant:tolerant taxa close in range with real-world values, especially for sites with high chl-a concentrations. Therefore, this model should be applied with caution.

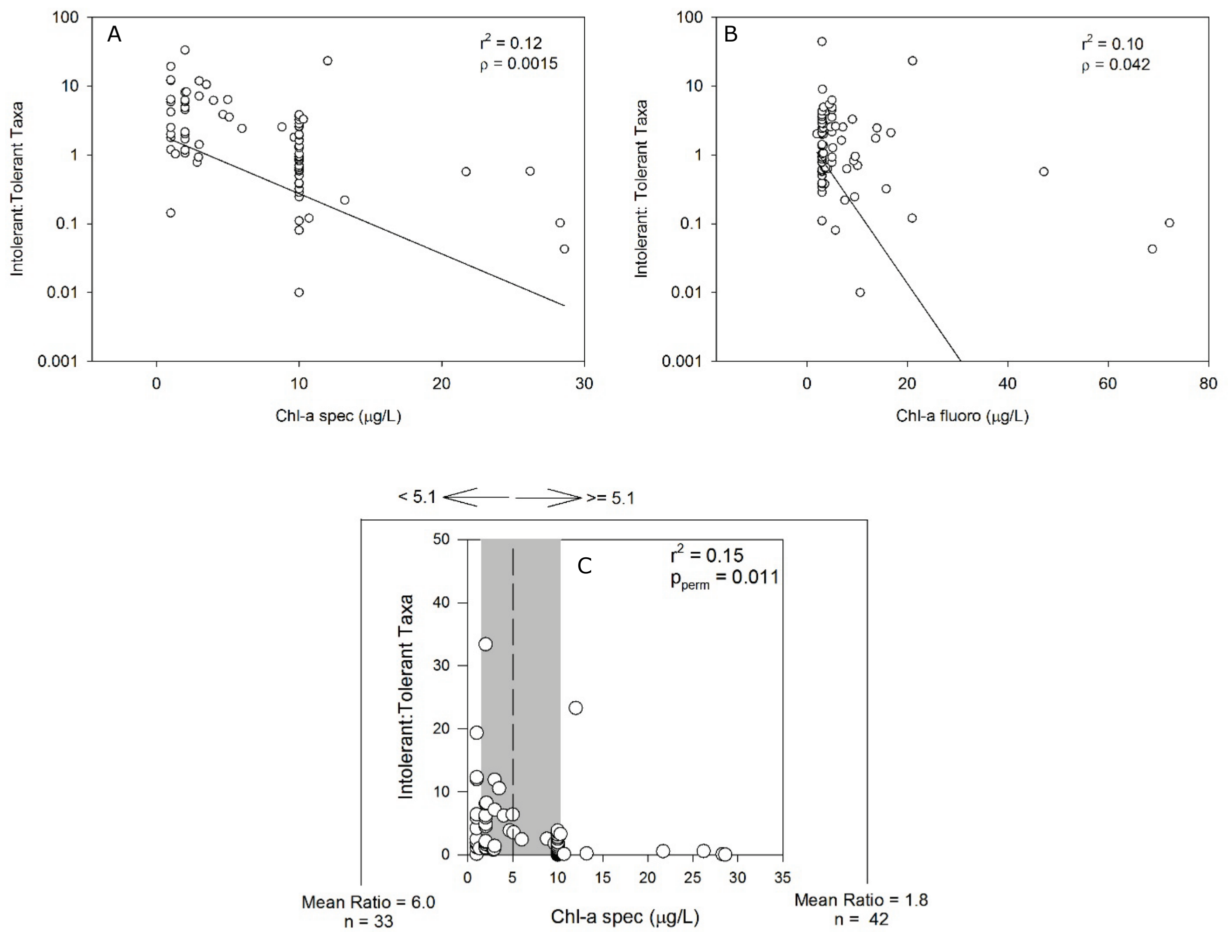


Figure 1.4.10. Analysis of the relationship between the ratio of intolerant to tolerant taxa and chlorophyll-a measured spectrophotometrically or fluorometrically (chl-a spec and fluoro, respectively) using A-B) logistic regression analysis and C) changepoint anlysis in Texas streams and rivers. For statistically significant models (p<0.05), the best fit line in regression analysis is shown as a solid line. Note that panels showing results of linear regression analyses show intolerant:tolerant taxa on the log10 scale. For changepoint analysis results, the habitat threshold and confidence interval are shown as a dashed line and shaded area, respectively.

For the intolerant:tolerant taxa vs. chl-a relationship, a threshold in chl-a spec = 5.1 µg/L was identified and accounted for approximately 15% of variability in ratios (Fig. 1.4.10C; $r^2 = 0.15$). This threshold was in range with average chl-a concentrations associated with low nutrient stream groups identified previously in analyses of the FY2012-2013 streams and rivers water quality median database (Table 1.1.1) and was identical to the chl-a fluoro threshold for HBI response. Ratios were 2 – 3x greater at high chl-a concentrations than at low concentrations, but average ratio values in each group were within the same order of magnitude. Therefore differences between the groups may not be substantial. No statistically significant changepoint relationship was identified between intolerant:tolerant taxa and chl-a fluoro.

As with HBI, a substantial number of chl-a medians paired with intolerant:tolerant taxa were equal to the value of the most common QL's (30 of 75 for chl-a spec and 25 of 69 for chl-a fluoro). The implications of assumptions about the value of censored observations are equally applicable to the relationship between intolerant:tolerant taxa and chl-a as for HBI, and some of the same potential censored data effects were observed. Nevertheless, for this stressor-response pair, other problems with the data appeared to weaken analyses more substantially, such as the uneven spread of chl-a fluoro values across the range of observed values, which resulted in poor predictive power for the regression model (Fig. 1.4.10B). In the case of changepoint analysis, censored data did not appear to have a strong signal for this stressor-response pair. The value of the threshold was not clearly leveraged by the value of the QL (CP = 5.1 µg/L vs. QL = 10 µg/L, and the range of ratios separated from the rest of the dataset by the threshold was an order of magnitude greater than the range associated with the station medians equal to the QL. Likely censored data effects can be seen, however, in the value of the upper 95th confidence interval of the threshold, which was approximately equal to the QL. Though any effect on analysis is undesirable, this censored data effect could be considered relatively minor.

Total macroinvertebrate taxa richness was inversely related with sestonic chl-a concentration (Fig. 1.4.11A-B). As chl-a concentrations increased, total taxa richness decreased, indicating a reduction in diversity. For richness, variability relative to chl-a did not exhibit trends that were well described by linear or non-linear exponential, logarithmic, or power regression models.

The relationship between richness and chl-a could be described, however, by changepoint models. Thresholds were identified in both chl-a spec and chl-a fluoro = 11 and 7.0 µg/L, respectively. Changepoint models of chl-a thresholds accounted for approximately 13 – 15% of variability in taxa richness (Fig. 1.4.11A-B; r^2 = 0.13 – 0.15). Thresholds were in range with average chl-a concentrations associated with high nutrient stream groups identified previously in analyses of the FY2012-2013 streams and rivers water quality median database (Table 1.1.1). For this stressor-response pair, uneven spread of both chl-a spec and chl-a fluoro data across the observed range may have been problematic, with changepoint models potentially driven by a just a few stressor-response pairs from the stations with the highest chl-a concentrations. Richness was approximately 30 – 40 % greater at high chl-a concentrations than at low concentrations, with a loss of 5 – 7 taxa on average above chl-a thresholds

As with the other metrics, a substantial number of chl-a medians paired with richness estimates were equal to the value of the most common QL's (31 of 63 for chl-a spec and 21 of 63 chl-a fluoro). The implications of assumptions made about the value of censored observations are equally applicable to the relationship between richness and chl-a as for the other metrics, and potential censored data effects were similar to those observed for changepoint analysis of HBI vs. chl-a. For chl-a spec, the value of the threshold was clearly leveraged by the medians equal to the QL (CP = 11 µg/L vs. QL = 10 µg/L). For chl-a fluoro, this effect was also possible, though, as with the relationship with HBI, numerous non-censored chl-a observations between the values of the QL and the threshold were included in analysis, making it more likely that the threshold could represent a real trend.

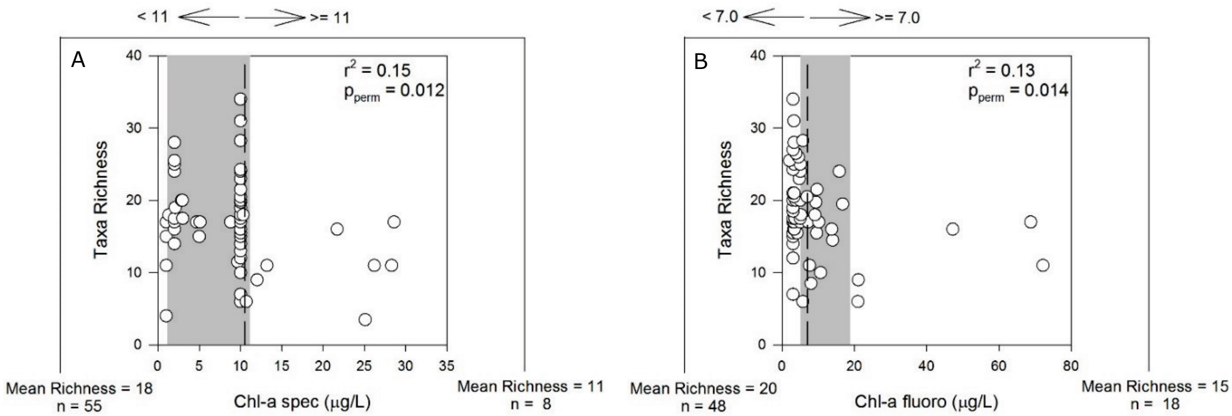


Figure 1.4.11. Analysis of the relationship between total taxa richness and chlorophyll-a measured A) spectrophotometrically or B) fluorometrically (chl-a spec and fluoro, respectively) using changepoint anlysis in Texas streams and rivers. The habitat threshold and confidence interval are shown as a dashed line and shaded area, respectively.

Summary of community metrics bioassessment analysis

Congruent with previous findings for multimetric IBI scores for fish and macroinvertebrates in Texas streams and rivers, nutrient concentrations were weak or not statistically significant predictors for macrobenthic community response variables, with the exception of taxa richness and TN. Further analysis to explore other potential sources of variability in community metrics indicated that HBI and intolerant:tolerant taxa were distributed differently between Omnerik Level III ecoregions and could be divided into groups representing low, mid-range, and high biotic integrity. The range of variability in taxa richness across ecoregions was too large for similar groupings. Also as in previous studies of multimetric indices, habitat quality was among the strongest predictors of macrobenthic community response in the study, and both regression and threshold relationships between the three community metrics and HQI were identified. Thresholds in HQI ranged between 18 and 24, among the highest and lowest habitat thresholds identified in the present or previous studies. Finally, sestonic chl-a was also a possible predictor variable for community metrics, although it's utility may be limited due to the amount of censored data present in the dataset for both analytical methods. Both regression and changepoint models effectively described variability in HBI, intolerant:tolerant taxa, and taxa richness relative to chl-a. Thresholds in chl-a ranged between 5.1 and 11 µg/L. All models developed in this study explained a relatively low amount of variability (<25%) in the analyzed stressor-response relationships, reflecting the complex interactions between macrobenthic communities and their environments.

1.5 EXPLORING POTENTIAL EFFECTS OF DROUGHT ON VALUES OF WATER QUALITY PARAMETERS

Methods

Data organization and compilation for annual medians database

Comparing water quality data collected under drought and non-drought conditions required that the FY2012-2013 Texas streams and rivers water quality database be expanded to include the years 2011 – 2014. During this period, Texas experienced wide-spread historic drought (United States Drought Monitor, droughtmonitor.unl.edu). To expand the database, TCEQ provided a data comprised of 116 water quality parameters with data collected from January 1, 2011 – December 31, 2014 from freshwater streams and rivers throughout Texas. The collected data was received in two installments: 1) in October 2013, spanning January 1, 2011-October 2013 and 2) in May 2015, spanning January 1, 2013-December 31, 2014. Only the complete 2013 data provided through the second installment were used in subsequent analyses.

Data from 2011 – 2014 were received in a format in which data for all parameters were stored in a single column. The data were therefore processed into a usable format identical to the FY2012-2013 water quality database. Data received as part of the present contract were organized through the same process and undergoing identical quality assurance requirements as applied to organize 2000 – 2010 data into the FY2012-2013 water quality database. Data collected under the monitoring type "Biased Flow" were removed by sorting the data by monitoring type code and deleting all biased flow observations. Although monitoring identified as "Biased Flow" may be planned to target either low or high flow conditions, typically this monitoring is planned to target storm events. Since these data were removed, samples collected during wet weather events may be under-represented in the dataset. Data points that were considered to be censored were replaced in the rearranged data with the value of the quantification limit. Data were then reorganized using a pivot table function in Microsoft Excel to rearrange the single column output from SWQMIS into a format with a column assigned to each unique parameter code and associated data. The reorganization process was accomplished using Microsoft Excel Macros (see Appendix 1.6 for code).

Several additional parameters were calculated. Nitrate plus nitrite-nitrogen (NO_x-N) and total nitrogen (TN) were calculated if the necessary N species were provided by TCEQ in the original data file. In addition, diel change (i.e., 24 hour maximum minus 24 hour minimum) was calculated for dissolved oxygen, temperature, conductivity, pH, and turbidity. The additional parameters were added to each station worksheet using a Microsoft Excel Macro (Appendix 1.6). Due to the volume of data provided, several parameters were removed because of lack of data and duplication of parameters, or because TCEQ indicated that the parameter could be removed from the database.

Once the 2011 – 2014 were formatted identically to 2000 – 2010 data in the FY2012-2013 water quality database, an annual median was calculated for all parameters for all years for which data were present for stream and river stations during the period 2000 – 2014. Annual medians were then automatically transferred to a summary tab for each year. This series of actions was carried out using a Microsoft Excel Macro (see Appendix 1.6 for code).

Initial analysis of statewide drought conditions in Texas by year from 2000 – 2014 was provided by TCEQ. These data and data used subsequently to assess the timing and extent of drought in Texas were acquired from the United States Drought Monitor (droughtmonitor.unl.edu). Initial analyses indicated that 2004 and 2011 represented extremes of wet and dry years, respectively, for a large proportion of the state, while the periods of 2001-2005 and 2011-2014 represented extended periods of wet and dry, respectively.

Data were fit to boxplots to illustrate frequency distributions for the different groups of annual medians for target water quality variables. These parameters of interest were total phosphorus (TP; parameter 00665), total nitrogen (TN; parameter 00600C), phosphate-phosphorus (SRP; parameter 00671C), nitrate+nitrite-nitrogen (NOx-N; parameter 00630), chlorophyll-a (chl-a) measured spectrophometrically (chl-a spec; parameter 32211) and fluorometrically (chl-a fluoro; parameter 79753), and Secchi transparency (parameter 00078C).

These analyses were conducted at the statewide scale, but data were also divided into several subgroups in order to reduce variability in the data known to originate from sources other than variability in precipitation and associated storm events. Statewide analyses did not reveal differences between groups of annual medians representing single or multiple years of wet or dry conditions; therefore, subgroups were created for 2004 and 2011 only. Subgroups were intended 1) to remove regions where drought conditions diverged from conditions that were representative of a large proportion of the state (i.e. drought in 2004 or non-drought in 2011) and 2) to separate stations receiving a high proportion of in-stream flow as municipal waste water treatment plant (WWTP) effluent discharge from streams with a lower effluent load.

In order to exclude areas of Texas where drought conditions diverged from the norm, the areal extent of drought in Texas for each month in 2004 and 2011 was assessed. Data illustrating the areal extent of drought on a weekly basis were downloaded from the United States Drought Monitor website for both years. For each month in 2004, all land area in Texas under severe to exceptional drought (DM = 2 – 4) for at least one week in a given month was identified and joined using the union tool in ArcMap 10.2.2. For each month in 2011, all land area in Texas classified as DM = 2 – 4, for all weeks within the given month was identified and separated from areas not classified as DM = 2 – 4 using the clip tool in ArcMap 10.2.2. For every month in both 2004 and 2010, Texas basin-ecoregion areas under severe to exceptional drought were identified by overlaying a GIS layer created and provided by TCEQ that was comprised of shapes representing unique unions of major Texas basins and Omnerik Level III ecoregions. Basin-ecoregion areas experiencing severe to exceptional drought were identified as the unions with drought area overlapping the centroid of the union. Finally, basin-ecoregion areas were selected for exclusion from the study for 2004 by eliminating areas that had drought area at the centroid for four or more months of the year, while basin-ecoregion areas were selected for exclusion for 2011 by eliminating areas that experienced no drought or drought designated DM <2 for four or more months of the year. Maps showing the basin-ecoregion union areas that experienced drought conditions for each month in 2004 and 2011 are included in this report in Appendix 1.7.

Texas stream and river stations and associated annual medians were divided into groups receiving low and high effluent discharge from WWTP's using a threshold in municipal flow identified through previous analyses of the Texas streams and rivers FY2012 – 2013 water quality median database. For these prior analyses, municipal WWTP flow was divided by watershed area in order to estimate the proportion of in-stream flow derived from municipal discharges. On average, both TP and TN concentrations were higher in streams receiving municipal flow > 0.031 mgd/km^2 than in streams with lower effluent loads proportional to watershed size. These subgroups were created for total and dissolved inorganic nutrient parameters only.

Results and Discussion

All Texas and targeted drought datasets

Results for drought comparisons for the statewide and targeted drought areas data groups were almost identical. Therefore, only the results for the statewide annual medians groups are presented in the body of the report. Results of analyses on the targeted drought subgroups of annual medians are presented in Appendix 1.8. No basin-ecoregion union areas represented in the water quality data were eliminated from the 2004 dataset as experiencing severe to exceptional drought (DM 2 – 4) conditions for four or more months out of the year. Two areas fitting these criteria were identified, but no streams and rivers data were available for these areas (23-23 and 1-25). In 2011, 26 basin-ecoregion areas were identified as diverging from the statewide drought trend, experiencing no drought or drought classified as DM < 2 for four months or more out of the year. The basin-ecoregion unions that were excluded from the targeted analysis for 2011 are 1-26, 2-25, 2-26, 2-29, 2-32, 2-33, 2-35, 3-32, 3-33, 3-35, 4-33, 5-32, 8-27, 829, 8-32, 11-34, 12-25, 14-27, 14-29, 17-34, 18-34, 19-34, 20-33, 20-34, 21-34, and 22-34. Of these basin-ecoregion unions, four were not represented in the streams and rivers water quality database: 2-25, 5-32, 8-27, and 17-34. Data belonging to the remaining basin-ecoregion unions were removed from the 2011 targeted drought subgroup, but comprised a relatively small percentage of the cumulative annual medians. The original assessment that the signal of widespread non-drought and drought conditions in 2004 and 2011, respectively, would outweigh the signal from sites deviating from the assumed drought trends appears, therefore, to have been valid for Texas streams and rivers.

For both the statewide and targeted drought annual medians groups, few or minor differences were identified between drought and non-drought years. Potential differences in measures of central tendency and the overall frequency distributions are discussed subsequently, but advanced analysis would be required to determine whether these data populations are statistically different.

Nutrients

Frequency distributions indicated little or no difference between medians in wet vs. drought years for TP or TN (Fig. 1.5.1A-B). For TP, medians across groups were approximately 0.11 – 0.13 mg/L. For TN, medians ranged between 1.3 and 1.5 mg/L. For both TP and TN, upper percentile estimates (>75th or greater) were higher in groups representing drought than in groups representing wet conditions by several mg/L. For TP, lower percentile estimates were also consistently lower in drought groups than in wet year groups, especially 90th percentile estimates. The 95th percentile estimate for TP in the 2001-2005 group did not fit this trend, however. For TN, lower percentile estimates were more similar across all groups of annual medians. For both TP and TN, means were higher in drought years than in wet years, approximately 0.30 mg/L vs. 0.50 mg/L for TP and ~2 mg/L vs. 3 mg/L for TN. Differences in means in drought years likely reflect the shift upward in the highest percentiles of the distributions, as nutrient means tend to be highly influenced by high outlier values.

As with TP and TN, little or no difference between wet vs. drought years was observed for PO_4-P and NO_x-N medians. For PO_4-P, medians were consistently equal to or close in value to common quantification limits (0.04 – 0.06 mg/L) across groups (Fig. 1.5.2A). Lower percentiles for PO_4-P were considerably higher in value, however, in drought years than in wet years, especially for the group composed of 2011 medians only. This difference could be attributed to differences in precipitation and associated flow regimes between the time periods, but might also reflect other differences, such as an increase in quantification limit. In general, the entire distribution for 2011 was shifted upward from the distribution of other annual median groups. Mean PO_4-P was almost 2x greater in the drought year of 2011 than in the wet year of 2004 (0.47 mg/L vs. 0.25 mg/L). This difference was reduced when the groups representing series of wet and dry years were considered (2001-2005 mean = 0.28 mg/L and 2011-2014 mean = 0.36 mg/L), though drought years still exhibited higher mean PO_4-P. Differences in means may reflect increases in the value of the lower percentile estimates in drought years. For NO_x-N (Fig. 1.5.2B), medians were approximately 40% lower in drought years than in wet years (0.23 – 0.24 mg/L vs. 0.37 – 0.38 mg/L, respectively), but were relatively low for stream nutrient concentrations across years. Means were approximately 30% higher (1.9 – 2.0 mg/L vs. 1.3 – 1.4 mg/L) in drought years. As with TP and TN, the spread of the data falling between the percentiles of 25th – 75th and 5th – 95th during drought years was wider than the spread of data between these percentiles in wet years.

For all the nutrient parameters of interest, differences in measures of central tendency were consistently seen for means, but rarely for medians, with the exception of NO_x-N. In general, the spread of data distributions, especially data in the 25th – 75th percentiles, encompassed a wider range of values in drought years than in wet years, which may account for the differences in means seen between wet and dry years. As the 50th percentile, however, medians were less likely to be strongly affected by changes to lower and higher percentiles, especially in cases where the interquartile range was wider in both directions from the median. Therefore, findings from these comparisons support the idea that medians are a more robust choice for setting water quality targets.

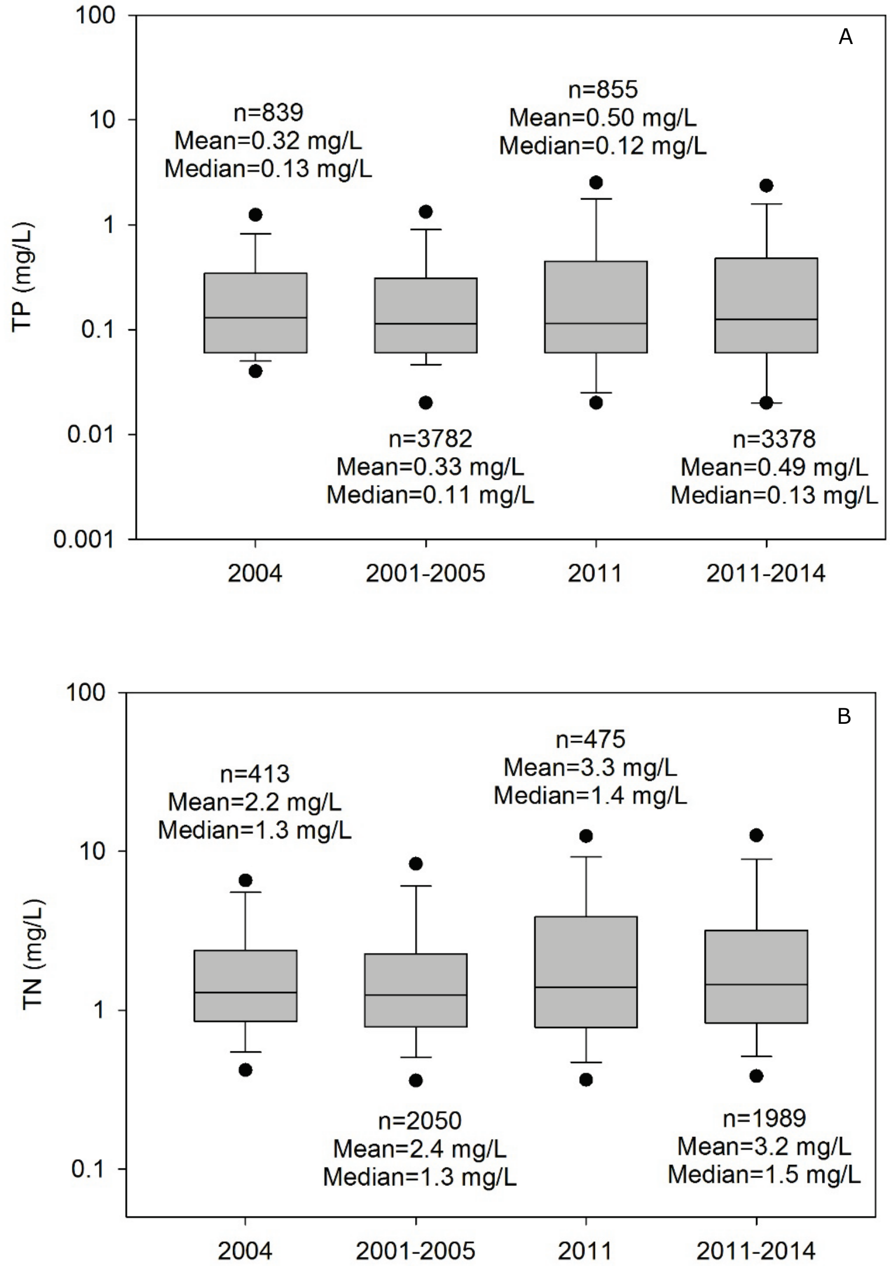
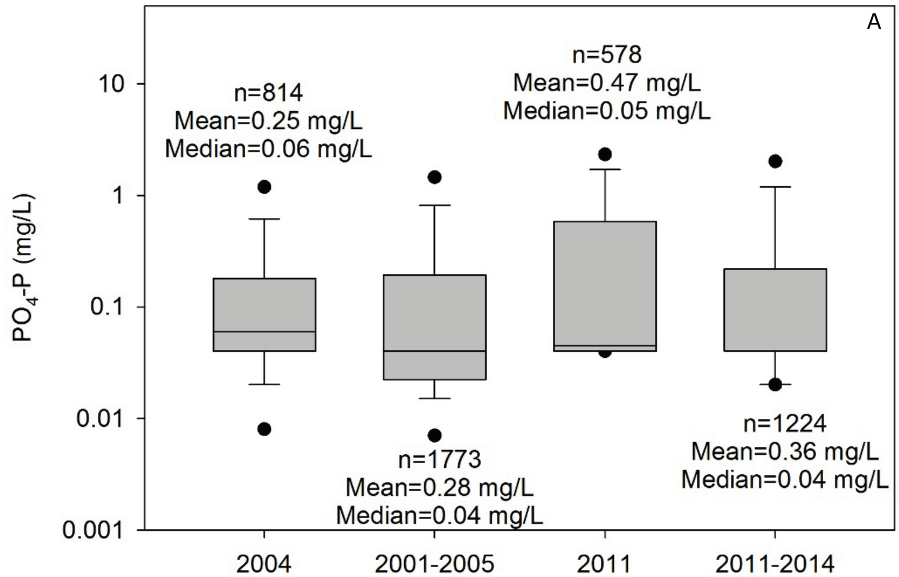


Figure 1.5.1. Data distributions for statewide station annual medians of A) total phosphorus (TP) and B) total nitrogen (TN) grouped by single or a series of wet (2004, 2001-2005) and drought (2011, 2011-2014) years in Texas. The shaded area represents data falling between the 25th and 75th percentiles, while error bars indicate the 10th and 90th percentiles and outlier icons represent 5th and 95th percentiles.



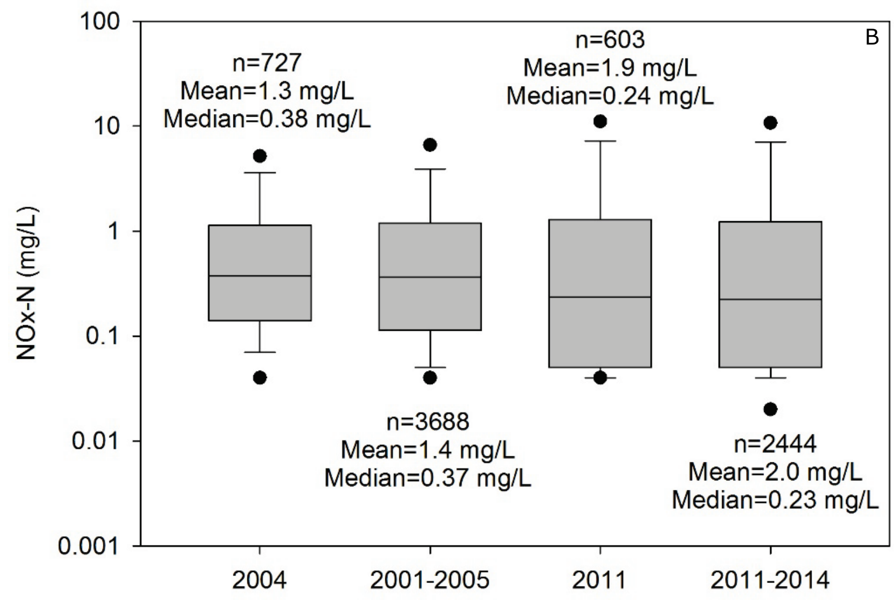


Figure. 1.5.2. Data distributions for statewide station annual medians of A) phosphate-phosphorus (PO_4-P) and B) nitrate+nitrite-nitrogen (NO_x-N) grouped by single or a series of wet (2004, 2001-2005) and drought (2011, 2011-2014) years in Texas. The shaded area represents data falling between the 25th and 75th percentiles, while error bars indicate the 10th and 90th percentiles and outlier icons represent 5th and 95th percentiles.

Sestonic chlorophyll-a and Secchi transparency

For chl-a spec, medians were approximately 3x higher in wet years compared to drought years, and the values of data falling between the 25th and 75th percentile were considerably more constrained in wet years than dry years (Fig. 1.5.3A). These trends, however, are most likely spurious and were likely introduced to the dataset when censored observations were replaced with the value of the common quantification limit. During 2001 – 2005, this value was 10 µg/L, but was 3 µg/L during 2011 – 2014. These values correspond exactly with the value of the medians calculated for each group during those periods. Since a wider range of values was possible for chl-a spec in years when quantification limits were lower, differences in the spread of distributions between the two periods can also likely be attributed to the effects of replacing censored data with the quantification limit.

For chl-a fluoro, medians were more similar across groups (chl-a fluoro = 5 – 6 µg/L), and potential effects of replacing censored observations with the quantification limit were less apparent (Fig. 1.5.3B). Mean chl-a fluoro was up to 40% higher in drought groups (13 – 14 µg/L vs. < 10 µg/L), and the spread of the data between the 25th and 75th percentiles was wider for drought year groups than for wet year groups. Higher means for drought years likely reflect that upper percentile estimates (75th or greater) were also higher in these years, especially the 75th percentile.

In addition to changes in QL, changes in the prevalence of the use of the different methods of chl-a analysis between the early 2000's and post 2010 make comparison of sestonic chl-a concentrations associated with drought and non-drought groups problematic. The sample size of annual medians for chl-a spec was much larger for 2004 than for chl-a fluoro the same year or for chl-a spec for 2011 (n = 484, 129, and 200, respectively), while the sample size for chl-a fluoro more than tripled between 2004 and 2011. These large changes in sample size between the periods inherently entail that the stations included in the different groups were not the same between the drought and non-drought periods to an extent that is likely not true for other parameters. These fundamental differences in the data population of chl-a observations between the early 2000's and post 2010 make it difficult to determine whether trends identified between the annual median groups can be attributed to the effects of drought.

For Secchi transparency, the estimated measures of central tendency and the shape of distributions were almost identical across the four groups (Fig. 1.5.3C). Median Secchi transparency was approximately 0.40 m across groups, while mean transparency varied by approximately 0.05 m between 0.47 and 0.53 m. In general, Secchi transparency appeared highly immune to potential drought effects.

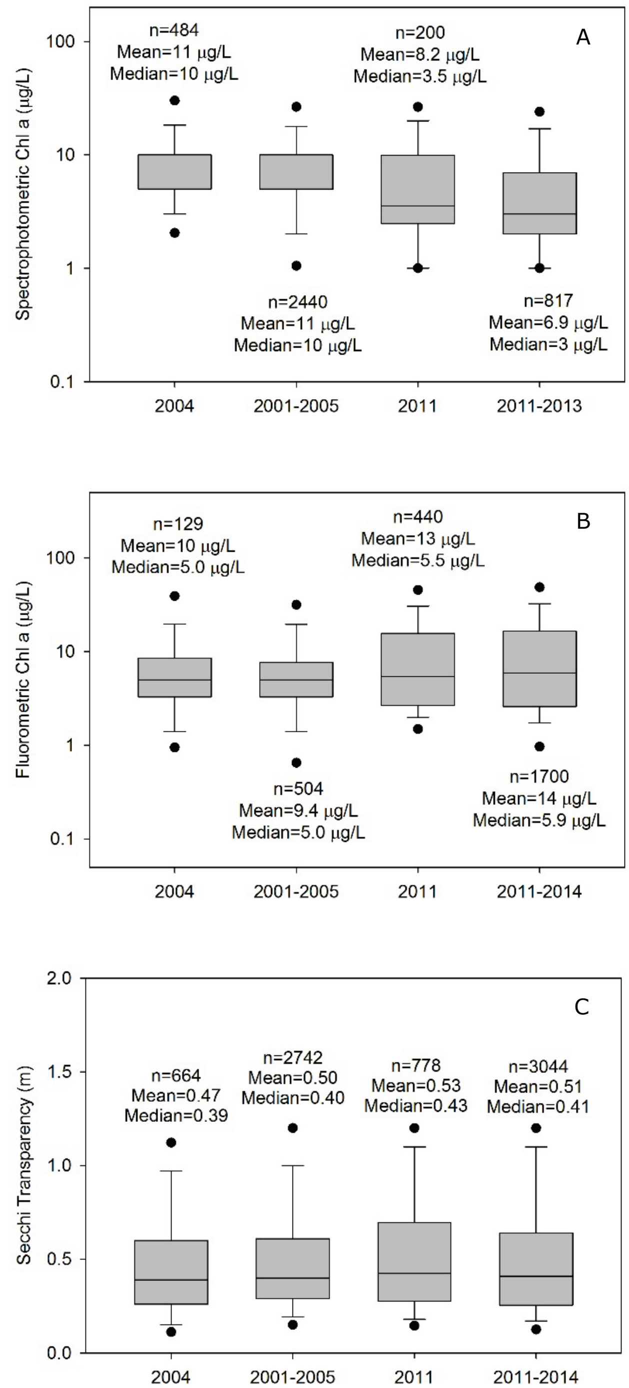


Figure. 1.5.3. Data distributions for statewide station annual medians of chlorophyll-a measured A) spectrophotometrically (chl-a spec) and B) fluorometrically (chl-a fluoro) and C) Secchi transparency grouped by single or a series of wet (2004, 2001-2005) and drought (2011, 2011-2014) years in Texas. The shaded area represents data falling between the 25th and 75th percentiles, while error bars indicate the 10th and 90th percentiles and outlier icons represent 5th and 95th percentiles.

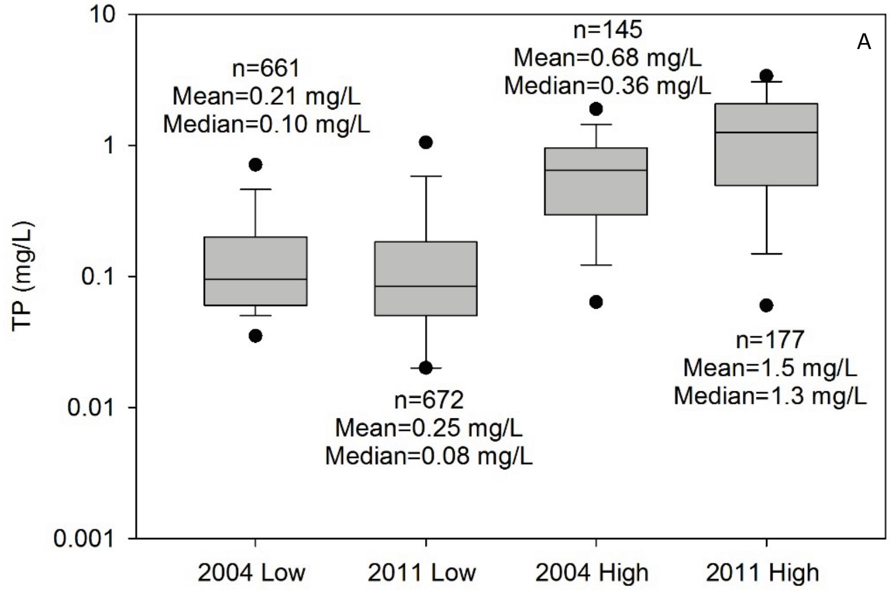
Annual median subgroups of stations receiving low or high municipal WWTP flow

Annual median subgroups based on watershed-proportional municipal WWTP flow were derived from station groups previously identified as low and high TP and TN. Therefore, it was congruent with expectations that TP and TN concentrations were considerably higher for stations with high area-weighted municipal discharges (Fig. 1.5.4A-B; means and medians 3 – 5x higher for TP; 2 – 4x higher for TN). For both TP and TN, potential drought trends in the low receiving flow annual medians groups were similar to observations from the statewide groups. Medians (~ 0.1 mg/L for TP; ~ 1.0 mg/L for TN) and means (0.21 – 0.25 mg/L for TP; ~ 2.0 mg/L for TN) were similar between 2004 and 2011, but the spread of the data was larger in the drought year, with more extreme values for percentiles ≥90th and ≤10th. Generally, however, differences between the wet and dry year were small or not present for the low receiving flow subgroups.

In contrast, probable drought effects were apparent in the high receiving flow subgroups. Mean TP was 2x higher in 2011 as in 2004 (1.5 vs. 0.68 mg/L), while median TP was approximately 4x greater (1.3 vs. 0.36 mg/L). Lower percentiles (≤10th) were comparable between the years, but percentiles ≥ 25th diverged substantially. For TN, differences between 2004 and 2011 were also pronounced, though less so than for TP. Both TN means (4.2 vs. 7.7 mg/L) and medians (3.7 vs. 7.7 mg/L) were approximately 2x higher in 2011 than in 2004.

Previous work showed that dissolved inorganic components of TN and TP were a larger proportion of the total nutrient pool above the area-weighted threshold in municipal WWTP flow of 0.031 mgd/km^2 (AWRC 2013). Therefore, higher PO_4-P and NO_x-N concentrations were also expected for high receiving flow groups (Fig. 1.5.5A-B). Dissolved inorganic nutrients followed the same trends as TP and TN between wet and drought years for low and high receiving flow subgroups. Potential differences between 2004 and 2011 were difficult to interpret for stations receiving proportionally low municipal WWTP flow. The most convincing potential difference between wet and dry years for these groups was that median NOx-N was approximately 50% less in 2011 than in 2004 (0.16 vs. 0.31 mg/L), but this difference could also reflect a change in quantification limit or some other factor.

In contrast, differences in the annual median groups between wet and dry years were pronounced for streams estimated to receive high proportions of in-stream flow as municipal WWTP discharge. For PO_4-P, medians and means were approximately 4x and 2x higher, respectively, in 2011 than in 2004. Mean NO_x-N was approximately 2x higher in 2011 than in 2004, while median NO_x-N was approximately 3x higher. The value of lower percentiles (≤10th) were comparable between years for PO_4-P, but percentiles >10th were divergent between wet and dry years. For NO_x-N, percentiles ≤25th were comparable, and divergence between years only became pronounced with medians and higher percentiles.



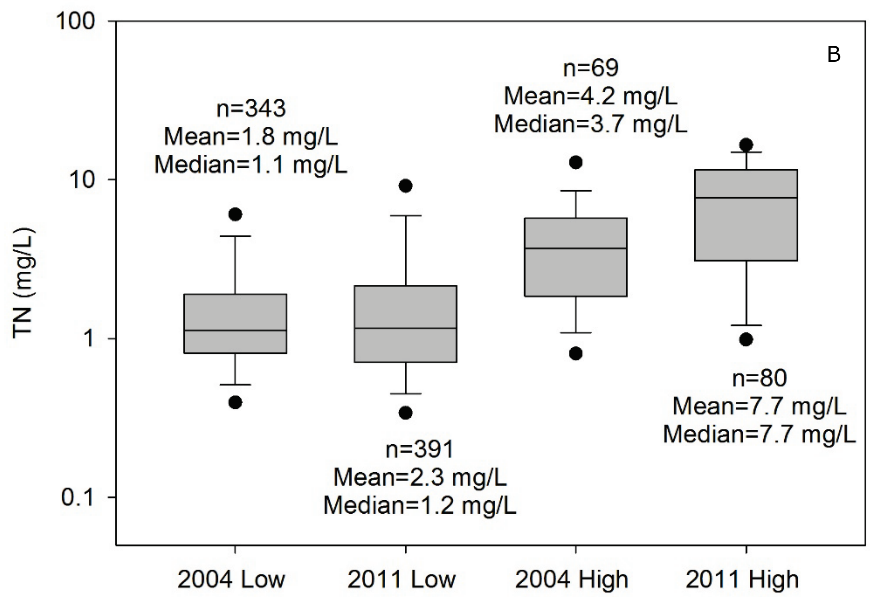


Figure 1.5.4. Data distributions for station annual medians of A) total phosphorus (TP) and B) total nitrogen (TN) grouped for a wet (2004) and drought (2011) year for two groups of Texas streams and rivers, estimated as receiving either a low or high municipal WWTP effluent load as a proportion of instream flow. The shaded area represents data falling between the 25th and 75th percentiles, while error bars indicate the 10th and 90th percentiles and outlier icons represent 5th and 95th percentiles.

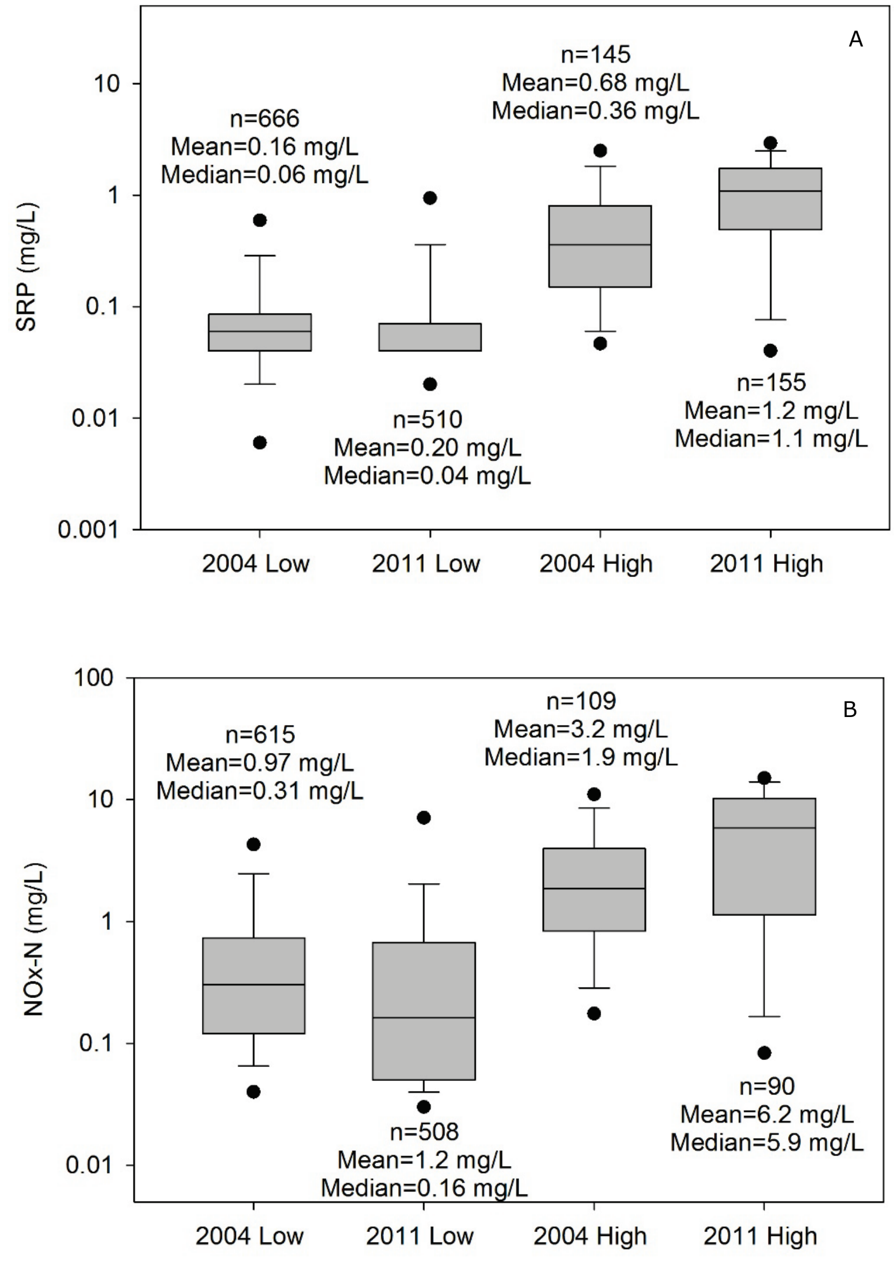


Figure 1.5.5. Data distributions for station annual medians of A) phosphate-phosphorus (PO_4-P) and B) nitrate+nitrite-nitrogen (NO_x-N) grouped for a wet (2004) and drought (2011) year for two groups of Texas streams and rivers, estimated as receiving either a low or high municipal WWTP effluent load as a proportion of instream flow. The shaded area represents data falling between the 25th and 75th percentiles, while error bars indicate the 10th and 90th percentiles and outlier icons represent 5th and 95th percentiles.

These findings indicated that Texas streams and rivers receiving municipal WWTP flow as a high proportion of in-stream flow were more susceptible to drought effects than streams receiving a proportionally lower municipal flow, or in the state on average. Enhanced nutrient transport from the landscape to adjacent water bodies has been strongly linked with precipitation and related storm events, but a decrease in nutrient concentrations was not clearly observed in any of the comparisons of wet vs. drought annual medians subgroups. This is likely because results from monitoring efforts targeting flow events (which typically target higher flows) were intentionally omitted from the study data set. Thus, observations included in the study data set were primarily collected during routine monitoring events, reflecting base flow conditions. Between storm flow events, a substantial portion of nutrients transported in streams may be stored in relatively unavailable pools, such as periphyton (Jarvie et al. 2012), and therefore not measurable in the water column at base flow.

However, past and present analyses of the Texas streams and rivers water quality data indicate that streams with a proportionally high effluent load may be oversaturated with nutrients and may have exceeded this capacity for nutrient assimilation (Dodds et al. 2002; Bernot et al. 2006). The findings of the present study suggest that drought magnified this effect for streams with a high effluent load, as these loads comprised an even greater proportion of in-stream flow in the absence of precipitation and runoff. For streams with a high effluent load, NO_x-N also comprised a greater proportion of TN during the drought year, when medians were compared between 2004 and 2011 (51% and 76%, respectively). Since municipal discharges typically have a higher ratio of dissolved inorganic nutrients to total nutrients, this finding also supports the interpretation that municipal discharges became even more dominant in high receiving streams in the absence of precipitation and runoff.

Summary of drought effects on water quality parameters

Drought conditions had few, if any, effects on distributions of station annual medians for water quality parameters of interest when all stream and river stations were grouped statewide, though differences were observed for the subgroup receiving high effluent loads. At the statewide scale, the largest potential differences between measures of central tendency that may be attributable to drought were observed for means and upper and lower percentiles. The data distributions for statewide wet and drought year groups were consistently anchored in relatively constant median values across years, indicating that medians were insensitive to drought effects and reinforcing the idea that medians are more robust than means for use in developing water quality targets.

Targeting drought effects by eliminating basin-ecoregion union areas not in drought (DM < 2) for at least a third of the year in 2011 did not reduce variability or refine analyses. However, a threshold in watershed-proportional municipal WWTP flow = 0.031 mgd/km^2 separated stations into groups receiving low and high municipal discharges that exhibited different responses to drought. Nutrient concentrations for low receiving flow stations did not differ substantially between 2004 and 2011. High receiving stations, in contrast, exhibited measures of central tendency (both means and medians) for nutrient concentrations that were up to 5x higher in drought years than in wet years. These trends most likely reflect an increase in the proportion of in-stream flow comprised of municipal discharges in streams that already received high effluent loading under normal precipitation regimes and that may be oversaturated with nutrients beyond assimilation capacity.

These findings have implications for the process of setting nutrient targets and suggest the need for defining the applicability of nutrient water quality standards under low-flow critical conditions during standards implementation. When all streams were considered together at the statewide scale, water quality data distributions in drought years did not deviate strongly or consistently from wet years, suggesting that the effects of drought would not cause data collected during dry years to be out of compliance with nutrient or biological response targets that did not specifically consider drought. However, one population of streams deviated from that trend, namely Texas streams and rivers receiving a high proportion of in-stream flow as municipal WWTP discharges. For these streams and rivers, data from drought years would have a high likelihood of non-compliance with targets based on data from years with higher precipitation.

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Appendix 1.1. GUIDE TO INTERPRETING CART AND NCPA MODELS AND SUMMARY STATISTICS

This appendix is intended as a guide to the users of this report for interpreting Classification and Regression Tree (CART) and non-parametric changepoint analysis (nCPA) stressor-response models, including thresholds, confidence intervals, r^2, and p values. For example, model summary statistics such as r^2, p values, and confidence intervals can assist the user in assessing the strength of the changepoint relationship identified by regression tree and non-parametric changepoint procedures. In addition to the threshold value itself, CART models also provide information on how many observations are grouped above and below the changepoint, as well as the average value of the response variable above and below the changepoint. In this user's guide to CART and nCPA models, we will 1) define the model summary statistics listed above, 2) describe and provide example uses for information appearing on the graphical display of a changepoint model, and 3) explore analyses on datasets generated to present idealized model outcomes to determine how summary statistics can vary with trends in the data.

Interpreting terminology of model output and summary statistics

Changepoint – The model changepoint is the value of the stressor variable that maximizes differences in the response variable related to magnitude and variability. If we assume that the data included in the analysis represent the general population without bias, we can assume the changepoint applies to the general population. Both CART and nCPA produce changepoint estimates. Usually these estimates are identical; however, in cases where r^2 differed between CART and nCPA, nCPA output was reported.

Confidence interval – The model confidence interval describes a range of values in the stressor variable surrounding the changepoint and bounded by the lower 5% confidence estimate and the upper 95% confidence estimate. Assuming that the data included in the analysis represent the general population without bias, we can be 95% confident that the changepoint value for the population falls within this range of values. Therefore, a more narrow confidence interval usually indicates a relatively small level of uncertainty associated with the changepoint estimate, also indicating a relatively strong model. However, it should be noted that confidence intervals may not accurately reflect uncertainty associated with the changepoint if bias exists in the data, such as censoring at a common detection limit. Only nCPA provides estimates of confidence levels.

R^2 - The model r^2 describes the variability in the data that can be explained by the model. Therefore, the higher the r^2, the greater the explanatory power and strength of the model. For example, if r^2=0.25, the identified changepoint in the stressor variable describes 25% of the variability in the response variable. Both CART and nCPA produce r^2 estimates. Usually these estimates are identical; however, in cases where model r^2 differed between CART and nCPA, output from nCPA was reported.

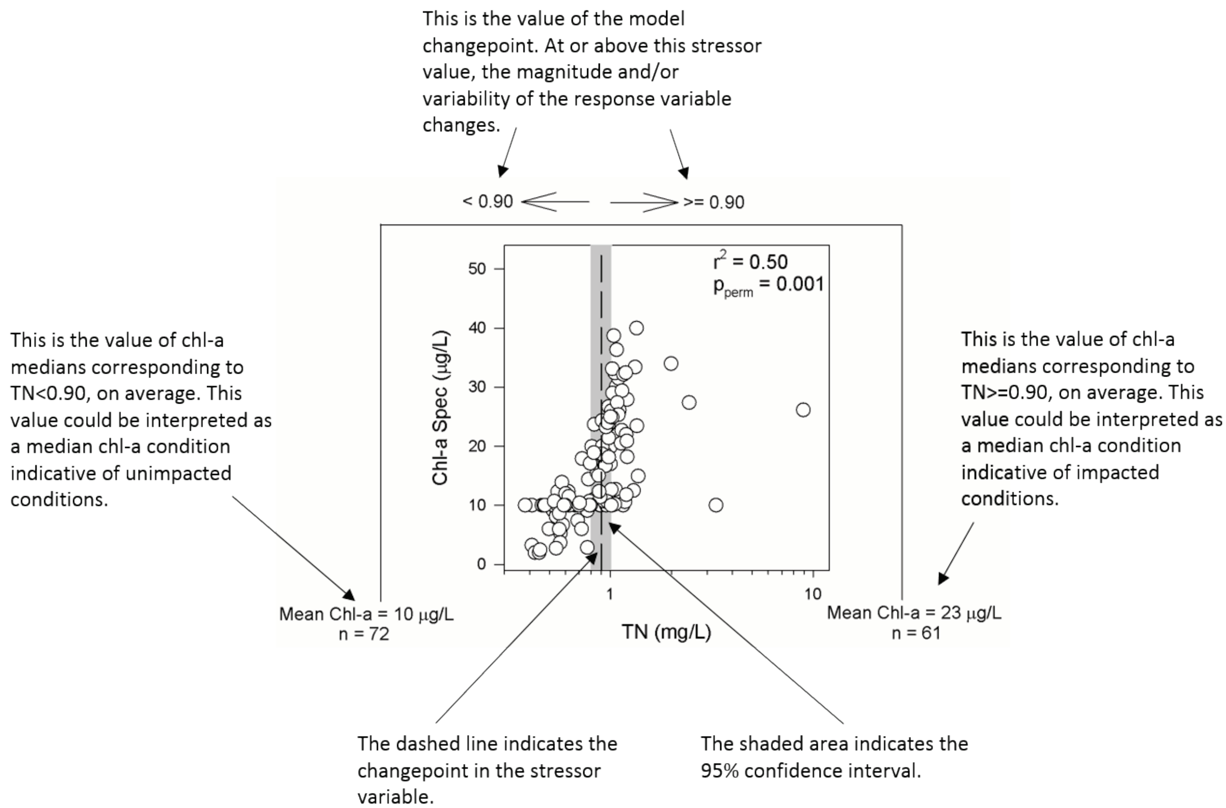


Figure A1.1.1. CART model of median spectrophotometric chl-a (chl-a spec) vs. medians TN concentrations for Texas reservoirs.

p_{perm}- The model p_{perm} is a measure of the statistical probability that a changepoint relationship exists between the stressor and response variables at the identified threshold level in the stressor variable. The acceptable level of uncertainty was defined for these analyses to be $p_{perm} < 0.05$. In other words, only results with a less than 5% probability of error were accepted as statistically significant. Therefore, the smaller the p_{perm}, the greater the probability that the model describes relationships in the general population, assuming that the data included in the analysis represent the general population without bias. Only nCPA provides estimates of p_{perm}.

Interpreting figures illustrating CART and nCPA models

The standard template for figures representing changepoint and regression tree models that was used throughout this report is shown in Figure A1.11.1. The changepoint model developed to describe the relationship between median chlorophyll-a measured spectrophotometrically (chl-a spec) and median total nitrogen (TN) concentrations in Texas reservoirs was randomly selected for this illustration (medians are from Dataset 1, see Sections 2.3-2.4). Notes have been added to the standard template for figures in order to assist with interpretation of graphical representations of regression tree and changepoint analysis results.

The water quality data included in CART and nCPA analysis were consistently station medians or means. Raw data were never analyzed. Therefore, the scatterplots representing water quality data throughout this report always depict measures of central tendency for waterbody stations. Where CART and nCPA yielded a statistically significant model, the value of the threshold is listed above the scatterplot. For statistically significant models, the changepoint is shown as a dashed line and the confidence interval is shown as a shaded area surrounding the changepoint. The number of observations and average median or mean value of the response variable associated with stressor values above or below the threshold are include to the right and left of the scatterplot, respectively.

Example scenarios

In order to explore how model summary statistics vary with specific datasets, 4 datasets were create to generate idealized changepoint models. These data were not derived from the TCEQ water quality databases and do not specifically represent any trends that may be present in those data.

Scenario 1. This data scenario is illustrated in Figure A1.1.2. The analysis identified a changepoint in response to the stressor variable equal to 50.5. The dataset used to generate this model represents a "perfect" changepoint relationship between the stressor and response variables. Every value in the response data that is paired with a stressor value <50.5 is equal to 1, while every response value paired with a stressor value ≥50.5 is equal to 2. In this scenario, a model that defines a changepoint in the stressor variable = 50.5 explains all variability in the response data. Therefore, the model r^2=1.

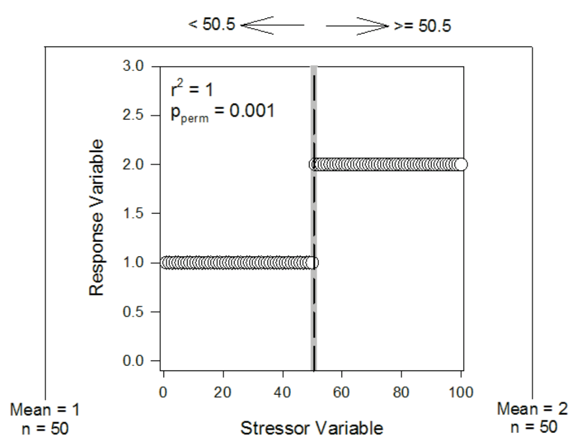


Figure A1.1.2. Sample model describing the changepoint relationship between a stressor and a response variable. In this scenario, the data grouped above and below the threshold are always different between groups, but no variability is present among groups.

In this scenario, the model identifying a changepoint in the stressor variable = 50.5 also has a low probability of error, as indicated by a $p_{perm} \leq 0.001$. This p_{perm} is < 0.05, the criteria required for the model to be statistically significant. Similarly, the confidence interval surrounding the threshold estimate is approximately 2% of the total stressor data range. Therefore, we can be 95% confident the changepoint is located within 49.5 to 51.5. Indeed the confidence interval, represented by the shaded area surrounding the threshold line, is barely visible.

In summary, we can conclude that this CART model provides excellent explanatory power for the dataset, and that it is highly probable that the analysis has identified a real relationship between the stressor and response variables. The narrow confidence interval indicates that the range of possible alternative threshold values is small. Scenario 1 is a highly idealized representation of a threshold relationship between two variables. It is highly improbable that this scenario would arise from analysis of an environmental dataset.

Scenario 2. This data scenario is illustrated in Figure A1.1.3. As in Scenario 1, the analysis identified a changepoint in response to the stressor variable = 50.5. However, the dataset used to generate this model differs from the dataset in Scenario 1. While values in the response variable corresponding to stressor values above and below the threshold never overlap, variability is now present in the data grouped above and below the threshold. Every value in the response data that is paired with a stressor value <50.5 falls within a range of values between 0 and 1, while every response value paired with a stressor value ≥50.5 is between 1.5 and 2.5. For this model, r^2 =0.77, a 23% reduction from Scenario 1.

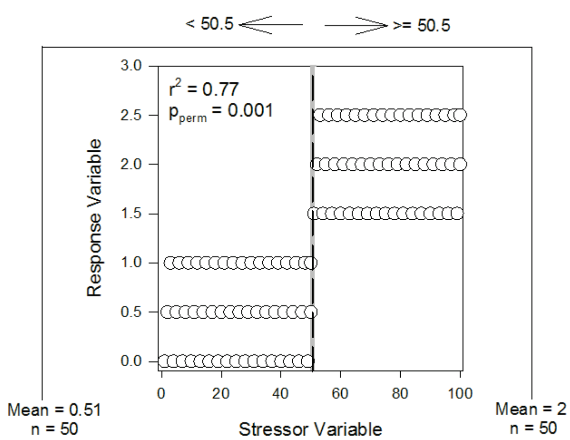


Figure A1.1.3. Sample model describing the changepoint relationship between a stressor and a response variable. In this scenario, the data grouped above and below the threshold are always different between groups, but variability is present among groups.

In this scenario, the model identifying a changepoint in the stressor variable = 50.5 has a low probability of error, as indicated by a $p_{perm} \leq 0.001$. This p_{perm} is < 0.05, the criteria required for the model to be statistically significant. Similarly, the confidence interval surrounding the threshold estimate is 1.5% of the total stressor data range. Therefore, we can be 95% confident the changepoint is within 50 to 51.5.

As in Scenario 1, we can conclude that the model provides excellent explanatory power, though not 100%. It is also highly probable that the analysis has identified a real relationship between the stressor and response variables, and the range of possible alternative threshold values is small. Scenario 2 is also an idealized representation of a threshold relationship between two variables, and achieving model explanatory power of 77% is unlikely in environmental datasets. However, when the "real-world" model in Fig. A1.1.1. is compared with Scenario 2, it is apparent that the variability in the data relative to the threshold is similar, though the ranges of values above and below the threshold overlap somewhat in Fig. A1.1.1. Despite this similarity and the obvious threshold relationship in Fig. A1.1.1, explanatory power for the model in Fig. A1.1.1 is only 50%, illustrating the magnitude of r^2 values that are likely in changepoint analysis of environmental data. In fact, r^2=0.50 is among the highest observed in this study.

Scenario 3. This data scenario is illustrated in Figure A1.1.4. The analysis identified a changepoint in response to the stressor variable equal to 51.5. In this dataset, values in the response variable corresponding to stressor values above and below the threshold overlap and variability is present in the data above and below the threshold. Every value in the response data paired with a stressor value <51.5 falls within a range of values between 0 and 1, while every response value paired with a stressor value ≥51.5 is between 0.5 and 2. In other words, mid-range response variable data appear on both sides of the threshold, but the lowest and highest values only appear below or above the threshold, respectively. For this model, r^2 =0.38, a 62% reduction from Scenario 1 and a 50% reduction from Scenario 2.

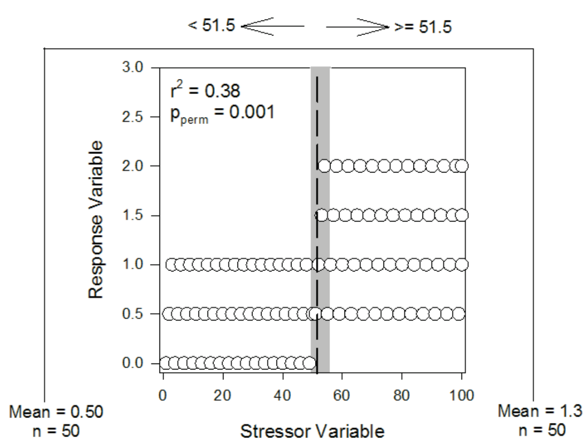


Figure A1.1.4. Sample model describing the changepoint relationship between a stressor and a response variable. In this scenario, the data grouped above and below the threshold overlap in the mid-range of observed values and variability is present among groups. Only the highest and lowest values are unique to the right or left of the threshold, respectively.

In this scenario, the model identifying a changepoint in the stressor variable equal to 51.5 also has a low probability of error, as indicated by a $p_{perm} \leq 0.001$. This p_{perm} is < 0.05, the criteria required for the model to be statistically significant. Similarly, the confidence interval surrounding the threshold estimate is approximately 6.5% of the total stressor data range. Therefore, we can be 95% confident the changepoint is located within 49.5 to 56. Though still a narrow range, the confidence interval for the model in Scenario 3 is approximately 3-5x greater than for the models in Scenarios 1-2.

We can conclude that this model provides good explanatory power. It is also highly probable that the analysis has identified a real relationship between the stressor and response variables, and the range of possible alternative threshold values is small. Scenario 3 is a less idealized representation of a threshold relationship between two variables than Scenarios 1-2, and many of the relationships in the TCEQ water quality databases were similar to that shown in Fig. A1.1.4 and had similar r^2. It is key to note, however, that the "real-world" water quality models that had similar explanatory power to the example in Scenario 3 were among the strongest models identified in the water quality database.

Scenario 4. This data scenario is illustrated in Figure A1.1.5. In this dataset, the analysis identified a changepoint in response to the stressor variable equal to 52.5.In this dataset, values in the response variable corresponding to stressor values above and below the threshold overlap and variability is present in the data above and below the threshold. Every value in the response data that is paired with a stressor value <52.5 falls within a range of values between 0 and 1, while every response value paired with a stressor value ≥52.5 is between 0 and 2.5. In other words, all response variable values associated with stressor values below the threshold are also present above the threshold. However, the highest values in the dataset are only present above the threshold. For this model r^2 =0.29, a 70% reduction from Scenario 1 and a 60% reduction from Scenario 2.

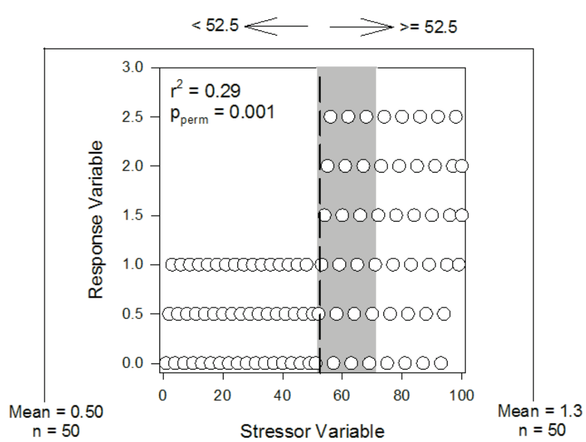


Figure A1.1.5. Sample model describing the changepoint relationship between a stressor and a response variable. In this scenario, the data grouped above and below the threshold overlap in value in the mid-range of observed values and variability is present among groups. Only the highest and lowest values are unique to the right or left of the threshold, respectively.

In this scenario, the model identifying a changepoint in the stressor variable equal to 52.5 also has a low probability of error, as indicated by a $p_{perm} \leq 0.001$. This p_{perm} is < 0.05, the criteria required for the model to be statistically significant. In contrast, the confidence interval surrounding the threshold estimate is much wider for Scenario 4 than for any of the previous scenarios, approximately 25% of the total stressor data range. While the analysis identified 52.5 as the changepoint, the value of the threshold could be as low as 51.5 and as high as 75.

We can conclude that this model provides good explanatory power. It is also highly probable that the analysis has identified a real relationship between the stressor and response variables. However, in contrast to previous scenarios, the 95% confidence interval is 25% of the range of possible values. Scenario 4 is a less idealized representation of a threshold relationship between two variables than Scenarios 1-2, and many of the relationships in the TCEQ water quality databases were similar to that shown in Fig. A1.1.5 and had similar r^2. It is key to note, however, that the "real-world" water quality models that had similar explanatory power to the example in Scenario 4 were among the strongest models identified in the water quality database. In the TCEQ data, similar trends to that shown in A1.1.5 are often visible, but analysis may also indicate an r^2 as low as 0.05.

Appendix 1.2. Statistical code from "flipped" changepoint analysis, regional threshold analysis, and community metric bioassessment

Flipped Changepoint Analysis

ANALYSIS: TP VS. SECCHI TRANSPARENCY (nCPA)

```
      cp        r2 mean left mean right pperm    5%    25%   50%   75%    95%
[1,] 0.465 0.04651025 0.4827919  0.2196945 0.001 0.285 0.2875 0.465 0.475 0.5725
```

ANALYSIS: TN VS. SECCHI TRANSPARENCY (nCPA)

```
       cp        r2 mean left mean right pperm    5%    25%    50%    75%    95%
[1,] 0.2875 0.03351609  4.369695   2.192592 0.038 0.265 0.2725 0.2875 0.2925 0.3975
```

ANALYSIS: TP VS. CHL-A SPEC (nCPA)

```
      cp        r2 mean left mean right pperm   5%   25% 50% 75%    95%
[1,] 3.475 0.02253533 0.1515781  0.2942973 0.024 1.95 3.475 8.9 9.9 20.025
```

ANALYSIS: TN VS. CHL-A SPEC (nCPA)

```
      cp         r2 mean left mean right pperm    5%  25%   50%  75%  95%
[1,] 10.25 0.009427022  2.171043   2.802568 0.404 2.425 4.15 10.25 12.1 21.4
```

ANALYSIS: TP VS. CHL-A FLUORO (nCPA)

```
      cp        r2 mean left mean right pperm     5%    25%   50%  75%  95%
[1,] 3.2625 0.01462862 0.2075082  0.3743852 0.238 3.1425 3.2625 3.285 5.14 32.5
```

Regional thresholds

ANALYSIS: BASIN 1 SECCHI TRANSPARENCY VS. NUTRIENTS (CART)

No splits possible

ANALYSIS: BASIN 1 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = basin1, xval = 10, method = "anova",
   minsplit = 10, minbucket = 5)
  n=15 (4 observations deleted due to missingness)

         CP nsplit rel error    xerror      xstd
1 0.3084774      0 1.0000000 1.1298116 0.3589451
```

```
2 0.0100000      1 0.6915226 0.9381457 0.2689428

Node number 1: 15 observations,    complexity param=0.3084774
  mean=7.606333, MSE=11.92986
  left son=2 (8 obs) right son=3 (7 obs)
  Primary splits:
      TP < 0.105 to the left,  improve=0.3084774, (0 missing)

Node number 2: 8 observations
  mean=5.811875, MSE=7.76315

Node number 3: 7 observations
  mean=9.657143, MSE=8.805906
```

ANALYSIS: BASIN 1 CHL-A FLUORO VS. NUTRIENTS (CART)

No splits possible

ANALYSIS: BASIN 2 SECCHI VS. NUTRIENTS

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = basin2, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=20 (83 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
1 0.20376942      0 1.0000000 1.089099 0.8118430
2 0.04898673      1 0.7962306 1.186400 0.8134326

Node number 1: 20 observations,    complexity param=0.2037694
  mean=0.35235, MSE=0.04666583
  left son=2 (15 obs) right son=3 (5 obs)
  Primary splits:
      TN < 1.0275 to the right, improve=0.2037694, (0 missing)
      TP < 0.065  to the right, improve=0.1713888, (0 missing)

Node number 2: 15 observations
  mean=0.29605, MSE=0.01044027

Node number 3: 5 observations
  mean=0.52125, MSE=0.1173062
```

ANALYSIS: BASIN 2 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
```

```
mvpart(form = CHLASPEC ~ TP + TN, data = basin2, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=38 (65 observations deleted due to missingness)

         CP nsplit rel error    xerror      xstd
1 0.2741409      0 1.0000000 1.0426832 0.4556817
2 0.0421290      1 0.7258591 0.8945434 0.3067643
3 0.0100000      2 0.6837301 0.8702367 0.3053816

Node number 1: 38 observations,    complexity param=0.2741409
  mean=11.54961, MSE=103.2016
  left son=2 (28 obs) right son=3 (10 obs)
  Primary splits:
      TP < 0.2125     to the left,  improve=0.2741409, (0 missing)
      TN < 1.595      to the left,  improve=0.1017129, (20 missing)

Node number 2: 28 observations,    complexity param=0.042129
  mean=8.370893, MSE=20.10265
  left son=4 (14 obs) right son=5 (14 obs)
  Primary splits:
      TP < 0.09916668 to the left,  improve=0.293521600, (0 missing)
      TN < 0.955      to the right, improve=0.002675159, (14 missing)

Node number 3: 10 observations
  mean=20.45, MSE=228.37

Node number 4: 14 observations
  mean=5.941786, MSE=13.22751

Node number 5: 14 observations
  mean=10.8, MSE=15.17666
```

ANALYSIS: CHL-A FLUORO VS. NUTRIENTS (CART)

No possible splits

ANALYSIS: BASIN 3 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = basin3, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=15 (45 observations deleted due to missingness)

        CP nsplit rel error   xerror      xstd
1 0.209527      0  1.000000 1.173250 0.6899347
```

```
2 0.010000      1  0.790473 1.356486 0.8146720

Node number 1: 15 observations,    complexity param=0.209527
  mean=0.3463333, MSE=0.01958156
  left son=2 (7 obs) right son=3 (8 obs)
  Primary splits:
      TP < 0.225   to the right, improve=0.20952700, (0 missing)
      TN < 1.10075 to the left,  improve=0.03167096, (0 missing)

Node number 2: 7 observations
  mean=0.2778571, MSE=0.003256122

Node number 3: 8 observations
  mean=0.40625, MSE=0.02617344
```

ANALYSIS: BASIN 3 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = basin3, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=11 (49 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.2396307      0 1.0000000 1.215487 0.6069283
2 0.0100000      1 0.7603693 1.233415 0.4575537

Node number 1: 11 observations,    complexity param=0.2396307
  mean=12.59091, MSE=25.71128
  left son=2 (6 obs) right son=3 (5 obs)
  Primary splits:
      TN < 1.2125 to the left,  improve=0.2396307, (0 missing)
      TP < 0.1275 to the left,  improve=0.1569999, (0 missing)

Node number 2: 6 observations
  mean=10.325, MSE=0.3414583

Node number 3: 5 observations
  mean=15.31, MSE=42.6004
```

ANALYSIS: BASIN 3 CHLASPEC VS. NUTRIENTS (CART)

```
mvpart(form = CHLAFLUORO ~ TP + TN, data = basin3, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=13 (47 observations deleted due to missingness)
```

```
        CP nsplit rel error    xerror      xstd
1 0.4840539      0 1.0000000 1.1871925 0.6056727
2 0.0100000      1 0.5159461 0.8356373 0.3792726

Node number 1: 13 observations,    complexity param=0.4840539
  mean=7.986154, MSE=64.60967
  left son=2 (8 obs) right son=3 (5 obs)
  Primary splits:
      TP < 0.165 to the right, improve=0.4840539, (0 missing)
      TN < 1.23  to the right, improve=0.2092685, (0 missing)

Node number 2: 8 observations
  mean=3.565, MSE=0.8673312

Node number 3: 5 observations
  mean=15.06, MSE=85.28356
```

ANALYSIS: BASIN 4 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = basin4, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=31 (48 observations deleted due to missingness)

        CP nsplit rel error   xerror      xstd
1 0.5121825      0 1.0000000 1.067339 0.2892314
2 0.0606644      1 0.4878175 1.235708 0.3002455

Node number 1: 31 observations,    complexity param=0.5121825
  mean=0.5253871, MSE=0.03280127
  left son=2 (20 obs) right son=3 (7 obs), 4 observations remain
  Primary splits:
      TN < 0.71615 to the right, improve=0.3717401, (4 missing)
      TP < 0.0856  to the right, improve=0.2936672, (0 missing)

Node number 2: 20 observations
  mean=0.471, MSE=0.0097465

Node number 3: 7 observations
  mean=0.741, MSE=0.04301457
```

ANALYSIS: BASIN 4 CHL-A SPEC VS. NUTRIENTS

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = basin4, xval = 10, method = "anova",
```

```
   minsplit = 10, minbucket = 5)
  n=18 (61 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.3354521      0 1.0000000 1.149649 0.1355887
2 0.0100000      1 0.6645479 1.028165 0.2699087

Node number 1: 18 observations,    complexity param=0.3354521
  mean=7.252778, MSE=11.95735
  left son=2 (9 obs) right son=3 (9 obs)
  Primary splits:
      TP < 0.095   to the left,  improve=0.3354521, (0 missing)
      TN < 0.72515 to the left,  improve=0.0954663, (0 missing)

Node number 2: 9 observations
  mean=5.25, MSE=11.45889

Node number 3: 9 observations
  mean=9.255556, MSE=4.43358
```

ANALYSIS: BASIN 4 CHL-A FLUORO VS. NUTRIENTS (CART)

```
mvpart(form = CHLAFLUORO ~ TP + TN, data = basin4, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=12 (67 observations deleted due to missingness)

         CP nsplit rel error    xerror      xstd
1 0.3083132      0 1.0000000 1.1760621 0.2679992
2 0.0100000      1 0.6916868 0.8747731 0.1988550

Node number 1: 12 observations,    complexity param=0.3083132
  mean=3.663333, MSE=0.7642014
  left son=2 (5 obs) right son=3 (7 obs)
  Primary splits:
      TP < 0.13 to the right, improve=0.3083132, (0 missing)
      TN < 0.94 to the right, improve=0.3083132, (0 missing)

Node number 2: 5 observations
  mean=3.089, MSE=0.023104

Node number 3: 7 observations
  mean=4.073571, MSE=0.889648
```

ANALYSIS: BASIN 5 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = basin5, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=30 (41 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
1 0.61948187      0 1.0000000 1.042769 0.4527798
2 0.04257782      1 0.3805181 1.119966 0.3393227

Node number 1: 30 observations,    complexity param=0.6194819
  mean=0.4515, MSE=0.04594025
  left son=2 (17 obs) right son=3 (5 obs), 8 observations remain
  Primary splits:
      TN < 0.86    to the right, improve=0.4806243, (8 missing)
      TP < 0.06625 to the right, improve=0.4636851, (0 missing)

Node number 2: 17 observations
  mean=0.3879412, MSE=0.01024429

Node number 3: 5 observations
  mean=0.802, MSE=0.070056
```

ANALYSIS: BASIN 5 CHL-A SPEC VS. NUTRIENTS (CART)

No splits possible

ANALYSIS: BASIN 5 CHL-A FLUORO VS. NUTRIENTS (CART)

No splits possible

ANALYSIS: BASIN 8 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = basin8, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=70 (200 observations deleted due to missingness)

          CP nsplit rel error    xerror      xstd
1 0.24565726      0 1.0000000 1.0315497 0.1439704
2 0.10718280      1 0.7543427 1.0000218 0.1228280
3 0.08696029      2 0.6471599 1.0346910 0.1324383
4 0.06529283      3 0.5601997 0.9634918 0.1347012

Node number 1: 70 observations,    complexity param=0.2456573
```

```
  mean=0.3729857, MSE=0.02568567
  left son=2 (27 obs) right son=3 (43 obs)
  Primary splits:
      TP < 0.11   to the right, improve=0.2456573, (0 missing)
      TN < 2.6625 to the right, improve=0.2016446, (5 missing)

Node number 2: 27 observations
  mean=0.2727407, MSE=0.01351827

Node number 3: 43 observations,    complexity param=0.1071828
  mean=0.4359302, MSE=0.02305379
  left son=6 (25 obs) right son=7 (16 obs), 2 observations remain
  Primary splits:
      TN < 0.875  to the right, improve=0.06486998, (2 missing)
      TP < 0.0725 to the right, improve=0.06155167, (0 missing)

Node number 6: 25 observations,    complexity param=0.08696029
  mean=0.396, MSE=0.016636
  left son=12 (9 obs) right son=13 (16 obs)
  Primary splits:
      TN < 0.995  to the left,  improve=0.375942200, (0 missing)
      TP < 0.0625 to the right, improve=0.002564719, (0 missing)

Node number 7: 16 observations
  mean=0.4771875, MSE=0.02391865

Node number 12: 9 observations
  mean=0.2905556, MSE=0.001402469

Node number 13: 16 observations
  mean=0.4553125, MSE=0.01543271
```

ANALYSIS: BASIN 8 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = basin8, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=91 (179 observations deleted due to missingness)

          CP nsplit rel error    xerror      xstd
1 0.34102911      0 1.0000000 1.0121153 0.2418820
2 0.07717132      1 0.6589709 0.6791118 0.1845079

Node number 1: 91 observations,    complexity param=0.3410291
  mean=8.867582, MSE=23.422
```

```
 left son=2 (44 obs) right son=3 (47 obs)
 Primary splits:
    TP < 0.0775 to the left,  improve=0.34102910, (0 missing)
    TN < 1.0525 to the left,  improve=0.08484991, (25 missing)

Node number 2: 44 observations
 mean=5.946591, MSE=6.911295

Node number 3: 47 observations
 mean=11.60213, MSE=23.41351
```

ANALYSIS: BASIN 8 CHL-A SPEC VS. NUTRIENTS (CART)

```
mvpart(form = CHLAFLUORO ~ TP + TN, data = basin8, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
 n=15 (255 observations deleted due to missingness)

        CP nsplit rel error   xerror      xstd
1 0.2599901      0 1.0000000 1.128057 0.3381315
2 0.0100000      1 0.7400099 1.078766 0.2874435

Node number 1: 15 observations,    complexity param=0.2599901
 mean=9.708333, MSE=34.67343
 left son=2 (7 obs) right son=3 (8 obs)
 Primary splits:
    TP < 0.13 to the left,  improve=0.25999010, (0 missing)
    TN < 1.03 to the left,  improve=0.01937869, (1 missing)

Node number 2: 7 observations
 mean=6.498571, MSE=17.82893

Node number 3: 8 observations
 mean=12.51688, MSE=32.50972
```

ANALYSIS: BASIN 10 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = basin10, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
 n=142 (54 observations deleted due to missingness)

         CP nsplit rel error    xerror      xstd
1 0.18566482      0 1.0000000 1.0156922 0.1496324
2 0.05657971      1 0.8143352 0.9598587 0.1515159
```

```
Node number 1: 142 observations,    complexity param=0.1856648
  mean=0.4357394, MSE=0.05210562
  left son=2 (107 obs) right son=3 (35 obs)
  Primary splits:
      TP < 0.1575 to the right, improve=0.185664800, (0 missing)
      TN < 3.715  to the right, improve=0.009868004, (127 missing)

Node number 2: 107 observations
  mean=0.379486, MSE=0.03948548

Node number 3: 35 observations
  mean=0.6077143, MSE=0.05143763
```

ANALYSIS: BASIN 10 CHL-A SPEC VS. NUTRIENTS (CART)

No possible splits

ANALYSIS: BASIN 10 CHL-A FLUORO VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLAFLUORO ~ TP + TN, data = basin10, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=14 (182 observations deleted due to missingness)

        CP nsplit rel error   xerror      xstd
1 0.274721      0  1.000000 1.077342 0.2249025
2 0.010000      1  0.725279 1.126556 0.3514812

Node number 1: 14 observations,    complexity param=0.274721
  mean=5.934643, MSE=6.347284
  left son=2 (5 obs) right son=3 (9 obs)
  Primary splits:
      TN < 4.865 to the left,  improve=0.27472100, (0 missing)
      TP < 1.07  to the left,  improve=0.04330035, (0 missing)

Node number 2: 5 observations
  mean=4.163, MSE=1.342876

Node number 3: 9 observations
  mean=6.918889, MSE=6.415038
```

ANALYSIS: BASIN 11 SECCHI VS. NUTRIENTS (CART)

Call:

```
mvpart(form = SECCHI ~ TP + TN, data = basin11, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=15 (43 observations deleted due to missingness)

          CP nsplit rel error    xerror      xstd
1 0.3010449      0 1.0000000 1.0322666 0.3743675
2 0.0100000      1 0.6989551 0.9865384 0.3803100

Node number 1: 15 observations,    complexity param=0.3010449
  mean=0.2916667, MSE=0.006698889
  left son=2 (9 obs) right son=3 (6 obs)
  Primary splits:
      TP < 0.1625 to the right, improve=0.3010449, (0 missing)

Node number 2: 9 observations
  mean=0.255, MSE=0.005027778

Node number 3: 6 observations
  mean=0.3466667, MSE=0.004163889
```

ANALYSIS: BASIN 11 CHL-A SPEC VS. NUTRIENTS (CART)

No possible splits

ANALYSIS: BASIN 11 CHL-A FLUORO VS. NUTRIENTS (CART)

No possible splits

ANALYSIS: BASIN 12 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = basin12, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=119 (249 observations deleted due to missingness)

          CP nsplit rel error    xerror       xstd
1 0.2305982      0 1.0000000 1.0280778 0.08828449
2 0.1413479      1 0.7694018 0.8314411 0.09021527

Node number 1: 119 observations,    complexity param=0.2305982
  mean=0.5901891, MSE=0.1344025
  left son=2 (78 obs) right son=3 (40 obs), 1 observation remains
  Primary splits:
      TP < 0.0625 to the right, improve=0.23058370, (1 missing)
      TN < 1.3275 to the right, improve=0.03235631, (28 missing)
```

```
Node number 2: 78 observations
  mean=0.4637179, MSE=0.09369323

Node number 3: 40 observations
  mean=0.8371875, MSE=0.1249416
```

ANALYSIS: BASIN 12 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = basin12, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=69 (299 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.3037886      0 1.0000000 1.026106 0.2538436
2 0.2927174      1 0.6962114 1.081768 0.2211619

Node number 1: 69 observations,    complexity param=0.3037886
  mean=11.23116, MSE=55.10318
  left son=2 (37 obs) right son=3 (32 obs)
  Primary splits:
      TP < 0.1225  to the left,  improve=0.30378860, (0 missing)
      TN < 2.96    to the left,  improve=0.04098884, (23 missing)

Node number 2: 37 observations
  mean=7.426216, MSE=12.38248

Node number 3: 32 observations,    complexity param=0.2927174
  mean=15.63063, MSE=68.40398
  left son=6 (15 obs) right son=7 (7 obs), 10 observations remain
  Primary splits:
      TN < 2.96    to the left,  improve=0.10164210, (10 missing)
      TP < 0.48525 to the left,  improve=0.04565085, (0 missing)

Node number 6: 15 observations
  mean=11.98667, MSE=21.05149

Node number 7: 7 observations
  mean=18.81429, MSE=108.6012
```

ANALYSIS: BASIN 12 CHL-A FLUORO VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLAFLUORO ~ TP + TN, data = basin12, xval = 10,
```

```
   method = "anova", minsplit = 10, minbucket = 5)
  n=101 (267 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.1355851      0 1.0000000 1.026926 0.3048722
2 0.1120642      1 0.8644149 1.092706 0.3036646

Node number 1: 101 observations,    complexity param=0.1355851
  mean=11.09178, MSE=162.4037
  left son=2 (54 obs) right son=3 (47 obs)
  Primary splits:
      TP < 0.1075 to the left,  improve=0.13558510, (0 missing)
      TN < 1.1475 to the left,  improve=0.04240554, (25 missing)

Node number 2: 54 observations
  mean=6.713981, MSE=53.89416

Node number 3: 47 observations
  mean=16.1216, MSE=239.7558
```

ANALYSIS: BASIN 13 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = basin13, xval = 10, method = "anova",
   minsplit = 10, minbucket = 5)
  n=10 (14 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.1857068      0 1.0000000 1.234568 0.9295124
2 0.0100000      1 0.8142932 1.234568 0.9295124

Node number 1: 10 observations,    complexity param=0.1857068
  mean=0.3445, MSE=0.02240225
  left son=2 (5 obs) right son=3 (5 obs)
  Primary splits:
      TP < 0.199655 to the right, improve=0.1857068, (0 missing)

Node number 2: 5 observations
  mean=0.28, MSE=0.00356

Node number 3: 5 observations
  mean=0.409, MSE=0.032924
```

ANALYSIS: BASIN 13 CHL-A SPEC VS. NUTRIENTS (CART)

No possible splits

ANALYSIS: BASIN 13 CHL-A FLUORO VS. NUTRIENTS (CART)

No possible splits

ANALYSIS: BASIN 14 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = basin14, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=96 (204 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
1 0.28751476      0 1.0000000 1.021371 0.1803719
2 0.03981791      2 0.4249705 0.910023 0.1678266

Node number 1: 96 observations,    complexity param=0.2875148
  mean=0.5701042, MSE=0.1167989
  left son=2 (27 obs) right son=3 (69 obs)
  Primary splits:
      TP < 0.0775 to the right, improve=0.12249570, (0 missing)
      TN < 0.51   to the right, improve=0.06336937, (29 missing)

Node number 2: 27 observations
  mean=0.3788889, MSE=0.0121358

Node number 3: 69 observations,    complexity param=0.2875148
  mean=0.6449275, MSE=0.1378482
  left son=6 (28 obs) right son=7 (17 obs), 24 observations remain
  Primary splits:
      TN < 0.51   to the right, improve=0.032786370, (24 missing)
      TP < 0.063  to the right, improve=0.009936821, (0 missing)

Node number 6: 28 observations
  mean=0.5153571, MSE=0.08624452

Node number 7: 17 observations
  mean=0.6870588, MSE=0.1189737
```

ANALYSIS: BASIN 14 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = basin14, xval = 10,
```

```
   method = "anova", minsplit = 10, minbucket = 5)
 n=72 (228 observations deleted due to missingness)

        CP nsplit rel error    xerror      xstd
1 0.19164329      0 1.0000000 1.0536652 0.4772105
2 0.03370283      3 0.4196705 0.9478539 0.3656974

Node number 1: 72 observations,    complexity param=0.1916433
  mean=10.29875, MSE=103.3251
  left son=2 (44 obs) right son=3 (28 obs)
  Primary splits:
      TP < 0.063    to the left,  improve=0.1811514, (0 missing)
      TN < 1.1705   to the left,  improve=0.1230495, (9 missing)

Node number 2: 44 observations
  mean=6.8475, MSE=16.25017

Node number 3: 28 observations,    complexity param=0.1916433
  mean=15.72214, MSE=192.0264
  left son=6 (12 obs) right son=7 (16 obs)
  Primary splits:
      TP < 0.291    to the right, improve=0.2796798, (0 missing)
      TN < 1.7415   to the right, improve=0.1116367, (4 missing)

Node number 6: 12 observations
  mean=7.26, MSE=32.33824

Node number 7: 16 observations,    complexity param=0.1916433
  mean=22.06875, MSE=217.8071
  left son=14 (8 obs) right son=15 (5 obs), 3 observations remain
  Primary splits:
      TN < 1.515225 to the left,  improve=0.3117296, (3 missing)
      TP < 0.12775  to the left,  improve=0.1149684, (0 missing)

Node number 14: 8 observations
  mean=13.45, MSE=43.285

Node number 15: 5 observations
  mean=32.24, MSE=334.5504
```

ANALYSIS: BASIN 14 CHL-A FLUORO VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLAFLUORO ~ TP + TN, data = basin14, xval = 10,
   method = "anova", minsplit = 10, minbucket = 5)
```

```
  n=57 (243 observations deleted due to missingness)

          CP nsplit rel error    xerror      xstd
1 0.25313043      0 1.0000000 1.0254520 0.4851769
2 0.01819188      2 0.4937391 0.9652068 0.4443902

Node number 1: 57 observations,    complexity param=0.2531304
  mean=10.13947, MSE=207.9907
  left son=2 (36 obs) right son=3 (21 obs)
  Primary splits:
      TN < 1.2805 to the left,  improve=0.1656096, (0 missing)
      TP < 0.065  to the left,  improve=0.1359142, (0 missing)

Node number 2: 36 observations
  mean=5.656944, MSE=10.95552

Node number 3: 21 observations,    complexity param=0.2531304
  mean=17.82381, MSE=452.2711
  left son=6 (14 obs) right son=7 (7 obs)
  Primary splits:
      TP < 0.176  to the right, improve=0.42521710, (0 missing)
      TN < 1.6815 to the right, improve=0.09660346, (0 missing)

Node number 6: 14 observations
  mean=8.017857, MSE=120.372

Node number 7: 7 observations
  mean=37.43571, MSE=539.1291
```

ANALYSIS: BASIN 18 SECCHI VS. NUTRIENTS

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = basin18, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=25 (109 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.4158475      0 1.0000000 1.091722 0.2890526
2 0.1361973      1 0.5841525 1.208588 0.2871744

Node number 1: 25 observations,    complexity param=0.4158475
  mean=1.0678, MSE=0.2165842
  left son=2 (5 obs) right son=3 (11 obs), 9 observations remain
  Primary splits:
```

```
    TN < 0.6775 to the left,  improve=0.1471034, (9 missing)
    TP < 0.055  to the right, improve=0.1061268, (0 missing)

Node number 2: 5 observations
  mean=0.725, MSE=0.0525

Node number 3: 11 observations
  mean=1.206364, MSE=0.2636777
```

ANALYSIS: BASIN 18 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = basin18, xval = 10,
   method = "anova", minsplit = 10, minbucket = 5)
  n=59 (75 observations deleted due to missingness)

         CP nsplit rel error    xerror      xstd
1 0.2258987      0 1.0000000 1.0337823 0.2082640
2 0.1412499      1 0.7741013 0.9772914 0.2184696

Node number 1: 59 observations,    complexity param=0.2258987
  mean=3.137119, MSE=11.15799
  left son=2 (34 obs) right son=3 (25 obs)
  Primary splits:
    TP < 0.0575 to the left,  improve=0.22589870, (0 missing)
    TN < 1.51   to the right, improve=0.03824136, (44 missing)

Node number 2: 34 observations
  mean=1.775735, MSE=5.461053

Node number 3: 25 observations
  mean=4.9886, MSE=12.95727
```

ANALYSIS: BASIN 18 CHL-A FLUORO VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLAFLUORO ~ TP + TN, data = basin18, xval = 10,
   method = "anova", minsplit = 10, minbucket = 5)
  n=10 (124 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
1 0.02564428      0 1.0000000 1.234568 0.8494921
2 0.01000000      1 0.9743557 1.234568 0.8494921
```

```
Node number 1: 10 observations,    complexity param=0.02564428
  mean=3.2255, MSE=0.2164322
  left son=2 (5 obs) right son=3 (5 obs)
  Primary splits:
      TN < 0.9125 to the right, improve=0.02564428, (0 missing)

Node number 2: 5 observations
  mean=3.151, MSE=0.061764

Node number 3: 5 observations
  mean=3.3, MSE=0.36
```

ANALYSIS: BASIN 19 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = basin19, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=69 (93 observations deleted due to missingness)

          CP nsplit rel error    xerror      xstd
1 0.48063745      0 1.0000000 1.0507578 0.1282815
2 0.06838008      1 0.5193626 0.6760214 0.1073029

Node number 1: 69 observations,    complexity param=0.4806374
  mean=0.6894203, MSE=0.1595286
  left son=2 (36 obs) right son=3 (33 obs)
  Primary splits:
      TP < 0.16   to the right, improve=0.4806374, (0 missing)
      TN < 4.8545 to the right, improve=0.3805645, (3 missing)

Node number 2: 36 observations
  mean=0.4243056, MSE=0.0692641

Node number 3: 33 observations
  mean=0.9786364, MSE=0.09767769
```

ANALYSIS: BASIN 19 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = basin19, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=50 (112 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
```

```
1 0.07778244      0 1.0000000 1.038370 0.1596310
2 0.07697551      2 0.8444351 1.570603 0.2328561

Node number 1: 50 observations,    complexity param=0.07778244
  mean=4.604, MSE=11.17598
  left son=2 (40 obs) right son=3 (7 obs), 3 observations remain
  Primary splits:
      TN < 1.22525 to the right, improve=0.06606233, (3 missing)
      TP < 0.33475 to the left,  improve=0.05853348, (0 missing)

Node number 2: 40 observations,    complexity param=0.07778244
  mean=4.225, MSE=10.19938
  left son=4 (19 obs) right son=5 (21 obs)
  Primary splits:
      TP < 0.33475 to the left,  improve=0.1165118, (0 missing)
      TN < 4.8545  to the left,  improve=0.1071867, (0 missing)

Node number 3: 7 observations
  mean=6.714286, MSE=15.91837

Node number 4: 19 observations
  mean=3.078947, MSE=5.612188

Node number 5: 21 observations
  mean=5.261905, MSE=12.08617
```

ANALYSIS: BASIN 19 CHL-A FLUORO VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLAFLUORO ~ TP + TN, data = basin19, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=16 (146 observations deleted due to missingness)

        CP nsplit rel error   xerror      xstd
1 0.114955      0  1.000000 1.134642 0.9547342
2 0.010000      1  0.885045 1.224181 0.9516576

Node number 1: 16 observations,    complexity param=0.114955
  mean=3.937187, MSE=6.784675
  left son=2 (9 obs) right son=3 (7 obs)
  Primary splits:
      TP < 0.07  to the right, improve=0.114955000, (0 missing)
      TN < 3.405 to the right, improve=0.006657592, (1 missing)
```

```
Node number 2: 9 observations
  mean=3.158333, MSE=0.1330444

Node number 3: 7 observations
  mean=4.938571, MSE=13.55407
```

ANALYSIS: BASIN 21 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = basin21, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=33 (21 observations deleted due to missingness)

         CP nsplit rel error    xerror      xstd
1 0.5547448      0 1.0000000 1.0322440 0.1842795
2 0.1881159      1 0.4452552 0.5576415 0.1180319

Node number 1: 33 observations,    complexity param=0.5547448
  mean=0.6368182, MSE=0.2449149
  left son=2 (16 obs) right son=3 (17 obs)
  Primary splits:
      TP < 0.065 to the right, improve=0.5547448, (0 missing)
      TN < 0.9   to the right, improve=0.1566500, (16 missing)

Node number 2: 16 observations
  mean=0.256875, MSE=0.005508984

Node number 3: 17 observations
  mean=0.9944118, MSE=0.2064997
```

ANALYSIS: BASIN 21 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = basin21, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=28 (26 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
1 0.17912132      0 1.0000000 1.035767 0.4532111
2 0.03224111      1 0.8208787 1.058048 0.4416514

Node number 1: 28 observations,    complexity param=0.1791213
  mean=9.756071, MSE=18.40431
  left son=2 (20 obs) right son=3 (8 obs)
```

```
  Primary splits:
      TP < 0.13375 to the left,  improve=0.179121300, (0 missing)
      TN < 1.015   to the left,  improve=0.007688692, (14 missing)

Node number 2: 20 observations
  mean=8.60775, MSE=6.770646

Node number 3: 8 observations
  mean=12.62688, MSE=35.95037
```

ANALYSIS: BASIN 21 CHL-A FLUORO VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLAFLUORO ~ TP + TN, data = basin21, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=24 (30 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
1 0.22316471      0 1.0000000 1.091257 0.5196958
2 0.03303817      1 0.7768353 1.171451 0.5081196

Node number 1: 24 observations,    complexity param=0.2231647
  mean=7.753125, MSE=53.1353
  left son=2 (18 obs) right son=3 (6 obs)
  Primary splits:
      TP < 0.13925 to the left,  improve=0.2231647, (0 missing)
      TN < 2.0025  to the right, improve=0.1159111, (11 missing)

Node number 2: 18 observations
  mean=5.765, MSE=19.56196

Node number 3: 6 observations
  mean=13.7175, MSE=106.4236
```

ANALYSIS: BASIN 23 SECCHI VS. NUTRIENTS (CART)

```
mvpart(form = SECCHI ~ TP + TN, data = basin23, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=48 (63 observations deleted due to missingness)

         CP nsplit rel error    xerror       xstd
1 0.6253990      0  1.000000 1.0540363 0.17473853
2 0.1113971      1  0.374601 0.4208588 0.08839859
```

```
Node number 1: 48 observations,    complexity param=0.625399
  mean=0.5858125, MSE=0.1737836
  left son=2 (26 obs) right son=3 (22 obs)
  Primary splits:
      TP < 0.0855 to the right, improve=0.625399, (0 missing)
      TN < 1.9575 to the right, improve=0.240545, (6 missing)

Node number 2: 26 observations
  mean=0.2825577, MSE=0.02920423

Node number 3: 22 observations
  mean=0.9442045, MSE=0.1075212
```

ANALYSIS: BASIN 23 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = basin23, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=55 (56 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
1 0.18515445      0 1.0000000 1.038189 0.5515298
2 0.07836805      2 0.6296911 1.614592 0.5970175

Node number 1: 55 observations,    complexity param=0.1851545
  mean=10.91645, MSE=54.69826
  left son=2 (34 obs) right son=3 (21 obs)
  Primary splits:
      TP < 0.13   to the left,  improve=0.1790371, (0 missing)
      TN < 1.66   to the left,  improve=0.1697066, (12 missing)

Node number 2: 34 observations
  mean=8.457059, MSE=6.22031

Node number 3: 21 observations,    complexity param=0.1851545
  mean=14.89833, MSE=107.538
  left son=6 (6 obs) right son=7 (12 obs), 3 observations remain
  Primary splits:
      TN < 1.66   to the left,  improve=0.1463144, (3 missing)
      TP < 0.2255 to the right, improve=0.0253384, (0 missing)

Node number 6: 6 observations
  mean=9.516667, MSE=4.601389
```

```
Node number 7: 12 observations
  mean=18.60542, MSE=137.9389
```

ANALYSIS: BASIN 23 CHL-A FLUORO VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLAFLUORO ~ TP + TN, data = basin23, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=27 (84 observations deleted due to missingness)

         CP nsplit rel error    xerror      xstd
1 0.5050530      0  1.000000 1.0674662 0.4767247
2 0.0751112      1  0.494947 0.7780845 0.2814699

Node number 1: 27 observations,    complexity param=0.505053
  mean=12.79815, MSE=152.7133
  left son=2 (22 obs) right son=3 (5 obs)
  Primary splits:
      TP < 0.329 to the left,  improve=0.5050530, (0 missing)
      TN < 1.66  to the left,  improve=0.4215044, (0 missing)

Node number 2: 22 observations
  mean=8.611364, MSE=45.3092

Node number 3: 5 observations
  mean=31.22, MSE=208.7986
```

ANALYSIS: BASIN 1 CHL-A SPEC VS. TP (nCPA)

```
        cp        r2 mean left mean right pperm        5%       25%       50%   75%  95%
[1,] 0.105 0.3084774  5.811875   9.657143 0.107 0.07666668 0.0866667 0.1033333 0.105 0.12
```

ANALYSIS: BASIN 2 SECCHI VS. TP (nCPA)

```
       cp        r2 mean left mean right pperm   5%  25%    50%    75%  95%
[1,] 0.06 0.8103647   0.50725  0.3007167  0.01 0.06 0.06 0.0875 0.1175 0.28
```

ANALYSIS: BASIN 2 SECCHI VS. TN (nCPA)

```
       cp        r2 mean left mean right pperm   5%    25%   50%    75%   95%
[1,] 1.0275 0.2037694   0.52125    0.29605 0.161 0.93 1.0275 1.075 1.3025 2.745
```

ANALYSIS: BASIN 2 CHL-A SPEC VS. TP (nCPA)

Split 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.2125 0.2741409 8.370893 20.45 0.012 0.09579159 0.1825 0.21 0.2125 0.2883335

Split 2 Left

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.09916668 0.2935216 5.941786 10.8 0.012 0.065 0.09 0.09916668 0.09916668 0.1049999

ANALYSIS: BASIN 2 CHL-A SPEC VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.49 0.1400812 10.64167 19.275 0.187 1.001375 1.365 1.49 1.53 2.4375

ANALYSIS: BASIN 3 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.225 0.209527 0.40625 0.2778571 0.152 0.105 0.1525 0.21 0.225 0.316

ANALYSIS: BASIN 3 SECCHI VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.10075 0.03167096 0.3158333 0.3666667 0.922 0.98 1.09575 1.14 1.22 2.2725

ANALYSIS: BASIN 3 CHL-A FLUORO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.165 0.4840539 15.06 3.565 0.004 0.115 0.1525 0.175 0.19 0.24

ANALYSIS: BASIN 3 CHL-A FLUORO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.17325 0.06442322 5.7825 9.875 0.704 1 1.09575 1.17325 1.22 1.23

ANALYSIS: BASIN 4 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0856 0.2936672 0.6577273 0.4526 0.006 0.0849 0.0856 0.0883 0.095 0.116125

ANALYSIS: BASIN 4 SECCHI VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.71615 0.4324784 0.741 0.471 0.004 0.6606 0.71615 0.721 0.83635 0.9275

ANALYSIS: BASIN 4 CHL-A SPEC VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.075 0.4871535 4.19 8.430769 0.011 0.055 0.06375 0.085 0.095 0.1025

ANALYSIS: BASIN 4 CHL-A SPEC VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.7203 0.1927607 5.53 7.915385 0.253 0.69575 0.7186 0.81345 0.91095 1.057537

ANALYSIS: BASIN 4 CHL-A FLUORO VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.8275 0.1475772 3.747 3.603571 0.593 0.7203 0.73 0.8275 0.93 0.98

ANALYSIS: BASIN 5 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.06625 0.4636851 0.6744444 0.3559524 0.001 0.06625 0.06625 0.06625 0.0695 0.105

ANALYSIS: BASIN 5 SECCHI VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.845 0.6360704 0.802 0.3879412 0.001 0.8425 0.845 0.875 0.98 1.125

ANALYSIS: BASIN 8 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.11 0.2456573 0.4359302 0.2727407 0.001 0.0625 0.0725 0.11 0.11 0.1325

ANALYSIS: BASIN 8 SECCHI VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 2.6625 0.2280959 0.4031731 0.2164615 0.003 0.7925 0.885 1.8575 2.6625 2.990125

ANALYSIS: BASIN 8 CHL-A SPEC VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0775 0.3410291 5.946591 11.60213 0.001 0.0675 0.0675 0.0775 0.0775 0.09

ANALYSIS: BASIN 8 CHL-A SPEC VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.0525 0.1293166 7.1625 10.51184 0.052 0.865 1.0525 1.1675 1.205 1.545

ANALYSIS: BASIN 8 CHL-A FLUORO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.13 0.2599901 6.498571 12.51688 0.137 0.075 0.075 0.105 0.13 0.1675

ANALYSIS: BASIN 8 CHL-A FLUORO VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.99 0.1462491 9.012 10.78278 0.528 0.88 0.99 1.0825 1.1575 1.61

ANALYSIS: BASIN 10 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.1575 0.1856648 0.6077143 0.379486 0.001 0.145 0.1575 0.2525 0.5525 1.62525

ANALYSIS: BASIN 10 CHL-A FLUORO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.9525 0.0772466 5.663 6.085556 0.714 0.46 0.81 0.9575 0.9975 1.077625

ANALYSIS: BASIN 10 CHL-A FLUORO VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 4.54 0.3038746 4.163 6.918889 0.089 2.71675 4.08 5.19 5.275 5.65

ANALYSIS: BASIN 11 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.1625 0.3010449 0.3466667 0.255 0.088 0.115 0.1625 0.1625 0.200625 0.3175

ANALYSIS: BASIN 12 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0625 0.230587 0.8371875 0.4637179 0.001 0.0625 0.0625 0.0625 0.0685 0.0975

ANALYSIS: BASIN 12 SECCHI VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.3275 0.04487002 0.6986029 0.5427193 0.361 0.685 0.82 1.19 1.3375 7.015

ANALYSIS: BASIN 12 CHL-A SPEC VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.1225 0.3037886 7.426216 15.63063 0.001 0.1 0.115 0.1225 0.135 0.48525

ANALYSIS: BASIN 12 CHL-A SPEC VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 2.96 0.09094477 10.74905 15.38889 0.264 1.1475 1.36 2.7925 3.42 4.19

ANALYSIS: BASIN 12 CHL-A FLUORO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.1075 0.1355851 6.713981 16.1216 0.008 0.075 0.07875 0.10125 0.1075 0.115

ANALYSIS: BASIN 12 CHL-A FLUORO VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.1475 0.04808694 6.795455 13.46611 0.421 1.118625 1.19 1.485 3.434375 6.08

ANALYSIS: BASIN 14 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0775 0.1224957 0.6449275 0.3788889 0.002 0.063 0.063 0.065 0.0775 0.0925

ANALYSIS: BASIN 14 SECCHI VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.51 0.1261249 0.6870588 0.4504 0.042 0.433 0.51 0.6075 0.9930188 1.455

ANALYSIS: BASIN 14 CHL-A SPEC VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.063 0.1811514 6.8475 15.72214 0.012 0.063 0.063 0.063 0.065 0.08

ANALYSIS: BASIN 14 CHL-A SPEC VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.1705 0.1512417 6.413846 14.26333 0.04 0.66 1.0684 1.1555 1.4465 1.510225

ANALYSIS: BASIN 14 CHL-A FLUORO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.065 0.1359142 5.924143 16.84568 0.074 0.065 0.065 0.065 0.065 0.22

ANALYSIS: BASIN 14 CHL-A FLUORO VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

```
[1,] 1.2805 0.1656096  5.656944   17.82381 0.041 0.9325 1.1555 1.2805 1.4465 1.9575
```

ANALYSIS: BASIN 18 SECCHI VS. TP (nCPA)

```
      cp       r2 mean left mean right pperm    5%   25%  50%  75%    95%
[1,] 0.06 0.1061268  1.155952      0.605 0.039 0.055 0.055 0.06 0.06 0.0625
```

ANALYSIS: BASIN 18 SECCHI VS. TN (nCPA)

```
       cp       r2 mean left mean right pperm     5%    25%   50%   75%   95%
[1,] 0.6775 0.2011654     0.725    1.206364 0.299 0.6225 0.6775 0.885 1.205 1.645
```

ANALYSIS: BASIN 18 CHL-A SPEC VS. TP (nCPA)

```
        cp       r2 mean left mean right pperm    5%   25%    50%    75%    95%
[1,] 0.0575 0.2258987  1.775735     4.9886 0.006 0.055 0.055 0.0575 0.0575 0.0575
```

ANALYSIS: BASIN 19 SECCHI VS. TP (nCPA)

```
      cp       r2 mean left mean right pperm    5%    25%    50%    75%     95%
[1,] 0.16 0.4806374 0.9786364  0.4243056 0.001 0.086 0.1525 0.1735 0.4435 0.58075
```

ANALYSIS: BASIN 19 SECCHI VS. TN (nCPA)

```
        cp       r2 mean left mean right pperm   5%    25%    50%     75%   95%
[1,] 4.8545 0.3959505 0.8628409  0.3284091 0.001 2.15 4.6155 4.8545 6.97725 7.032
```

ANALYSIS: BASIN 19 CHL-A SPEC VS. TP (nCPA)

```
         cp        r2 mean left mean right pperm    5%  25%     50%   75%      95%
[1,] 0.33475 0.05853348  3.826923   5.445833 0.476 0.055 0.16 0.33475 0.689 0.9191875
```

ANALYSIS: BASIN 19 CHL-A SPEC VS. TN (nCPA)

```
        cp        r2 mean left mean right pperm      5%     25%   50%    75%     95%
[1,] 1.22525 0.06635683  6.714286      4.225 0.562 1.21775 1.22525 1.477 4.8545 8.06125
```

ANALYSIS: BASIN 21 SECCHI VS. TP (nCPA)

```
      cp       r2 mean left mean right pperm     5%   25%   50%    75%      95%
[1,] 0.065 0.5547448 0.9944118   0.256875 0.001 0.0575 0.065 0.065 0.0725 0.075725
```

ANALYSIS: BASIN 21 SECCHI VS. TN (nCPA)

```
     cp       r2 mean left mean right pperm    5% 25%  50%   75%     95%
```

[1,] 0.9 0.3131387 1.333333 0.7622727 0.098 0.875 0.9 0.91 1.025 3.82075

ANALYSIS: BASIN 21 CHL-A SPEC VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.13375 0.1791213 8.60775 12.62688 0.115 0.065 0.11625 0.13325 0.1345 0.149

ANALYSIS: BASIN 21 CHL-A FLUORO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.13675 0.1871788 5.81 12.47214 0.073 0.065 0.0725 0.11625 0.1375 0.13925

ANALYSIS: BASIN 23 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0855 0.625399 0.9442045 0.2825577 0.001 0.08 0.085 0.0855 0.0855 0.095

ANALYSIS: BASIN 23 SECCHI VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.9575 0.2648812 0.7145438 0.20136 0.006 1.101375 1.935 1.9575 1.9575 2.165

ANALYSIS: BASIN 23 CHL-A SPEC VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.13 0.1790371 8.457059 14.89833 0.047 0.12825 0.13 0.13 0.27 0.4648625

ANALYSIS: BASIN 23 CHL-A SPEC VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.66 0.2044292 9.32537 16.45406 0.032 1.6225 1.66 1.86 2.0575 2.83

ANALYSIS: BASIN 23 CHL-A FLUORO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.219 0.4004882 7.609444 23.17556 0.001 0.1365 0.1415 0.219 0.2775 0.329

ANALYSIS: BASIN 23 CHL-A FLUORO VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.66 0.4215044 7.592105 25.1625 0.003 1.1375 1.575 1.66 1.6625 1.9525

ANALYSIS: ECOREGION 24 SECCHI VS. NUTRIENTS (CART)

Call:

```
mvpart(form = SECCHI ~ TP + TN, data = eco24, xval = 10, method = "anova",
   minsplit = 10, minbucket = 5)
  n=23 (45 observations deleted due to missingness)

        CP nsplit rel error    xerror      xstd
1 0.7611816      0 1.0000000 1.0608564 0.3353207
2 0.0100000      1 0.2388184 0.3096006 0.1527208

Node number 1: 23 observations,    complexity param=0.7611816
  mean=0.416913, MSE=0.1586868
  left son=2 (15 obs) right son=3 (8 obs)
  Primary splits:
      TP < 0.075  to the right, improve=0.7611816, (0 missing)
      TN < 1.1375 to the right, improve=0.4371870, (1 missing)

Node number 2: 15 observations
  mean=0.1631, MSE=0.00303306

Node number 3: 8 observations
  mean=0.8928125, MSE=0.1032679
```

ANALYSIS: ECOREGION 24 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = eco24, xval = 10, method = "anova",
   minsplit = 10, minbucket = 5)
  n=24 (44 observations deleted due to missingness)

        CP nsplit rel error    xerror      xstd
1 0.3947153      0 1.0000000 1.1473898 0.4474880
2 0.0100000      1 0.6052847 0.9346593 0.2979159

Node number 1: 24 observations,    complexity param=0.3947153
  mean=12.84854, MSE=27.28434
  left son=2 (14 obs) right son=3 (10 obs)
  Primary splits:
      TP < 0.22525 to the left,  improve=0.3947153, (0 missing)
      TN < 1.485   to the left,  improve=0.3676996, (2 missing)

Node number 2: 14 observations
  mean=10.075, MSE=0.5345536

Node number 3: 10 observations
  mean=16.7315, MSE=38.88713
```

ANALYSIS: ECOREGION 24 CHL-A FLUORO VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLAFLUORO ~ TP + TN, data = eco24, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=17 (51 observations deleted due to missingness)

         CP nsplit rel error    xerror      xstd
1 0.4667682      0 1.0000000 1.1094818 0.5516312
2 0.0100000      1 0.5332318 0.9182995 0.3782107

Node number 1: 17 observations,    complexity param=0.4667682
  mean=18.04294, MSE=166.9571
  left son=2 (9 obs) right son=3 (8 obs)
  Primary splits:
      TN < 1.2925  to the left,  improve=0.4667682, (0 missing)
      TP < 0.22525 to the left,  improve=0.4435626, (0 missing)

Node number 2: 9 observations
  mean=9.72, MSE=29.22434

Node number 3: 8 observations
  mean=27.40625, MSE=156.3046
```

ANALYSIS: ECOREGION 26 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = eco26, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=21 (56 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
1 0.38701276      0 1.0000000 1.071619 0.3801608
2 0.09040008      1 0.6129872 1.407986 0.3381165

Node number 1: 21 observations,    complexity param=0.3870128
  mean=0.4335119, MSE=0.05954221
  left son=2 (11 obs) right son=3 (5 obs), 5 observations remain
  Primary splits:
      TN < 1.66  to the left,  improve=0.2381034, (5 missing)
      TP < 0.296 to the left,  improve=0.1301729, (0 missing)

Node number 2: 11 observations
  mean=0.3767045, MSE=0.02665008
```

```
Node number 3: 5 observations
  mean=0.671, MSE=0.094664
```

ANALYSIS: ECOREGION 26 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = eco26, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=30 (47 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
1 0.20766585      0 1.0000000 1.081905 0.5974947
2 0.03192525      1 0.7923341 1.044425 0.4941607

Node number 1: 30 observations,    complexity param=0.2076659
  mean=9.523333, MSE=54.0966
  left son=2 (18 obs) right son=3 (12 obs)
  Primary splits:
      TP < 0.105 to the left,  improve=0.20766590, (0 missing)
      TN < 1.06  to the left,  improve=0.01419802, (19 missing)

Node number 2: 18 observations
  mean=6.786667, MSE=18.85285

Node number 3: 12 observations
  mean=13.62833, MSE=78.87718
```

ANALYSIS: ECOREGION 27 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = eco27, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=44 (49 observations deleted due to missingness)

          CP nsplit rel error    xerror      xstd
1 0.33143766      0 1.0000000 1.0384508 0.3515805
2 0.02469119      2 0.3371247 0.8696963 0.2497699

Node number 1: 44 observations,    complexity param=0.3314377
  mean=0.4195625, MSE=0.05148295
  left son=2 (20 obs) right son=3 (24 obs)
  Primary splits:
      TP < 0.07625 to the right, improve=0.2306652, (0 missing)
      TN < 1.2725  to the right, improve=0.0355225, (16 missing)
```

```
Node number 2: 20 observations
  mean=0.3001875, MSE=0.007011918

Node number 3: 24 observations,    complexity param=0.3314377
  mean=0.5190417, MSE=0.06677071
  left son=6 (5 obs) right son=7 (5 obs), 14 observations remain
  Primary splits:
      TN < 1.3975  to the right, improve=0.03973823, (14 missing)
      TP < 0.063   to the right, improve=0.02375856, (0 missing)

Node number 6: 5 observations
  mean=0.3604, MSE=0.00452664

Node number 7: 5 observations
  mean=0.52, MSE=0.12016
```

ANALYSIS: ECOREGION 27 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = eco27, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=30 (63 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.5508118      0 1.0000000 1.079255 0.4401573
2 0.0100000      1 0.4491882 1.488811 0.5252077

Node number 1: 30 observations,    complexity param=0.5508118
  mean=18.00833, MSE=210.4572
  left son=2 (12 obs) right son=3 (8 obs), 10 observations remain
  Primary splits:
      TN < 1.550225 to the left,  improve=0.2895175, (10 missing)
      TP < 0.063    to the left,  improve=0.2200175, (0 missing)

Node number 2: 12 observations
  mean=10.96667, MSE=7.193889

Node number 3: 8 observations
  mean=30.48125, MSE=343.715
```

ANALYSIS: ECOREGION 27 CHL-A FLUORO VS. NUTRIENTS (CART)

Call:

```
mvpart(form = CHLAFLUORO ~ TP + TN, data = eco27, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=19 (74 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
1 0.45135361      0 1.0000000 1.138303 0.4250300
2 0.08020552      1 0.5486464 1.375581 0.4555635
3 0.01000000      2 0.4684409 1.119356 0.4127728

Node number 1: 19 observations,    complexity param=0.4513536
  mean=23.97474, MSE=377.9097
  left son=2 (13 obs) right son=3 (5 obs), 1 observation remains
  Primary splits:
      TN < 1.9075 to the left,  improve=0.3999205, (1 missing)
      TP < 0.085  to the left,  improve=0.2934117, (0 missing)

Node number 2: 13 observations,    complexity param=0.08020552
  mean=17.18077, MSE=127.6269
  left son=4 (6 obs) right son=5 (7 obs)
  Primary splits:
      TP < 0.065  to the left,  improve=0.3471046, (0 missing)
      TN < 1.28   to the left,  improve=0.1421002, (0 missing)

Node number 3: 5 observations
  mean=45.38, MSE=456.0576

Node number 4: 6 observations
  mean=9.991667, MSE=31.67315

Node number 5: 7 observations
  mean=23.34286, MSE=127.6017
```

ANALYSIS: ECOREGION 29 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = eco29, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=71 (202 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.2642669      0 1.0000000 1.029061 0.1287669
2 0.0814727      1 0.7357331 1.118747 0.1421193

Node number 1: 71 observations,    complexity param=0.2642669
```

```
 mean=0.5916901, MSE=0.1092655
 left son=2 (44 obs) right son=3 (14 obs), 13 observations remain
 Primary splits:
    TN < 2.0375 to the left,  improve=0.07034084, (13 missing)
    TP < 0.7825 to the left,  improve=0.03244112, (0 missing)

Node number 2: 44 observations,    complexity param=0.0814727
 mean=0.5451136, MSE=0.1058392
 left son=4 (16 obs) right son=5 (28 obs)
 Primary splits:
    TP < 0.085  to the right, improve=0.13572320, (0 missing)
    TN < 1.0125 to the left,  improve=0.01749599, (0 missing)

Node number 3: 14 observations
 mean=0.7717857, MSE=0.07505574

Node number 4: 16 observations
 mean=0.3865625, MSE=0.05524287

Node number 5: 28 observations
 mean=0.6357143, MSE=0.1121781
```

ANALYSIS: ECOREGION 29 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = eco29, xval = 10, method = "anova",
   minsplit = 10, minbucket = 5)
 n=65 (208 observations deleted due to missingness)

          CP nsplit rel error    xerror      xstd
1 0.29770089      0 1.0000000 1.0199915 0.2369692
2 0.06309491      1 0.7022991 0.8235908 0.1539944

Node number 1: 65 observations,    complexity param=0.2977009
 mean=10.86077, MSE=48.11548
 left son=2 (36 obs) right son=3 (29 obs)
 Primary splits:
    TP < 0.0975 to the left,  improve=0.29770090, (0 missing)
    TN < 1.1175 to the left,  improve=0.04776663, (24 missing)

Node number 2: 36 observations
 mean=7.463889, MSE=19.28059

Node number 3: 29 observations
```

```
  mean=15.07759, MSE=51.80496
```

ANALYSIS: ECOREGION 29 CHL-A FLUORO VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLAFLUORO ~ TP + TN, data = eco29, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=57 (216 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.1678818      0 1.0000000 1.035261 0.3214871
2 0.1143937      1 0.8321182 1.109826 0.3227272

Node number 1: 57 observations,    complexity param=0.1678818
  mean=9.891579, MSE=64.71069
  left son=2 (32 obs) right son=3 (25 obs)
  Primary splits:
      TP < 0.085  to the left,  improve=0.16788180, (0 missing)
      TN < 3.0225 to the right, improve=0.02284792, (12 missing)

Node number 2: 32 observations
  mean=6.978281, MSE=25.55478

Node number 3: 25 observations
  mean=13.6206, MSE=90.06091
```

ANALYSIS: ECOREGION 30 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = eco30, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=66 (174 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.3914883      0 1.0000000 1.031871 0.1433141
2 0.0487354      1 0.6085117 1.016841 0.1402582

Node number 1: 66 observations,    complexity param=0.3914883
  mean=0.9230303, MSE=0.169084
  left son=2 (5 obs) right son=3 (44 obs), 17 observations remain
  Primary splits:
      TN < 0.305  to the left,  improve=0.08619583, (17 missing)
      TP < 0.0575 to the right, improve=0.06600874, (0 missing)
```

```
Node number 2: 5 observations
  mean=0.436, MSE=0.044384

Node number 3: 44 observations,    complexity param=0.0487354
  mean=0.8988636, MSE=0.1492908
  left son=6 (32 obs) right son=7 (12 obs)
  Primary splits:
      TP < 0.0575 to the right, improve=0.08279524, (0 missing)
      TN < 1.1025 to the left,  improve=0.03323797, (0 missing)

Node number 6: 32 observations
  mean=0.8307813, MSE=0.154197

Node number 7: 12 observations
  mean=1.080417, MSE=0.09088524
```

ANALYSIS: ECOREGION 30 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = eco30, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=63 (177 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.2780115      0  1.000000 1.011098 0.1795941
2 0.1341879      2  0.443977 1.116541 0.2123039

Node number 1: 63 observations,    complexity param=0.2780115
  mean=5.923333, MSE=21.41722
  left son=2 (12 obs) right son=3 (51 obs)
  Primary splits:
      TP < 0.0445 to the left,  improve=0.2279005, (0 missing)
      TN < 1.0584 to the left,  improve=0.1298790, (19 missing)

Node number 2: 12 observations
  mean=1.36875, MSE=0.7243005

Node number 3: 51 observations,    complexity param=0.2780115
  mean=6.995, MSE=20.25668
  left son=6 (33 obs) right son=7 (10 obs), 8 observations remain
  Primary splits:
      TN < 1.0584 to the left,  improve=0.156413500, (8 missing)
      TP < 0.0575 to the right, improve=0.003060719, (0 missing)
```

```
Node number 6: 33 observations
  mean=6.901364, MSE=14.10397

Node number 7: 10 observations
  mean=11.49, MSE=12.4929
```

ANALYSIS: ECOREGION 30 CHL-A FLUORO VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLAFLUORO ~ TP + TN, data = eco30, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=42 (198 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.1413187      0 1.0000000 1.048681 0.9518277
2 0.0100000      1 0.8586813 1.265594 0.9520016

Node number 1: 42 observations,    complexity param=0.1413187
  mean=5.046548, MSE=45.93415
  left son=2 (35 obs) right son=3 (5 obs), 2 observations remain
  Primary splits:
      TN < 1.3475 to the left,  improve=0.1340006, (2 missing)
      TP < 0.0575 to the left,  improve=0.0284943, (0 missing)

Node number 2: 35 observations
  mean=4.213, MSE=2.826212

Node number 3: 5 observations
  mean=11.9, MSE=311.536
```

ANALYSIS: ECOREGION 31 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = eco31, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=40 (22 observations deleted due to missingness)

          CP nsplit rel error    xerror      xstd
1 0.45313653      0 1.0000000 1.0674949 0.1988789
2 0.05836505      1 0.5468635 0.7649928 0.1236454

Node number 1: 40 observations,    complexity param=0.4531365
  mean=0.629375, MSE=0.2117952
  left son=2 (19 obs) right son=3 (21 obs)
```

```
  Primary splits:
    TP < 0.083 to the right, improve=0.45313650, (0 missing)
    TN < 1.96  to the right, improve=0.03204728, (17 missing)

Node number 2: 19 observations
  mean=0.3036842, MSE=0.01726537

Node number 3: 21 observations
  mean=0.9240476, MSE=0.2049943
```

ANALYSIS: ECOREGION 31 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = eco31, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=40 (22 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
1 0.15191598      0  1.000000 1.036395 0.7190230
2 0.01528552      1  0.848084 1.164964 0.7458234

Node number 1: 40 observations,    complexity param=0.151916
  mean=9.579375, MSE=61.24792
  left son=2 (31 obs) right son=3 (9 obs)
  Primary splits:
    TP < 0.146 to the left,  improve=0.15191600, (0 missing)
    TN < 1.96  to the left,  improve=0.07005107, (19 missing)

Node number 2: 31 observations
  mean=7.935806, MSE=6.541836

Node number 3: 9 observations
  mean=15.24056, MSE=208.3265
```

ANALYSIS: ECOREGION 31 CHL-A FLUORO VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLAFLUORO ~ TP + TN, data = eco31, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=22 (40 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
1 0.17645304      0 1.0000000 1.106509 0.5313195
2 0.04759409      1 0.8235470 1.164112 0.5852655
```

```
3 0.01000000      2 0.7759529 1.166426 0.5568312

Node number 1: 22 observations,    complexity param=0.176453
  mean=6.696591, MSE=30.73964
  left son=2 (17 obs) right son=3 (5 obs)
  Primary splits:
      TP < 0.13075 to the left,  improve=0.17645300, (0 missing)
      TN < 2.0025  to the right, improve=0.02489235, (8 missing)

Node number 2: 17 observations,    complexity param=0.04759409
  mean=5.433529, MSE=19.37025
  left son=4 (6 obs) right son=5 (8 obs), 3 observations remain
  Primary splits:
      TN < 2.0025  to the right, improve=0.05112147, (3 missing)
      TP < 0.0775  to the left,  improve=0.01339907, (0 missing)

Node number 3: 5 observations
  mean=10.991, MSE=45.52952

Node number 4: 6 observations
  mean=3.871667, MSE=2.886481

Node number 5: 8 observations
  mean=6.0875, MSE=34.97359
```

ANALYSIS: ECOREGION 32 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = eco32, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=144 (329 observations deleted due to missingness)

         CP nsplit rel error    xerror      xstd
1 0.1743534      0 1.0000000 1.0105461 0.1378289
2 0.1013737      1 0.8256466 0.8587851 0.1117349

Node number 1: 144 observations,    complexity param=0.1743534
  mean=0.6377431, MSE=0.1584843
  left son=2 (130 obs) right son=3 (14 obs)
  Primary splits:
      TP < 0.055 to the right, improve=0.17435340, (0 missing)
      TN < 7.41  to the right, improve=0.02562916, (12 missing)

Node number 2: 130 observations
```

```
  mean=0.5831923, MSE=0.1254285

Node number 3: 14 observations
  mean=1.144286, MSE=0.1812138
```

ANALYSIS: ECOREGION 32 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = eco32, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=147 (326 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.1210510      0 1.0000000 1.016315 0.2069010
2 0.0925737      2 0.7578979 1.142383 0.2331455

Node number 1: 147 observations,    complexity param=0.121051
  mean=6.47517, MSE=21.09782
  left son=2 (80 obs) right son=3 (67 obs)
  Primary splits:
      TP < 0.079  to the left,  improve=0.08027650, (0 missing)
      TN < 6.314  to the left,  improve=0.03775448, (37 missing)

Node number 2: 80 observations
  mean=5.284187, MSE=11.09788

Node number 3: 67 observations,    complexity param=0.121051
  mean=7.897239, MSE=29.3221
  left son=6 (37 obs) right son=7 (14 obs), 16 observations remain
  Primary splits:
      TN < 1.617  to the right, improve=0.04629845, (16 missing)
      TP < 0.1275 to the right, improve=0.03035778, (0 missing)

Node number 6: 37 observations
  mean=7.021757, MSE=22.04854

Node number 7: 14 observations
  mean=10.01429, MSE=46.2073
```

ANALYSIS: ECOREGION 32 CHL-A FLUORO VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLAFLUORO ~ TP + TN, data = eco32, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
```

```
  n=51 (422 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.2079581      0 1.0000000 1.021939 0.3960178
2 0.1002236      2 0.5840838 1.044988 0.4063644

Node number 1: 51 observations,    complexity param=0.2079581
  mean=5.729804, MSE=22.46483
  left son=2 (29 obs) right son=3 (22 obs)
  Primary splits:
      TP < 0.1425 to the left,  improve=0.07188986, (0 missing)
      TN < 1.905  to the right, improve=0.04344759, (7 missing)

Node number 2: 29 observations
  mean=4.622931, MSE=8.328544

Node number 3: 22 observations,    complexity param=0.2079581
  mean=7.188864, MSE=37.35518
  left son=6 (15 obs) right son=7 (5 obs), 2 observations remain
  Primary splits:
      TN < 2.515  to the right, improve=0.22093690, (2 missing)
      TP < 0.2425 to the right, improve=0.02057303, (0 missing)

Node number 6: 15 observations
  mean=4.861667, MSE=7.919522

Node number 7: 5 observations
  mean=11.82, MSE=61.7736
```

ANALYSIS: ECOREGION 33 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = eco33, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=55 (162 observations deleted due to missingness)

         CP nsplit rel error    xerror      xstd
1 0.3502560      0  1.000000 1.0239799 0.2688661
2 0.1315228      1  0.649744 0.8670922 0.2061333

Node number 1: 55 observations,    complexity param=0.350256
  mean=0.3467091, MSE=0.02780337
  left son=2 (26 obs) right son=3 (28 obs), 1 observation remains
  Primary splits:
```

```
    TP < 0.432 to the right, improve=0.3155435, (1 missing)
    TN < 3.21  to the right, improve=0.2884675, (3 missing)

Node number 2: 26 observations
  mean=0.2443846, MSE=0.01224562

Node number 3: 28 observations
  mean=0.4335714, MSE=0.02411403
```

ANALYSIS: ECOREGION 33 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = eco33, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=46 (171 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.3256834      0 1.0000000 1.041294 0.3096788
2 0.1092797      1 0.6743166 1.267793 0.2840973

Node number 1: 46 observations,    complexity param=0.3256834
  mean=7.057391, MSE=24.55231
  left son=2 (5 obs) right son=3 (31 obs), 10 observations remain
  Primary splits:
      TN < 9.219  to the right, improve=0.11459740, (10 missing)
      TP < 0.0925 to the left,  improve=0.08692756, (0 missing)

Node number 2: 5 observations
  mean=3.1, MSE=0.64

Node number 3: 31 observations
  mean=8.582742, MSE=24.46379
```

ANALYSIS: ECOREGION 33 CHL-A FLUORO VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLAFLUORO ~ TP + TN, data = eco33, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=31 (186 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.1591046      0 1.0000000 1.060347 0.6632163
2 0.0100000      2 0.6817908 1.142730 0.5030256
```

```
Node number 1: 31 observations,    complexity param=0.1591046
  mean=9.253871, MSE=242.8667
  left son=2 (17 obs) right son=3 (14 obs)
  Primary splits:
      TP < 0.2025  to the right, improve=0.11170940, (0 missing)
      TN < 1.655   to the right, improve=0.09123036, (1 missing)

Node number 2: 17 observations
  mean=4.527059, MSE=5.632894

Node number 3: 14 observations,    complexity param=0.1591046
  mean=14.99357, MSE=470.8618
  left son=6 (6 obs) right son=7 (7 obs), 1 observation remains
  Primary splits:
      TN < 1.025   to the left,  improve=0.2127364, (1 missing)
      TP < 0.07875 to the left,  improve=0.1151856, (0 missing)

Node number 6: 6 observations
  mean=4.69, MSE=1.833667

Node number 7: 7 observations
  mean=25.52429, MSE=718.0503
```

ANALYSIS: ECOREGION 34 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = eco34, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=182 (152 observations deleted due to missingness)

         CP nsplit rel error    xerror      xstd
1 0.1785812      0 1.0000000 1.0087684 0.1749064
2 0.0226988      1 0.8214188 0.8510849 0.1348945

Node number 1: 182 observations,    complexity param=0.1785812
  mean=0.3827198, MSE=0.04787845
  left son=2 (138 obs) right son=3 (44 obs)
  Primary splits:
      TP < 0.15725 to the right, improve=0.17858120, (0 missing)
      TN < 0.905   to the right, improve=0.02852608, (133 missing)

Node number 2: 138 observations
  mean=0.3305072, MSE=0.02740771
```

```
Node number 3: 44 observations
  mean=0.5464773, MSE=0.07671543
```

ANALYSIS: ECOREGION 34 CHL-A SPEC VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLASPEC ~ TP + TN, data = eco34, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=62 (272 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
1 0.39730254      0 1.0000000 1.031476 0.3174639
2 0.04940234      1 0.6026975 1.353507 0.2979539

Node number 1: 62 observations,    complexity param=0.3973025
  mean=9.402473, MSE=28.82314
  left son=2 (21 obs) right son=3 (24 obs), 17 observations remain
  Primary splits:
      TN < 1.62475 to the left,  improve=0.11310600, (17 missing)
      TP < 0.229   to the left,  improve=0.09077145, (0 missing)

Node number 2: 21 observations
  mean=8.323095, MSE=10.83531

Node number 3: 24 observations
  mean=12.57125, MSE=35.39582
```

ANALYSIS: ECOREGION 34 CHL-A FLUORO VS. NUTRIENTS (CART)

```
Call:
mvpart(form = CHLAFLUORO ~ TP + TN, data = eco34, xval = 10,
    method = "anova", minsplit = 10, minbucket = 5)
  n=48 (286 observations deleted due to missingness)

         CP nsplit rel error   xerror      xstd
1 0.1961851      0 1.0000000 1.031428 0.5485602
2 0.0154126      2 0.6076299 1.551279 0.5838840

Node number 1: 48 observations,    complexity param=0.1961851
  mean=12.13786, MSE=335.1708
  left son=2 (14 obs) right son=3 (28 obs), 6 observations remain
  Primary splits:
      TN < 1.4825    to the left,  improve=0.05486265, (6 missing)
      TP < 0.1877875 to the right, improve=0.05381299, (0 missing)
```

```
Node number 2: 14 observations
  mean=6.056607, MSE=25.5858

Node number 3: 28 observations,    complexity param=0.1961851
  mean=15.78125, MSE=514.4261
  left son=6 (23 obs) right son=7 (5 obs)
  Primary splits:
      TP < 0.2425    to the right, improve=0.34618760, (0 missing)
      TN < 2.42      to the right, improve=0.06410243, (0 missing)

Node number 6: 23 observations
  mean=9.55913, MSE=80.52708

Node number 7: 5 observations
  mean=44.403, MSE=1513.069
```

ANALYSIS: ECOREGION 35 SECCHI VS. NUTRIENTS (CART)

```
Call:
mvpart(form = SECCHI ~ TP + TN, data = eco35, xval = 10, method = "anova",
    minsplit = 10, minbucket = 5)
  n=165 (134 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
1 0.67476642      0 1.0000000 1.014528 0.1643377
2 0.03303391      1 0.3252336 1.368468 0.1446861

Node number 1: 165 observations,    complexity param=0.6747664
  mean=0.4752242, MSE=0.03689249
  left son=2 (48 obs) right son=3 (26 obs), 91 observations remain
  Primary splits:
      TN < 0.84135 to the right, improve=0.1290101, (91 missing)
      TP < 0.0883  to the right, improve=0.1000866, (0 missing)

Node number 2: 48 observations
  mean=0.4119792, MSE=0.01312265

Node number 3: 26 observations
  mean=0.6277692, MSE=0.05191902
```

ANALYSIS: ECOREGION 35 CHL-A SPEC VS. NUTRIENTS (CART)

Call:

```
mvpart(form = CHLASPEC ~ TP + TN, data = eco35, xval = 10, method = "anova",
   minsplit = 10, minbucket = 5)
  n=80 (219 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
1 0.59175159      0 1.0000000 1.026377 0.2512250
2 0.05610089      1 0.4082484 2.049993 0.2998737

Node number 1: 80 observations,    complexity param=0.5917516
  mean=8.092813, MSE=15.38897
  left son=2 (41 obs) right son=3 (6 obs), 33 observations remain
  Primary splits:
      TN < 1.1975  to the left,  improve=0.08650466, (33 missing)
      TP < 0.155   to the right, improve=0.07985160, (0 missing)

Node number 2: 41 observations,    complexity param=0.05610089
  mean=8.697561, MSE=8.520238
  left son=4 (27 obs) right son=5 (14 obs)
  Primary splits:
      TP < 0.109   to the left,  improve=0.19771230, (0 missing)
      TN < 0.71375 to the left,  improve=0.06327917, (0 missing)

Node number 3: 6 observations
  mean=13.20833, MSE=25.54535

Node number 4: 27 observations
  mean=7.762963, MSE=10.00548

Node number 5: 14 observations
  mean=10.5, MSE=0.7225
```

ANALYSIS: ECOREGION 35 CHL-A FLUORO VS. NUTRIENTS (CART)

```
mvpart(form = CHLAFLUORO ~ TP + TN, data = eco35, xval = 10,
   method = "anova", minsplit = 10, minbucket = 5)
  n=36 (263 observations deleted due to missingness)

          CP nsplit rel error   xerror      xstd
1 0.13577267      0 1.0000000 1.078028 0.3535640
2 0.09029813      2 0.7284547 1.205844 0.3464198

Node number 1: 36 observations,    complexity param=0.1357727
  mean=9.642917, MSE=106.6701
  left son=2 (9 obs) right son=3 (25 obs), 2 observations remain
```

Primary splits:
TN < 0.785 to the left, improve=0.10302660, (2 missing)
TP < 0.17 to the right, improve=0.08249574, (0 missing)

Node number 2: 9 observations
mean=4.348333, MSE=6.804822

Node number 3: 25 observations, complexity param=0.1357727
mean=12.0804, MSE=131.5919
left son=6 (6 obs) right son=7 (19 obs)
Primary splits:
TP < 0.17 to the right, improve=0.16830350, (0 missing)
TN < 0.865 to the right, improve=0.07264298, (0 missing)

Node number 6: 6 observations
mean=3.705833, MSE=1.066487

Node number 7: 19 observations
mean=14.725, MSE=143.6692

ANALYSIS: ECOREGION 24 SECCHI VS. TP (nCPA)

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	0.075	0.7611816	0.8928125	0.1631	0.001	0.075	0.075	0.075	0.08	0.1

ANALYSIS: ECOREGION 24 SECCHI VS. TP (nCPA)

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	1.1375	0.455732	0.7903125	0.2304643	0.004	1.0225	1.1075	1.1375	1.21	1.525

ANALYSIS: ECOREGION 24 CHL-A SPEC VS. TP (nCPA)

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	0.22525	0.3947153	10.075	16.7315	0.005	0.17	0.2115	0.22525	0.329	0.595

ANALYSIS: ECOREGION 24 CHL-A SPEC VS. TN (nCPA)

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	1.485	0.3779168	10.0875	16.7315	0.015	1.3	1.4775	1.485	1.525	2.86

ANALYSIS: ECOREGION 24 CHL-A FLUORO VS. TP (nCPA)

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	0.22525	0.4435626	10.843	28.32857	0.007	0.09	0.1415	0.183	0.22525	0.329

ANALYSIS: ECOREGION 24 CHL-A FLUORO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.2925 0.4667682 9.72 27.40625 0.007 1.1075 1.2 1.2925 1.4775 1.71

ANALYSIS: ECOREGION 26 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.13 0.06749478 0.3984821 0.5035714 0.562 0.06333335 0.075 0.1 0.19275 0.296

ANALYSIS: ECOREGION 26 SECCHI VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.295 0.1104316 0.3959722 0.5621429 0.34 0.53 0.72 1.255 1.46 1.67

ANALYSIS: ECOREGION 26 CHL-A SPEC VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.105 0.2076659 6.786667 13.62833 0.069 0.075 0.1033333 0.105 0.125 0.206

ANALYSIS: ECOREGION 26 CHL-A FLUORO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.08 0.3750552 7.944 25.34833 0.04 0.07 0.08 0.08 0.12 0.31

ANALYSIS: ECOREGION 26 CHL-A FLUORO VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.255 0.4156266 7.944 25.34833 0.033 0.53 0.62 1.255 1.46 4.19

ANALYSIS: ECOREGION 27 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.06625 0.2751341 0.5315 0.3262813 0.001 0.06 0.065 0.075 0.07625 0.105

ANALYSIS: ECOREGION 27 SECCHI VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.2 0.1304657 0.445 0.3143523 0.318 1.0275 1.09 1.28 1.4625 1.9075

ANALYSIS: ECOREGION 27 CHL-A SPEC VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.063 0.2200175 8.385 22.82 0.054 0.063 0.063 0.1225 0.13025 0.2075

ANALYSIS: ECOREGION 27 CHL-A SPEC VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.550225 0.3919254 10.96667 30.48125 0.018 1.43 1.53 1.550225 1.66 1.8125

ANALYSIS: ECOREGION 27 CHL-A FLUORO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.085 0.2934117 13.985 35.07444 0.094 0.065 0.06875 0.085 0.085 0.205

ANALYSIS: ECOREGION 27 CHL-A FLUORO VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.45 0.1849256 17.97083 39.1 0.131 1.17 1.315 1.41875 1.7075 1.9075

ANALYSIS: ECOREGION 29 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0685 0.02901136 0.6556452 0.542125 0.635 0.0575 0.0685 0.09 0.215 0.865

ANALYSIS: ECOREGION 29 SECCHI VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 2.0375 0.08726351 0.5451136 0.7717857 0.249 0.865 1.1775 1.69 2.0375 3.0225

ANALYSIS: ECOREGION 29 CHL-A SPEC VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0975 0.2977009 7.463889 15.07759 0.001 0.075 0.0975 0.14125 0.17625 0.48525

ANALYSIS: ECOREGION 29 CHL-A SPEC VS. Tn (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.1175 0.1424151 8.903611 12.75 0.114 1.0875 1.1175 1.1175 1.635 3.235

ANALYSIS: ECOREGION 29 CHL-A FLUORO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.085 0.1678818 6.978281 13.6206 0.017 0.0735 0.085 0.085 0.095 0.1

ANALYSIS: ECOREGION 29 CHL-A FLUORO VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 3.0225 0.03333452 10.11513 6.339286 0.884 0.865 1.1475 1.4325 1.98875 3.0225

ANALYSIS: ECOREGION 30 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0575 0.06600874 1.08325 0.8533696 0.071 0.0525 0.055 0.0575 0.0575 0.0775

ANALYSIS: ECOREGION 30 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.3 0.1284829 0.436 0.8988636 0.083 0.283525 0.31 0.368175 0.535 1.1025

ANALYSIS: ECOREGION 30 CHL-A SPEC VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0445 0.2279005 1.36875 6.995 0.002 0.03725 0.04425 0.0445 0.0445 0.055

ANALYSIS: ECOREGION 30 CHL-A SPEC VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.0584 0.2192176 6.727794 11.49 0.01 0.305 0.448 0.966525 1.0584 1.2025

ANALYSIS: ECOREGION 30 CHL-A FLUORO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.06 0.0284943 3.972179 19.01333 0.005 0.0575 0.0575 0.06 0.06 0.06

ANALYSIS: ECOREGION 30 CHL-A FLUORO VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.11 0.1034365 4.115147 11.17333 0.221 0.5975 0.74 1.095 1.23 1.575

ANALYSIS: ECOREGION 31 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.083 0.4531365 0.9240476 0.3036842 0.001 0.0575 0.065 0.0775 0.083 0.0885

ANALYSIS: ECOREGION 31 SECCHI VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.385 0.07855985 0.8254545 0.8670833 0.631 0.9 0.974 1.56 2.266 5.93

ANALYSIS: ECOREGION 31 CHL-A SPEC VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.146 0.151916 7.935806 15.24056 0.111 0.065 0.13825 0.146 0.146 0.16575

ANALYSIS: ECOREGION 31 CHL-A FLUORO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.103 0.1713739 5.128667 10.05643 0.152 0.065 0.0775 0.09825 0.106 0.135

ANALYSIS: ECOREGION 32 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.055 0.1743534 1.144286 0.5831923 0.001 0.055 0.055 0.055 0.064 0.146

ANALYSIS: ECOREGION 32 SECCHI VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 7.41 0.02877105 0.6460924 0.4226923 0.505 0.76975 1.617 3.0405 6.4975 7.435

ANALYSIS: ECOREGION 32 CHL-A SPEC VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.079 0.0802765 5.284187 7.897239 0.005 0.0725 0.079 0.079 0.70575 0.8535

ANALYSIS: ECOREGION 32 CHL-A SPEC VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 6.314 0.05079115 6.475161 9.329412 0.232 0.8295 1.625 5.4275 6.314 7.7625

ANALYSIS: ECOREGION 32 CHL-A FLUORO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.1425 0.07188986 4.622931 7.188864 0.273 0.055 0.135 0.1425 0.35 0.85

ANALYSIS: ECOREGION 32 CHL-A FLUORO VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.905 0.06144612 6.492955 4.365682 0.501 0.83 1.725 1.905 1.925 7.615

ANALYSIS: ECOREGION 33 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.432 0.3268907 0.4335714 0.2443846 0.002 0.09125 0.1325 0.422 0.432 0.5225

ANALYSIS: ECOREGION 33 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 3.21 0.3457772 0.4287037 0.24436 0.001 2.895 3.21 3.21 3.56 4.714513

ANALYSIS: ECOREGION 33 CHL-A SPEC VS. TP (nCPA)

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	0.0925	0.08692756	4.2855	7.827361	0.302	0.075	0.0925	0.095	0.295	0.90525

ANALYSIS: ECOREGION 33 CHL-A SPEC VS. TN (nCPA)

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	1.692	0.1335615	10.3925	6.535625	0.16	0.6175	1.687	1.766	7.03425	9.219

ANALYSIS: ECOREGION 33 CHL-A FLUORO VS. TP (nCPA)

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	0.2025	0.1117094	14.99357	4.527059	0.288	0.085	0.17875	0.2025	0.205	0.2575

ANALYSIS: ECOREGION 33 CHL-A FLUORO VS. TN (nCPA)

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	1.655	0.09170702	14.57429	4.983125	0.415	1.17	1.4325	1.655	1.655	1.93

ANALYSIS: ECOREGION 34 SECCHI VS. TP (nCPA)

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	0.15725	0.1785812	0.5464773	0.3305072	0.001	0.0948	0.13425	0.15725	0.1585	0.2375

ANALYSIS: ECOREGION 34 SECCHI VS. TN (nCPA)

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	0.905	0.2952522	0.527	0.2917045	0.006	0.905	0.905	1.22	1.375	2.56

ANALYSIS: ECOREGION 34 CHL-A SPEC VS. TP (nCPA)

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	0.229	0.09077145	7.560864	10.82314	0.175	0.09	0.13485	0.2117383	0.234	0.73825

ANALYSIS: ECOREGION 34 CHL-A SPEC VS. TN (nCPA)

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	1.62475	0.1580127	8.323095	12.57125	0.08	1.31615	1.62475	1.62475	2.0875	4.815

ANALYSIS: ECOREGION 34 CHL-A FLUORO VS. TP (nCPA)

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	0.1877875	0.05381299	18.75625	9.412647	0.607	0.096	0.13105	0.1877875	0.22125	0.71

ANALYSIS: ECOREGION 34 CHL-A FLUORO VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.4825 0.05641763 6.056607 15.78125 0.585 1.35 1.4825 1.502008 1.9475 5.623

ANALYSIS: ECOREGION 35 SECCHI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0883 0.1000866 0.5577586 0.430486 0.003 0.06175 0.0679 0.0785 0.0883 1.38

ANALYSIS: ECOREGION 35 SECCHI VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.84135 0.2840108 0.6277692 0.4119792 0.001 0.785 0.83635 0.84135 0.85135 0.9275

ANALYSIS: ECOREGION 35 CHL-A SPEC VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.105 0.09808587 7.406452 8.527041 0.09 0.055 0.055 0.105 0.15 0.155

ANALYSIS: ECOREGION 35 CHL-A SPEC VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.1725 0.1686401 8.665 12.75 0.026 0.7006 0.815 1.116 1.1725 1.2

ANALYSIS: ECOREGION 35 CHL-A FLUORO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.17 0.08249574 11.10034 3.605 0.359 0.0625 0.0625 0.1125 0.165 0.17

ANALYSIS: ECOREGION 35 CHL-A FLUORO VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.785 0.1055963 4.348333 12.0804 0.332 0.765 0.785 0.8175 1.036875 1.2175

Community metrics bioassessment

ANALYSIS: ALL STREAMS HBI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.085 0.06543681 4.629856 5.159327 0.058 0.0575 0.085 0.085 0.1995 0.421375

ANALYSIS: ALL STREAMS HBI VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.02 0.07079689 4.373149 4.989834 0.108 0.891375 1.015 1.02 2.81575 4.46

ANALYSIS: PERENNIAL STREAMS HBI VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.085 0.05419231 4.623289 5.109603 0.162 0.055 0.085 0.085 0.3265 0.945

ANALYSIS: PERENNIAL STREAMS HBI VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.926525 0.07558843 4.25603 4.980769 0.163 0.7996063 0.926525 1.015 3.915 4.46

ANALYSIS: ALL STREAMS INTOLERANT:TOLERANT RATIO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.6955 0.009163939 3.326566 1.714435 0.931 0.068 0.085 0.19375 0.563 0.7005

ANALYSIS: ALL STREAMS INTOLERANT:TOLERANT RATIO VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 3.915 0.03020513 4.158343 1.177101 0.53 1.1125 1.1325 2.0425 3.888 4.46

ANALYSIS: PERENNIAL STREAMS INTOLERANT:TOLERANT RATIO VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.6955 0.01179409 3.705354 1.776602 0.882 0.0718 0.085 0.19375 0.563 0.7005

ANALYSIS: PERENNIAL STREAMS INTOLERANT:TOLERANT RATIO VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 3.915 0.0383371 4.731237 1.166947 0.491 1.1125 1.1875 2.69475 3.915 4.46

ANALYSIS: ALL STREAMS RICHNESS VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.267 0.0863436 18.44944 17.29464 0.125 0.045 0.05 0.08 0.267 0.5145

ANALYSIS: ALL STREAMS RICHNESS VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.02 0.1372204 21.4375 16.62981 0.019 0.77025 1.015 1.02 1.153 1.915

ANALYSIS: PERENNIAL STREAMS RICHNESS VS. TP (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.267 0.08712968 18.7 16.875 0.213 0.045 0.055 0.0875 0.267 0.5145

ANALYSIS: PERENNIAL STREAMS RICHNESS VS. TN (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.015 0.1602666 22.0625 16.4375 0.021 0.77025 0.974025 1.015 1.045 2.1275

ANALYSIS: ALL STREAMS HBI VS. HQI (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 21.375 0.1990973 5.164563 4.312759 0.001 19.625 19.625 20.75 21.375 21.625

ANALYSIS: ALL STREAMS HBI VS. CHL-A SPEC (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 9.225 0.2358327 4.306114 5.38578 0.001 5.5 7.16 9.225 9.4 11

ANALYSIS: ALL STREAMS HBI VS. CHL-A FLUORO (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 5.08 0.1236133 4.617721 5.481083 0.029 5.08 5.08 5.3475 7.445625 14.52587

ANALYSIS: ALL STREAMS INTOLERANT: TOLERANT RATIO vs. HQI (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 23.625 0.1759433 2.264129 9.95239 0.006 20.75 23.375 23.625 24 25

ANALYSIS: ALL STREAMS INTOLERANT: TOLERANT RATIO vs. CHL-A SPEC (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 5.05 0.1456012 5.986165 1.790934 0.011 1.5 4.335 5.05 5.55 10.3

ANALYSIS: ALL STREAMS INTOLERANT: TOLERANT RATIO vs. CHL-A FLUORO (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 3.1775 0.007753474 3.401912 2.337076 0.98 3.125 3.2025 7.005 13.95 21

ANALYSIS: ALL STREAMS RICHNESS vs. HQI (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 18.125 0.1208372 16.00962 20.04348 0.004 16.74375 18.125 18.125 19.25 21.875

ANALYSIS ALL STREAMS RICHNESS vs. CHL-A SPEC (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 10.5 0.1521682 17.76818 10.5625 0.012 1.165 1.5 10.35 10.5 11.15

ANALYSIS ALL STREAMS RICHNESS vs. CHL-A FLUORO (nCPA)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 7.0175 0.1318039 19.65625 15.06944 0.014 5.08 5.4275 7.0175 9.885 18.8325

ANALYSIS: ALL STREAMS HBI VS. TP (REGRESSION)

Data Source: Data 1 in Bio_HBI_TP_All.JNB
Equation: Logarithm, 2 Parameter I
f = if(x>0, y0+a*ln(abs(x)), 0)

R	Rsqr	Adj Rsqr	Standard Error of Estimate
0.1851	0.0342	0.0270	1.0245

	Coefficient	Std. Error	t	P
y0	5.2300	0.1756	29.7759	<0.0001
a	0.1619	0.0743	2.1798	0.0310

Analysis of Variance:

	DF	SS	MS
Regression	2	3268.3276	1634.1638
Residual	134	140.6421	1.0496
Total	136	3408.9698	25.0660

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	4.9870	4.9870	4.7515	0.0310
Residual	134	140.6421	1.0496		
Total	135	145.6291	1.0787		

Statistical Tests:

Normality Test (Shapiro-Wilk) Passed (P = 0.5654)
W Statistic= 0.9913 Significance Level = 0.0500

Constant Variance Test Passed (P = 0.2591)

Fit Equation Description:
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_x = 1/abs(x)
reciprocal_xsquare = 1/x^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
weight_Cauchy = 1/(1+4*(y-f)^2)
'Automatic Initial Parameter Estimate Functions
F(q) = ape(ln(abs(x)),y,1,0,1)
[Parameters]
y0 = F(0)[1] "Auto {{previous: 5.23003}}
a = F(0)[2] "Auto {{previous: 0.161942}}
[Equation]
f = if(x>0, y0+a*ln(abs(x)), 0)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_x
"fit f to y with weight reciprocal_xsquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
"fit f to y with weight weight_Cauchy
[Constraints]
[Options]
tolerance=1e-10
stepsize=1
iterations=200

Number of Iterations Performed = 1

ANALYSIS: ALL STREAMS HBI VS. TN (REGRESSION)

Data Source: Data 1 in Bio_HBI_TN_All.JNB
Equation: Logarithm, 2 Parameter I
f = if(x>0, y0+a*ln(abs(x)), 0)

R	Rsqr	Adj Rsqr	Standard Error of Estimate
0.1419	0.0201	0.0094	1.0528

	Coefficient	Std. Error	t	P

y0	4.7245	0.1261	37.4720	<0.0001
a	0.1572	0.1149	1.3677	0.1748

Analysis of Variance:

	DF	SS	MS
Regression	2	2154.4428	1077.2214
Residual	91	100.8560	1.1083
Total	93	2255.2988	24.2505

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	2.0731	2.0731	1.8705	0.1748
Residual	91	100.8560	1.1083		
Total	92	102.9290	1.1188		

Statistical Tests:

Normality Test (Shapiro-Wilk) Passed (P = 0.8904)
W Statistic= 0.9926 Significance Level = 0.0500

Constant Variance Test Passed (P = 0.8101)

Fit Equation Description:

```
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_x = 1/abs(x)
reciprocal_xsquare = 1/x^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
weight_Cauchy = 1/(1+4*(y-f)^2)
'Automatic Initial Parameter Estimate Functions
F(q) = ape(ln(abs(x)),y,1,0,1)
[Parameters]
y0 = F(0)[1] "Auto {{previous: 4.72452}}
a = F(0)[2] "Auto {{previous: 0.157175}}
[Equation]
f = if(x>0, y0+a*ln(abs(x)), 0)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_x
"fit f to y with weight reciprocal_xsquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
"fit f to y with weight weight_Cauchy
[Constraints]
[Options]
tolerance=1e-10
```

stepsize=1
iterations=200

Number of Iterations Performed = 1

ANALYSIS: PERENNIAL STREAMS HBI VS. TP (REGRESSION)

Data Source: Data 1 in Bio_HBI_TP_Perennial.JNB
Equation: Logarithm, 2 Parameter I
f = if(x>0, y0+a*ln(abs(x)), 0)

R	Rsqr	Adj Rsqr	Standard Error of Estimate
0.2049	0.0420	0.0335	1.0313

	Coefficient	Std. Error	t	P
y0	5.2565	0.1991	26.4043	<0.0001
a	0.1878	0.0844	2.2255	0.0280

Analysis of Variance:

	DF	SS	MS
Regression	2	2731.0994	1365.5497
Residual	113	120.1906	1.0636
Total	115	2851.2900	24.7938

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	5.2680	5.2680	4.9528	0.0280
Residual	113	120.1906	1.0636		
Total	114	125.4586	1.1005		

Statistical Tests:

Normality Test (Shapiro-Wilk) Passed (P = 0.4827)
W Statistic= 0.9890 Significance Level = 0.0500

Constant Variance Test Passed (P = 0.3583)

Fit Equation Description:
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_x = 1/abs(x)
reciprocal_xsquare = 1/x^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
weight_Cauchy = 1/(1+4*(y-f)^2)

```
'Automatic Initial Parameter Estimate Functions
F(q) = ape(ln(abs(x)),y,1,0,1)
[Parameters]
y0 = F(0)[1] "Auto {{previous: 5.25648}}
a = F(0)[2] "Auto {{previous: 0.187761}}
[Equation]
f = if(x>0, y0+a*ln(abs(x)), 0)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_x
"fit f to y with weight reciprocal_xsquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
"fit f to y with weight weight_Cauchy
[Constraints]
[Options]
tolerance=1e-10
stepsize=1
iterations=200
```

Number of Iterations Performed = 1

ANALYSIS: PERENNIAL STEAMS HBI VS. TN (REGRESSION)

Data Source: Data 1 in Bio_HBI_TN_Perennial.JNB
Equation: Logarithm, 2 Parameter I
f = if(x>0, y0+a*ln(abs(x)), 0)

R	Rsqr	Adj Rsqr	Standard Error of Estimate
0.1780	0.0317	0.0188	1.0902

	Coefficient	Std. Error	t	P
y0	4.6863	0.1510	31.0304	<0.0001
a	0.2354	0.1503	1.5662	0.1215

Analysis of Variance:

	DF	SS	MS
Regression	2	1792.3755	896.1878
Residual	75	89.1332	1.1884
Total	77	1881.5087	24.4352

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	2.9153	2.9153	2.4530	0.1215
Residual	75	89.1332	1.1884		
Total	76	92.0485	1.2112		

Statistical Tests:

Normality Test (Shapiro-Wilk) Passed (P = 0.6418)
W Statistic= 0.9873 Significance Level = 0.0500

Constant Variance Test Passed (P = 0.8013)

Fit Equation Description:

```
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_x = 1/abs(x)
reciprocal_xsquare = 1/x^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
weight_Cauchy = 1/(1+4*(y-f)^2)
'Automatic Initial Parameter Estimate Functions
F(q) = ape(ln(abs(x)),y,1,0,1)
[Parameters]
y0 = F(0)[1] "Auto {{previous: 4.68627}}
a = F(0)[2] "Auto {{previous: 0.235433}}
[Equation]
f = if(x>0, y0+a*ln(abs(x)), 0)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_x
"fit f to y with weight reciprocal_xsquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
"fit f to y with weight weight_Cauchy
[Constraints]
[Options]
tolerance=1e-10
stepsize=1
iterations=200
```

Number of Iterations Performed = 1

ANALYSIS: ALL STREAMS INTOLERANT:TOLERANT RATIO VS. TP (REGRESSION)

Data Source: Data 1 in Bio_Rat_TP_All.JNB
Equation: Power, 2 Parameter
f = a*x^b

R	Rsqr	Adj Rsqr	Standard Error of Estimate
(NAN)	-1.0844E-011	-0.0089	6.0568

	Coefficient	Std. Error	t	P
a	3.4516	1.1713	2.9468	0.0039
b	3.4081E-010	0.1436	2.3738E-009	1.0000

Analysis of Variance:

	DF	SS	MS
Regression	2	1358.1209	679.0605
Residual	112	4108.7507	36.6853
Total	114	5466.8716	47.9550

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	-4.4554E-008	-4.4554E-008	-1.2145E-009	1.0000
Residual	112	4108.7507	36.6853		
Total	113	4108.7507	36.3606		

Statistical Tests:

Normality Test (Shapiro-Wilk) Failed (P = <0.0001)
W Statistic= 0.5097 Significance Level = 0.0500

Constant Variance Test Passed (P = 0.1257)

Fit Equation Description:
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_x = 1/abs(x)
reciprocal_xsquare = 1/x^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
weight_Cauchy = 1/(1+4*(y-f)^2)
[Parameters]
a = mean(y) "Auto {{previous: 3.45157}}
b = 1 "Auto {{previous: 3.40815e-010}}
[Equation]
f = a*x^b
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_x
"fit f to y with weight reciprocal_xsquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
"fit f to y with weight weight_Cauchy
[Constraints]
b>0
[Options]

tolerance=1e-10
stepsize=1
iterations=200

Number of Iterations Performed = 5

ANALYSIS: ALL STREAMS INTOLERANT: TOLERANT RATIO VS. TN (REGRESSION)

Data Source: Data 1 in Bio_Rat_TN_All.JNB
Equation: Power, 2 Parameter
f = a*x^b

R	Rsqr	Adj Rsqr	Standard Error of Estimate
(NAN)	-3.6413E-011	-0.0111	6.5737

	Coefficient	Std. Error	t	P
a	3.6399	0.7888	4.6145	<0.0001
b	7.9507E-010	0.1975	4.0263E-009	1.0000

Analysis of Variance:

	DF	SS	MS
Regression	2	1218.8735	609.4367
Residual	90	3889.1938	43.2133
Total	92	5108.0673	55.5225

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	-1.4162E-007	-1.4162E-007	-3.2772E-009	1.0000
Residual	90	3889.1938	43.2133		
Total	91	3889.1938	42.7384		

Statistical Tests:

Normality Test (Shapiro-Wilk) Failed (P = <0.0001)
W Statistic= 0.5019 Significance Level = 0.0500

Constant Variance Test Failed (P = 0.0403)

Fit Equation Description:
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_x = 1/abs(x)
reciprocal_xsquare = 1/x^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2

```
weight_Cauchy = 1/(1+4*(y-f)^2)
[Parameters]
a = mean(y) "Auto {{previous: 3.63987}}
b = 1 "Auto {{previous: 7.95072e-010}}
[Equation]
f = a*x^b
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_x
"fit f to y with weight reciprocal_xsquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
"fit f to y with weight weight_Cauchy
[Constraints]
b>0
[Options]
tolerance=1e-10
stepsize=1
iterations=200
```

Number of Iterations Performed = 8

ANALYSIS: PERENNIAL STREAMS INTOLERANT:TOLERANT RATIO VS. TP (REGRESSION)

Data Source: Data 1 in Bio_Rat_TP_Perennial.JNB
Equation: Power, 2 Parameter
f = a*x^b

R	Rsqr	Adj Rsqr	Standard Error of Estimate
(NAN)	-3.9041E-010	-0.0105	6.4876

	Coefficient	Std. Error	t	P
a	18.2861	1.3629	13.4170	<0.0001
b	3.7524E-010	0.0315	1.1923E-008	1.0000

Analysis of Variance:

	DF	SS	MS
Regression	2	32434.9388	16217.4694
Residual	95	3998.4987	42.0895
Total	97	36433.4375	375.6024

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	-1.5611E-006	-1.5611E-006	-3.7089E-008	1.0000
Residual	95	3998.4987	42.0895		
Total	96	3998.4987	41.6510		

Statistical Tests:

Normality Test (Shapiro-Wilk) Passed (P = 0.1428)
W Statistic= 0.9799 Significance Level = 0.0500

Constant Variance Test Passed (P = 0.2468)

Fit Equation Description:
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_x = 1/abs(x)
reciprocal_xsquare = 1/x^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
weight_Cauchy = 1/(1+4*(y-f)^2)
[Parameters]
a = mean(y) "Auto {{previous: 18.2861}}
b = 1 "Auto {{previous: 3.75238e-010}}
[Equation]
f = a*x^b
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_x
"fit f to y with weight reciprocal_xsquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
"fit f to y with weight weight_Cauchy
[Constraints]
b>0
[Options]
tolerance=1e-10
stepsize=1
iterations=200

Number of Iterations Performed = 6

ANALYSIS: PERENNIAL STREAMS INTOLERANT: TOLERANT RATIO VS. TN (REGRESSION)

Data Source: Data 1 in Bio_Rat_TN_Perennial.JNB
Equation: Power, 2 Parameter
f = a*x^b

R	Rsqr	Adj Rsqr	Standard Error of Estimate
(NAN)	-6.7979E-011	-0.0135	7.1516

	Coefficient	Std. Error	t	P

a	4.0747	0.9922	4.1066	0.0001
b	1.2120E-009	0.2426	4.9962E-009	1.0000

Analysis of Variance:

	DF	SS	MS
Regression	2	1261.8151	630.9076
Residual	74	3784.7127	51.1448
Total	76	5046.5278	66.4017

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	-2.5728E-007	-2.5728E-007	-5.0304E-009	1.0000
Residual	74	3784.7127	51.1448		
Total	75	3784.7127	50.4628		

Statistical Tests:

Normality Test (Shapiro-Wilk) Failed (P = <0.0001)
W Statistic= 0.5337 Significance Level = 0.0500

Constant Variance Test Failed (P = 0.0416)

Fit Equation Description:
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_x = 1/abs(x)
reciprocal_xsquare = 1/x^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
weight_Cauchy = 1/(1+4*(y-f)^2)
[Parameters]
a = mean(y) "Auto {{previous: 4.07466}}
b = 1 "Auto {{previous: 1.21202e-009}}
[Equation]
f = a*x^b
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_x
"fit f to y with weight reciprocal_xsquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
"fit f to y with weight weight_Cauchy
[Constraints]
b>0
[Options]
tolerance=1e-10

stepsize=1
iterations=200

Number of Iterations Performed = 6

ANALYSIS: ALL STREAMS RICHNESS VS. TP (REGRESSION)

Data Source: Data 1 in Bio_Rich_TP_All.JNB
Equation: Logarithm, 2 Parameter I
f = if(x>0, y0+a*ln(abs(x)), 0)

R	Rsqr	Adj Rsqr	Standard Error of Estimate
0.1515	0.0230	0.0145	6.2713

	Coefficient	Std. Error	t	P
y0	16.5423	1.1489	14.3981	<0.0001
a	-0.7994	0.4862	-1.6440	0.1029

Analysis of Variance:

	DF	SS	MS
Regression	2	38746.8077	19373.4039
Residual	115	4522.8798	39.3294
Total	117	43269.6875	369.8264

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	106.3029	106.3029	2.7029	0.1029
Residual	115	4522.8798	39.3294		
Total	116	4629.1827	39.9067		

Statistical Tests:

Normality Test (Shapiro-Wilk) Passed (P = 0.2203)
W Statistic= 0.9850 Significance Level = 0.0500

Constant Variance Test Failed (P = 0.0086)

Fit Equation Description:
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_x = 1/abs(x)
reciprocal_xsquare = 1/x^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
weight_Cauchy = 1/(1+4*(y-f)^2)

```
'Automatic Initial Parameter Estimate Functions
F(q) = ape(ln(abs(x)),y,1,0,1)
[Parameters]
y0 = F(0)[1] "Auto {{previous: 16.5423}}
a = F(0)[2] "Auto {{previous: -0.799371}}
[Equation]
f = if(x>0, y0+a*ln(abs(x)), 0)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_x
"fit f to y with weight reciprocal_xsquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
"fit f to y with weight weight_Cauchy
[Constraints]
[Options]
tolerance=1e-10
stepsize=1
iterations=200
```

Number of Iterations Performed = 1

ANALYSIS: ALL STREAMS RICHNESS VS. TN (REGRESSION)

Data Source: Data 1 in Bio_Rich_TN_All.JNB
Equation: Logarithm, 2 Parameter I
f = if(x>0, y0+a*ln(abs(x)), 0)

R	Rsqr	Adj Rsqr	Standard Error of Estimate
0.2482	0.0616	0.0489	5.9225

	Coefficient	Std. Error	t	P
y0	18.9626	0.7734	24.5192	<0.0001
a	-1.5305	0.6944	-2.2041	0.0306

Analysis of Variance:

	DF	SS	MS
Regression	2	25201.0671	12600.5335
Residual	74	2595.6204	35.0760
Total	76	27796.6875	365.7459

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	170.4018	170.4018	4.8581	0.0306
Residual	74	2595.6204	35.0760		
Total	75	2766.0222	36.8803		

Statistical Tests:

Normality Test (Shapiro-Wilk) Passed (P = 0.5622)
W Statistic= 0.9859 Significance Level = 0.0500

Constant Variance Test Passed (P = 0.1221)

Fit Equation Description:
```
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_x = 1/abs(x)
reciprocal_xsquare = 1/x^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
weight_Cauchy = 1/(1+4*(y-f)^2)
'Automatic Initial Parameter Estimate Functions
F(q) = ape(ln(abs(x)),y,1,0,1)
[Parameters]
y0 = F(0)[1] "Auto {{previous: 18.9626}}
a = F(0)[2] "Auto {{previous: -1.53047}}
[Equation]
f = if(x>0, y0+a*ln(abs(x)), 0)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_x
"fit f to y with weight reciprocal_xsquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
"fit f to y with weight weight_Cauchy
[Constraints]
[Options]
tolerance=1e-10
stepsize=1
iterations=200
```

Number of Iterations Performed = 1

ANALYSIS: PERENNIAL STREAMS RICHNESS VS. TP (REGRESSION)

Data Source: Data 1 in Bio_Rich_TP_Perennial.JNB
Equation: Logarithm, 2 Parameter I
f = if(x>0, y0+a*ln(abs(x)), 0)

R	Rsqr	Adj Rsqr	Standard Error of Estimate
0.1596	0.0255	0.0152	6.4045

	Coefficient	Std. Error	t	P
y0	16.4302	1.3454	12.2117	<0.0001
a	-0.8952	0.5681	-1.5756	0.1184

Analysis of Variance:

	DF	SS	MS
Regression	2	32536.7673	16268.3837
Residual	95	3896.6702	41.0176
Total	97	36433.4375	375.6024

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	101.8285	101.8285	2.4826	0.1184
Residual	95	3896.6702	41.0176		
Total	96	3998.4987	41.6510		

Statistical Tests:

Normality Test (Shapiro-Wilk) Passed (P = 0.1251)
W Statistic= 0.9791 Significance Level = 0.0500

Constant Variance Test Failed (P = 0.0164)

Fit Equation Description:
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_x = 1/abs(x)
reciprocal_xsquare = 1/x^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
weight_Cauchy = 1/(1+4*(y-f)^2)
'Automatic Initial Parameter Estimate Functions
F(q) = ape(ln(abs(x)),y,1,0,1)
[Parameters]
y0 = F(0)[1] "Auto {{previous: 16.4302}}
a = F(0)[2] "Auto {{previous: -0.89518}}
[Equation]
f = if(x>0, y0+a*ln(abs(x)), 0)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_x
"fit f to y with weight reciprocal_xsquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
"fit f to y with weight weight_Cauchy
[Constraints]

[Options]
tolerance=1e-10
stepsize=1
iterations=200

Number of Iterations Performed = 1

ANALYSIS: PERENNIAL STREAMS RICHNESS VS. TN (REGRESSION)

Data Source: Data 1 in Bio_Rich_TN_Perennial.JNB
Equation: Logarithm, 2 Parameter I
f = if(x>0, y0+a*ln(abs(x)), 0)

R	**Rsqr**	**Adj Rsqr**	**Standard Error of Estimate**
0.2597	0.0674	0.0514	6.1029

	Coefficient	**Std. Error**	**t**	**P**
y0	19.0174	0.9480	20.0595	<0.0001
a	-1.9406	0.9476	-2.0480	0.0451

Analysis of Variance:

	DF	**SS**	**MS**
Regression	2	19461.4495	9730.7247
Residual	58	2160.2380	37.2455
Total	60	21621.6875	360.3615

Corrected for the mean of the observations:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	156.2151	156.2151	4.1942	0.0451
Residual	58	2160.2380	37.2455		
Total	59	2316.4531	39.2619		

Statistical Tests:

Normality Test (Shapiro-Wilk) Passed (P = 0.5659)
W Statistic= 0.9830 Significance Level = 0.0500

Constant Variance Test Passed (P = 0.0567)

Fit Equation Description:
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_x = 1/abs(x)
reciprocal_xsquare = 1/x^2
reciprocal_pred = 1/abs(f)

```
reciprocal_predsqr = 1/f^2
weight_Cauchy = 1/(1+4*(y-f)^2)
'Automatic Initial Parameter Estimate Functions
F(q) = ape(ln(abs(x)),y,1,0,1)
[Parameters]
y0 = F(0)[1] "Auto {{previous: 19.0174}}
a = F(0)[2] "Auto {{previous: -1.94057}}
[Equation]
f = if(x>0, y0+a*ln(abs(x)), 0)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_x
"fit f to y with weight reciprocal_xsquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
"fit f to y with weight weight_Cauchy
[Constraints]
[Options]
tolerance=1e-10
stepsize=1
iterations=200
```

Number of Iterations Performed = 1

ANALYSIS: PERENNIAL STREAMS HBI VS. HQI (REGRESSION)

Data Source: Data 1 in Notebook3

Equation: Polynomial, Linear
f = y0+a*x

R	Rsqr	Adj Rsqr	Standard Error of Estimate
0.4505	0.2030	0.1959	0.8371

	Coefficient	Std. Error	t	P
y0	7.8965	0.5784	13.6522	<0.0001
a	-0.1512	0.0283	-5.3409	<0.0001

Analysis of Variance:

	DF	SS	MS
Regression	2	2685.8680	1342.9340
Residual	112	78.4737	0.7007
Total	114	2764.3417	24.2486

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	19.9864	19.9864	28.5251	<0.0001

Residual	112	78.4737	0.7007
Total	113	98.4601	0.8713

Statistical Tests:

Normality Test (Shapiro-Wilk) Passed (P = 0.4577)

W Statistic= 0.9886 Significance Level = 0.0500

Constant Variance Test Passed (P = 0.0604)

Fit Equation Description:
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
'Automatic Initial Parameter Estimate Functions
F(q) = ape(x,y,1,0,1)
[Parameters]
y0 = F(0)[1] "Auto {{previous: 7.89648}} {{MinRange: -12.3}} {{MaxRange: 36.9}}
a = F(0)[2] "Auto {{previous: -0.151178}} {{MinRange: -4.5}} {{MaxRange: 1.5}}
[Equation]
f = y0+a*x
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
[Constraints]
[Options]
tolerance=0.0000000001
stepsize=1
iterations=200

Number of Iterations Performed = 1

ANALYSIS: PERENNIAL STREAMS HBI VS. CHL-A FLUORO (REGRESSION)

Data Source: Data 1 in Notebook6
Equation: Polynomial, Linear
f = y0+a*x

R	Rsqr	Adj Rsqr	Standard Error of Estimate
0.2696	0.0727	0.0588	1.1183

	Coefficient	Std. Error	t	P

y0	4.6950	0.1600	29.3470	<0.0001
a	0.0245	0.0107	2.2915	0.0251

Analysis of Variance:

	DF	SS	MS
Regression	2	1658.5245	829.2623
Residual	67	83.7960	1.2507
Total	69	1742.3205	25.2510

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	6.5672	6.5672	5.2509	0.0251
Residual	67	83.7960	1.2507		
Total	68	90.3632	1.3289		

Statistical Tests:

Normality Test (Shapiro-Wilk) Passed (P = 0.9931)

W Statistic= 0.9947 Significance Level = 0.0500

Constant Variance Test Passed (P = 0.3742)

Fit Equation Description:

```
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
'Automatic Initial Parameter Estimate Functions
F(q) = ape(x,y,1,0,1)
[Parameters]
y0 = F(0)[1] "Auto {{previous: 4.69497}} {{MinRange: -12.3}} {{MaxRange: 36.9}}
a = F(0)[2] "Auto {{previous: 0.0245101}} {{MinRange: -4.5}} {{MaxRange: 1.5}}
[Equation]
f = y0+a*x
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
[Constraints]
[Options]
tolerance=0.0000000001
stepsize=1
iterations=200
```

Number of Iterations Performed = 1

ANALYSIS: PERENNIAL STREAMS INTOLERANT:TOLERANT RATIO VS. HQI (REGRESSION)

Data Source: Data 1 in Notebook4
Equation: Exponential Growth, Single, 2 Parameter
f = a*exp(b*x)

R	Rsqr	Adj Rsqr	Standard Error of Estimate
0.3852	0.1484	0.1407	5.2579

	Coefficient	Std. Error	t	P
a	0.0048	0.0081	0.5993	0.5502
b	0.3008	0.0705	4.2633	<0.0001

Analysis of Variance:

	DF	SS	MS
Regression	2	1607.0851	803.5426
Residual	111	3068.6438	27.6454
Total	113	4675.7289	41.3781

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	534.7169	534.7169	19.3420	<0.0001
Residual	111	3068.6438	27.6454		
Total	112	3603.3607	32.1729		

Statistical Tests:

Normality Test (Shapiro-Wilk) Failed (P = <0.0001)

W Statistic= 0.6126 Significance Level = 0.0500

Constant Variance Test Failed (P = <0.0001)

Fit Equation Description:
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
'Automatic Initial Parameter Estimate Functions
F(q) = ape(x,ln(y),1,0,1)
[Parameters]
a = exp(F(0)[1]) "Auto {{previous: 0.00483819}}
b = F(0)[2] "Auto {{previous: 0.300755}}
[Equation]
f = a*exp(b*x)

fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
[Constraints]
b>0
[Options]
tolerance=0.0000000001
stepsize=1
iterations=200

Number of Iterations Performed = 20

ANALYSIS: PERENNIAL STREAMS INTOLERANT:TOLERANT RATIO VS. CHL-A SPEC (REGRESSION)

Data Source: Data 1 in Notebook7
Equation: Exponential Decay, Single, 2 Parameter
f = a*exp(-b*x)

R	Rsqr	Adj Rsqr	Standard Error of Estimate
0.3609	0.1303	0.1183	1.7200

	Coefficient	Std. Error	t	P
a	2.0600	0.6403	3.2174	0.0019
b	0.2018	0.0627	3.2185	0.0019

Analysis of Variance:

	DF	SS	MS
Regression	2	56.8112	28.4056
Residual	73	215.9515	2.9582
Total	75	272.7627	3.6368

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	32.3420	32.3420	10.9329	0.0015
Residual	73	215.9515	2.9582		
Total	74	248.2935	3.3553		

Statistical Tests:

Fit Equation Description:
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_pred = 1/abs(f)

```
reciprocal_predsqr = 1/f^2
'Automatic Initial Parameter Estimate Functions
F(q) = if(size(x)>1, if(total(abs(y))>0, ape(x,log(abs(y)),1,0,1), -306), 0)
asign(q) = if(mean(q)>=0,1,-1)
[Parameters]
a = if(F(0)[1]< 307, if(F(0)[1]>-307, asign(y)*10^F(0)[1], asign(y)*10^(-307)), asign(y)*10^307) "Auto {{previous: 2.05995}} {{MinRange: -3}} {{MaxRange: 9}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.201799}} {{MinRange: 0}} {{MaxRange: 1}}
[Equation]
f = a*exp(-b*x)
fit f to y with weight reciprocal_y
"fit f to y
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance=0.0000000001
stepsize=1
iterations=200
```

Number of Iterations Performed = 8

ANALYSIS: PERENNIAL STREAMS INTOLERANT: TOLERANT RATIO VS. CHL-A FLUORO (REGRESSION)

Data Source: Data 1 in Notebook8
Equation: Exponential Decay, Single, 2 Parameter
f = a*exp(-b*x)

R	Rsqr	Adj Rsqr	Standard Error of Estimate
0.3402	0.1158	0.1026	1.4946

	Coefficient	Std. Error	t	P
a	1.7819	0.9671	1.8426	0.0698
b	0.2440	0.1305	1.8699	0.0659

Analysis of Variance:

	DF	SS	MS
Regression	2	40.3505	20.1752
Residual	67	149.6583	2.2337
Total	69	190.0088	2.7538

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	19.5938	19.5938	8.7719	0.0042
Residual	67	149.6583	2.2337		

Total	68	169.2521	2.4890

Statistical Tests:

Fit Equation Description:
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
'Automatic Initial Parameter Estimate Functions
F(q) = if(size(x)>1, if(total(abs(y))>0, ape(x,log(abs(y)),1,0,1), -306), 0)
asign(q) = if(mean(q)>=0,1,-1)
[Parameters]
a = if(F(0)[1]< 307, if(F(0)[1]>-307, asign(y)*10^F(0)[1], asign(y)*10^(-307)), asign(y)*10^307) ''Auto {{previous: 1.78188}} {{MinRange: -3}} {{MaxRange: 9}}
b = if(x50(x,y)-min(x)=0, 1, -ln(.5)/(x50(x,y)-min(x))) ''Auto {{previous: 0.244039}} {{MinRange: 0}} {{MaxRange: 1}}
[Equation]
f = a*exp(-b*x)
fit f to y with weight reciprocal_y
''fit f to y
''fit f to y with weight reciprocal_pred
''fit f to y with weight reciprocal_predsqr
''fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance=0.0000000001
stepsize=1
iterations=200

Number of Iterations Performed = 8

ANALYSIS: PERENNIAL STREAMS RICHNESS VS. HQI (REGRESSION)

Data Source: Data 1 in Bio_Rich_HQI_Perennial
Equation: Polynomial, Linear
f = y0+a*x

R	Rsqr	Adj Rsqr	Standard Error of Estimate
0.2914	0.0849	0.0751	5.0022

	Coefficient	Std. Error	t	P
y0	8.2687	3.6687	2.2539	0.0266
a	0.5334	0.1816	2.9375	0.0042

Analysis of Variance:

	DF	SS	MS
Regression	2	34292.7566	17146.3783
Residual	93	2327.0559	25.0221
Total	95	36619.8125	385.4717

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	215.9086	215.9086	8.6287	0.0042
Residual	93	2327.0559	25.0221		
Total	94	2542.9645	27.0528		

Statistical Tests:

Normality Test (Shapiro-Wilk) Passed (P = 0.9336)

W Statistic= 0.9936 Significance Level = 0.0500

Constant Variance Test Passed (P = 0.6195)

Fit Equation Description:

```
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
'Automatic Initial Parameter Estimate Functions
F(q) = ape(x,y,1,0,1)
[Parameters]
y0 = F(0)[1] "Auto {{previous: 8.26873}} {{MinRange: -12.3}} {{MaxRange: 36.9}}
a = F(0)[2] "Auto {{previous: 0.533397}} {{MinRange: -4.5}} {{MaxRange: 1.5}}
[Equation]
f = y0+a*x
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
[Constraints]
[Options]
tolerance=0.0000000001
stepsize=1
iterations=200
```

Number of Iterations Performed = 1

ANALYSIS: PERENNIAL STREAMS RICHNESS VS. CHL-A SPEC (REGRESSION)

Data Source: Data 1 in Bio_Rich_CHLAS_Perennial
Equation: Polynomial, Linear
f = y0+a*x

R	Rsqr	Adj Rsqr	Standard Error of Estimate
0.1951	0.0380	0.0223	6.1303

	Coefficient	Std. Error	t	P
y0	18.5197	1.3220	14.0086	<0.0001
a	-0.1900	0.1223	-1.5532	0.1255

Analysis of Variance:

	DF	SS	MS
Regression	2	17984.5240	8992.2620
Residual	61	2292.4135	37.5805
Total	63	20276.9375	321.8562

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	90.6658	90.6658	2.4126	0.1255
Residual	61	2292.4135	37.5805		
Total	62	2383.0794	38.4368		

Statistical Tests:

Normality Test (Shapiro-Wilk) Passed (P = 0.2055)

W Statistic= 0.9741 Significance Level = 0.0500

Constant Variance Test Passed (P = 0.9141)

Fit Equation Description:
[Variables]
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
'Automatic Initial Parameter Estimate Functions
F(q) = ape(x,y,1,0,1)
[Parameters]
y0 = F(0)[1] "Auto {{previous: 18.5197}} {{MinRange: -12.3}} {{MaxRange: 36.9}}
a = F(0)[2] "Auto {{previous: -0.190015}} {{MinRange: -4.5}} {{MaxRange: 1.5}}
[Equation]
f = y0+a*x

fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
[Constraints]
[Options]
tolerance=0.0000000001
stepsize=1
iterations=200

Number of Iterations Performed = 1

ANALYSIS: PERENNIAL STREAMS RICHNESS VS. CHL-A FLUORO (REGRESSION)

Data Source: Data 1 in Bio_Rich_CHLAF_Perennial
Equation: Logarithm, 2 Parameter I
f = if(x>0, y0+a*ln(abs(x)), 0)

R	Rsqr	Adj Rsqr	Standard Error of Estimate
0.3235	0.1046	0.0907	5.4068

	Coefficient	Std. Error	t	P
y0	22.3482	1.5879	14.0745	<0.0001
a	-2.3608	0.8632	-2.7350	0.0081

Analysis of Variance:

	DF	SS	MS
Regression	2	22576.5082	11288.2541
Residual	64	1870.9293	29.2333
Total	66	24447.4375	370.4157

Corrected for the mean of the observations:

	DF	SS	MS	F	P
Regression	1	218.6663	218.6663	7.4801	0.0081
Residual	64	1870.9293	29.2333		
Total	65	2089.5956	32.1476		

Statistical Tests:

Normality Test (Shapiro-Wilk) Passed (P = 0.8017)

W Statistic= 0.9885 Significance Level = 0.0500

Constant Variance Test Passed (P = 0.9903)

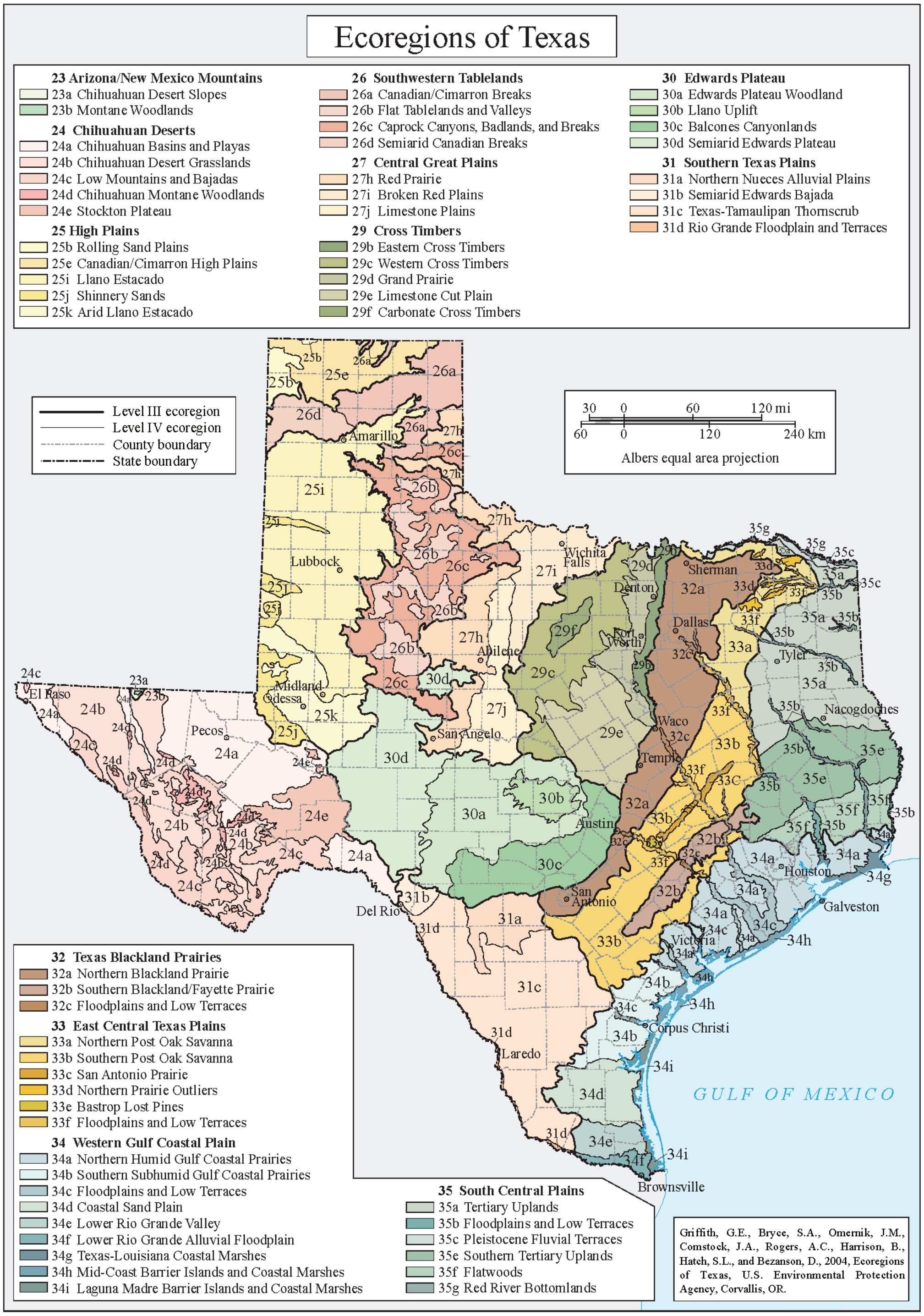
Fit Equation Description:
[Variables]

```
x = col(2)
y = col(1)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
reciprocal_pred = 1/abs(f)
reciprocal_predsqr = 1/f^2
'Automatic Initial Parameter Estimate Functions
F(q) = ape(ln(abs(x)),y,1,0,1)
[Parameters]
y0 = F(0)[1] "Auto {{previous: 22.3482}}
a = F(0)[2] "Auto {{previous: -2.36078}}
[Equation]
f = if(x>0, y0+a*ln(abs(x)), 0)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
"fit f to y with weight reciprocal_pred
"fit f to y with weight reciprocal_predsqr
[Constraints]
[Options]
tolerance=0.0000000001
stepsize=1
iterations=200
```

Number of Iterations Performed = 1

Appendix 1.3. Texas River and Coastal Basins (http://www.tceq.texas.gov/publications/gi/gi-316/gi-316_intro.html/at_download/file).

Appendix 1.4. Level III and Level IV Ecoregions in Texas (epa.gov/wed/ecoregions/tx/tx_eco_pg.pdf).



Appendix 1.5 Frequency distributions of water quality parameters for Texas stream and river segments

Table A1.5.1. Frequency distribution of median nutrient and chlorophyll-a concentrations for stream and river segments in Texas, using data from 2000-2010 and the median dataset generated in FY2012-2013.

Total Phosphorus (TP; mg/L)

Segment	n	MIN	10th	25th	Median	75th	90th	MAX
0101	4	0.067	-	0.077	0.083	0.095	-	0.120
0103	3	0.060	-	-	0.070	-	-	0.120
0104	2	0.083	-	-	0.087	-	-	0.090
0201	1	-	-	-	0.150	-	-	-
0202	4	0.100	-	0.108	0.113	0.116	-	0.120
0204	3	0.200	-	-	0.210	-	-	0.240
0205	2	0.120	-	-	0.133	-	-	0.146
0206	1	-	-	-	0.060	-	-	-
0207	2	0.060	-	-	0.135	-	-	0.210
0211	2	0.260	-	-	0.270	-	-	0.280
0214	8	0.075	0.100	0.111	0.170	0.309	0.707	0.980
0216	1	-	-	-	0.040	-	-	-
0218	4	0.040	-	0.048	0.050	0.053	-	0.060
0220	2	0.060	-	-	0.060	-	-	0.060
0221	0	-	-	-	-	-	-	-
0222	1	-	-	-	0.020	-	-	-
0224	1	-	-	-	0.050	-	-	-
0226	3	0.040	-	-	0.050	-	-	0.060
0227	0	-	-	-	-	-	-	-
0229	2	0.760	-	-	0.885	-	-	1.010
0230	2	0.060	-	-	0.065	-	-	0.070
0301	2	0.115	-	-	0.128	-	-	0.140
0303	3	0.095	-	-	0.105	-	-	0.190
0304	1	-	-	-	0.210	-	-	-
0305	1	-	-	-	0.060	-	-	-
0306	2	0.060	-	-	0.458	-	-	0.855
0401	1	-	-	-	0.087	-	-	-
0402	4	0.060	-	0.064	0.075	0.085	-	0.090
0404	2	0.300	-	-	0.795	-	-	1.290
0406	3	0.100	-	-	0.120	-	-	0.140
0407	2	0.040	-	-	0.062	-	-	0.085
0409	7	0.100	0.108	0.127	0.140	0.189	0.192	0.195
0501	2	0.060	-	-	0.068	-	-	0.075
0502	2	0.060	-	-	0.080	-	-	0.100

0503	5	0.060	-	0.060	0.060	0.060	-	0.210
0504	0	-	-	-	-	-	-	-
0505	5	0.100	-	0.100	0.130	0.130	-	0.150
0506	4	0.100	-	0.108	0.125	0.145	-	0.160
0513	1	-	-	-	0.060	-	-	-
0514	3	0.060	-	-	0.100	-	-	0.120
0515	1	-	-	-	0.090	-	-	-
0602	3	0.070	-	-	0.080	-	-	0.090
0604	7	0.060	0.060	0.060	0.060	0.110	0.140	0.140
0606	3	0.120	-	-	0.190	-	-	0.330
0607	4	0.090	-	0.098	0.110	0.120	-	0.120
0608	4	0.060	-	0.060	0.060	0.060	-	0.060
0609	1	-	-	-	0.060	-	-	-
0610	1	-	-	-	0.160	-	-	-
0611	4	0.120	-	0.128	0.165	0.215	-	0.260
0612	3	0.140	-	-	0.160	-	-	0.200
0701	2	0.110	-	-	0.135	-	-	0.160
0704	3	0.180	-	-	0.230	-	-	0.345
0801	0	-	-	-	-	-	-	-
0802	3	0.140	-	-	0.140	-	-	0.140
0803	0	-	-	-	-	-	-	-
0804	4	0.655	-	0.771	0.865	0.960	-	1.080
0805	5	0.960	-	1.060	1.100	1.165	-	1.178
0806	4	0.070	-	0.078	0.080	0.085	-	0.100
0809	0	-	-	-	-	-	-	-
0810	1	-	-	-	0.140	-	-	-
0812	1	-	-	-	0.280	-	-	-
0814	2	0.100	-	-	0.230	-	-	0.360
0815	0	-	-	-	-	-	-	-
0817	0	-	-	-	-	-	-	-
0818	0	-	-	-	-	-	-	-
0819	3	0.750	-	-	1.700	-	-	2.880
0821	0	-	-	-	-	-	-	-
0822	8	0.050	0.071	0.080	0.115	0.121	0.133	0.150
0824	2	0.090	-	-	0.985	-	-	1.880
0825	1	-	-	-	0.195	-	-	-
0829	1	-	-	-	0.060	-	-	-
0830	0	-	-	-	-	-	-	-
0831	1	-	-	-	0.865	-	-	-
0833	0	-	-	-	-	-	-	-

0835	0	-	-	-	-	-	-	-
0836	0	-	-	-	-	-	-	-
0837	0	-	-	-	-	-	-	-
0838	0	-	-	-	-	-	-	-
0839	0	-	-	-	-	-	-	-
0840	0	-	-	-	-	-	-	-
0841	4	0.910	-	0.910	0.910	0.965	-	1.020
0902	2	0.125	-	-	0.138	-	-	0.150
1002	0	-	-	-	-	-	-	-
1003	3	0.060	-	-	0.080	-	-	0.085
1004	1	-	-	-	0.110	-	-	-
1006	1	-	-	-	0.460	-	-	-
1007	1	-	-	-	1.145	-	-	-
1008	6	0.130	-	0.158	0.180	0.285	-	0.815
1009	8	0.330	0.722	0.909	0.960	1.456	1.559	1.650
1010	4	0.040	-	0.055	0.088	0.120	-	0.135
1011	3	0.060	-	-	0.065	-	-	0.075
1013	0	-	-	-	-	-	-	-
1014	12	0.910	0.946	0.958	1.010	1.164	1.330	1.560
1015	2	0.150	-	-	0.150	-	-	0.150
1016	6	0.985	-	1.204	1.290	1.376	-	1.475
1017	10	0.690	0.879	0.961	1.013	1.474	2.202	2.760
1101	1	-	-	-	0.420	-	-	-
1102	9	0.220	0.324	0.380	0.470	0.620	0.628	0.660
1103	3	0.080	-	-	0.150	-	-	0.178
1104	1	-	-	-	0.090	-	-	-
1105	1	-	-	-	0.235	-	-	-
1108	1	-	-	-	0.100	-	-	-
1110	1	-	-	-	0.400	-	-	-
1201	0	-	-	-	-	-	-	-
1202	2	0.130	-	-	0.190	-	-	0.250
1204	1	-	-	-	0.060	-	-	-
1205	0	-	-	-	-	-	-	-
1206	0	-	-	-	-	-	-	-
1208	2	0.080	-	-	0.143	-	-	0.205
1209	0	-	-	-	-	-	-	-
1211	1	-	-	-	0.080	-	-	-
1213	4	0.175	-	0.179	0.195	0.226	-	0.275
1214	1	-	-	-	0.340	-	-	-
1215	1	-	-	-	0.050	-	-	-

1217	0	-	-	-	-	-	-	-
1218	1	-	-	-	1.230	-	-	-
1219	1	-	-	-	0.320	-	-	-
1220	0	-	-	-	-	-	-	-
1221	8	0.050	0.057	0.060	0.095	0.133	0.188	0.230
1223	1	-	-	-	0.125	-	-	-
1226	12	0.040	0.061	0.077	0.085	0.220	0.438	0.640
1227	3	0.220	-	-	0.480	-	-	0.980
1229	0	-	-	-	-	-	-	-
1232	5	0.080	-	0.340	0.460	0.470	-	1.250
1236	0	-	-	-	-	-	-	-
1238	1	-	-	-	0.060	-	-	-
1239	0	-	-	-	-	-	-	-
1241	1	-	-	-	0.080	-	-	-
1242	1	-	-	-	0.165	-	-	-
1243	3	0.050	-	-	0.050	-	-	0.060
1244	1	-	-	-	0.480	-	-	-
1245	1	-	-	-	0.215	-	-	-
1246	5	0.060	-	0.060	0.060	0.070	-	0.086
1248	2	0.060	-	-	0.065	-	-	0.070
1250	4	0.050	-	0.050	0.055	0.060	-	0.060
1251	1	-	-	-	0.060	-	-	-
1253	1	-	-	-	0.150	-	-	-
1255	3	0.450	-	-	0.700	-	-	0.975
1256	2	0.060	-	-	0.090	-	-	0.120
1257	1	-	-	-	0.060	-	-	-
1301	1	-	-	-	0.240	-	-	-
1302	6	0.070	-	0.140	0.181	0.214	-	0.225
1305	1	-	-	-	0.390	-	-	-
1402	6	0.274	-	0.307	0.339	0.360	-	0.370
1403	0	-	-	-	-	-	-	-
1406	0	-	-	-	-	-	-	-
1409	1	-	-	-	0.060	-	-	-
1410	2	0.060	-	-	0.060	-	-	0.060
1412	3	0.060	-	-	0.140	-	-	0.282
1414	5	0.060	-	0.060	0.060	0.060	-	0.080
1415	8	0.050	0.054	0.059	0.060	0.060	0.060	0.060
1416	2	0.060	-	-	0.060	-	-	0.060
1417	1	-	-	-	0.158	-	-	-
1420	2	0.060	-	-	0.078	-	-	0.095

1421	10	0.060	0.060	0.060	0.068	0.072	0.090	0.090
1424	2	0.060	-	-	0.060	-	-	0.060
1426	4	0.060	-	0.060	0.060	0.075	-	0.120
1427	8	0.020	0.020	0.020	0.035	0.050	0.053	0.060
1428	4	0.060	-	0.060	0.125	0.264	-	0.484
1430	9	0.020	0.020	0.020	0.025	0.030	0.042	0.050
1431	1	-	-	-	1.300	-	-	-
1432	1	-	-	-	0.060	-	-	-
1434	2	0.370	-	-	0.380	-	-	0.390
1501	0	-	-	-	-	-	-	-
1502	1	-	-	-	0.370	-	-	-
1602	3	0.085	-	-	0.185	-	-	0.200
1605	2	0.210	-	-	0.220	-	-	0.230
1801	0	-	-	-	-	-	-	-
1802	1	-	-	-	0.305	-	-	-
1803	3	0.090	-	-	0.130	-	-	0.180
1804	10	0.050	0.050	0.050	0.060	0.069	0.091	0.100
1806	9	0.016	0.018	0.020	0.039	0.050	0.050	0.050
1807	2	0.050	-	-	0.055	-	-	0.060
1808	3	0.050	-	-	0.060	-	-	0.090
1809	2	0.060	-	-	0.060	-	-	0.060
1810	4	0.060	-	0.293	0.595	1.043	-	1.710
1811	2	0.050	-	-	0.050	-	-	0.050
1812	6	0.050	-	0.050	0.055	0.060	-	0.060
1813	4	0.050	-	0.050	0.050	0.050	-	0.050
1814	1	-	-	-	0.050	-	-	-
1815	4	0.050	-	0.050	0.050	0.050	-	0.050
1816	1	-	-	-	0.009	-	-	-
1817	1	-	-	-	0.016	-	-	-
1818	1	-	-	-	0.008	-	-	-
1901	10	0.602	0.645	0.688	0.712	0.789	0.893	0.918
1902	5	0.163	-	0.193	0.270	0.380	-	0.581
1903	6	0.050	-	0.060	0.190	0.719	-	0.955
1905	1	-	-	-	0.060	-	-	-
1906	4	0.060	-	0.060	0.060	0.060	-	0.060
1907	1	-	-	-	0.050	-	-	-
1908	3	0.026	-	-	0.560	-	-	1.780
1910	7	0.060	0.064	0.072	0.080	0.117	0.125	0.130
1911	21	0.060	0.060	0.123	0.290	0.835	0.874	1.195
1912	1	-	-	-	1.100	-	-	-

1913	2	0.060	-	-	0.475	-	-	0.890
2002	1	-	-	-	0.060	-	-	-
2003	0	-	-	-	-	-	-	-
2004	1	-	-	-	1.240	-	-	-
2102	2	0.139	-	-	0.143	-	-	0.148
2103	1	-	-	-	0.172	-	-	-
2104	2	0.091	-	-	0.128	-	-	0.164
2105	2	0.060	-	-	0.073	-	-	0.085
2106	4	0.106	-	0.121	0.128	0.131	-	0.135
2107	2	0.140	-	-	0.232	-	-	0.323
2108	1	-	-	-	0.160	-	-	-
2109	4	0.060	-	0.060	0.060	0.060	-	0.060
2110	1	-	-	-	0.060	-	-	-
2111	1	-	-	-	0.055	-	-	-
2112	4	0.002	-	0.038	0.055	0.060	-	0.060
2113	2	0.050	-	-	0.050	-	-	0.050
2114	2	0.050	-	-	0.055	-	-	0.060
2115	1	-	-	-	0.050	-	-	-
2117	4	0.060	-	0.068	0.083	0.108	-	0.142
2202	6	0.667	-	0.717	0.740	0.925	-	1.415
2204	2	0.092	-	-	0.136	-	-	0.180
2301	0	-	-	-	-	-	-	-
2302	11	0.040	0.060	0.077	0.090	0.234	0.255	0.270
2304	15	0.007	0.060	0.070	0.100	0.110	0.204	0.248
2305	0	-	-	-	-	-	-	-
2306	5	0.090	-	0.100	0.100	0.183	-	0.240
2307	5	0.358	-	0.595	0.730	0.760	-	0.790
2308	3	0.400	-	-	0.529	-	-	0.600
2309	2	0.060	-	-	0.060	-	-	0.060
2310	3	0.005	-	-	0.050	-	-	0.060
2311	9	0.060	0.060	0.060	0.060	0.060	0.065	0.085
2313	3	0.050	-	-	0.050	-	-	0.055
2314	2	0.211	-	-	0.255	-	-	0.300
2431	1	-	-	-	0.170	-	-	-
2472	0	-	-	-	-	-	-	-
0101A	1	-	-	-	0.310	-	-	-
0101B	2	0.130	-	-	0.319	-	-	0.508
0101C	1	-	-	-	0.085	-	-	-
0102A	1	-	-	-	0.060	-	-	-
0103A	1	-	-	-	0.190	-	-	-

0103C	1	-	-	-	0.130	-	-	-
0199A	0	-	-	-	-	-	-	-
0201A	1	-	-	-	0.333	-	-	-
0202A	3	0.080	-	-	0.120	-	-	0.147
0202C	1	-	-	-	0.120	-	-	-
0202D	1	-	-	-	0.192	-	-	-
0202E	3	0.150	-	-	0.195	-	-	4.200
0202F	3	0.060	-	-	2.310	-	-	3.500
0202G	1	-	-	-	0.950	-	-	-
0202H	0	-	-	-	-	-	-	-
0202I	0	-	-	-	-	-	-	-
0202J	1	-	-	-	0.280	-	-	-
0202K	0	-	-	-	-	-	-	-
0203A	0	-	-	-	-	-	-	-
0203C	0	-	-	-	-	-	-	-
0203D	0	-	-	-	-	-	-	-
0206B	1	-	-	-	0.060	-	-	-
0207A	0	-	-	-	-	-	-	-
0214A	2	0.130	-	-	0.213	-	-	0.297
0214B	1	-	-	-	1.300	-	-	-
0218A	1	-	-	-	0.040	-	-	-
0222A	1	-	-	-	0.050	-	-	-
0224A	1	-	-	-	0.060	-	-	-
0230A	1	-	-	-	0.220	-	-	-
0299A	2	0.080	-	-	0.089	-	-	0.098
0302A	0	-	-	-	-	-	-	-
0302B	0	-	-	-	-	-	-	-
0302C	1	-	-	-	0.392	-	-	-
0302D	0	-	-	-	-	-	-	-
0302E	0	-	-	-	-	-	-	-
0302F	0	-	-	-	-	-	-	-
0303B	4	0.240	-	0.319	0.445	0.641	-	0.930
0303D	1	-	-	-	1.680	-	-	-
0303E	0	-	-	-	-	-	-	-
0303F	0	-	-	-	-	-	-	-
0303G	0	-	-	-	-	-	-	-
0303H	0	-	-	-	-	-	-	-
0303I	0	-	-	-	-	-	-	-
0303J	0	-	-	-	-	-	-	-
0303K	0	-	-	-	-	-	-	-

0303L	0	-	-	-	-	-	-	-
0304A	0	-	-	-	-	-	-	-
0304B	0	-	-	-	-	-	-	-
0304C	0	-	-	-	-	-	-	-
0304D	0	-	-	-	-	-	-	-
0305A	0	-	-	-	-	-	-	-
0305B	0	-	-	-	-	-	-	-
0305C	0	-	-	-	-	-	-	-
0305D	0	-	-	-	-	-	-	-
0307A	0	-	-	-	-	-	-	-
0307B	0	-	-	-	-	-	-	-
0307C	0	-	-	-	-	-	-	-
0401A	1	-	-	-	0.132	-	-	-
0401B	0	-	-	-	-	-	-	-
0402A	6	0.077	-	0.080	0.090	0.104	-	0.140
0402B	0	-	-	-	-	-	-	-
0402C	0	-	-	-	-	-	-	-
0402D	0	-	-	-	-	-	-	-
0402E	0	-	-	-	-	-	-	-
0404B	0	-	-	-	-	-	-	-
0404C	0	-	-	-	-	-	-	-
0404I	1	-	-	-	0.050	-	-	-
0404J	1	-	-	-	0.090	-	-	-
0404K	1	-	-	-	0.105	-	-	-
0404O	0	-	-	-	-	-	-	-
0404P	0	-	-	-	-	-	-	-
0404Q	0	-	-	-	-	-	-	-
0404R	0	-	-	-	-	-	-	-
0405A	0	-	-	-	-	-	-	-
0405B	0	-	-	-	-	-	-	-
0405C	0	-	-	-	-	-	-	-
0407A	0	-	-	-	-	-	-	-
0407B	1	-	-	-	0.023	-	-	-
0408B	0	-	-	-	-	-	-	-
0408C	0	-	-	-	-	-	-	-
0408D	0	-	-	-	-	-	-	-
0409A	1	-	-	-	0.050	-	-	-
0409B	0	-	-	-	-	-	-	-
0409E	0	-	-	-	-	-	-	-
0501B	0	-	-	-	-	-	-	-

0502A	1	-	-	-	0.079	-	-	-
0502B	0	-	-	-	-	-	-	-
0502D	0	-	-	-	-	-	-	-
0502E	1	-	-	-	0.073	-	-	-
0504C	0	-	-	-	-	-	-	-
0504D	0	-	-	-	-	-	-	-
0505B	1	-	-	-	0.060	-	-	-
0505D	0	-	-	-	-	-	-	-
0505G	1	-	-	-	0.112	-	-	-
0505P	1	-	-	-	0.168	-	-	-
0506A	0	-	-	-	-	-	-	-
0506C	0	-	-	-	-	-	-	-
0507A	2	0.190	-	-	0.218	-	-	0.246
0507B	0	-	-	-	-	-	-	-
0507D	0	-	-	-	-	-	-	-
0507E	0	-	-	-	-	-	-	-
0507F	0	-	-	-	-	-	-	-
0507G	0	-	-	-	-	-	-	-
0507H	0	-	-	-	-	-	-	-
0508A	0	-	-	-	-	-	-	-
0508C	0	-	-	-	-	-	-	-
0511C	0	-	-	-	-	-	-	-
0511E	0	-	-	-	-	-	-	-
0512A	0	-	-	-	-	-	-	-
0602A	0	-	-	-	-	-	-	-
0602B	0	-	-	-	-	-	-	-
0603A	1	-	-	-	0.180	-	-	-
0603B	1	-	-	-	0.060	-	-	-
0604A	2	0.200	-	-	1.750	-	-	3.300
0604B	1	-	-	-	0.245	-	-	-
0604C	1	-	-	-	1.620	-	-	-
0604D	2	0.160	-	-	0.165	-	-	0.170
0604M	1	-	-	-	0.245	-	-	-
0604N	1	-	-	-	0.170	-	-	-
0605A	1	-	-	-	0.300	-	-	-
0605E	0	-	-	-	-	-	-	-
0606A	1	-	-	-	0.080	-	-	-
0606C	0	-	-	-	-	-	-	-
0606D	1	-	-	-	0.090	-	-	-
0607A	1	-	-	-	0.060	-	-	-

0607B	2	0.060	-	-	0.075	-	-	0.090
0607C	1	-	-	-	0.100	-	-	-
0608A	3	0.060	-	-	0.061	-	-	0.064
0608B	2	0.060	-	-	0.060	-	-	0.060
0608C	1	-	-	-	0.071	-	-	-
0608D	1	-	-	-	0.060	-	-	-
0608E	0	-	-	-	-	-	-	-
0608F	2	0.085	-	-	0.130	-	-	0.175
0608J	0	-	-	-	-	-	-	-
0610A	1	-	-	-	0.110	-	-	-
0611A	1	-	-	-	0.070	-	-	-
0611B	3	0.080	-	-	0.085	-	-	1.130
0611C	2	0.150	-	-	0.160	-	-	0.170
0611D	3	0.060	-	-	0.215	-	-	0.450
0612A	1	-	-	-	0.080	-	-	-
0612B	1	-	-	-	0.095	-	-	-
0615A	1	-	-	-	0.290	-	-	-
0702A	1	-	-	-	0.170	-	-	-
0704A	0	-	-	-	-	-	-	-
0801C	0	-	-	-	-	-	-	-
0802B	0	-	-	-	-	-	-	-
0802D	1	-	-	-	0.060	-	-	-
0803A	1	-	-	-	0.960	-	-	-
0803B	1	-	-	-	0.125	-	-	-
0803E	0	-	-	-	-	-	-	-
0803F	0	-	-	-	-	-	-	-
0804F	0	-	-	-	-	-	-	-
0804G	1	-	-	-	0.060	-	-	-
0804H	0	-	-	-	-	-	-	-
0805A	0	-	-	-	-	-	-	-
0805B	0	-	-	-	-	-	-	-
0805D	0	-	-	-	-	-	-	-
0806C	0	-	-	-	-	-	-	-
0806D	0	-	-	-	-	-	-	-
0806E	0	-	-	-	-	-	-	-
0810A	0	-	-	-	-	-	-	-
0810B	0	-	-	-	-	-	-	-
0810C	0	-	-	-	-	-	-	-
0810D	0	-	-	-	-	-	-	-
0814A	0	-	-	-	-	-	-	-

0814B	0	-	-	-	-	-	-	-
0815A	0	-	-	-	-	-	-	-
0816A	0	-	-	-	-	-	-	-
0817A	0	-	-	-	-	-	-	-
0819A	0	-	-	-	-	-	-	-
0819B	0	-	-	-	-	-	-	-
0820B	1	-	-	-	0.190	-	-	-
0820C	1	-	-	-	0.220	-	-	-
0821B	0	-	-	-	-	-	-	-
0821C	1	-	-	-	0.060	-	-	-
0821D	1	-	-	-	0.120	-	-	-
0822A	5	0.060	-	0.070	0.080	0.100	-	0.100
0822B	2	0.060	-	-	0.060	-	-	0.060
0822C	4	0.060	-	0.060	0.060	0.065	-	0.080
0823A	1	-	-	-	0.285	-	-	-
0823B	0	-	-	-	-	-	-	-
0823C	0	-	-	-	-	-	-	-
0823D	1	-	-	-	0.140	-	-	-
0826A	1	-	-	-	0.370	-	-	-
0826C	0	-	-	-	-	-	-	-
0827A	2	0.060	-	-	0.135	-	-	0.210
0828A	0	-	-	-	-	-	-	-
0831A	0	-	-	-	-	-	-	-
0836B	0	-	-	-	-	-	-	-
0836C	0	-	-	-	-	-	-	-
0836D	0	-	-	-	-	-	-	-
0838A	0	-	-	-	-	-	-	-
0838B	1	-	-	-	0.060	-	-	-
0838C	1	-	-	-	0.085	-	-	-
0839A	2	0.029	-	-	0.045	-	-	0.060
0840A	0	-	-	-	-	-	-	-
0841B	8	0.060	0.060	0.060	0.060	0.065	0.067	0.070
0841C	1	-	-	-	0.060	-	-	-
0841D	1	-	-	-	0.060	-	-	-
0841E	1	-	-	-	0.060	-	-	-
0841F	2	0.060	-	-	0.060	-	-	0.060
0841G	1	-	-	-	0.065	-	-	-
0841H	6	0.060	-	0.060	0.060	0.064	-	0.180
0841I	1	-	-	-	0.060	-	-	-
0841J	1	-	-	-	0.080	-	-	-

0841K	2	0.060	-	-	0.060	-	-	0.060
0841L	3	0.060	-	-	0.060	-	-	0.060
0841M	0	-	-	-	-	-	-	-
0841N	1	-	-	-	0.060	-	-	-
0841O	3	0.060	-	-	0.060	-	-	0.075
0841P	2	0.060	-	-	0.060	-	-	0.060
0841Q	1	-	-	-	0.060	-	-	-
0841R	1	-	-	-	0.080	-	-	-
0841T	0	-	-	-	-	-	-	-
0841U	1	-	-	-	0.155	-	-	-
0841V	1	-	-	-	0.100	-	-	-
1002A	1	-	-	-	1.415	-	-	-
1002B	2	0.070	-	-	0.075	-	-	0.080
1004D	0	-	-	-	-	-	-	-
1004E	1	-	-	-	1.380	-	-	-
1006D	8	0.905	1.014	1.060	1.335	1.456	1.741	2.080
1006F	1	-	-	-	0.270	-	-	-
1006H	1	-	-	-	0.235	-	-	-
1006I	2	0.110	-	-	0.130	-	-	0.150
1006J	1	-	-	-	0.545	-	-	-
1007A	1	-	-	-	0.075	-	-	-
1007B	13	0.775	0.862	0.920	0.980	1.095	1.190	1.765
1007C	2	1.505	-	-	1.748	-	-	1.990
1007D	8	0.060	0.533	0.784	0.838	0.960	1.310	1.495
1007E	1	-	-	-	0.060	-	-	-
1007F	1	-	-	-	1.920	-	-	-
1007G	1	-	-	-	0.100	-	-	-
1007H	1	-	-	-	0.200	-	-	-
1007I	1	-	-	-	0.210	-	-	-
1007K	2	0.110	-	-	0.120	-	-	0.130
1007L	1	-	-	-	0.340	-	-	-
1007N	1	-	-	-	0.130	-	-	-
1007O	1	-	-	-	0.150	-	-	-
1007Q	0	-	-	-	-	-	-	-
1007R	4	0.105	-	0.124	0.155	0.193	-	0.230
1008B	4	0.135	-	1.234	1.700	2.171	-	3.285
1008C	2	0.180	-	-	0.330	-	-	0.480
1008E	1	-	-	-	0.200	-	-	-
1008H	1	-	-	-	1.200	-	-	-
1008J	1	-	-	-	0.140	-	-	-

1009C	1	-	-	-	1.630	-	-	-
1009D	1	-	-	-	1.980	-	-	-
1009E	2	0.560	-	-	1.025	-	-	1.490
1010C	1	-	-	-	0.165	-	-	-
1013A	1	-	-	-	0.155	-	-	-
1013C	1	-	-	-	0.150	-	-	-
1014A	1	-	-	-	1.920	-	-	-
1014B	1	-	-	-	2.290	-	-	-
1014C	1	-	-	-	2.950	-	-	-
1014E	1	-	-	-	2.300	-	-	-
1014H	2	1.770	-	-	1.950	-	-	2.130
1014K	2	0.340	-	-	0.355	-	-	0.370
1014L	1	-	-	-	3.100	-	-	-
1014M	1	-	-	-	0.167	-	-	-
1014N	1	-	-	-	0.130	-	-	-
1014O	1	-	-	-	0.090	-	-	-
1015A	1	-	-	-	0.160	-	-	-
1015B	0	-	-	-	-	-	-	-
1016A	2	1.600	-	-	1.830	-	-	2.060
1016B	1	-	-	-	0.130	-	-	-
1016C	1	-	-	-	0.775	-	-	-
1016D	1	-	-	-	0.320	-	-	-
1017A	1	-	-	-	0.330	-	-	-
1017B	1	-	-	-	0.440	-	-	-
1017C	1	-	-	-	0.980	-	-	-
1017D	1	-	-	-	0.145	-	-	-
1017E	1	-	-	-	0.100	-	-	-
1017F	1	-	-	-	3.280	-	-	-
1101B	1	-	-	-	0.130	-	-	-
1101F	1	-	-	-	0.080	-	-	-
1102A	2	0.150	-	-	0.180	-	-	0.210
1102B	8	0.215	0.247	0.268	0.775	0.858	0.952	0.980
1102C	1	-	-	-	0.150	-	-	-
1102D	0	-	-	-	-	-	-	-
1102E	0	-	-	-	-	-	-	-
1102F	2	0.640	-	-	0.695	-	-	0.750
1103F	0	-	-	-	-	-	-	-
1104A	0	-	-	-	-	-	-	-
1105A	1	-	-	-	0.195	-	-	-
1105B	1	-	-	-	0.130	-	-	-

1105C	1	-	-	-	0.205	-	-	-
1105D	0	-	-	-	-	-	-	-
1113A	1	-	-	-	0.090	-	-	-
1202H	1	-	-	-	0.780	-	-	-
1202J	2	0.290	-	-	1.000	-	-	1.710
1202K	1	-	-	-	0.090	-	-	-
1202P	1	-	-	-	0.272	-	-	-
1204A	1	-	-	-	0.055	-	-	-
1205B	0	-	-	-	-	-	-	-
1205C	0	-	-	-	-	-	-	-
1205D	0	-	-	-	-	-	-	-
1205E	0	-	-	-	-	-	-	-
1205F	0	-	-	-	-	-	-	-
1205G	0	-	-	-	-	-	-	-
1205H	0	-	-	-	-	-	-	-
1206D	0	-	-	-	-	-	-	-
1209C	2	1.850	-	-	2.245	-	-	2.640
1209D	1	-	-	-	0.230	-	-	-
1209E	0	-	-	-	-	-	-	-
1209G	0	-	-	-	-	-	-	-
1209H	1	-	-	-	0.078	-	-	-
1209I	3	0.065	-	-	0.090	-	-	0.172
1209J	0	-	-	-	-	-	-	-
1209K	0	-	-	-	-	-	-	-
1209L	0	-	-	-	-	-	-	-
1209P	0	-	-	-	-	-	-	-
1210A	0	-	-	-	-	-	-	-
1211A	1	-	-	-	0.093	-	-	-
1212A	0	-	-	-	-	-	-	-
1212B	1	-	-	-	0.080	-	-	-
1213A	1	-	-	-	0.105	-	-	-
1213B	0	-	-	-	-	-	-	-
1213C	0	-	-	-	-	-	-	-
1216A	1	-	-	-	0.055	-	-	-
1216B	0	-	-	-	-	-	-	-
1217A	1	-	-	-	0.060	-	-	-
1217B	7	0.060	0.060	0.060	0.060	0.080	0.112	0.160
1217E	0	-	-	-	-	-	-	-
1217F	0	-	-	-	-	-	-	-
1218B	0	-	-	-	-	-	-	-

1220A	0	-	-	-	-	-	-	-
1221A	3	0.075	-	-	0.120	-	-	0.120
1221B	1	-	-	-	0.060	-	-	-
1221C	0	-	-	-	-	-	-	-
1221D	1	-	-	-	0.220	-	-	-
1221E	0	-	-	-	-	-	-	-
1221F	1	-	-	-	0.060	-	-	-
1222A	1	-	-	-	0.120	-	-	-
1222B	0	-	-	-	-	-	-	-
1222C	1	-	-	-	0.060	-	-	-
1222D	0	-	-	-	-	-	-	-
1222E	0	-	-	-	-	-	-	-
1222F	0	-	-	-	-	-	-	-
1223A	0	-	-	-	-	-	-	-
1223B	0	-	-	-	-	-	-	-
1225A	1	-	-	-	0.070	-	-	-
1226A	2	0.060	-	-	0.071	-	-	0.082
1226B	3	0.080	-	-	0.099	-	-	0.125
1226C	2	0.050	-	-	0.055	-	-	0.060
1226D	1	-	-	-	0.060	-	-	-
1226E	1	-	-	-	0.323	-	-	-
1226F	1	-	-	-	0.110	-	-	-
1226G	1	-	-	-	0.060	-	-	-
1226H	1	-	-	-	0.255	-	-	-
1226I	1	-	-	-	0.089	-	-	-
1226J	1	-	-	-	0.065	-	-	-
1226K	1	-	-	-	0.537	-	-	-
1226L	0	-	-	-	-	-	-	-
1226M	1	-	-	-	0.119	-	-	-
1226Q	0	-	-	-	-	-	-	-
1227A	1	-	-	-	1.960	-	-	-
1232A	1	-	-	-	0.125	-	-	-
1232B	2	1.980	-	-	2.478	-	-	2.975
1232C	1	-	-	-	0.060	-	-	-
1233A	0	-	-	-	-	-	-	-
1233B	0	-	-	-	-	-	-	-
1236A	0	-	-	-	-	-	-	-
1238A	0	-	-	-	-	-	-	-
1240A	0	-	-	-	-	-	-	-
1241A	3	0.145	-	-	0.230	-	-	1.130

1241D	0	-	-	-	-	-	-	-
1242B	1	-	-	-	7.430	-	-	-
1242C	1	-	-	-	1.790	-	-	-
1242D	2	0.209	-	-	1.935	-	-	3.660
1242E	0	-	-	-	-	-	-	-
1242F	0	-	-	-	-	-	-	-
1242I	0	-	-	-	-	-	-	-
1242J	0	-	-	-	-	-	-	-
1242K	0	-	-	-	-	-	-	-
1242L	0	-	-	-	-	-	-	-
1242M	0	-	-	-	-	-	-	-
1242N	1	-	-	-	0.880	-	-	-
1242O	0	-	-	-	-	-	-	-
1242P	0	-	-	-	-	-	-	-
1242Q	0	-	-	-	-	-	-	-
1244A	1	-	-	-	0.060	-	-	-
1244B	0	-	-	-	-	-	-	-
1244D	0	-	-	-	-	-	-	-
1245B	0	-	-	-	-	-	-	-
1245C	0	-	-	-	-	-	-	-
1245D	0	-	-	-	-	-	-	-
1245I	0	-	-	-	-	-	-	-
1246C	0	-	-	-	-	-	-	-
1246D	1	-	-	-	0.064	-	-	-
1246E	2	0.060	-	-	0.065	-	-	0.070
1247A	2	0.050	-	-	0.055	-	-	0.060
1248A	1	-	-	-	0.050	-	-	-
1248B	1	-	-	-	0.050	-	-	-
1248C	2	1.330	-	-	1.428	-	-	1.525
1248D	1	-	-	-	0.060	-	-	-
1254A	0	-	-	-	-	-	-	-
1254B	0	-	-	-	-	-	-	-
1255A	1	-	-	-	0.859	-	-	-
1255B	1	-	-	-	0.491	-	-	-
1255C	1	-	-	-	1.135	-	-	-
1255D	1	-	-	-	0.280	-	-	-
1255E	0	-	-	-	-	-	-	-
1255F	1	-	-	-	0.264	-	-	-
1255I	1	-	-	-	0.617	-	-	-
1256A	0	-	-	-	-	-	-	-

1302A	1	-	-	-	0.208	-	-	-
1302B	2	0.190	-	-	0.190	-	-	0.191
1302C	0	-	-	-	-	-	-	-
1402A	2	0.060	-	-	0.060	-	-	0.060
1402C	1	-	-	-	0.165	-	-	-
1402H	1	-	-	-	0.125	-	-	-
1403A	3	0.020	-	-	0.020	-	-	0.060
1403B	1	-	-	-	0.020	-	-	-
1403E	0	-	-	-	-	-	-	-
1403F	0	-	-	-	-	-	-	-
1403H	2	0.020	-	-	0.020	-	-	0.020
1403I	0	-	-	-	-	-	-	-
1403J	1	-	-	-	0.060	-	-	-
1403K	1	-	-	-	0.060	-	-	-
1403L	0	-	-	-	-	-	-	-
1403M	0	-	-	-	-	-	-	-
1403N	0	-	-	-	-	-	-	-
1403O	0	-	-	-	-	-	-	-
1403P	0	-	-	-	-	-	-	-
1403Q	0	-	-	-	-	-	-	-
1403R	1	-	-	-	0.080	-	-	-
1404A	1	-	-	-	0.060	-	-	-
1404B	1	-	-	-	0.050	-	-	-
1404C	0	-	-	-	-	-	-	-
1404D	0	-	-	-	-	-	-	-
1406A	1	-	-	-	0.060	-	-	-
1407A	1	-	-	-	0.060	-	-	-
1409A	1	-	-	-	0.060	-	-	-
1412B	3	0.070	-	-	1.125	-	-	2.230
1412C	0	-	-	-	-	-	-	-
1414A	0	-	-	-	-	-	-	-
1414B	1	-	-	-	0.050	-	-	-
1414D	0	-	-	-	-	-	-	-
1415A	1	-	-	-	0.060	-	-	-
1415C	1	-	-	-	0.060	-	-	-
1416A	2	0.131	-	-	1.013	-	-	1.895
1416B	0	-	-	-	-	-	-	-
1416C	0	-	-	-	-	-	-	-
1418B	0	-	-	-	-	-	-	-
1421A	1	-	-	-	0.060	-	-	-

1421B	1	-	-	-	0.060	-	-	-
1421C	1	-	-	-	0.060	-	-	-
1423A	2	0.060	-	-	0.060	-	-	0.060
1423B	1	-	-	-	0.060	-	-	-
1424A	1	-	-	-	0.060	-	-	-
1424B	1	-	-	-	0.060	-	-	-
1425A	3	0.060	-	-	0.060	-	-	0.075
1426B	2	0.060	-	-	0.060	-	-	0.060
1426C	1	-	-	-	0.060	-	-	-
1426D	1	-	-	-	0.060	-	-	-
1427A	1	-	-	-	0.060	-	-	-
1427B	0	-	-	-	-	-	-	-
1427C	1	-	-	-	0.060	-	-	-
1427E	0	-	-	-	-	-	-	-
1427F	0	-	-	-	-	-	-	-
1427G	0	-	-	-	-	-	-	-
1428A	0	-	-	-	-	-	-	-
1428B	0	-	-	-	-	-	-	-
1428C	2	0.187	-	-	0.259	-	-	0.330
1428D	0	-	-	-	-	-	-	-
1428E	0	-	-	-	-	-	-	-
1428F	0	-	-	-	-	-	-	-
1428I	0	-	-	-	-	-	-	-
1428J	0	-	-	-	-	-	-	-
1429A	0	-	-	-	-	-	-	-
1429B	0	-	-	-	-	-	-	-
1429C	3	0.090	-	-	0.140	-	-	0.165
1429D	0	-	-	-	-	-	-	-
1429E	0	-	-	-	-	-	-	-
1429F	0	-	-	-	-	-	-	-
1429G	0	-	-	-	-	-	-	-
1429H	0	-	-	-	-	-	-	-
1430B	1	-	-	-	0.030	-	-	-
1434B	1	-	-	-	0.060	-	-	-
1601C	0	-	-	-	-	-	-	-
1602B	1	-	-	-	0.220	-	-	-
1604A	1	-	-	-	0.300	-	-	-
1604B	1	-	-	-	0.310	-	-	-
1604C	1	-	-	-	0.170	-	-	-
1803A	0	-	-	-	-	-	-	-

1803B	1	-	-	-	0.410	-	-	-
1803C	1	-	-	-	0.260	-	-	-
1804A	3	0.050	-	-	0.050	-	-	0.390
1806A	1	-	-	-	0.039	-	-	-
1806D	0	-	-	-	-	-	-	-
1806E	0	-	-	-	-	-	-	-
1806G	1	-	-	-	0.007	-	-	-
1806H	0	-	-	-	-	-	-	-
1807A	0	-	-	-	-	-	-	-
1811A	1	-	-	-	0.050	-	-	-
1813A	0	-	-	-	-	-	-	-
1813B	0	-	-	-	-	-	-	-
1813C	0	-	-	-	-	-	-	-
1813D	0	-	-	-	-	-	-	-
1813E	0	-	-	-	-	-	-	-
1813F	0	-	-	-	-	-	-	-
1813G	0	-	-	-	-	-	-	-
1813H	0	-	-	-	-	-	-	-
1813I	0	-	-	-	-	-	-	-
1901A	0	-	-	-	-	-	-	-
1901B	0	-	-	-	-	-	-	-
1901C	0	-	-	-	-	-	-	-
1901D	0	-	-	-	-	-	-	-
1902A	0	-	-	-	-	-	-	-
1902B	0	-	-	-	-	-	-	-
1905A	1	-	-	-	0.020	-	-	-
1906A	0	-	-	-	-	-	-	-
1910A	0	-	-	-	-	-	-	-
1910B	0	-	-	-	-	-	-	-
1910C	0	-	-	-	-	-	-	-
1910D	0	-	-	-	-	-	-	-
1910E	0	-	-	-	-	-	-	-
1911B	2	0.060	-	-	0.069	-	-	0.078
1911C	3	0.060	-	-	0.060	-	-	0.112
1911D	2	0.060	-	-	0.062	-	-	0.063
1911E	0	-	-	-	-	-	-	-
1911H	0	-	-	-	-	-	-	-
1912A	1	-	-	-	2.205	-	-	-
2004A	0	-	-	-	-	-	-	-
2004B	0	-	-	-	-	-	-	-

2302A	1	-	-	-	0.150	-	-	-
2304B	1	-	-	-	0.223	-	-	-
2306A	1	-	-	-	0.180	-	-	-
2309A	1	-	-	-	0.060	-	-	-
2310A	1	-	-	-	0.050	-	-	-
2422B	0	-	-	-	-	-	-	-
2424A	0	-	-	-	-	-	-	-
2424D	0	-	-	-	-	-	-	-
2424E	1	-	-	-	0.130	-	-	-
2431A	1	-	-	-	0.100	-	-	-
2432A	0	-	-	-	-	-	-	-
2432B	2	0.100	-	-	0.120	-	-	0.140
2485B	1	-	-	-	0.635	-	-	-
2485D	1	-	-	-	0.660	-	-	-
2492A	0	-	-	-	-	-	-	-

Total Nitrogen (TN; mg/L)

Segment	n	MIN	10th	25th	Median	75th	90th	MAX
0101	3	0.48	-	-	1.26	-	-	1.86
0103	3	0.40	-	-	0.53	-	-	0.71
0104	0	-	-	-	-	-	-	-
0201	1	-	-	-	1.15	-	-	-
0202	3	0.81	-	-	0.81	-	-	0.93
0204	1	-	-	-	1.55	-	-	-
0205	1	-	-	-	1.49	-	-	-
0206	1	-	-	-	1.43	-	-	-
0207	0	-	-	-	-	-	-	-
0211	1	-	-	-	1.53	-	-	-
0214	5	1.20	-	1.35	1.37	3.22	-	5.28
0216	0	-	-	-	-	-	-	-
0218	1	-	-	-	0.72	-	-	-
0220	1	-	-	-	0.79	-	-	-
0221	0	-	-	-	-	-	-	-
0222	0	-	-	-	-	-	-	-
0224	0	-	-	-	-	-	-	-
0226	0	-	-	-	-	-	-	-
0227	0	-	-	-	-	-	-	-
0229	2	5.11	-	-	5.64	-	-	6.18
0230	1	-	-	-	1.66	-	-	-

0301	2	1.21	-	-	1.21	-	-	1.22
0303	3	0.89	-	-	0.91	-	-	1.05
0304	1	-	-	-	9.42	-	-	-
0305	1	-	-	-	0.94	-	-	-
0306	2	0.85	-	-	3.71	-	-	6.57
0401	1	-	-	-	0.84	-	-	-
0402	4	0.63	-	0.64	0.68	0.71	-	0.71
0404	2	1.25	-	-	3.86	-	-	6.46
0406	3	0.93	-	-	0.93	-	-	0.98
0407	2	0.63	-	-	0.65	-	-	0.67
0409	5	0.72	-	1.03	1.08	1.20	-	1.23
0501	1	-	-	-	0.80	-	-	-
0502	2	0.88	-	-	0.98	-	-	1.09
0503	5	0.82	-	0.84	0.98	1.04	-	1.60
0504	0	-	-	-	-	-	-	-
0505	5	1.22	-	1.24	1.57	1.60	-	1.64
0506	3	1.20	-	-	1.21	-	-	1.32
0513	1	-	-	-	0.85	-	-	-
0514	3	0.78	-	-	1.07	-	-	1.24
0515	1	-	-	-	1.01	-	-	-
0602	1	-	-	-	0.65	-	-	-
0604	6	0.80	-	0.81	0.83	0.91	-	0.98
0606	0	-	-	-	-	-	-	-
0607	0	-	-	-	-	-	-	-
0608	1	-	-	-	0.56	-	-	-
0609	0	-	-	-	-	-	-	-
0610	0	-	-	-	-	-	-	-
0611	3	0.81	-	-	0.86	-	-	0.96
0612	0	-	-	-	-	-	-	-
0701	1	-	-	-	1.24	-	-	-
0704	1	-	-	-	1.63	-	-	-
0801	0	-	-	-	-	-	-	-
0802	2	0.99	-	-	1.03	-	-	1.07
0803	0	-	-	-	-	-	-	-
0804	4	4.04	-	5.55	6.10	6.62	-	8.03
0805	4	7.52	-	7.54	7.71	8.14	-	8.94
0806	3	1.14	-	-	1.18	-	-	1.21
0809	0	-	-	-	-	-	-	-
0810	1	-	-	-	1.22	-	-	-
0812	1	-	-	-	1.43	-	-	-

0814	1	-	-	-	1.72	-	-	-
0815	0	-	-	-	-	-	-	-
0817	0	-	-	-	-	-	-	-
0818	0	-	-	-	-	-	-	-
0819	3	3.40	-	-	8.99	-	-	12.68
0821	0	-	-	-	-	-	-	-
0822	4	1.21	-	1.24	1.27	1.37	-	1.61
0824	1	-	-	-	1.89	-	-	-
0825	1	-	-	-	1.61	-	-	-
0829	1	-	-	-	0.88	-	-	-
0830	0	-	-	-	-	-	-	-
0831	0	-	-	-	-	-	-	-
0833	0	-	-	-	-	-	-	-
0835	0	-	-	-	-	-	-	-
0836	0	-	-	-	-	-	-	-
0837	0	-	-	-	-	-	-	-
0838	0	-	-	-	-	-	-	-
0839	0	-	-	-	-	-	-	-
0840	0	-	-	-	-	-	-	-
0841	3	10.02	-	-	11.86	-	-	13.70
0902	1	-	-	-	1.32	-	-	-
1002	0	-	-	-	-	-	-	-
1003	1	-	-	-	0.62	-	-	-
1004	1	-	-	-	1.20	-	-	-
1006	0	-	-	-	-	-	-	-
1007	0	-	-	-	-	-	-	-
1008	0	-	-	-	-	-	-	-
1009	2	2.89	-	-	4.45	-	-	6.01
1010	1	-	-	-	0.90	-	-	-
1011	1	-	-	-	0.77	-	-	-
1013	0	-	-	-	-	-	-	-
1014	2	4.54	-	-	5.23	-	-	5.91
1015	0	-	-	-	-	-	-	-
1016	2	5.68	-	-	5.97	-	-	6.26
1017	2	5.28	-	-	5.45	-	-	5.62
1101	0	-	-	-	-	-	-	-
1102	2	1.54	-	-	2.49	-	-	3.44
1103	0	-	-	-	-	-	-	-
1104	1	-	-	-	0.59	-	-	-
1105	0	-	-	-	-	-	-	-

1108	1	-	-	-	0.94	-	-	-
1110	1	-	-	-	1.71	-	-	-
1201	0	-	-	-	-	-	-	-
1202	0	-	-	-	-	-	-	-
1204	1	-	-	-	1.94	-	-	-
1205	0	-	-	-	-	-	-	-
1206	0	-	-	-	-	-	-	-
1208	2	1.37	-	-	1.61	-	-	1.85
1209	0	-	-	-	-	-	-	-
1211	1	-	-	-	1.25	-	-	-
1213	3	2.57	-	-	2.70	-	-	3.33
1214	1	-	-	-	4.13	-	-	-
1215	1	-	-	-	1.14	-	-	-
1217	0	-	-	-	-	-	-	-
1218	1	-	-	-	5.42	-	-	-
1219	1	-	-	-	2.34	-	-	-
1220	0	-	-	-	-	-	-	-
1221	3	0.84	-	-	1.16	-	-	1.64
1223	1	-	-	-	1.00	-	-	-
1226	5	0.80	-	0.99	1.03	1.18	-	1.46
1227	2	2.74	-	-	4.10	-	-	5.45
1229	0	-	-	-	-	-	-	-
1232	5	1.20	-	1.39	1.41	1.45	-	5.14
1236	0	-	-	-	-	-	-	-
1238	1	-	-	-	0.46	-	-	-
1239	0	-	-	-	-	-	-	-
1241	1	-	-	-	0.62	-	-	-
1242	1	-	-	-	1.82	-	-	-
1243	1	-	-	-	2.99	-	-	-
1244	1	-	-	-	7.35	-	-	-
1245	1	-	-	-	1.38	-	-	-
1246	3	2.13	-	-	3.73	-	-	5.74
1248	1	-	-	-	1.89	-	-	-
1250	3	0.37	-	-	0.58	-	-	0.74
1251	1	-	-	-	0.43	-	-	-
1253	1	-	-	-	1.25	-	-	-
1255	1	-	-	-	2.33	-	-	-
1256	2	0.80	-	-	0.88	-	-	0.97
1257	1	-	-	-	0.75	-	-	-
1301	0	-	-	-	-	-	-	-

1302	5	1.26	-	1.28	1.37	1.43	-	1.51
1305	1	-	-	-	1.12	-	-	-
1402	6	1.71	-	1.79	1.90	1.95	-	2.34
1403	0	-	-	-	-	-	-	-
1406	0	-	-	-	-	-	-	-
1409	1	-	-	-	0.77	-	-	-
1410	2	0.86	-	-	0.88	-	-	0.89
1412	1	-	-	-	1.46	-	-	-
1414	5	0.43	-	0.88	0.91	1.04	-	1.10
1415	8	0.26	0.29	0.30	0.32	0.59	0.76	1.11
1416	2	0.35	-	-	0.60	-	-	0.84
1417	1	-	-	-	1.20	-	-	-
1420	2	0.92	-	-	0.95	-	-	0.99
1421	3	1.36	-	-	1.97	-	-	2.90
1424	1	-	-	-	1.45	-	-	-
1426	1	-	-	-	1.37	-	-	-
1427	4	0.31	-	0.52	0.60	0.61	-	0.62
1428	4	0.58	-	0.62	1.03	1.76	-	2.74
1430	4	0.27	-	0.29	0.30	0.33	-	0.40
1431	1	-	-	-	9.77	-	-	-
1432	1	-	-	-	0.83	-	-	-
1434	2	2.32	-	-	2.47	-	-	2.62
1501	0	-	-	-	-	-	-	-
1502	1	-	-	-	1.44	-	-	-
1602	0	-	-	-	-	-	-	-
1605	0	-	-	-	-	-	-	-
1801	0	-	-	-	-	-	-	-
1802	0	-	-	-	-	-	-	-
1803	0	-	-	-	-	-	-	-
1804	5	1.20	-	1.38	1.64	1.65	-	1.66
1806	1	-	-	-	1.08	-	-	-
1807	1	-	-	-	0.55	-	-	-
1808	1	-	-	-	1.73	-	-	-
1809	1	-	-	-	0.49	-	-	-
1810	1	-	-	-	7.47	-	-	-
1811	1	-	-	-	1.98	-	-	-
1812	5	0.50	-	0.52	0.66	0.70	-	0.75
1813	0	-	-	-	-	-	-	-
1814	0	-	-	-	-	-	-	-
1815	0	-	-	-	-	-	-	-

1816	0	-	-	-	-	-	-	-
1817	0	-	-	-	-	-	-	-
1818	0	-	-	-	-	-	-	-
1901	9	5.36	6.66	7.09	7.23	9.03	9.61	9.95
1902	5	1.72	-	1.88	1.98	2.65	-	3.08
1903	6	0.53	-	2.84	3.73	5.45	-	9.00
1905	1	-	-	-	0.60	-	-	-
1906	3	1.16	-	-	1.33	-	-	1.57
1907	1	-	-	-	1.18	-	-	-
1908	1	-	-	-	1.02	-	-	-
1910	8	0.83	0.94	1.09	1.28	1.64	1.75	1.93
1911	21	1.94	2.07	2.40	4.13	8.85	9.50	10.40
1912	1	-	-	-	3.17	-	-	-
1913	2	1.63	-	-	4.62	-	-	7.62
2002	0	-	-	-	-	-	-	-
2003	0	-	-	-	-	-	-	-
2004	0	-	-	-	-	-	-	-
2102	0	-	-	-	-	-	-	-
2103	0	-	-	-	-	-	-	-
2104	0	-	-	-	-	-	-	-
2105	2	0.91	-	-	1.03	-	-	1.14
2106	0	-	-	-	-	-	-	-
2107	1	-	-	-	1.14	-	-	-
2108	0	-	-	-	-	-	-	-
2109	3	2.87	-	-	3.63	-	-	8.01
2110	1	-	-	-	7.06	-	-	-
2111	1	-	-	-	0.55	-	-	-
2112	2	0.89	-	-	1.08	-	-	1.26
2113	2	0.66	-	-	0.75	-	-	0.84
2114	2	0.46	-	-	3.59	-	-	6.72
2115	1	-	-	-	0.46	-	-	-
2117	2	5.93	-	-	11.11	-	-	16.30
2202	3	5.09	-	-	6.64	-	-	8.06
2204	2	1.49	-	-	1.72	-	-	1.95
2301	0	-	-	-	-	-	-	-
2302	7	0.86	0.87	0.95	1.37	1.56	2.06	2.67
2304	7	0.56	0.60	0.71	0.97	1.01	1.25	1.58
2305	0	-	-	-	-	-	-	-
2306	4	0.77	-	1.07	1.23	1.38	-	1.67
2307	5	1.75	-	2.47	2.96	3.57	-	3.68

2308	3	2.83	-	-	2.86	-	-	3.25
2309	2	1.47	-	-	1.52	-	-	1.58
2310	2	0.94	-	-	0.99	-	-	1.04
2311	8	0.87	0.91	0.96	1.02	1.13	1.25	1.30
2313	3	1.81	-	-	1.84	-	-	1.86
2314	2	1.21	-	-	1.63	-	-	2.06
2431	0	-	-	-	-	-	-	-
2472	0	-	-	-	-	-	-	-
0101A	1	-	-	-	4.19	-	-	-
0101B	0	-	-	-	-	-	-	-
0101C	0	-	-	-	-	-	-	-
0102A	0	-	-	-	-	-	-	-
0103A	0	-	-	-	-	-	-	-
0103C	0	-	-	-	-	-	-	-
0199A	0	-	-	-	-	-	-	-
0201A	0	-	-	-	-	-	-	-
0202A	0	-	-	-	-	-	-	-
0202C	0	-	-	-	-	-	-	-
0202D	0	-	-	-	-	-	-	-
0202E	0	-	-	-	-	-	-	-
0202F	0	-	-	-	-	-	-	-
0202G	0	-	-	-	-	-	-	-
0202H	0	-	-	-	-	-	-	-
0202I	0	-	-	-	-	-	-	-
0202J	0	-	-	-	-	-	-	-
0202K	0	-	-	-	-	-	-	-
0203A	0	-	-	-	-	-	-	-
0203C	0	-	-	-	-	-	-	-
0203D	0	-	-	-	-	-	-	-
0206B	1	-	-	-	3.83	-	-	-
0207A	0	-	-	-	-	-	-	-
0214A	1	-	-	-	1.08	-	-	-
0214B	0	-	-	-	-	-	-	-
0218A	0	-	-	-	-	-	-	-
0222A	1	-	-	-	0.98	-	-	-
0224A	0	-	-	-	-	-	-	-
0230A	0	-	-	-	-	-	-	-
0299A	0	-	-	-	-	-	-	-
0302A	0	-	-	-	-	-	-	-
0302B	0	-	-	-	-	-	-	-

0302C	1	-	-	-	1.14	-	-	-
0302D	0	-	-	-	-	-	-	-
0302E	0	-	-	-	-	-	-	-
0302F	0	-	-	-	-	-	-	-
0303B	4	1.06	-	1.20	1.45	2.08	-	3.34
0303D	1	-	-	-	10.95	-	-	-
0303E	0	-	-	-	-	-	-	-
0303F	0	-	-	-	-	-	-	-
0303G	0	-	-	-	-	-	-	-
0303H	0	-	-	-	-	-	-	-
0303I	0	-	-	-	-	-	-	-
0303J	0	-	-	-	-	-	-	-
0303K	0	-	-	-	-	-	-	-
0303L	0	-	-	-	-	-	-	-
0304A	0	-	-	-	-	-	-	-
0304B	0	-	-	-	-	-	-	-
0304C	0	-	-	-	-	-	-	-
0304D	0	-	-	-	-	-	-	-
0305A	0	-	-	-	-	-	-	-
0305B	0	-	-	-	-	-	-	-
0305C	0	-	-	-	-	-	-	-
0305D	0	-	-	-	-	-	-	-
0307A	0	-	-	-	-	-	-	-
0307B	0	-	-	-	-	-	-	-
0307C	0	-	-	-	-	-	-	-
0401A	0	-	-	-	-	-	-	-
0401B	0	-	-	-	-	-	-	-
0402A	5	0.73	-	0.73	0.77	0.83	-	0.95
0402B	0	-	-	-	-	-	-	-
0402C	0	-	-	-	-	-	-	-
0402D	0	-	-	-	-	-	-	-
0402E	0	-	-	-	-	-	-	-
0404B	0	-	-	-	-	-	-	-
0404C	0	-	-	-	-	-	-	-
0404I	1	-	-	-	0.90	-	-	-
0404J	1	-	-	-	1.15	-	-	-
0404K	1	-	-	-	1.04	-	-	-
0404O	0	-	-	-	-	-	-	-
0404P	0	-	-	-	-	-	-	-
0404Q	0	-	-	-	-	-	-	-

0404R	0	-	-	-	-	-	-	-
0405A	0	-	-	-	-	-	-	-
0405B	0	-	-	-	-	-	-	-
0405C	0	-	-	-	-	-	-	-
0407A	0	-	-	-	-	-	-	-
0407B	1	-	-	-	0.59	-	-	-
0408B	0	-	-	-	-	-	-	-
0408C	0	-	-	-	-	-	-	-
0408D	0	-	-	-	-	-	-	-
0409A	1	-	-	-	1.08	-	-	-
0409B	0	-	-	-	-	-	-	-
0409E	0	-	-	-	-	-	-	-
0501B	0	-	-	-	-	-	-	-
0502A	0	-	-	-	-	-	-	-
0502B	0	-	-	-	-	-	-	-
0502D	0	-	-	-	-	-	-	-
0502E	0	-	-	-	-	-	-	-
0504C	0	-	-	-	-	-	-	-
0504D	0	-	-	-	-	-	-	-
0505B	0	-	-	-	-	-	-	-
0505D	0	-	-	-	-	-	-	-
0505G	0	-	-	-	-	-	-	-
0505P	0	-	-	-	-	-	-	-
0506A	0	-	-	-	-	-	-	-
0506C	0	-	-	-	-	-	-	-
0507A	1	-	-	-	1.44	-	-	-
0507B	0	-	-	-	-	-	-	-
0507D	0	-	-	-	-	-	-	-
0507E	0	-	-	-	-	-	-	-
0507F	0	-	-	-	-	-	-	-
0507G	0	-	-	-	-	-	-	-
0507H	0	-	-	-	-	-	-	-
0508A	0	-	-	-	-	-	-	-
0508C	0	-	-	-	-	-	-	-
0511C	0	-	-	-	-	-	-	-
0511E	0	-	-	-	-	-	-	-
0512A	0	-	-	-	-	-	-	-
0602A	0	-	-	-	-	-	-	-
0602B	0	-	-	-	-	-	-	-
0603A	0	-	-	-	-	-	-	-

0603B	0	-	-	-	-	-	-	-
0604A	0	-	-	-	-	-	-	-
0604B	0	-	-	-	-	-	-	-
0604C	0	-	-	-	-	-	-	-
0604D	0	-	-	-	-	-	-	-
0604M	0	-	-	-	-	-	-	-
0604N	0	-	-	-	-	-	-	-
0605A	0	-	-	-	-	-	-	-
0605E	0	-	-	-	-	-	-	-
0606A	0	-	-	-	-	-	-	-
0606C	0	-	-	-	-	-	-	-
0606D	0	-	-	-	-	-	-	-
0607A	0	-	-	-	-	-	-	-
0607B	0	-	-	-	-	-	-	-
0607C	0	-	-	-	-	-	-	-
0608A	0	-	-	-	-	-	-	-
0608B	0	-	-	-	-	-	-	-
0608C	0	-	-	-	-	-	-	-
0608D	0	-	-	-	-	-	-	-
0608E	0	-	-	-	-	-	-	-
0608F	0	-	-	-	-	-	-	-
0608J	0	-	-	-	-	-	-	-
0610A	0	-	-	-	-	-	-	-
0611A	1	-	-	-	0.64	-	-	-
0611B	0	-	-	-	-	-	-	-
0611C	0	-	-	-	-	-	-	-
0611D	0	-	-	-	-	-	-	-
0612A	0	-	-	-	-	-	-	-
0612B	0	-	-	-	-	-	-	-
0615A	1	-	-	-	1.24	-	-	-
0702A	1	-	-	-	2.23	-	-	-
0704A	0	-	-	-	-	-	-	-
0801C	0	-	-	-	-	-	-	-
0802B	0	-	-	-	-	-	-	-
0802D	0	-	-	-	-	-	-	-
0803A	0	-	-	-	-	-	-	-
0803B	0	-	-	-	-	-	-	-
0803E	0	-	-	-	-	-	-	-
0803F	0	-	-	-	-	-	-	-
0804F	0	-	-	-	-	-	-	-

0804G	1	-	-	-	0.70	-	-	-
0804H	0	-	-	-	-	-	-	-
0805A	0	-	-	-	-	-	-	-
0805B	0	-	-	-	-	-	-	-
0805D	0	-	-	-	-	-	-	-
0806C	0	-	-	-	-	-	-	-
0806D	0	-	-	-	-	-	-	-
0806E	0	-	-	-	-	-	-	-
0810A	0	-	-	-	-	-	-	-
0810B	0	-	-	-	-	-	-	-
0810C	0	-	-	-	-	-	-	-
0810D	0	-	-	-	-	-	-	-
0814A	0	-	-	-	-	-	-	-
0814B	0	-	-	-	-	-	-	-
0815A	0	-	-	-	-	-	-	-
0816A	0	-	-	-	-	-	-	-
0817A	0	-	-	-	-	-	-	-
0819A	0	-	-	-	-	-	-	-
0819B	0	-	-	-	-	-	-	-
0820B	1	-	-	-	4.29	-	-	-
0820C	0	-	-	-	-	-	-	-
0821B	0	-	-	-	-	-	-	-
0821C	1	-	-	-	1.10	-	-	-
0821D	1	-	-	-	1.93	-	-	-
0822A	0	-	-	-	-	-	-	-
0822B	1	-	-	-	0.59	-	-	-
0822C	2	0.70	-	-	0.82	-	-	0.93
0823A	0	-	-	-	-	-	-	-
0823B	1	-	-	-	12.69	-	-	-
0823C	0	-	-	-	-	-	-	-
0823D	1	-	-	-	1.39	-	-	-
0826A	0	-	-	-	-	-	-	-
0826C	0	-	-	-	-	-	-	-
0827A	1	-	-	-	1.30	-	-	-
0828A	0	-	-	-	-	-	-	-
0831A	0	-	-	-	-	-	-	-
0836B	0	-	-	-	-	-	-	-
0836C	0	-	-	-	-	-	-	-
0836D	0	-	-	-	-	-	-	-
0838A	0	-	-	-	-	-	-	-

0838B	1	-	-	-	1.19	-	-	-
0838C	1	-	-	-	0.85	-	-	-
0839A	1	-	-	-	0.47	-	-	-
0840A	0	-	-	-	-	-	-	-
0841B	5	0.70	-	0.70	0.90	0.92	-	0.93
0841C	1	-	-	-	0.81	-	-	-
0841D	1	-	-	-	0.99	-	-	-
0841E	1	-	-	-	1.20	-	-	-
0841F	2	0.79	-	-	0.89	-	-	0.99
0841G	1	-	-	-	1.16	-	-	-
0841H	1	-	-	-	0.77	-	-	-
0841I	0	-	-	-	-	-	-	-
0841J	0	-	-	-	-	-	-	-
0841K	2	0.87	-	-	0.92	-	-	0.97
0841L	3	0.74	-	-	0.74	-	-	1.00
0841M	0	-	-	-	-	-	-	-
0841N	1	-	-	-	1.43	-	-	-
0841O	3	0.74	-	-	0.78	-	-	0.97
0841P	2	1.11	-	-	1.12	-	-	1.14
0841Q	1	-	-	-	0.74	-	-	-
0841R	1	-	-	-	1.04	-	-	-
0841T	0	-	-	-	-	-	-	-
0841U	0	-	-	-	-	-	-	-
0841V	1	-	-	-	1.48	-	-	-
1002A	0	-	-	-	-	-	-	-
1002B	0	-	-	-	-	-	-	-
1004D	0	-	-	-	-	-	-	-
1004E	0	-	-	-	-	-	-	-
1006D	1	-	-	-	5.27	-	-	-
1006F	0	-	-	-	-	-	-	-
1006H	0	-	-	-	-	-	-	-
1006I	0	-	-	-	-	-	-	-
1006J	0	-	-	-	-	-	-	-
1007A	0	-	-	-	-	-	-	-
1007B	1	-	-	-	7.02	-	-	-
1007C	0	-	-	-	-	-	-	-
1007D	1	-	-	-	5.19	-	-	-
1007E	0	-	-	-	-	-	-	-
1007F	0	-	-	-	-	-	-	-
1007G	0	-	-	-	-	-	-	-

1007H	0	-	-	-	-	-	-	-
1007I	0	-	-	-	-	-	-	-
1007K	0	-	-	-	-	-	-	-
1007L	0	-	-	-	-	-	-	-
1007N	0	-	-	-	-	-	-	-
1007O	0	-	-	-	-	-	-	-
1007Q	0	-	-	-	-	-	-	-
1007R	0	-	-	-	-	-	-	-
1008B	0	-	-	-	-	-	-	-
1008C	0	-	-	-	-	-	-	-
1008E	0	-	-	-	-	-	-	-
1008H	0	-	-	-	-	-	-	-
1008J	0	-	-	-	-	-	-	-
1009C	0	-	-	-	-	-	-	-
1009D	0	-	-	-	-	-	-	-
1009E	0	-	-	-	-	-	-	-
1010C	0	-	-	-	-	-	-	-
1013A	0	-	-	-	-	-	-	-
1013C	0	-	-	-	-	-	-	-
1014A	0	-	-	-	-	-	-	-
1014B	0	-	-	-	-	-	-	-
1014C	0	-	-	-	-	-	-	-
1014E	0	-	-	-	-	-	-	-
1014H	0	-	-	-	-	-	-	-
1014K	0	-	-	-	-	-	-	-
1014L	0	-	-	-	-	-	-	-
1014M	0	-	-	-	-	-	-	-
1014N	0	-	-	-	-	-	-	-
1014O	0	-	-	-	-	-	-	-
1015A	0	-	-	-	-	-	-	-
1015B	0	-	-	-	-	-	-	-
1016A	0	-	-	-	-	-	-	-
1016B	0	-	-	-	-	-	-	-
1016C	0	-	-	-	-	-	-	-
1016D	0	-	-	-	-	-	-	-
1017A	0	-	-	-	-	-	-	-
1017B	0	-	-	-	-	-	-	-
1017C	0	-	-	-	-	-	-	-
1017D	0	-	-	-	-	-	-	-
1017E	0	-	-	-	-	-	-	-

1017F	0	-	-	-	-	-	-	-
1101B	0	-	-	-	-	-	-	-
1101F	0	-	-	-	-	-	-	-
1102A	0	-	-	-	-	-	-	-
1102B	0	-	-	-	-	-	-	-
1102C	0	-	-	-	-	-	-	-
1102D	0	-	-	-	-	-	-	-
1102E	0	-	-	-	-	-	-	-
1102F	0	-	-	-	-	-	-	-
1103F	0	-	-	-	-	-	-	-
1104A	0	-	-	-	-	-	-	-
1105A	0	-	-	-	-	-	-	-
1105B	0	-	-	-	-	-	-	-
1105C	0	-	-	-	-	-	-	-
1105D	0	-	-	-	-	-	-	-
1113A	0	-	-	-	-	-	-	-
1202H	0	-	-	-	-	-	-	-
1202J	2	1.35	-	-	3.34	-	-	5.34
1202K	1	-	-	-	0.64	-	-	-
1202P	0	-	-	-	-	-	-	-
1204A	1	-	-	-	1.97	-	-	-
1205B	0	-	-	-	-	-	-	-
1205C	0	-	-	-	-	-	-	-
1205D	0	-	-	-	-	-	-	-
1205E	0	-	-	-	-	-	-	-
1205F	0	-	-	-	-	-	-	-
1205G	0	-	-	-	-	-	-	-
1205H	0	-	-	-	-	-	-	-
1206D	0	-	-	-	-	-	-	-
1209C	2	10.59	-	-	10.85	-	-	11.10
1209D	1	-	-	-	1.03	-	-	-
1209E	0	-	-	-	-	-	-	-
1209G	0	-	-	-	-	-	-	-
1209H	1	-	-	-	1.20	-	-	-
1209I	2	1.91	-	-	2.18	-	-	2.45
1209J	0	-	-	-	-	-	-	-
1209K	0	-	-	-	-	-	-	-
1209L	0	-	-	-	-	-	-	-
1209P	0	-	-	-	-	-	-	-
1210A	0	-	-	-	-	-	-	-

1211A	1	-	-	-	1.62	-	-	-
1212A	0	-	-	-	-	-	-	-
1212B	1	-	-	-	0.81	-	-	-
1213A	1	-	-	-	1.92	-	-	-
1213B	0	-	-	-	-	-	-	-
1213C	0	-	-	-	-	-	-	-
1216A	0	-	-	-	-	-	-	-
1216B	0	-	-	-	-	-	-	-
1217A	1	-	-	-	0.85	-	-	-
1217B	7	1.14	1.18	1.25	1.51	2.04	2.49	2.73
1217E	0	-	-	-	-	-	-	-
1217F	0	-	-	-	-	-	-	-
1218B	0	-	-	-	-	-	-	-
1220A	0	-	-	-	-	-	-	-
1221A	2	1.14	-	-	1.48	-	-	1.81
1221B	1	-	-	-	1.10	-	-	-
1221C	0	-	-	-	-	-	-	-
1221D	1	-	-	-	24.95	-	-	-
1221E	0	-	-	-	-	-	-	-
1221F	1	-	-	-	2.11	-	-	-
1222A	1	-	-	-	1.63	-	-	-
1222B	0	-	-	-	-	-	-	-
1222C	1	-	-	-	0.78	-	-	-
1222D	0	-	-	-	-	-	-	-
1222E	0	-	-	-	-	-	-	-
1222F	0	-	-	-	-	-	-	-
1223A	0	-	-	-	-	-	-	-
1223B	0	-	-	-	-	-	-	-
1225A	0	-	-	-	-	-	-	-
1226A	1	-	-	-	1.09	-	-	-
1226B	1	-	-	-	1.24	-	-	-
1226C	0	-	-	-	-	-	-	-
1226D	0	-	-	-	-	-	-	-
1226E	0	-	-	-	-	-	-	-
1226F	0	-	-	-	-	-	-	-
1226G	0	-	-	-	-	-	-	-
1226H	0	-	-	-	-	-	-	-
1226I	0	-	-	-	-	-	-	-
1226J	0	-	-	-	-	-	-	-
1226K	0	-	-	-	-	-	-	-

1226L	0	-	-	-	-	-	-	-
1226M	0	-	-	-	-	-	-	-
1226Q	0	-	-	-	-	-	-	-
1227A	1	-	-	-	9.47	-	-	-
1232A	1	-	-	-	4.10	-	-	-
1232B	1	-	-	-	11.60	-	-	-
1232C	1	-	-	-	0.90	-	-	-
1233A	0	-	-	-	-	-	-	-
1233B	0	-	-	-	-	-	-	-
1236A	0	-	-	-	-	-	-	-
1238A	0	-	-	-	-	-	-	-
1240A	0	-	-	-	-	-	-	-
1241A	3	3.18	-	-	4.25	-	-	5.74
1241D	0	-	-	-	-	-	-	-
1242B	1	-	-	-	82.50	-	-	-
1242C	1	-	-	-	12.20	-	-	-
1242D	1	-	-	-	37.60	-	-	-
1242E	0	-	-	-	-	-	-	-
1242F	0	-	-	-	-	-	-	-
1242I	0	-	-	-	-	-	-	-
1242J	0	-	-	-	-	-	-	-
1242K	0	-	-	-	-	-	-	-
1242L	0	-	-	-	-	-	-	-
1242M	0	-	-	-	-	-	-	-
1242N	0	-	-	-	-	-	-	-
1242O	0	-	-	-	-	-	-	-
1242P	0	-	-	-	-	-	-	-
1242Q	0	-	-	-	-	-	-	-
1244A	1	-	-	-	2.03	-	-	-
1244B	0	-	-	-	-	-	-	-
1244D	0	-	-	-	-	-	-	-
1245B	0	-	-	-	-	-	-	-
1245C	0	-	-	-	-	-	-	-
1245D	0	-	-	-	-	-	-	-
1245I	0	-	-	-	-	-	-	-
1246C	0	-	-	-	-	-	-	-
1246D	0	-	-	-	-	-	-	-
1246E	1	-	-	-	3.31	-	-	-
1247A	1	-	-	-	8.55	-	-	-
1248A	1	-	-	-	1.09	-	-	-

1248B	1	-	-	-	2.71	-	-	-
1248C	2	6.43	-	-	6.55	-	-	6.68
1248D	1	-	-	-	0.80	-	-	-
1254A	0	-	-	-	-	-	-	-
1254B	0	-	-	-	-	-	-	-
1255A	0	-	-	-	-	-	-	-
1255B	0	-	-	-	-	-	-	-
1255C	0	-	-	-	-	-	-	-
1255D	0	-	-	-	-	-	-	-
1255E	0	-	-	-	-	-	-	-
1255F	0	-	-	-	-	-	-	-
1255I	0	-	-	-	-	-	-	-
1256A	0	-	-	-	-	-	-	-
1302A	1	-	-	-	1.51	-	-	-
1302B	1	-	-	-	1.62	-	-	-
1302C	0	-	-	-	-	-	-	-
1402A	2	0.57	-	-	0.58	-	-	0.60
1402C	1	-	-	-	1.65	-	-	-
1402H	1	-	-	-	1.14	-	-	-
1403A	3	0.33	-	-	0.44	-	-	0.44
1403B	1	-	-	-	0.38	-	-	-
1403E	0	-	-	-	-	-	-	-
1403F	0	-	-	-	-	-	-	-
1403H	2	0.45	-	-	0.54	-	-	0.64
1403I	0	-	-	-	-	-	-	-
1403J	1	-	-	-	2.80	-	-	-
1403K	1	-	-	-	2.23	-	-	-
1403L	0	-	-	-	-	-	-	-
1403M	0	-	-	-	-	-	-	-
1403N	0	-	-	-	-	-	-	-
1403O	0	-	-	-	-	-	-	-
1403P	0	-	-	-	-	-	-	-
1403Q	0	-	-	-	-	-	-	-
1403R	1	-	-	-	0.97	-	-	-
1404A	1	-	-	-	0.69	-	-	-
1404B	1	-	-	-	0.25	-	-	-
1404C	0	-	-	-	-	-	-	-
1404D	0	-	-	-	-	-	-	-
1406A	1	-	-	-	0.24	-	-	-
1407A	1	-	-	-	0.52	-	-	-

1409A	1	-	-	-	0.47	-	-	-
1412B	1	-	-	-	1.34	-	-	-
1412C	0	-	-	-	-	-	-	-
1414A	0	-	-	-	-	-	-	-
1414B	1	-	-	-	0.31	-	-	-
1414D	0	-	-	-	-	-	-	-
1415A	1	-	-	-	0.50	-	-	-
1415C	1	-	-	-	0.37	-	-	-
1416A	2	1.57	-	-	4.28	-	-	6.98
1416B	0	-	-	-	-	-	-	-
1416C	0	-	-	-	-	-	-	-
1418B	0	-	-	-	-	-	-	-
1421A	0	-	-	-	-	-	-	-
1421B	0	-	-	-	-	-	-	-
1421C	0	-	-	-	-	-	-	-
1423A	0	-	-	-	-	-	-	-
1423B	0	-	-	-	-	-	-	-
1424A	0	-	-	-	-	-	-	-
1424B	0	-	-	-	-	-	-	-
1425A	0	-	-	-	-	-	-	-
1426B	1	-	-	-	1.43	-	-	-
1426C	0	-	-	-	-	-	-	-
1426D	0	-	-	-	-	-	-	-
1427A	1	-	-	-	0.49	-	-	-
1427B	0	-	-	-	-	-	-	-
1427C	1	-	-	-	0.43	-	-	-
1427E	0	-	-	-	-	-	-	-
1427F	0	-	-	-	-	-	-	-
1427G	0	-	-	-	-	-	-	-
1428A	0	-	-	-	-	-	-	-
1428B	0	-	-	-	-	-	-	-
1428C	2	6.20	-	-	6.77	-	-	7.35
1428D	0	-	-	-	-	-	-	-
1428E	0	-	-	-	-	-	-	-
1428F	0	-	-	-	-	-	-	-
1428I	0	-	-	-	-	-	-	-
1428J	0	-	-	-	-	-	-	-
1429A	0	-	-	-	-	-	-	-
1429B	0	-	-	-	-	-	-	-
1429C	3	1.03	-	-	1.31	-	-	1.34

1429D	0	-	-	-	-	-	-	-
1429E	0	-	-	-	-	-	-	-
1429F	0	-	-	-	-	-	-	-
1429G	0	-	-	-	-	-	-	-
1429H	0	-	-	-	-	-	-	-
1430B	1	-	-	-	0.28	-	-	-
1434B	1	-	-	-	0.56	-	-	-
1601C	0	-	-	-	-	-	-	-
1602B	0	-	-	-	-	-	-	-
1604A	0	-	-	-	-	-	-	-
1604B	0	-	-	-	-	-	-	-
1604C	0	-	-	-	-	-	-	-
1803A	0	-	-	-	-	-	-	-
1803B	0	-	-	-	-	-	-	-
1803C	0	-	-	-	-	-	-	-
1804A	0	-	-	-	-	-	-	-
1806A	0	-	-	-	-	-	-	-
1806D	0	-	-	-	-	-	-	-
1806E	0	-	-	-	-	-	-	-
1806G	0	-	-	-	-	-	-	-
1806H	0	-	-	-	-	-	-	-
1807A	0	-	-	-	-	-	-	-
1811A	0	-	-	-	-	-	-	-
1813A	0	-	-	-	-	-	-	-
1813B	0	-	-	-	-	-	-	-
1813C	0	-	-	-	-	-	-	-
1813D	0	-	-	-	-	-	-	-
1813E	0	-	-	-	-	-	-	-
1813F	0	-	-	-	-	-	-	-
1813G	0	-	-	-	-	-	-	-
1813H	0	-	-	-	-	-	-	-
1813I	0	-	-	-	-	-	-	-
1901A	0	-	-	-	-	-	-	-
1901B	0	-	-	-	-	-	-	-
1901C	0	-	-	-	-	-	-	-
1901D	0	-	-	-	-	-	-	-
1902A	0	-	-	-	-	-	-	-
1902B	0	-	-	-	-	-	-	-
1905A	1	-	-	-	0.34	-	-	-
1906A	0	-	-	-	-	-	-	-

1910A	0	-	-	-	-	-	-	-
1910B	0	-	-	-	-	-	-	-
1910C	0	-	-	-	-	-	-	-
1910D	0	-	-	-	-	-	-	-
1910E	0	-	-	-	-	-	-	-
1911B	2	1.20	-	-	2.54	-	-	3.87
1911C	3	0.88	-	-	0.99	-	-	1.31
1911D	2	2.04	-	-	2.09	-	-	2.14
1911E	0	-	-	-	-	-	-	-
1911H	0	-	-	-	-	-	-	-
1912A	1	-	-	-	6.95	-	-	-
2004A	0	-	-	-	-	-	-	-
2004B	0	-	-	-	-	-	-	-
2302A	1	-	-	-	2.06	-	-	-
2304B	0	-	-	-	-	-	-	-
2306A	0	-	-	-	-	-	-	-
2309A	1	-	-	-	1.85	-	-	-
2310A	1	-	-	-	1.01	-	-	-
2422B	0	-	-	-	-	-	-	-
2424A	0	-	-	-	-	-	-	-
2424D	0	-	-	-	-	-	-	-
2424E	0	-	-	-	-	-	-	-
2431A	0	-	-	-	-	-	-	-
2432A	0	-	-	-	-	-	-	-
2432B	0	-	-	-	-	-	-	-
2485B	0	-	-	-	-	-	-	-
2485D	0	-	-	-	-	-	-	-
2492A	0	-	-	-	-	-	-	-

Nitrite plus Nitrate-Nitrogen (NO_x-N; mg/L)

Segment	n	MIN	10th	25th	Median	75th	90th	MAX
0101	4	0.040	-	0.059	0.180	0.466	-	0.980
0103	3	0.050	-	-	0.250	-	-	0.350
0104	2	0.040	-	-	0.040	-	-	0.040
0201	1	-	-	-	0.100	-	-	-
0202	4	0.080	-	0.095	0.100	0.134	-	0.235
0204	1	-	-	-	0.055	-	-	-
0205	2	0.040	-	-	0.145	-	-	0.250
0206	1	-	-	-	0.570	-	-	-

0207	2	0.350	-	-	0.518	-	-	0.685
0211	1	-	-	-	0.100	-	-	-
0214	8	0.020	0.062	0.163	0.228	0.783	2.413	3.715
0216	0	-	-	-	-	-	-	-
0218	1	-	-	-	0.165	-	-	-
0220	2	0.040	-	-	0.095	-	-	0.150
0221	0	-	-	-	-	-	-	-
0222	1	-	-	-	1.260	-	-	-
0224	1	-	-	-	0.050	-	-	-
0226	0	-	-	-	-	-	-	-
0227	0	-	-	-	-	-	-	-
0229	2	3.080	-	-	3.713	-	-	4.345
0230	1	-	-	-	0.220	-	-	-
0301	2	0.050	-	-	0.085	-	-	0.120
0303	3	0.130	-	-	0.200	-	-	0.200
0304	1	-	-	-	10.220	-	-	-
0305	1	-	-	-	0.120	-	-	-
0306	2	0.040	-	-	2.523	-	-	5.005
0401	1	-	-	-	0.040	-	-	-
0402	4	0.040	-	0.047	0.068	0.094	-	0.110
0404	2	0.440	-	-	3.123	-	-	5.805
0406	3	0.050	-	-	0.050	-	-	0.080
0407	2	0.040	-	-	0.041	-	-	0.043
0409	5	0.067	-	0.160	0.180	0.400	-	0.500
0501	2	0.090	-	-	0.091	-	-	0.092
0502	2	0.080	-	-	0.080	-	-	0.080
0503	5	0.090	-	0.100	0.100	0.130	-	0.235
0504	1	-	-	-	0.075	-	-	-
0505	5	0.150	-	0.160	0.290	0.410	-	0.670
0506	4	0.140	-	0.140	0.150	0.161	-	0.165
0513	1	-	-	-	0.120	-	-	-
0514	4	0.155	-	0.200	0.218	0.231	-	0.265
0515	1	-	-	-	0.110	-	-	-
0602	3	0.050	-	-	0.050	-	-	0.050
0604	7	0.040	0.076	0.130	0.160	0.178	0.201	0.210
0606	3	0.050	-	-	0.080	-	-	3.290
0607	4	0.050	-	0.050	0.080	0.113	-	0.120
0608	4	0.050	-	0.058	0.060	0.068	-	0.090
0609	1	-	-	-	0.050	-	-	-
0610	1	-	-	-	0.090	-	-	-

0611	4	0.200	-	0.215	0.225	0.249	-	0.305
0612	3	0.205	-	-	0.360	-	-	0.615
0701	2	0.050	-	-	0.063	-	-	0.075
0704	3	0.085	-	-	0.210	-	-	0.305
0801	0	-	-	-	-	-	-	-
0802	3	0.150	-	-	0.225	-	-	0.255
0803	0	-	-	-	-	-	-	-
0804	4	2.535	-	4.114	4.920	5.518	-	6.470
0805	4	5.310	-	5.970	6.383	6.861	-	7.720
0806	3	0.190	-	-	0.250	-	-	0.270
0809	0	-	-	-	-	-	-	-
0810	1	-	-	-	0.425	-	-	-
0812	1	-	-	-	0.110	-	-	-
0814	1	-	-	-	0.760	-	-	-
0815	0	-	-	-	-	-	-	-
0817	0	-	-	-	-	-	-	-
0818	0	-	-	-	-	-	-	-
0819	3	2.430	-	-	7.570	-	-	11.180
0821	0	-	-	-	-	-	-	-
0822	4	0.495	-	0.589	0.635	0.660	-	0.690
0824	1	-	-	-	0.740	-	-	-
0825	1	-	-	-	0.885	-	-	-
0829	1	-	-	-	0.285	-	-	-
0830	0	-	-	-	-	-	-	-
0831	1	-	-	-	1.520	-	-	-
0833	0	-	-	-	-	-	-	-
0835	0	-	-	-	-	-	-	-
0836	0	-	-	-	-	-	-	-
0837	0	-	-	-	-	-	-	-
0838	0	-	-	-	-	-	-	-
0839	0	-	-	-	-	-	-	-
0840	0	-	-	-	-	-	-	-
0841	3	8.600	-	-	10.825	-	-	13.050
0902	2	0.040	-	-	0.168	-	-	0.295
1002	1	-	-	-	0.845	-	-	-
1003	4	0.040	-	0.085	0.110	0.123	-	0.130
1004	2	0.185	-	-	0.343	-	-	0.500
1006	1	-	-	-	0.250	-	-	-
1007	0	-	-	-	-	-	-	-
1008	4	0.045	-	0.184	0.283	0.670	-	1.675

1009	5	0.040	-	1.805	2.810	3.640	-	4.420
1010	4	0.040	-	0.040	0.170	0.315	-	0.360
1011	4	0.040	-	0.104	0.153	0.190	-	0.220
1013	0	-	-	-	-	-	-	-
1014	2	3.550	-	-	4.208	-	-	4.865
1015	2	0.040	-	-	0.040	-	-	0.040
1016	2	4.520	-	-	4.735	-	-	4.950
1017	2	4.145	-	-	4.218	-	-	4.290
1101	1	-	-	-	0.570	-	-	-
1102	10	0.040	0.247	0.418	0.745	1.040	1.202	1.850
1103	0	-	-	-	-	-	-	-
1104	1	-	-	-	0.040	-	-	-
1105	1	-	-	-	0.040	-	-	-
1108	1	-	-	-	0.155	-	-	-
1110	1	-	-	-	0.460	-	-	-
1201	0	-	-	-	-	-	-	-
1202	3	0.440	-	-	0.500	-	-	0.850
1204	1	-	-	-	0.095	-	-	-
1205	1	-	-	-	0.080	-	-	-
1206	6	0.040	-	0.040	0.040	0.040	-	0.080
1208	4	0.100	-	0.123	0.185	0.255	-	0.300
1209	4	0.200	-	0.215	0.230	0.518	-	1.350
1211	2	0.040	-	-	0.090	-	-	0.140
1213	4	1.580	-	1.614	1.670	1.754	-	1.870
1214	1	-	-	-	2.845	-	-	-
1215	1	-	-	-	0.770	-	-	-
1217	2	0.250	-	-	0.365	-	-	0.480
1218	1	-	-	-	4.500	-	-	-
1219	1	-	-	-	1.680	-	-	-
1220	0	-	-	-	-	-	-	-
1221	9	0.095	0.103	0.180	0.310	0.340	0.690	0.730
1223	1	-	-	-	0.075	-	-	-
1226	6	0.040	-	0.085	0.150	0.238	-	0.355
1227	4	0.455	-	1.216	1.595	2.463	-	4.690
1229	1	-	-	-	0.100	-	-	-
1232	5	0.040	-	0.040	0.125	0.225	-	4.665
1236	0	-	-	-	-	-	-	-
1238	2	0.040	-	-	0.040	-	-	0.040
1239	0	-	-	-	-	-	-	-
1241	1	-	-	-	0.090	-	-	-

1242	5	0.235	-	0.570	0.620	0.780	-	0.910
1243	2	2.770	-	-	2.973	-	-	3.175
1244	4	0.675	-	0.941	1.075	1.673	-	3.330
1245	3	0.255	-	-	0.400	-	-	0.695
1246	3	1.780	-	-	2.535	-	-	4.750
1248	1	-	-	-	1.480	-	-	-
1250	3	0.120	-	-	0.140	-	-	0.180
1251	1	-	-	-	0.040	-	-	-
1253	3	0.100	-	-	0.110	-	-	0.300
1255	1	-	-	-	0.555	-	-	-
1256	2	0.175	-	-	0.190	-	-	0.205
1257	2	0.090	-	-	0.115	-	-	0.140
1301	1	-	-	-	0.040	-	-	-
1302	6	0.040	-	0.256	0.344	0.444	-	0.470
1305	1	-	-	-	0.230	-	-	-
1402	6	1.034	-	1.159	1.326	1.427	-	1.780
1403	0	-	-	-	-	-	-	-
1406	0	-	-	-	-	-	-	-
1409	1	-	-	-	0.260	-	-	-
1410	2	0.020	-	-	0.035	-	-	0.050
1412	6	0.020	-	0.020	0.020	0.028	-	0.085
1414	5	0.090	-	0.380	0.575	0.600	-	0.606
1415	8	0.020	0.020	0.032	0.075	0.408	0.553	0.885
1416	2	0.034	-	-	0.222	-	-	0.410
1417	1	-	-	-	0.150	-	-	-
1420	2	0.090	-	-	0.115	-	-	0.140
1421	10	0.070	0.106	0.214	0.520	1.563	3.720	6.600
1424	2	1.150	-	-	1.560	-	-	1.970
1426	8	0.020	0.020	0.020	0.075	0.155	0.212	0.240
1427	12	0.035	0.050	0.073	0.168	0.350	0.472	1.395
1428	4	0.205	-	0.269	0.663	1.323	-	2.185
1430	12	0.050	0.070	0.074	0.100	0.315	0.830	1.230
1431	1	-	-	-	9.440	-	-	-
1432	1	-	-	-	0.100	-	-	-
1434	2	1.760	-	-	2.015	-	-	2.270
1501	0	-	-	-	-	-	-	-
1502	1	-	-	-	0.500	-	-	-
1602	2	0.230	-	-	0.245	-	-	0.260
1605	2	0.160	-	-	0.230	-	-	0.300
1801	0	-	-	-	-	-	-	-

1802	1	-	-	-	1.050	-	-	-
1803	3	0.540	-	-	0.570	-	-	0.620
1804	7	0.710	0.722	0.790	1.110	1.390	1.444	1.450
1806	8	0.310	0.380	0.455	0.540	0.603	0.655	0.690
1807	2	0.025	-	-	0.038	-	-	0.050
1808	3	0.635	-	-	0.660	-	-	1.530
1809	1	-	-	-	0.260	-	-	-
1810	3	1.100	-	-	3.875	-	-	6.960
1811	2	0.845	-	-	1.308	-	-	1.770
1812	6	0.175	-	0.223	0.350	0.459	-	0.520
1813	4	0.130	-	0.160	0.180	0.209	-	0.265
1814	1	-	-	-	0.760	-	-	-
1815	3	0.070	-	-	0.075	-	-	0.150
1816	1	-	-	-	0.380	-	-	-
1817	1	-	-	-	0.370	-	-	-
1818	1	-	-	-	0.200	-	-	-
1901	10	2.560	4.397	6.231	6.518	8.015	8.671	9.310
1902	5	1.250	-	1.307	1.390	2.420	-	2.520
1903	6	0.280	-	2.616	3.380	4.842	-	7.690
1905	1	-	-	-	0.371	-	-	-
1906	4	0.340	-	0.663	0.805	0.948	-	1.270
1907	1	-	-	-	0.980	-	-	-
1908	1	-	-	-	0.580	-	-	-
1910	8	0.040	0.481	0.685	0.777	1.219	1.701	1.960
1911	21	1.650	1.800	2.061	3.585	7.730	8.846	9.531
1912	1	-	-	-	2.502	-	-	-
1913	2	1.180	-	-	3.898	-	-	6.615
2002	1	-	-	-	0.070	-	-	-
2003	0	-	-	-	-	-	-	-
2004	1	-	-	-	2.341	-	-	-
2102	2	0.031	-	-	0.051	-	-	0.070
2103	1	-	-	-	0.020	-	-	-
2104	2	0.020	-	-	0.020	-	-	0.020
2105	2	0.040	-	-	0.070	-	-	0.100
2106	4	0.101	-	0.115	0.130	0.158	-	0.213
2107	2	0.060	-	-	0.090	-	-	0.120
2108	1	-	-	-	0.020	-	-	-
2109	4	2.545	-	2.620	2.986	4.328	-	7.330
2110	1	-	-	-	6.780	-	-	-
2111	1	-	-	-	0.295	-	-	-

2112	4	0.620	-	0.684	0.833	0.968	-	0.990
2113	2	0.460	-	-	0.535	-	-	0.610
2114	2	0.215	-	-	3.228	-	-	6.240
2115	1	-	-	-	0.210	-	-	-
2117	4	0.550	-	0.963	3.340	8.173	-	15.950
2202	6	3.520	-	3.889	4.043	4.969	-	5.640
2204	2	0.150	-	-	0.188	-	-	0.225
2301	0	-	-	-	-	-	-	-
2302	10	0.100	0.127	0.135	0.168	0.494	0.534	0.660
2304	13	0.190	0.241	0.250	0.270	0.400	0.488	0.726
2305	0	-	-	-	-	-	-	-
2306	5	0.060	-	0.110	0.191	0.335	-	0.730
2307	7	0.280	0.294	0.494	0.783	0.993	1.102	1.165
2308	3	0.580	-	-	0.710	-	-	1.725
2309	2	1.280	-	-	1.325	-	-	1.370
2310	2	0.545	-	-	0.558	-	-	0.570
2311	9	0.040	0.040	0.040	0.040	0.040	0.134	0.350
2313	3	1.625	-	-	1.645	-	-	1.660
2314	2	0.450	-	-	0.485	-	-	0.520
2431	1	-	-	-	0.040	-	-	-
2472	0	-	-	-	-	-	-	-
0101A	1	-	-	-	3.035	-	-	-
0101B	2	4.225	-	-	5.543	-	-	6.860
0101C	0	-	-	-	-	-	-	-
0102A	1	-	-	-	0.065	-	-	-
0103A	1	-	-	-	4.900	-	-	-
0103C	1	-	-	-	0.120	-	-	-
0199A	0	-	-	-	-	-	-	-
0201A	1	-	-	-	0.040	-	-	-
0202A	2	0.060	-	-	0.145	-	-	0.230
0202C	1	-	-	-	0.040	-	-	-
0202D	1	-	-	-	0.140	-	-	-
0202E	1	-	-	-	0.490	-	-	-
0202F	1	-	-	-	9.340	-	-	-
0202G	1	-	-	-	0.100	-	-	-
0202H	0	-	-	-	-	-	-	-
0202I	0	-	-	-	-	-	-	-
0202J	0	-	-	-	-	-	-	-
0202K	0	-	-	-	-	-	-	-
0203A	0	-	-	-	-	-	-	-

0203C	0	-	-	-	-	-	-	-
0203D	0	-	-	-	-	-	-	-
0206B	1	-	-	-	3.370	-	-	-
0207A	1	-	-	-	3.350	-	-	-
0214A	2	0.080	-	-	0.145	-	-	0.210
0214B	0	-	-	-	-	-	-	-
0218A	0	-	-	-	-	-	-	-
0222A	1	-	-	-	0.630	-	-	-
0224A	1	-	-	-	0.040	-	-	-
0230A	1	-	-	-	1.640	-	-	-
0299A	2	0.040	-	-	0.125	-	-	0.210
0302A	0	-	-	-	-	-	-	-
0302B	0	-	-	-	-	-	-	-
0302C	1	-	-	-	0.177	-	-	-
0302D	0	-	-	-	-	-	-	-
0302E	0	-	-	-	-	-	-	-
0302F	0	-	-	-	-	-	-	-
0303B	4	0.139	-	0.200	0.370	0.889	-	1.995
0303D	1	-	-	-	8.640	-	-	-
0303E	0	-	-	-	-	-	-	-
0303F	0	-	-	-	-	-	-	-
0303G	0	-	-	-	-	-	-	-
0303H	0	-	-	-	-	-	-	-
0303I	0	-	-	-	-	-	-	-
0303J	0	-	-	-	-	-	-	-
0303K	0	-	-	-	-	-	-	-
0303L	0	-	-	-	-	-	-	-
0304A	0	-	-	-	-	-	-	-
0304B	0	-	-	-	-	-	-	-
0304C	0	-	-	-	-	-	-	-
0304D	0	-	-	-	-	-	-	-
0305A	0	-	-	-	-	-	-	-
0305B	0	-	-	-	-	-	-	-
0305C	0	-	-	-	-	-	-	-
0305D	0	-	-	-	-	-	-	-
0307A	0	-	-	-	-	-	-	-
0307B	0	-	-	-	-	-	-	-
0307C	0	-	-	-	-	-	-	-
0401A	0	-	-	-	-	-	-	-
0401B	0	-	-	-	-	-	-	-

0402A	5	0.054	-	0.065	0.080	0.100	-	0.240
0402B	0	-	-	-	-	-	-	-
0402C	0	-	-	-	-	-	-	-
0402D	0	-	-	-	-	-	-	-
0402E	0	-	-	-	-	-	-	-
0404B	0	-	-	-	-	-	-	-
0404C	0	-	-	-	-	-	-	-
0404I	1	-	-	-	0.252	-	-	-
0404J	1	-	-	-	0.393	-	-	-
0404K	1	-	-	-	0.411	-	-	-
0404O	0	-	-	-	-	-	-	-
0404P	0	-	-	-	-	-	-	-
0404Q	0	-	-	-	-	-	-	-
0404R	0	-	-	-	-	-	-	-
0405A	0	-	-	-	-	-	-	-
0405B	0	-	-	-	-	-	-	-
0405C	0	-	-	-	-	-	-	-
0407A	0	-	-	-	-	-	-	-
0407B	1	-	-	-	0.055	-	-	-
0408B	0	-	-	-	-	-	-	-
0408C	0	-	-	-	-	-	-	-
0408D	0	-	-	-	-	-	-	-
0409A	2	0.178	-	-	0.271	-	-	0.363
0409B	0	-	-	-	-	-	-	-
0409E	0	-	-	-	-	-	-	-
0501B	0	-	-	-	-	-	-	-
0502A	0	-	-	-	-	-	-	-
0502B	2	0.140	-	-	0.155	-	-	0.170
0502D	0	-	-	-	-	-	-	-
0502E	0	-	-	-	-	-	-	-
0504C	0	-	-	-	-	-	-	-
0504D	1	-	-	-	0.740	-	-	-
0505B	0	-	-	-	-	-	-	-
0505D	0	-	-	-	-	-	-	-
0505G	0	-	-	-	-	-	-	-
0505P	0	-	-	-	-	-	-	-
0506A	1	-	-	-	0.155	-	-	-
0506C	1	-	-	-	0.135	-	-	-
0507A	1	-	-	-	0.150	-	-	-
0507B	0	-	-	-	-	-	-	-

0507D	0	-	-	-	-	-	-	-
0507E	0	-	-	-	-	-	-	-
0507F	0	-	-	-	-	-	-	-
0507G	0	-	-	-	-	-	-	-
0507H	0	-	-	-	-	-	-	-
0508A	1	-	-	-	0.060	-	-	-
0508C	0	-	-	-	-	-	-	-
0511C	0	-	-	-	-	-	-	-
0511E	0	-	-	-	-	-	-	-
0512A	0	-	-	-	-	-	-	-
0602A	0	-	-	-	-	-	-	-
0602B	0	-	-	-	-	-	-	-
0603A	1	-	-	-	0.605	-	-	-
0603B	1	-	-	-	0.100	-	-	-
0604A	2	0.040	-	-	4.490	-	-	8.940
0604B	1	-	-	-	0.170	-	-	-
0604C	1	-	-	-	1.025	-	-	-
0604D	1	-	-	-	0.600	-	-	-
0604M	0	-	-	-	-	-	-	-
0604N	1	-	-	-	0.040	-	-	-
0605A	1	-	-	-	0.489	-	-	-
0605E	0	-	-	-	-	-	-	-
0606A	1	-	-	-	0.240	-	-	-
0606C	0	-	-	-	-	-	-	-
0606D	1	-	-	-	0.374	-	-	-
0607A	0	-	-	-	-	-	-	-
0607B	2	0.050	-	-	0.050	-	-	0.050
0607C	1	-	-	-	0.080	-	-	-
0608A	1	-	-	-	0.040	-	-	-
0608B	2	0.095	-	-	0.273	-	-	0.450
0608C	1	-	-	-	0.050	-	-	-
0608D	1	-	-	-	0.060	-	-	-
0608E	0	-	-	-	-	-	-	-
0608F	2	0.110	-	-	0.203	-	-	0.295
0608J	0	-	-	-	-	-	-	-
0610A	1	-	-	-	0.240	-	-	-
0611A	1	-	-	-	0.180	-	-	-
0611B	3	0.240	-	-	0.520	-	-	1.400
0611C	2	0.530	-	-	0.648	-	-	0.766
0611D	3	0.420	-	-	3.450	-	-	4.785

0612A	1	-	-	-	0.890	-	-	-
0612B	1	-	-	-	0.040	-	-	-
0615A	1	-	-	-	0.290	-	-	-
0702A	1	-	-	-	0.755	-	-	-
0704A	0	-	-	-	-	-	-	-
0801C	0	-	-	-	-	-	-	-
0802B	0	-	-	-	-	-	-	-
0802D	1	-	-	-	0.090	-	-	-
0803A	1	-	-	-	3.540	-	-	-
0803B	0	-	-	-	-	-	-	-
0803E	0	-	-	-	-	-	-	-
0803F	0	-	-	-	-	-	-	-
0804F	0	-	-	-	-	-	-	-
0804G	1	-	-	-	0.115	-	-	-
0804H	0	-	-	-	-	-	-	-
0805A	0	-	-	-	-	-	-	-
0805B	0	-	-	-	-	-	-	-
0805D	0	-	-	-	-	-	-	-
0806C	0	-	-	-	-	-	-	-
0806D	0	-	-	-	-	-	-	-
0806E	0	-	-	-	-	-	-	-
0810A	0	-	-	-	-	-	-	-
0810B	0	-	-	-	-	-	-	-
0810C	0	-	-	-	-	-	-	-
0810D	0	-	-	-	-	-	-	-
0814A	0	-	-	-	-	-	-	-
0814B	0	-	-	-	-	-	-	-
0815A	0	-	-	-	-	-	-	-
0816A	0	-	-	-	-	-	-	-
0817A	0	-	-	-	-	-	-	-
0819A	0	-	-	-	-	-	-	-
0819B	0	-	-	-	-	-	-	-
0820B	1	-	-	-	3.140	-	-	-
0820C	0	-	-	-	-	-	-	-
0821B	0	-	-	-	-	-	-	-
0821C	1	-	-	-	0.760	-	-	-
0821D	1	-	-	-	1.290	-	-	-
0822A	0	-	-	-	-	-	-	-
0822B	1	-	-	-	0.075	-	-	-
0822C	2	0.100	-	-	0.243	-	-	0.385

0823A	0	-	-	-	-	-	-	-
0823B	1	-	-	-	11.300	-	-	-
0823C	0	-	-	-	-	-	-	-
0823D	1	-	-	-	0.800	-	-	-
0826A	0	-	-	-	-	-	-	-
0826C	0	-	-	-	-	-	-	-
0827A	1	-	-	-	0.800	-	-	-
0828A	0	-	-	-	-	-	-	-
0831A	0	-	-	-	-	-	-	-
0836B	0	-	-	-	-	-	-	-
0836C	0	-	-	-	-	-	-	-
0836D	0	-	-	-	-	-	-	-
0838A	0	-	-	-	-	-	-	-
0838B	1	-	-	-	0.270	-	-	-
0838C	1	-	-	-	0.250	-	-	-
0839A	1	-	-	-	0.040	-	-	-
0840A	0	-	-	-	-	-	-	-
0841B	5	0.150	-	0.180	0.230	0.248	-	0.250
0841C	1	-	-	-	0.150	-	-	-
0841D	1	-	-	-	0.325	-	-	-
0841E	1	-	-	-	0.615	-	-	-
0841F	2	0.305	-	-	0.358	-	-	0.410
0841G	1	-	-	-	0.255	-	-	-
0841H	1	-	-	-	0.120	-	-	-
0841I	0	-	-	-	-	-	-	-
0841J	0	-	-	-	-	-	-	-
0841K	2	0.360	-	-	0.375	-	-	0.390
0841L	3	0.090	-	-	0.175	-	-	0.410
0841M	0	-	-	-	-	-	-	-
0841N	1	-	-	-	0.880	-	-	-
0841O	3	0.090	-	-	0.140	-	-	0.340
0841P	2	0.410	-	-	0.443	-	-	0.475
0841Q	1	-	-	-	0.270	-	-	-
0841R	1	-	-	-	0.220	-	-	-
0841T	0	-	-	-	-	-	-	-
0841U	0	-	-	-	-	-	-	-
0841V	1	-	-	-	0.900	-	-	-
1002A	1	-	-	-	0.040	-	-	-
1002B	1	-	-	-	0.050	-	-	-
1004D	1	-	-	-	0.220	-	-	-

1004E	0	-	-	-	-	-	-	-
1006D	2	0.040	-	-	1.895	-	-	3.750
1006F	0	-	-	-	-	-	-	-
1006H	0	-	-	-	-	-	-	-
1006I	0	-	-	-	-	-	-	-
1006J	0	-	-	-	-	-	-	-
1007A	0	-	-	-	-	-	-	-
1007B	1	-	-	-	4.435	-	-	-
1007C	0	-	-	-	-	-	-	-
1007D	1	-	-	-	1.645	-	-	-
1007E	0	-	-	-	-	-	-	-
1007F	0	-	-	-	-	-	-	-
1007G	0	-	-	-	-	-	-	-
1007H	0	-	-	-	-	-	-	-
1007I	0	-	-	-	-	-	-	-
1007K	0	-	-	-	-	-	-	-
1007L	0	-	-	-	-	-	-	-
1007N	0	-	-	-	-	-	-	-
1007O	0	-	-	-	-	-	-	-
1007Q	0	-	-	-	-	-	-	-
1007R	0	-	-	-	-	-	-	-
1008B	2	0.295	-	-	6.343	-	-	12.390
1008C	1	-	-	-	1.090	-	-	-
1008E	1	-	-	-	0.450	-	-	-
1008H	0	-	-	-	-	-	-	-
1008J	1	-	-	-	0.040	-	-	-
1009C	0	-	-	-	-	-	-	-
1009D	0	-	-	-	-	-	-	-
1009E	1	-	-	-	0.040	-	-	-
1010C	1	-	-	-	0.040	-	-	-
1013A	0	-	-	-	-	-	-	-
1013C	0	-	-	-	-	-	-	-
1014A	0	-	-	-	-	-	-	-
1014B	1	-	-	-	0.120	-	-	-
1014C	1	-	-	-	0.060	-	-	-
1014E	0	-	-	-	-	-	-	-
1014H	0	-	-	-	-	-	-	-
1014K	0	-	-	-	-	-	-	-
1014L	0	-	-	-	-	-	-	-
1014M	0	-	-	-	-	-	-	-

1014N	0	-	-	-	-	-	-	-
1014O	0	-	-	-	-	-	-	-
1015A	1	-	-	-	0.040	-	-	-
1015B	0	-	-	-	-	-	-	-
1016A	0	-	-	-	-	-	-	-
1016B	0	-	-	-	-	-	-	-
1016C	0	-	-	-	-	-	-	-
1016D	0	-	-	-	-	-	-	-
1017A	0	-	-	-	-	-	-	-
1017B	0	-	-	-	-	-	-	-
1017C	0	-	-	-	-	-	-	-
1017D	0	-	-	-	-	-	-	-
1017E	0	-	-	-	-	-	-	-
1017F	0	-	-	-	-	-	-	-
1101B	2	0.040	-	-	0.040	-	-	0.040
1101F	1	-	-	-	0.040	-	-	-
1102A	4	0.040	-	0.123	0.160	0.173	-	0.180
1102B	9	0.015	0.075	0.155	0.830	1.970	2.196	2.480
1102C	1	-	-	-	0.080	-	-	-
1102D	1	-	-	-	3.510	-	-	-
1102E	2	2.500	-	-	3.210	-	-	3.920
1102F	2	1.050	-	-	1.210	-	-	1.370
1103F	0	-	-	-	-	-	-	-
1104A	0	-	-	-	-	-	-	-
1105A	1	-	-	-	0.110	-	-	-
1105B	1	-	-	-	0.040	-	-	-
1105C	1	-	-	-	0.100	-	-	-
1105D	0	-	-	-	-	-	-	-
1113A	0	-	-	-	-	-	-	-
1202H	1	-	-	-	0.630	-	-	-
1202J	3	0.190	-	-	0.730	-	-	2.180
1202K	1	-	-	-	0.130	-	-	-
1202P	0	-	-	-	-	-	-	-
1204A	1	-	-	-	0.840	-	-	-
1205B	1	-	-	-	0.040	-	-	-
1205C	1	-	-	-	1.150	-	-	-
1205D	1	-	-	-	0.080	-	-	-
1205E	1	-	-	-	0.080	-	-	-
1205F	1	-	-	-	0.090	-	-	-
1205G	1	-	-	-	0.080	-	-	-

1205H	1	-	-	-	0.115	-	-	-
1206D	1	-	-	-	0.100	-	-	-
1209C	2	8.210	-	-	8.885	-	-	9.560
1209D	1	-	-	-	0.100	-	-	-
1209E	1	-	-	-	0.245	-	-	-
1209G	1	-	-	-	0.330	-	-	-
1209H	2	0.230	-	-	0.290	-	-	0.350
1209I	2	0.100	-	-	0.100	-	-	0.100
1209J	0	-	-	-	-	-	-	-
1209K	0	-	-	-	-	-	-	-
1209L	1	-	-	-	11.550	-	-	-
1209P	0	-	-	-	-	-	-	-
1210A	1	-	-	-	0.200	-	-	-
1211A	1	-	-	-	0.150	-	-	-
1212A	0	-	-	-	-	-	-	-
1212B	2	0.040	-	-	0.070	-	-	0.100
1213A	1	-	-	-	1.055	-	-	-
1213B	0	-	-	-	-	-	-	-
1213C	0	-	-	-	-	-	-	-
1216A	1	-	-	-	0.200	-	-	-
1216B	0	-	-	-	-	-	-	-
1217A	1	-	-	-	0.060	-	-	-
1217B	7	0.170	0.182	0.193	0.520	0.910	1.236	1.350
1217E	0	-	-	-	-	-	-	-
1217F	0	-	-	-	-	-	-	-
1218B	0	-	-	-	-	-	-	-
1220A	2	0.175	-	-	0.178	-	-	0.180
1221A	4	0.100	-	0.265	0.320	0.683	-	1.770
1221B	1	-	-	-	0.340	-	-	-
1221C	1	-	-	-	0.470	-	-	-
1221D	2	0.680	-	-	9.995	-	-	19.310
1221E	0	-	-	-	-	-	-	-
1221F	1	-	-	-	0.910	-	-	-
1222A	2	0.205	-	-	0.623	-	-	1.040
1222B	1	-	-	-	0.080	-	-	-
1222C	1	-	-	-	0.100	-	-	-
1222D	0	-	-	-	-	-	-	-
1222E	1	-	-	-	0.040	-	-	-
1222F	0	-	-	-	-	-	-	-
1223A	1	-	-	-	1.030	-	-	-

1223B	0	-	-	-	-	-	-	-
1225A	0	-	-	-	-	-	-	-
1226A	1	-	-	-	0.100	-	-	-
1226B	1	-	-	-	0.100	-	-	-
1226C	1	-	-	-	0.130	-	-	-
1226D	1	-	-	-	0.460	-	-	-
1226E	0	-	-	-	-	-	-	-
1226F	0	-	-	-	-	-	-	-
1226G	0	-	-	-	-	-	-	-
1226H	0	-	-	-	-	-	-	-
1226I	0	-	-	-	-	-	-	-
1226J	0	-	-	-	-	-	-	-
1226K	0	-	-	-	-	-	-	-
1226L	0	-	-	-	-	-	-	-
1226M	0	-	-	-	-	-	-	-
1226Q	0	-	-	-	-	-	-	-
1227A	1	-	-	-	8.445	-	-	-
1232A	1	-	-	-	2.110	-	-	-
1232B	2	10.160	-	-	10.730	-	-	11.300
1232C	1	-	-	-	0.040	-	-	-
1233A	1	-	-	-	0.080	-	-	-
1233B	0	-	-	-	-	-	-	-
1236A	0	-	-	-	-	-	-	-
1238A	1	-	-	-	0.040	-	-	-
1240A	1	-	-	-	0.625	-	-	-
1241A	3	0.760	-	-	1.880	-	-	2.610
1241D	0	-	-	-	-	-	-	-
1242B	2	0.220	-	-	35.410	-	-	70.600
1242C	2	0.680	-	-	5.033	-	-	9.385
1242D	2	0.240	-	-	8.755	-	-	17.270
1242E	0	-	-	-	-	-	-	-
1242F	1	-	-	-	0.835	-	-	-
1242I	0	-	-	-	-	-	-	-
1242J	1	-	-	-	1.240	-	-	-
1242K	1	-	-	-	0.410	-	-	-
1242L	1	-	-	-	0.170	-	-	-
1242M	1	-	-	-	0.180	-	-	-
1242N	1	-	-	-	0.580	-	-	-
1242O	1	-	-	-	0.210	-	-	-
1242P	1	-	-	-	0.340	-	-	-

1242Q	0	-	-	-	-	-	-	-
1244A	1	-	-	-	0.570	-	-	-
1244B	1	-	-	-	0.820	-	-	-
1244D	1	-	-	-	1.280	-	-	-
1245B	1	-	-	-	0.420	-	-	-
1245C	2	0.245	-	-	3.483	-	-	6.720
1245D	1	-	-	-	0.110	-	-	-
1245I	1	-	-	-	2.440	-	-	-
1246C	0	-	-	-	-	-	-	-
1246D	0	-	-	-	-	-	-	-
1246E	1	-	-	-	2.170	-	-	-
1247A	1	-	-	-	7.725	-	-	-
1248A	1	-	-	-	0.860	-	-	-
1248B	1	-	-	-	2.410	-	-	-
1248C	2	6.070	-	-	6.080	-	-	6.090
1248D	1	-	-	-	0.285	-	-	-
1254A	0	-	-	-	-	-	-	-
1254B	0	-	-	-	-	-	-	-
1255A	0	-	-	-	-	-	-	-
1255B	0	-	-	-	-	-	-	-
1255C	0	-	-	-	-	-	-	-
1255D	0	-	-	-	-	-	-	-
1255E	0	-	-	-	-	-	-	-
1255F	0	-	-	-	-	-	-	-
1255I	0	-	-	-	-	-	-	-
1256A	1	-	-	-	0.860	-	-	-
1302A	1	-	-	-	0.239	-	-	-
1302B	1	-	-	-	0.210	-	-	-
1302C	0	-	-	-	-	-	-	-
1402A	2	0.020	-	-	0.020	-	-	0.020
1402C	1	-	-	-	0.050	-	-	-
1402H	1	-	-	-	0.100	-	-	-
1403A	5	0.040	-	0.060	0.090	0.110	-	0.130
1403B	2	0.140	-	-	0.168	-	-	0.195
1403E	0	-	-	-	-	-	-	-
1403F	0	-	-	-	-	-	-	-
1403H	2	0.410	-	-	0.425	-	-	0.700
1403I	1	-	-	-	0.425	-	-	-
1403J	1	-	-	-	2.370	-	-	-
1403K	1	-	-	-	1.960	-	-	-

1403L	1	-	-	-	0.260	-	-	-
1403M	0	-	-	-	-	-	-	-
1403N	0	-	-	-	-	-	-	-
1403O	0	-	-	-	-	-	-	-
1403P	1	-	-	-	0.205	-	-	-
1403Q	0	-	-	-	-	-	-	-
1403R	1	-	-	-	0.490	-	-	-
1404A	1	-	-	-	0.050	-	-	-
1404B	1	-	-	-	0.055	-	-	-
1404C	0	-	-	-	-	-	-	-
1404D	0	-	-	-	-	-	-	-
1406A	1	-	-	-	0.029	-	-	-
1407A	1	-	-	-	0.020	-	-	-
1409A	1	-	-	-	0.030	-	-	-
1412B	5	0.020	-	0.040	0.475	5.500	-	12.560
1412C	0	-	-	-	-	-	-	-
1414A	0	-	-	-	-	-	-	-
1414B	1	-	-	-	0.090	-	-	-
1414D	0	-	-	-	-	-	-	-
1415A	1	-	-	-	0.280	-	-	-
1415C	1	-	-	-	0.110	-	-	-
1416A	2	0.020	-	-	2.688	-	-	5.355
1416B	0	-	-	-	-	-	-	-
1416C	0	-	-	-	-	-	-	-
1418B	0	-	-	-	-	-	-	-
1421A	1	-	-	-	2.360	-	-	-
1421B	1	-	-	-	0.030	-	-	-
1421C	1	-	-	-	1.725	-	-	-
1423A	2	0.110	-	-	0.955	-	-	1.800
1423B	1	-	-	-	0.080	-	-	-
1424A	1	-	-	-	0.020	-	-	-
1424B	1	-	-	-	1.815	-	-	-
1425A	3	0.020	-	-	0.050	-	-	0.110
1426B	3	0.205	-	-	0.220	-	-	0.295
1426C	1	-	-	-	5.100	-	-	-
1426D	1	-	-	-	2.035	-	-	-
1427A	1	-	-	-	0.040	-	-	-
1427B	0	-	-	-	-	-	-	-
1427C	1	-	-	-	0.060	-	-	-
1427E	0	-	-	-	-	-	-	-

1427F	0	-	-	-	-	-	-	-
1427G	0	-	-	-	-	-	-	-
1428A	0	-	-	-	-	-	-	-
1428B	4	0.255	-	0.356	0.425	0.491	-	0.585
1428C	2	4.950	-	-	5.698	-	-	6.445
1428D	0	-	-	-	-	-	-	-
1428E	0	-	-	-	-	-	-	-
1428F	0	-	-	-	-	-	-	-
1428I	0	-	-	-	-	-	-	-
1428J	0	-	-	-	-	-	-	-
1429A	0	-	-	-	-	-	-	-
1429B	0	-	-	-	-	-	-	-
1429C	3	0.380	-	-	0.460	-	-	0.680
1429D	0	-	-	-	-	-	-	-
1429E	0	-	-	-	-	-	-	-
1429F	0	-	-	-	-	-	-	-
1429G	0	-	-	-	-	-	-	-
1429H	0	-	-	-	-	-	-	-
1430B	11	0.030	0.080	0.103	0.305	1.518	2.270	3.060
1434B	1	-	-	-	0.020	-	-	-
1601C	0	-	-	-	-	-	-	-
1602B	0	-	-	-	-	-	-	-
1604A	1	-	-	-	0.805	-	-	-
1604B	1	-	-	-	0.210	-	-	-
1604C	1	-	-	-	0.080	-	-	-
1803A	0	-	-	-	-	-	-	-
1803B	1	-	-	-	0.275	-	-	-
1803C	1	-	-	-	0.175	-	-	-
1804A	2	11.000	-	-	11.350	-	-	11.700
1806A	1	-	-	-	0.780	-	-	-
1806D	0	-	-	-	-	-	-	-
1806E	0	-	-	-	-	-	-	-
1806G	1	-	-	-	0.265	-	-	-
1806H	0	-	-	-	-	-	-	-
1807A	0	-	-	-	-	-	-	-
1811A	1	-	-	-	0.495	-	-	-
1813A	0	-	-	-	-	-	-	-
1813B	0	-	-	-	-	-	-	-
1813C	0	-	-	-	-	-	-	-
1813D	0	-	-	-	-	-	-	-

1813E	0	-	-	-	-	-	-	-
1813F	0	-	-	-	-	-	-	-
1813G	0	-	-	-	-	-	-	-
1813H	0	-	-	-	-	-	-	-
1813I	0	-	-	-	-	-	-	-
1901A	0	-	-	-	-	-	-	-
1901B	0	-	-	-	-	-	-	-
1901C	0	-	-	-	-	-	-	-
1901D	0	-	-	-	-	-	-	-
1902A	0	-	-	-	-	-	-	-
1902B	0	-	-	-	-	-	-	-
1905A	1	-	-	-	0.140	-	-	-
1906A	0	-	-	-	-	-	-	-
1910A	0	-	-	-	-	-	-	-
1910B	0	-	-	-	-	-	-	-
1910C	0	-	-	-	-	-	-	-
1910D	0	-	-	-	-	-	-	-
1910E	0	-	-	-	-	-	-	-
1911B	2	0.275	-	-	1.415	-	-	2.556
1911C	3	0.114	-	-	0.242	-	-	0.373
1911D	2	1.463	-	-	1.606	-	-	1.750
1911E	0	-	-	-	-	-	-	-
1911H	0	-	-	-	-	-	-	-
1912A	1	-	-	-	5.555	-	-	-
2004A	0	-	-	-	-	-	-	-
2004B	0	-	-	-	-	-	-	-
2302A	1	-	-	-	0.055	-	-	-
2304B	1	-	-	-	0.128	-	-	-
2306A	0	-	-	-	-	-	-	-
2309A	1	-	-	-	1.660	-	-	-
2310A	1	-	-	-	0.820	-	-	-
2422B	0	-	-	-	-	-	-	-
2424A	1	-	-	-	0.035	-	-	-
2424D	1	-	-	-	0.050	-	-	-
2424E	1	-	-	-	0.040	-	-	-
2431A	1	-	-	-	0.040	-	-	-
2432A	0	-	-	-	-	-	-	-
2432B	2	0.035	-	-	0.038	-	-	0.040
2485B	0	-	-	-	-	-	-	-
2485D	0	-	-	-	-	-	-	-

2492A	0	-	-	-	-	-	-	-

Ortho-Phosphate (PO_4-P; mg/L)

Segment	n	MIN	10th	25th	Median	75th	90th	MAX
0101	4	0.040	-	0.040	0.050	0.060	-	0.060
0103	3	0.020	-	-	0.040	-	-	0.060
0104	2	0.040	-	-	0.043	-	-	0.045
0201	1	-	-	-	0.060	-	-	-
0202	4	0.060	-	0.060	0.060	0.063	-	0.070
0204	3	0.040	-	-	0.040	-	-	0.040
0205	2	0.020	-	-	0.040	-	-	0.060
0206	1	-	-	-	0.045	-	-	-
0207	2	0.040	-	-	0.070	-	-	0.100
0211	2	0.040	-	-	0.050	-	-	0.060
0214	8	0.040	0.040	0.040	0.050	0.139	0.503	0.800
0216	1	-	-	-	0.020	-	-	-
0218	4	0.020	-	0.020	0.020	0.045	-	0.120
0220	2	0.040	-	-	0.045	-	-	0.050
0221	0	-	-	-	-	-	-	-
0222	1	-	-	-	0.040	-	-	-
0224	1	-	-	-	0.020	-	-	-
0226	3	0.020	-	-	0.020	-	-	0.020
0227	0	-	-	-	-	-	-	-
0229	2	0.510	-	-	0.630	-	-	0.750
0230	2	0.040	-	-	0.080	-	-	0.120
0301	2	0.060	-	-	0.060	-	-	0.060
0303	3	0.055	-	-	0.060	-	-	0.060
0304	0	-	-	-	-	-	-	-
0305	1	-	-	-	0.060	-	-	-
0306	2	0.040	-	-	0.383	-	-	0.725
0401	0	-	-	-	-	-	-	-
0402	4	0.010	-	0.018	0.020	0.026	-	0.045
0404	2	0.155	-	-	0.538	-	-	0.920
0406	3	0.040	-	-	0.060	-	-	0.060
0407	1	-	-	-	0.010	-	-	-
0409	6	0.050	-	0.060	0.060	0.060	-	0.060
0501	2	0.040	-	-	0.040	-	-	0.040
0502	2	0.040	-	-	0.040	-	-	0.040
0503	5	0.040	-	0.040	0.040	0.040	-	0.070

0504	1	-	-	-	0.280	-	-	-
0505	5	0.040	-	0.040	0.040	0.040	-	0.050
0506	4	0.040	-	0.040	0.045	0.050	-	0.050
0513	1	-	-	-	0.040	-	-	-
0514	4	0.040	-	0.040	0.045	0.053	-	0.060
0515	1	-	-	-	0.040	-	-	-
0602	3	0.015	-	-	0.020	-	-	0.060
0604	7	0.025	0.034	0.040	0.060	0.060	0.060	0.060
0606	3	0.060	-	-	0.060	-	-	0.185
0607	4	0.030	-	0.034	0.038	0.040	-	0.040
0608	2	0.025	-	-	0.033	-	-	0.040
0609	1	-	-	-	0.010	-	-	-
0610	1	-	-	-	0.050	-	-	-
0611	4	0.060	-	0.060	0.065	0.077	-	0.100
0612	3	0.040	-	-	0.050	-	-	0.060
0701	2	0.030	-	-	0.045	-	-	0.060
0704	2	0.070	-	-	0.138	-	-	0.206
0801	0	-	-	-	-	-	-	-
0802	4	0.045	-	0.056	0.060	0.060	-	0.060
0803	0	-	-	-	-	-	-	-
0804	4	0.320	-	0.410	0.525	0.664	-	0.825
0805	5	0.809	-	0.835	0.850	0.898	-	0.910
0806	4	0.008	-	0.016	0.020	0.025	-	0.040
0809	0	-	-	-	-	-	-	-
0810	1	-	-	-	0.060	-	-	-
0812	1	-	-	-	0.070	-	-	-
0814	2	0.020	-	-	0.115	-	-	0.210
0815	0	-	-	-	-	-	-	-
0817	0	-	-	-	-	-	-	-
0818	0	-	-	-	-	-	-	-
0819	3	0.560	-	-	1.670	-	-	2.210
0821	0	-	-	-	-	-	-	-
0822	8	0.010	0.017	0.028	0.040	0.043	0.055	0.065
0824	2	0.060	-	-	0.778	-	-	1.495
0825	2	0.020	-	-	0.083	-	-	0.145
0829	1	-	-	-	0.050	-	-	-
0830	0	-	-	-	-	-	-	-
0831	1	-	-	-	0.700	-	-	-
0833	0	-	-	-	-	-	-	-
0835	0	-	-	-	-	-	-	-

0836	0	-	-	-	-	-	-	-
0837	1	-	-	-	0.018	-	-	-
0838	0	-	-	-	-	-	-	-
0839	0	-	-	-	-	-	-	-
0840	0	-	-	-	-	-	-	-
0841	4	0.720	-	0.725	0.730	0.865	-	1.000
0902	2	0.050	-	-	0.065	-	-	0.080
1002	1	-	-	-	0.120	-	-	-
1003	4	0.030	-	0.030	0.035	0.045	-	0.060
1004	2	0.010	-	-	0.030	-	-	0.050
1006	1	-	-	-	0.310	-	-	-
1007	1	-	-	-	1.330	-	-	-
1008	7	0.020	0.044	0.065	0.100	0.250	0.420	0.600
1009	7	0.100	0.424	0.735	1.020	1.265	1.512	1.800
1010	4	0.010	-	0.033	0.043	0.046	-	0.050
1011	4	0.010	-	0.018	0.030	0.040	-	0.040
1013	0	-	-	-	-	-	-	-
1014	12	0.850	0.874	0.918	0.945	1.168	1.379	1.410
1015	2	0.070	-	-	0.073	-	-	0.075
1016	6	1.050	-	1.175	1.298	1.424	-	1.460
1017	9	0.695	0.807	0.885	1.130	1.880	2.223	2.955
1101	1	-	-	-	0.270	-	-	-
1102	10	0.040	0.171	0.211	0.315	0.380	0.421	0.605
1103	0	-	-	-	-	-	-	-
1104	1	-	-	-	0.050	-	-	-
1105	1	-	-	-	0.085	-	-	-
1108	1	-	-	-	0.060	-	-	-
1110	1	-	-	-	0.260	-	-	-
1201	0	-	-	-	-	-	-	-
1202	4	0.040	-	0.040	0.040	0.043	-	0.050
1204	2	0.020	-	-	0.030	-	-	0.040
1205	1	-	-	-	0.040	-	-	-
1206	6	0.040	-	0.040	0.040	0.040	-	0.040
1208	4	0.040	-	0.040	0.040	0.045	-	0.060
1209	5	0.040	-	0.040	0.040	0.260	-	0.330
1211	2	0.040	-	-	0.040	-	-	0.040
1213	4	0.060	-	0.060	0.070	0.103	-	0.170
1214	1	-	-	-	0.198	-	-	-
1215	1	-	-	-	0.040	-	-	-
1217	2	0.040	-	-	0.043	-	-	0.045

1218	1	-	-	-	1.290	-	-	-
1219	1	-	-	-	0.370	-	-	-
1220	0	-	-	-	-	-	-	-
1221	9	0.040	0.040	0.040	0.040	0.050	0.080	0.120
1223	1	-	-	-	0.060	-	-	-
1226	12	0.004	0.005	0.006	0.016	0.126	0.324	0.590
1227	4	0.260	-	0.328	0.385	0.550	-	0.940
1229	2	0.040	-	-	0.040	-	-	0.040
1232	5	0.040	-	0.170	0.270	0.300	-	1.670
1236	0	-	-	-	-	-	-	-
1238	2	0.040	-	-	0.040	-	-	0.040
1239	0	-	-	-	-	-	-	-
1241	1	-	-	-	0.040	-	-	-
1242	5	0.040	-	0.040	0.040	0.050	-	0.060
1243	3	0.040	-	-	0.040	-	-	0.040
1244	4	0.040	-	0.040	0.045	0.148	-	0.440
1245	5	0.040	-	0.070	0.100	0.265	-	0.485
1246	5	0.005	-	0.005	0.006	0.007	-	0.040
1248	2	0.040	-	-	0.045	-	-	0.050
1250	4	0.040	-	0.040	0.040	0.045	-	0.060
1251	1	-	-	-	0.040	-	-	-
1253	3	0.040	-	-	0.060	-	-	0.080
1255	3	0.275	-	-	0.570	-	-	0.770
1256	3	0.009	-	-	0.040	-	-	0.050
1257	3	0.020	-	-	0.040	-	-	0.040
1301	1	-	-	-	0.130	-	-	-
1302	6	0.040	-	0.096	0.106	0.113	-	0.125
1305	1	-	-	-	0.250	-	-	-
1402	6	0.170	-	0.210	0.240	0.274	-	0.300
1403	0	-	-	-	-	-	-	-
1406	0	-	-	-	-	-	-	-
1409	1	-	-	-	0.040	-	-	-
1410	2	0.040	-	-	0.050	-	-	0.060
1412	3	0.036	-	-	0.060	-	-	0.083
1414	5	0.025	-	0.040	0.040	0.040	-	0.060
1415	8	0.030	0.037	0.040	0.040	0.040	0.040	0.040
1416	2	0.027	-	-	0.033	-	-	0.040
1417	1	-	-	-	0.070	-	-	-
1420	2	0.040	-	-	0.050	-	-	0.060
1421	10	0.040	0.040	0.043	0.200	0.276	0.300	0.310

1424	2	0.060	-	-	0.153	-	-	0.246
1426	4	0.020	-	0.035	0.040	0.040	-	0.040
1427	12	0.020	0.020	0.020	0.020	0.040	0.040	0.060
1428	4	0.020	-	0.035	0.105	0.235	-	0.430
1430	15	0.020	0.020	0.020	0.020	0.020	0.023	0.030
1431	1	-	-	-	1.190	-	-	-
1432	1	-	-	-	0.060	-	-	-
1434	2	0.290	-	-	0.325	-	-	0.360
1501	0	-	-	-	-	-	-	-
1502	1	-	-	-	0.180	-	-	-
1602	1	-	-	-	0.120	-	-	-
1605	1	-	-	-	0.140	-	-	-
1801	0	-	-	-	-	-	-	-
1802	0	-	-	-	-	-	-	-
1803	0	-	-	-	-	-	-	-
1804	5	0.030	-	0.040	0.040	0.040	-	0.060
1806	1	-	-	-	0.040	-	-	-
1807	1	-	-	-	0.060	-	-	-
1808	1	-	-	-	0.040	-	-	-
1809	1	-	-	-	0.040	-	-	-
1810	1	-	-	-	0.745	-	-	-
1811	1	-	-	-	0.020	-	-	-
1812	5	0.020	-	0.030	0.040	0.040	-	0.040
1813	1	-	-	-	0.060	-	-	-
1814	0	-	-	-	-	-	-	-
1815	0	-	-	-	-	-	-	-
1816	0	-	-	-	-	-	-	-
1817	0	-	-	-	-	-	-	-
1818	0	-	-	-	-	-	-	-
1901	8	0.420	0.523	0.586	0.705	0.724	0.809	0.964
1902	5	0.134	-	0.145	0.170	0.270	-	0.446
1903	5	0.020	-	0.040	0.098	0.680	-	0.880
1905	1	-	-	-	0.020	-	-	-
1906	4	0.020	-	0.035	0.040	0.040	-	0.040
1907	1	-	-	-	0.040	-	-	-
1908	3	0.020	-	-	0.500	-	-	1.800
1910	8	0.034	0.038	0.040	0.049	0.063	0.080	0.114
1911	15	0.040	0.049	0.077	0.397	0.839	0.972	1.120
1912	1	-	-	-	1.090	-	-	-
1913	2	0.040	-	-	0.448	-	-	0.855

2002	1	-	-	-	0.020	-	-	-
2003	0	-	-	-	-	-	-	-
2004	1	-	-	-	1.170	-	-	-
2102	2	0.130	-	-	0.135	-	-	0.140
2103	1	-	-	-	0.040	-	-	-
2104	1	-	-	-	0.040	-	-	-
2105	2	0.040	-	-	0.050	-	-	0.060
2106	3	0.060	-	-	0.060	-	-	0.070
2107	2	0.060	-	-	0.133	-	-	0.205
2108	1	-	-	-	0.040	-	-	-
2109	3	0.040	-	-	0.050	-	-	0.060
2110	1	-	-	-	0.040	-	-	-
2111	1	-	-	-	0.040	-	-	-
2112	2	0.040	-	-	0.050	-	-	0.060
2113	2	0.040	-	-	0.050	-	-	0.060
2114	2	0.040	-	-	0.040	-	-	0.040
2115	1	-	-	-	0.060	-	-	-
2117	3	0.030	-	-	0.040	-	-	0.060
2202	6	0.364	-	0.389	0.428	0.573	-	0.970
2204	2	0.040	-	-	0.055	-	-	0.070
2301	0	-	-	-	-	-	-	-
2302	10	0.006	0.037	0.053	0.060	0.163	0.181	0.190
2304	15	0.007	0.040	0.043	0.060	0.060	0.140	0.190
2305	0	-	-	-	-	-	-	-
2306	5	0.007	-	0.045	0.060	0.060	-	0.060
2307	5	0.070	-	0.375	0.445	0.550	-	0.570
2308	3	0.070	-	-	0.075	-	-	0.220
2309	2	0.040	-	-	0.040	-	-	0.040
2310	3	0.006	-	-	0.040	-	-	0.060
2311	6	0.040	-	0.040	0.040	0.044	-	0.060
2313	3	0.040	-	-	0.050	-	-	0.060
2314	2	0.060	-	-	0.070	-	-	0.080
2431	1	-	-	-	0.070	-	-	-
2472	0	-	-	-	-	-	-	-
0101A	1	-	-	-	0.160	-	-	-
0101B	2	0.110	-	-	0.235	-	-	0.360
0101C	1	-	-	-	0.040	-	-	-
0102A	1	-	-	-	0.040	-	-	-
0103A	1	-	-	-	0.105	-	-	-
0103C	1	-	-	-	0.040	-	-	-

0199A	0	-	-	-	-	-	-	-
0201A	1	-	-	-	0.130	-	-	-
0202A	3	0.050	-	-	0.056	-	-	0.085
0202C	1	-	-	-	0.040	-	-	-
0202D	1	-	-	-	0.100	-	-	-
0202E	1	-	-	-	0.205	-	-	-
0202F	1	-	-	-	3.860	-	-	-
0202G	1	-	-	-	0.770	-	-	-
0202H	0	-	-	-	-	-	-	-
0202I	0	-	-	-	-	-	-	-
0202J	0	-	-	-	-	-	-	-
0202K	1	-	-	-	0.045	-	-	-
0203A	0	-	-	-	-	-	-	-
0203C	0	-	-	-	-	-	-	-
0203D	0	-	-	-	-	-	-	-
0206B	1	-	-	-	0.060	-	-	-
0207A	0	-	-	-	-	-	-	-
0214A	2	0.040	-	-	0.061	-	-	0.082
0214B	1	-	-	-	1.180	-	-	-
0218A	1	-	-	-	0.020	-	-	-
0222A	1	-	-	-	0.060	-	-	-
0224A	1	-	-	-	0.040	-	-	-
0230A	1	-	-	-	0.040	-	-	-
0299A	2	0.040	-	-	0.065	-	-	0.090
0302A	0	-	-	-	-	-	-	-
0302B	0	-	-	-	-	-	-	-
0302C	0	-	-	-	-	-	-	-
0302D	0	-	-	-	-	-	-	-
0302E	0	-	-	-	-	-	-	-
0302F	0	-	-	-	-	-	-	-
0303B	3	0.060	-	-	0.140	-	-	0.660
0303D	0	-	-	-	-	-	-	-
0303E	0	-	-	-	-	-	-	-
0303F	0	-	-	-	-	-	-	-
0303G	0	-	-	-	-	-	-	-
0303H	0	-	-	-	-	-	-	-
0303I	0	-	-	-	-	-	-	-
0303J	0	-	-	-	-	-	-	-
0303K	0	-	-	-	-	-	-	-
0303L	0	-	-	-	-	-	-	-

0304A	0	-	-	-	-	-	-	-
0304B	0	-	-	-	-	-	-	-
0304C	0	-	-	-	-	-	-	-
0304D	0	-	-	-	-	-	-	-
0305A	0	-	-	-	-	-	-	-
0305B	0	-	-	-	-	-	-	-
0305C	0	-	-	-	-	-	-	-
0305D	0	-	-	-	-	-	-	-
0307A	0	-	-	-	-	-	-	-
0307B	0	-	-	-	-	-	-	-
0307C	0	-	-	-	-	-	-	-
0401A	0	-	-	-	-	-	-	-
0401B	0	-	-	-	-	-	-	-
0402A	5	0.040	-	0.060	0.060	0.060	-	0.060
0402B	0	-	-	-	-	-	-	-
0402C	0	-	-	-	-	-	-	-
0402D	0	-	-	-	-	-	-	-
0402E	0	-	-	-	-	-	-	-
0404B	0	-	-	-	-	-	-	-
0404C	0	-	-	-	-	-	-	-
0404I	1	-	-	-	0.010	-	-	-
0404J	1	-	-	-	0.010	-	-	-
0404K	1	-	-	-	0.010	-	-	-
0404O	0	-	-	-	-	-	-	-
0404P	0	-	-	-	-	-	-	-
0404Q	0	-	-	-	-	-	-	-
0404R	0	-	-	-	-	-	-	-
0405A	0	-	-	-	-	-	-	-
0405B	0	-	-	-	-	-	-	-
0405C	0	-	-	-	-	-	-	-
0407A	0	-	-	-	-	-	-	-
0407B	1	-	-	-	0.010	-	-	-
0408B	0	-	-	-	-	-	-	-
0408C	0	-	-	-	-	-	-	-
0408D	0	-	-	-	-	-	-	-
0409A	1	-	-	-	0.010	-	-	-
0409B	0	-	-	-	-	-	-	-
0409E	0	-	-	-	-	-	-	-
0501B	0	-	-	-	-	-	-	-
0502A	0	-	-	-	-	-	-	-

0502B	2	0.040	-	-	0.040	-	-	0.040
0502D	0	-	-	-	-	-	-	-
0502E	0	-	-	-	-	-	-	-
0504C	0	-	-	-	-	-	-	-
0504D	1	-	-	-	0.865	-	-	-
0505B	0	-	-	-	-	-	-	-
0505D	0	-	-	-	-	-	-	-
0505G	0	-	-	-	-	-	-	-
0505P	1	-	-	-	0.060	-	-	-
0506A	1	-	-	-	0.050	-	-	-
0506C	1	-	-	-	0.230	-	-	-
0507A	1	-	-	-	0.120	-	-	-
0507B	0	-	-	-	-	-	-	-
0507D	0	-	-	-	-	-	-	-
0507E	0	-	-	-	-	-	-	-
0507F	0	-	-	-	-	-	-	-
0507G	0	-	-	-	-	-	-	-
0507H	0	-	-	-	-	-	-	-
0508A	1	-	-	-	0.105	-	-	-
0508C	0	-	-	-	-	-	-	-
0511C	0	-	-	-	-	-	-	-
0511E	0	-	-	-	-	-	-	-
0512A	0	-	-	-	-	-	-	-
0602A	0	-	-	-	-	-	-	-
0602B	0	-	-	-	-	-	-	-
0603A	1	-	-	-	0.120	-	-	-
0603B	1	-	-	-	0.010	-	-	-
0604A	2	0.130	-	-	1.453	-	-	2.775
0604B	1	-	-	-	0.120	-	-	-
0604C	1	-	-	-	1.007	-	-	-
0604D	2	0.080	-	-	0.081	-	-	0.082
0604M	1	-	-	-	0.105	-	-	-
0604N	1	-	-	-	0.060	-	-	-
0605A	1	-	-	-	0.160	-	-	-
0605E	0	-	-	-	-	-	-	-
0606A	1	-	-	-	0.040	-	-	-
0606C	0	-	-	-	-	-	-	-
0606D	1	-	-	-	0.050	-	-	-
0607A	0	-	-	-	-	-	-	-
0607B	1	-	-	-	0.035	-	-	-

0607C	1	-	-	-	0.040	-	-	-
0608A	1	-	-	-	0.035	-	-	-
0608B	1	-	-	-	0.020	-	-	-
0608C	1	-	-	-	0.030	-	-	-
0608D	1	-	-	-	0.020	-	-	-
0608E	0	-	-	-	-	-	-	-
0608F	1	-	-	-	0.040	-	-	-
0608J	0	-	-	-	-	-	-	-
0610A	1	-	-	-	0.040	-	-	-
0611A	1	-	-	-	0.060	-	-	-
0611B	3	0.040	-	-	0.040	-	-	0.780
0611C	2	0.060	-	-	0.066	-	-	0.071
0611D	3	0.040	-	-	0.140	-	-	0.380
0612A	1	-	-	-	0.040	-	-	-
0612B	1	-	-	-	0.040	-	-	-
0615A	1	-	-	-	0.150	-	-	-
0702A	1	-	-	-	0.060	-	-	-
0704A	0	-	-	-	-	-	-	-
0801C	0	-	-	-	-	-	-	-
0802B	0	-	-	-	-	-	-	-
0802D	0	-	-	-	-	-	-	-
0803A	1	-	-	-	0.900	-	-	-
0803B	1	-	-	-	0.040	-	-	-
0803E	0	-	-	-	-	-	-	-
0803F	0	-	-	-	-	-	-	-
0804F	1	-	-	-	0.020	-	-	-
0804G	1	-	-	-	0.040	-	-	-
0804H	0	-	-	-	-	-	-	-
0805A	0	-	-	-	-	-	-	-
0805B	0	-	-	-	-	-	-	-
0805D	0	-	-	-	-	-	-	-
0806C	0	-	-	-	-	-	-	-
0806D	0	-	-	-	-	-	-	-
0806E	0	-	-	-	-	-	-	-
0810A	0	-	-	-	-	-	-	-
0810B	0	-	-	-	-	-	-	-
0810C	0	-	-	-	-	-	-	-
0810D	0	-	-	-	-	-	-	-
0814A	0	-	-	-	-	-	-	-
0814B	0	-	-	-	-	-	-	-

0815A	1	-	-	-	0.030	-	-	-
0816A	0	-	-	-	-	-	-	-
0817A	1	-	-	-	0.020	-	-	-
0819A	0	-	-	-	-	-	-	-
0819B	0	-	-	-	-	-	-	-
0820B	1	-	-	-	0.080	-	-	-
0820C	1	-	-	-	0.120	-	-	-
0821B	0	-	-	-	-	-	-	-
0821C	1	-	-	-	0.040	-	-	-
0821D	1	-	-	-	0.070	-	-	-
0822A	5	0.020	-	0.040	0.040	0.040	-	0.040
0822B	2	0.040	-	-	0.050	-	-	0.060
0822C	5	0.020	-	0.035	0.040	0.040	-	0.060
0823A	1	-	-	-	0.115	-	-	-
0823B	1	-	-	-	2.170	-	-	-
0823C	1	-	-	-	0.025	-	-	-
0823D	1	-	-	-	0.040	-	-	-
0826A	2	0.020	-	-	0.165	-	-	0.310
0826C	1	-	-	-	0.020	-	-	-
0827A	2	0.020	-	-	0.075	-	-	0.130
0828A	1	-	-	-	0.020	-	-	-
0831A	0	-	-	-	-	-	-	-
0836B	0	-	-	-	-	-	-	-
0836C	0	-	-	-	-	-	-	-
0836D	0	-	-	-	-	-	-	-
0838A	1	-	-	-	0.010	-	-	-
0838B	1	-	-	-	0.040	-	-	-
0838C	1	-	-	-	0.040	-	-	-
0839A	2	0.020	-	-	0.030	-	-	0.040
0840A	0	-	-	-	-	-	-	-
0841B	9	0.020	0.028	0.040	0.040	0.040	0.044	0.060
0841C	1	-	-	-	0.040	-	-	-
0841D	1	-	-	-	0.060	-	-	-
0841E	1	-	-	-	0.040	-	-	-
0841F	2	0.040	-	-	0.040	-	-	0.040
0841G	1	-	-	-	0.040	-	-	-
0841H	6	0.020	-	0.040	0.040	0.040	-	0.040
0841I	1	-	-	-	0.040	-	-	-
0841J	1	-	-	-	0.040	-	-	-
0841K	2	0.040	-	-	0.040	-	-	0.040

0841L	3	0.040	-	-	0.040	-	-	0.040
0841M	0	-	-	-	-	-	-	-
0841N	1	-	-	-	0.040	-	-	-
0841O	3	0.020	-	-	0.040	-	-	0.040
0841P	2	0.040	-	-	0.040	-	-	0.040
0841Q	1	-	-	-	0.040	-	-	-
0841R	1	-	-	-	0.040	-	-	-
0841T	0	-	-	-	-	-	-	-
0841U	1	-	-	-	0.080	-	-	-
0841V	1	-	-	-	0.040	-	-	-
1002A	1	-	-	-	0.905	-	-	-
1002B	1	-	-	-	0.020	-	-	-
1004D	1	-	-	-	0.010	-	-	-
1004E	1	-	-	-	1.630	-	-	-
1006D	8	1.015	1.040	1.088	1.625	1.845	1.962	1.990
1006F	1	-	-	-	0.220	-	-	-
1006H	1	-	-	-	0.180	-	-	-
1006I	2	0.060	-	-	0.070	-	-	0.080
1006J	1	-	-	-	0.520	-	-	-
1007A	0	-	-	-	-	-	-	-
1007B	13	0.760	0.773	0.795	0.860	1.100	1.669	1.910
1007C	2	1.820	-	-	1.953	-	-	2.085
1007D	8	0.040	0.453	0.656	0.748	0.930	1.257	1.460
1007E	1	-	-	-	0.040	-	-	-
1007F	1	-	-	-	1.930	-	-	-
1007G	1	-	-	-	0.040	-	-	-
1007H	1	-	-	-	0.120	-	-	-
1007I	1	-	-	-	0.120	-	-	-
1007K	2	0.060	-	-	0.060	-	-	0.060
1007L	1	-	-	-	0.275	-	-	-
1007N	1	-	-	-	0.055	-	-	-
1007O	1	-	-	-	0.090	-	-	-
1007Q	0	-	-	-	-	-	-	-
1007R	4	0.050	-	0.054	0.083	0.131	-	0.195
1008B	2	0.060	-	-	1.490	-	-	2.920
1008C	2	0.110	-	-	0.270	-	-	0.430
1008E	1	-	-	-	0.090	-	-	-
1008H	1	-	-	-	0.990	-	-	-
1008J	1	-	-	-	0.050	-	-	-
1009C	1	-	-	-	1.560	-	-	-

1009D	1	-	-	-	2.075	-	-	-
1009E	2	0.330	-	-	1.000	-	-	1.670
1010C	1	-	-	-	0.070	-	-	-
1013A	1	-	-	-	0.120	-	-	-
1013C	1	-	-	-	0.060	-	-	-
1014A	1	-	-	-	2.060	-	-	-
1014B	1	-	-	-	1.310	-	-	-
1014C	1	-	-	-	2.200	-	-	-
1014E	1	-	-	-	2.440	-	-	-
1014H	2	1.880	-	-	2.090	-	-	2.300
1014K	2	0.275	-	-	0.360	-	-	0.445
1014L	1	-	-	-	3.480	-	-	-
1014M	1	-	-	-	0.080	-	-	-
1014N	1	-	-	-	0.080	-	-	-
1014O	1	-	-	-	0.080	-	-	-
1015A	1	-	-	-	0.050	-	-	-
1015B	0	-	-	-	-	-	-	-
1016A	2	1.870	-	-	1.950	-	-	2.030
1016B	1	-	-	-	0.125	-	-	-
1016C	1	-	-	-	0.640	-	-	-
1016D	1	-	-	-	0.320	-	-	-
1017A	1	-	-	-	0.270	-	-	-
1017B	1	-	-	-	0.550	-	-	-
1017C	1	-	-	-	0.775	-	-	-
1017D	1	-	-	-	0.100	-	-	-
1017E	1	-	-	-	0.080	-	-	-
1017F	1	-	-	-	3.190	-	-	-
1101B	1	-	-	-	0.040	-	-	-
1101F	1	-	-	-	0.040	-	-	-
1102A	4	0.065	-	0.069	0.070	0.085	-	0.130
1102B	9	0.110	0.134	0.215	0.655	0.750	0.764	0.780
1102C	1	-	-	-	0.090	-	-	-
1102D	0	-	-	-	-	-	-	-
1102E	2	0.280	-	-	0.300	-	-	0.320
1102F	2	0.560	-	-	0.585	-	-	0.610
1103F	0	-	-	-	-	-	-	-
1104A	0	-	-	-	-	-	-	-
1105A	1	-	-	-	0.060	-	-	-
1105B	1	-	-	-	0.040	-	-	-
1105C	1	-	-	-	0.065	-	-	-

1105D	0	-	-	-	-	-	-	-
1113A	1	-	-	-	0.040	-	-	-
1202H	1	-	-	-	0.455	-	-	-
1202J	3	0.050	-	-	0.160	-	-	1.690
1202K	1	-	-	-	0.060	-	-	-
1202P	1	-	-	-	0.095	-	-	-
1204A	1	-	-	-	0.060	-	-	-
1205B	1	-	-	-	0.040	-	-	-
1205C	1	-	-	-	0.170	-	-	-
1205D	1	-	-	-	0.040	-	-	-
1205E	1	-	-	-	0.040	-	-	-
1205F	1	-	-	-	0.040	-	-	-
1205G	1	-	-	-	0.040	-	-	-
1205H	1	-	-	-	0.040	-	-	-
1206D	2	0.040	-	-	0.040	-	-	0.040
1209C	2	2.270	-	-	2.315	-	-	2.360
1209D	1	-	-	-	0.135	-	-	-
1209E	1	-	-	-	0.050	-	-	-
1209G	1	-	-	-	0.040	-	-	-
1209H	2	0.040	-	-	0.040	-	-	0.040
1209I	3	0.040	-	-	0.040	-	-	0.075
1209J	0	-	-	-	-	-	-	-
1209K	0	-	-	-	-	-	-	-
1209L	1	-	-	-	2.545	-	-	-
1209P	0	-	-	-	-	-	-	-
1210A	1	-	-	-	0.090	-	-	-
1211A	1	-	-	-	0.040	-	-	-
1212A	1	-	-	-	0.040	-	-	-
1212B	2	0.040	-	-	0.040	-	-	0.040
1213A	1	-	-	-	0.060	-	-	-
1213B	0	-	-	-	-	-	-	-
1213C	0	-	-	-	-	-	-	-
1216A	1	-	-	-	0.040	-	-	-
1216B	0	-	-	-	-	-	-	-
1217A	1	-	-	-	0.040	-	-	-
1217B	7	0.040	0.040	0.040	0.060	0.090	0.132	0.150
1217E	0	-	-	-	-	-	-	-
1217F	0	-	-	-	-	-	-	-
1218B	0	-	-	-	-	-	-	-
1220A	2	0.040	-	-	0.040	-	-	0.040

1221A	4	0.050	-	0.058	0.060	0.163	-	0.470
1221B	1	-	-	-	0.060	-	-	-
1221C	1	-	-	-	0.165	-	-	-
1221D	2	0.050	-	-	0.110	-	-	0.170
1221E	0	-	-	-	-	-	-	-
1221F	1	-	-	-	0.040	-	-	-
1222A	2	0.040	-	-	0.050	-	-	0.060
1222B	1	-	-	-	0.040	-	-	-
1222C	1	-	-	-	0.050	-	-	-
1222D	0	-	-	-	-	-	-	-
1222E	1	-	-	-	0.040	-	-	-
1222F	0	-	-	-	-	-	-	-
1223A	1	-	-	-	0.040	-	-	-
1223B	0	-	-	-	-	-	-	-
1225A	1	-	-	-	0.005	-	-	-
1226A	2	0.008	-	-	0.011	-	-	0.014
1226B	3	0.012	-	-	0.045	-	-	0.060
1226C	2	0.003	-	-	0.022	-	-	0.040
1226D	1	-	-	-	0.005	-	-	-
1226E	1	-	-	-	0.170	-	-	-
1226F	1	-	-	-	0.020	-	-	-
1226G	1	-	-	-	0.005	-	-	-
1226H	1	-	-	-	0.113	-	-	-
1226I	1	-	-	-	0.019	-	-	-
1226J	1	-	-	-	0.005	-	-	-
1226K	1	-	-	-	0.378	-	-	-
1226L	0	-	-	-	-	-	-	-
1226M	1	-	-	-	0.030	-	-	-
1226Q	0	-	-	-	-	-	-	-
1227A	1	-	-	-	1.790	-	-	-
1232A	1	-	-	-	0.060	-	-	-
1232B	2	2.485	-	-	2.573	-	-	2.660
1232C	1	-	-	-	0.040	-	-	-
1233A	1	-	-	-	0.040	-	-	-
1233B	0	-	-	-	-	-	-	-
1236A	0	-	-	-	-	-	-	-
1238A	1	-	-	-	0.040	-	-	-
1240A	1	-	-	-	0.050	-	-	-
1241A	3	0.060	-	-	0.060	-	-	0.780
1241D	0	-	-	-	-	-	-	-

1242B	2	0.040	-	-	4.025	-	-	8.010
1242C	2	0.115	-	-	1.197	-	-	2.278
1242D	2	0.050	-	-	1.923	-	-	3.795
1242E	1	-	-	-	0.040	-	-	-
1242F	1	-	-	-	0.050	-	-	-
1242I	0	-	-	-	-	-	-	-
1242J	1	-	-	-	0.040	-	-	-
1242K	1	-	-	-	0.040	-	-	-
1242L	1	-	-	-	0.040	-	-	-
1242M	1	-	-	-	0.040	-	-	-
1242N	2	0.050	-	-	0.700	-	-	1.350
1242O	1	-	-	-	0.045	-	-	-
1242P	1	-	-	-	0.090	-	-	-
1242Q	0	-	-	-	-	-	-	-
1244A	1	-	-	-	0.045	-	-	-
1244B	1	-	-	-	0.125	-	-	-
1244D	1	-	-	-	0.040	-	-	-
1245B	1	-	-	-	0.160	-	-	-
1245C	2	0.260	-	-	0.973	-	-	1.685
1245D	1	-	-	-	0.145	-	-	-
1245I	1	-	-	-	0.930	-	-	-
1246C	0	-	-	-	-	-	-	-
1246D	1	-	-	-	0.005	-	-	-
1246E	2	0.005	-	-	0.023	-	-	0.040
1247A	2	0.040	-	-	0.040	-	-	0.040
1248A	1	-	-	-	0.060	-	-	-
1248B	1	-	-	-	0.060	-	-	-
1248C	2	1.195	-	-	1.303	-	-	1.410
1248D	1	-	-	-	0.040	-	-	-
1254A	0	-	-	-	-	-	-	-
1254B	0	-	-	-	-	-	-	-
1255A	1	-	-	-	0.600	-	-	-
1255B	1	-	-	-	0.302	-	-	-
1255C	1	-	-	-	0.957	-	-	-
1255D	1	-	-	-	0.188	-	-	-
1255E	0	-	-	-	-	-	-	-
1255F	1	-	-	-	0.101	-	-	-
1255I	1	-	-	-	0.426	-	-	-
1256A	1	-	-	-	0.040	-	-	-
1302A	1	-	-	-	0.070	-	-	-

1302B	2	0.070	-	-	0.085	-	-	0.099
1302C	0	-	-	-	-	-	-	-
1402A	2	0.040	-	-	0.040	-	-	0.040
1402C	1	-	-	-	0.060	-	-	-
1402H	1	-	-	-	0.060	-	-	-
1403A	5	0.020	-	0.020	0.020	0.020	-	0.040
1403B	2	0.020	-	-	0.020	-	-	0.020
1403E	0	-	-	-	-	-	-	-
1403F	0	-	-	-	-	-	-	-
1403H	2	0.020	-	-	0.020	-	-	0.020
1403I	1	-	-	-	0.020	-	-	-
1403J	1	-	-	-	0.040	-	-	-
1403K	1	-	-	-	0.040	-	-	-
1403L	1	-	-	-	0.020	-	-	-
1403M	0	-	-	-	-	-	-	-
1403N	0	-	-	-	-	-	-	-
1403O	0	-	-	-	-	-	-	-
1403P	1	-	-	-	0.020	-	-	-
1403Q	0	-	-	-	-	-	-	-
1403R	1	-	-	-	0.040	-	-	-
1404A	1	-	-	-	0.060	-	-	-
1404B	1	-	-	-	0.040	-	-	-
1404C	0	-	-	-	-	-	-	-
1404D	0	-	-	-	-	-	-	-
1406A	1	-	-	-	0.040	-	-	-
1407A	1	-	-	-	0.040	-	-	-
1409A	1	-	-	-	0.040	-	-	-
1412B	2	0.040	-	-	0.950	-	-	1.860
1412C	0	-	-	-	-	-	-	-
1414A	0	-	-	-	-	-	-	-
1414B	1	-	-	-	0.040	-	-	-
1414D	0	-	-	-	-	-	-	-
1415A	1	-	-	-	0.040	-	-	-
1415C	1	-	-	-	0.040	-	-	-
1416A	2	0.040	-	-	0.795	-	-	1.550
1416B	0	-	-	-	-	-	-	-
1416C	0	-	-	-	-	-	-	-
1418B	0	-	-	-	-	-	-	-
1421A	1	-	-	-	0.040	-	-	-
1421B	0	-	-	-	-	-	-	-

1421C	0	-	-	-	-	-	-	-
1423A	2	0.221	-	-	0.229	-	-	0.237
1423B	1	-	-	-	0.172	-	-	-
1424A	0	-	-	-	-	-	-	-
1424B	0	-	-	-	-	-	-	-
1425A	2	0.089	-	-	0.158	-	-	0.227
1426B	2	0.040	-	-	0.040	-	-	0.040
1426C	1	-	-	-	0.040	-	-	-
1426D	1	-	-	-	0.040	-	-	-
1427A	1	-	-	-	0.040	-	-	-
1427B	0	-	-	-	-	-	-	-
1427C	1	-	-	-	0.040	-	-	-
1427E	0	-	-	-	-	-	-	-
1427F	0	-	-	-	-	-	-	-
1427G	0	-	-	-	-	-	-	-
1428A	0	-	-	-	-	-	-	-
1428B	4	0.020	-	0.020	0.023	0.025	-	0.025
1428C	2	0.155	-	-	0.191	-	-	0.227
1428D	0	-	-	-	-	-	-	-
1428E	0	-	-	-	-	-	-	-
1428F	0	-	-	-	-	-	-	-
1428I	0	-	-	-	-	-	-	-
1428J	0	-	-	-	-	-	-	-
1429A	0	-	-	-	-	-	-	-
1429B	0	-	-	-	-	-	-	-
1429C	3	0.061	-	-	0.091	-	-	0.120
1429D	0	-	-	-	-	-	-	-
1429E	0	-	-	-	-	-	-	-
1429F	0	-	-	-	-	-	-	-
1429G	0	-	-	-	-	-	-	-
1429H	0	-	-	-	-	-	-	-
1430B	11	0.020	0.020	0.020	0.020	0.020	0.020	0.020
1434B	1	-	-	-	0.040	-	-	-
1601C	0	-	-	-	-	-	-	-
1602B	0	-	-	-	-	-	-	-
1604A	1	-	-	-	0.145	-	-	-
1604B	1	-	-	-	0.120	-	-	-
1604C	1	-	-	-	0.065	-	-	-
1803A	0	-	-	-	-	-	-	-
1803B	0	-	-	-	-	-	-	-

1803C	0	-	-	-	-	-	-	-
1804A	0	-	-	-	-	-	-	-
1806A	0	-	-	-	-	-	-	-
1806D	0	-	-	-	-	-	-	-
1806E	0	-	-	-	-	-	-	-
1806G	0	-	-	-	-	-	-	-
1806H	0	-	-	-	-	-	-	-
1807A	0	-	-	-	-	-	-	-
1811A	0	-	-	-	-	-	-	-
1813A	0	-	-	-	-	-	-	-
1813B	0	-	-	-	-	-	-	-
1813C	0	-	-	-	-	-	-	-
1813D	0	-	-	-	-	-	-	-
1813E	0	-	-	-	-	-	-	-
1813F	0	-	-	-	-	-	-	-
1813G	0	-	-	-	-	-	-	-
1813H	0	-	-	-	-	-	-	-
1813I	0	-	-	-	-	-	-	-
1901A	0	-	-	-	-	-	-	-
1901B	0	-	-	-	-	-	-	-
1901C	0	-	-	-	-	-	-	-
1901D	0	-	-	-	-	-	-	-
1902A	0	-	-	-	-	-	-	-
1902B	0	-	-	-	-	-	-	-
1905A	1	-	-	-	0.020	-	-	-
1906A	0	-	-	-	-	-	-	-
1910A	0	-	-	-	-	-	-	-
1910B	0	-	-	-	-	-	-	-
1910C	0	-	-	-	-	-	-	-
1910D	0	-	-	-	-	-	-	-
1910E	0	-	-	-	-	-	-	-
1911B	1	-	-	-	0.020	-	-	-
1911C	1	-	-	-	0.020	-	-	-
1911D	1	-	-	-	0.020	-	-	-
1911E	0	-	-	-	-	-	-	-
1911H	0	-	-	-	-	-	-	-
1912A	1	-	-	-	2.240	-	-	-
2004A	0	-	-	-	-	-	-	-
2004B	0	-	-	-	-	-	-	-
2302A	1	-	-	-	0.085	-	-	-

2304B	0	-	-	-	-	-	-	-
2306A	1	-	-	-	0.020	-	-	-
2309A	1	-	-	-	0.040	-	-	-
2310A	1	-	-	-	0.040	-	-	-
2422B	0	-	-	-	-	-	-	-
2424A	1	-	-	-	0.065	-	-	-
2424D	0	-	-	-	-	-	-	-
2424E	1	-	-	-	0.080	-	-	-
2431A	1	-	-	-	0.040	-	-	-
2432A	0	-	-	-	-	-	-	-
2432B	2	0.030	-	-	0.035	-	-	0.040
2485B	1	-	-	-	0.390	-	-	-
2485D	1	-	-	-	0.260	-	-	-
2492A	0	-	-	-	-	-	-	-

Fluorometric Chlorophyll-a (Chl-a; µg/L)

Segment	n	MIN	10th	25th	Median	75th	90th	MAX
0101	2	7.06	-	-	12.98	-	-	18.90
0103	2	3.00	-	-	3.14	-	-	3.28
0104	0	-	-	-	-	-	-	-
0201	1	-	-	-	38.85	-	-	-
0202	0	-	-	-	-	-	-	-
0204	1	-	-	-	39.85	-	-	-
0205	0	-	-	-	-	-	-	-
0206	1	-	-	-	5.28	-	-	-
0207	0	-	-	-	-	-	-	-
0211	0	-	-	-	-	-	-	-
0214	3	19.40	-	-	21.45	-	-	37.90
0216	0	-	-	-	-	-	-	-
0218	0	-	-	-	-	-	-	-
0220	0	-	-	-	-	-	-	-
0221	0	-	-	-	-	-	-	-
0222	0	-	-	-	-	-	-	-
0224	0	-	-	-	-	-	-	-
0226	0	-	-	-	-	-	-	-
0227	0	-	-	-	-	-	-	-
0229	2	38.20	-	-	38.40	-	-	38.60
0230	0	-	-	-	-	-	-	-
0301	2	24.10	-	-	26.23	-	-	28.35

0303	3	5.85	-	-	7.10	-	-	8.73
0304	1	-	-	-	4.10	-	-	-
0305	1	-	-	-	7.02	-	-	-
0306	0	-	-	-	-	-	-	-
0401	0	-	-	-	-	-	-	-
0402	2	4.68	-	-	4.87	-	-	5.06
0404	1	-	-	-	3.00	-	-	-
0406	2	4.66	-	-	4.89	-	-	5.12
0407	0	-	-	-	-	-	-	-
0409	4	3.00	-	3.00	3.03	3.14	-	3.39
0501	0	-	-	-	-	-	-	-
0502	0	-	-	-	-	-	-	-
0503	0	-	-	-	-	-	-	-
0504	0	-	-	-	-	-	-	-
0505	0	-	-	-	-	-	-	-
0506	0	-	-	-	-	-	-	-
0513	0	-	-	-	-	-	-	-
0514	0	-	-	-	-	-	-	-
0515	0	-	-	-	-	-	-	-
0602	1	-	-	-	11.40	-	-	-
0604	6	8.39	-	10.34	16.50	21.83	-	41.30
0606	2	3.00	-	-	3.00	-	-	3.00
0607	0	-	-	-	-	-	-	-
0608	1	-	-	-	3.00	-	-	-
0609	0	-	-	-	-	-	-	-
0610	0	-	-	-	-	-	-	-
0611	1	-	-	-	6.14	-	-	-
0612	0	-	-	-	-	-	-	-
0701	1	-	-	-	16.50	-	-	-
0704	1	-	-	-	39.60	-	-	-
0801	0	-	-	-	-	-	-	-
0802	2	20.65	-	-	20.88	-	-	21.10
0803	0	-	-	-	-	-	-	-
0804	0	-	-	-	-	-	-	-
0805	0	-	-	-	-	-	-	-
0806	0	-	-	-	-	-	-	-
0809	0	-	-	-	-	-	-	-
0810	1	-	-	-	7.63	-	-	-
0812	0	-	-	-	-	-	-	-
0814	1	-	-	-	14.90	-	-	-

0815	0	-	-	-	-	-	-	-
0817	0	-	-	-	-	-	-	-
0818	0	-	-	-	-	-	-	-
0819	2	10.24	-	-	10.82	-	-	11.40
0821	0	-	-	-	-	-	-	-
0822	0	-	-	-	-	-	-	-
0824	1	-	-	-	14.00	-	-	-
0825	1	-	-	-	10.70	-	-	-
0829	1	-	-	-	11.60	-	-	-
0830	0	-	-	-	-	-	-	-
0831	1	-	-	-	3.52	-	-	-
0833	0	-	-	-	-	-	-	-
0835	0	-	-	-	-	-	-	-
0836	0	-	-	-	-	-	-	-
0837	0	-	-	-	-	-	-	-
0838	0	-	-	-	-	-	-	-
0839	0	-	-	-	-	-	-	-
0840	0	-	-	-	-	-	-	-
0841	0	-	-	-	-	-	-	-
0902	1	-	-	-	3.00	-	-	-
1002	0	-	-	-	-	-	-	-
1003	0	-	-	-	-	-	-	-
1004	1	-	-	-	3.80	-	-	-
1006	0	-	-	-	-	-	-	-
1007	0	-	-	-	-	-	-	-
1008	0	-	-	-	-	-	-	-
1009	2	5.16	-	-	6.77	-	-	8.38
1010	1	-	-	-	3.00	-	-	-
1011	1	-	-	-	3.00	-	-	-
1013	0	-	-	-	-	-	-	-
1014	2	5.86	-	-	7.98	-	-	10.10
1015	0	-	-	-	-	-	-	-
1016	2	3.56	-	-	3.89	-	-	4.21
1017	2	6.94	-	-	7.25	-	-	7.56
1101	0	-	-	-	-	-	-	-
1102	2	3.00	-	-	3.20	-	-	3.39
1103	0	-	-	-	-	-	-	-
1104	1	-	-	-	3.00	-	-	-
1105	0	-	-	-	-	-	-	-
1108	1	-	-	-	3.00	-	-	-

1110	1	-	-	-	15.80	-	-	-
1201	0	-	-	-	-	-	-	-
1202	1	-	-	-	27.20	-	-	-
1204	1	-	-	-	13.95	-	-	-
1205	0	-	-	-	-	-	-	-
1206	0	-	-	-	-	-	-	-
1208	2	7.70	-	-	11.10	-	-	14.50
1209	0	-	-	-	-	-	-	-
1211	1	-	-	-	50.60	-	-	-
1213	3	3.40	-	-	4.80	-	-	8.50
1214	1	-	-	-	5.57	-	-	-
1215	1	-	-	-	3.00	-	-	-
1217	1	-	-	-	3.30	-	-	-
1218	1	-	-	-	3.30	-	-	-
1219	1	-	-	-	3.30	-	-	-
1220	0	-	-	-	-	-	-	-
1221	8	3.97	5.41	8.72	16.66	22.41	30.91	37.00
1223	1	-	-	-	15.81	-	-	-
1226	6	5.00	-	6.06	10.95	14.28	-	19.70
1227	3	8.90	-	-	13.45	-	-	14.80
1229	0	-	-	-	-	-	-	-
1232	4	13.90	-	14.31	25.98	37.80	-	38.70
1236	0	-	-	-	-	-	-	-
1238	1	-	-	-	3.00	-	-	-
1239	0	-	-	-	-	-	-	-
1241	1	-	-	-	11.54	-	-	-
1242	1	-	-	-	25.20	-	-	-
1243	3	3.00	-	-	3.00	-	-	3.00
1244	1	-	-	-	4.62	-	-	-
1245	2	6.61	-	-	11.90	-	-	17.20
1246	1	-	-	-	3.00	-	-	-
1248	2	4.50	-	-	5.69	-	-	6.89
1250	3	3.00	-	-	3.30	-	-	3.30
1251	1	-	-	-	3.00	-	-	-
1253	0	-	-	-	-	-	-	-
1255	1	-	-	-	21.50	-	-	-
1256	1	-	-	-	13.90	-	-	-
1257	1	-	-	-	9.85	-	-	-
1301	0	-	-	-	-	-	-	-
1302	5	0.73	-	1.07	2.64	3.46	-	5.71

1305	1	-	-	-	3.00	-	-	-
1402	6	5.00	-	5.00	5.00	5.00	-	7.55
1403	0	-	-	-	-	-	-	-
1406	0	-	-	-	-	-	-	-
1409	1	-	-	-	7.15	-	-	-
1410	2	6.65	-	-	7.69	-	-	8.72
1412	1	-	-	-	26.55	-	-	-
1414	5	5.00	-	5.00	5.00	5.00	-	6.84
1415	8	3.00	3.00	3.00	4.00	5.00	5.00	5.00
1416	2	5.00	-	-	5.00	-	-	5.00
1417	1	-	-	-	11.45	-	-	-
1420	1	-	-	-	20.10	-	-	-
1421	3	28.60	-	-	29.70	-	-	68.80
1424	0	-	-	-	-	-	-	-
1426	1	-	-	-	20.70	-	-	-
1427	3	3.00	-	-	3.00	-	-	5.00
1428	3	5.00	-	-	5.00	-	-	5.00
1430	0	-	-	-	-	-	-	-
1431	1	-	-	-	8.10	-	-	-
1432	1	-	-	-	9.70	-	-	-
1434	2	5.00	-	-	5.00	-	-	5.00
1501	0	-	-	-	-	-	-	-
1502	1	-	-	-	9.31	-	-	-
1602	0	-	-	-	-	-	-	-
1605	0	-	-	-	-	-	-	-
1801	0	-	-	-	-	-	-	-
1802	0	-	-	-	-	-	-	-
1803	0	-	-	-	-	-	-	-
1804	2	3.12	-	-	3.38	-	-	3.64
1806	1	-	-	-	3.00	-	-	-
1807	1	-	-	-	4.50	-	-	-
1808	1	-	-	-	3.00	-	-	-
1809	1	-	-	-	3.00	-	-	-
1810	1	-	-	-	3.00	-	-	-
1811	0	-	-	-	-	-	-	-
1812	3	3.00	-	-	3.00	-	-	3.00
1813	0	-	-	-	-	-	-	-
1814	0	-	-	-	-	-	-	-
1815	0	-	-	-	-	-	-	-
1816	0	-	-	-	-	-	-	-

1817	0	-	-	-	-	-	-	-
1818	0	-	-	-	-	-	-	-
1901	0	-	-	-	-	-	-	-
1902	2	3.14	-	-	3.66	-	-	4.18
1903	3	3.00	-	-	3.00	-	-	3.11
1905	0	-	-	-	-	-	-	-
1906	3	3.00	-	-	5.57	-	-	13.70
1907	0	-	-	-	-	-	-	-
1908	1	-	-	-	3.00	-	-	-
1910	1	-	-	-	3.00	-	-	-
1911	2	3.00	-	-	3.00	-	-	3.00
1912	0	-	-	-	-	-	-	-
1913	2	3.00	-	-	3.15	-	-	3.30
2002	1	-	-	-	5.00	-	-	-
2003	0	-	-	-	-	-	-	-
2004	1	-	-	-	5.00	-	-	-
2102	2	5.00	-	-	5.50	-	-	6.00
2103	1	-	-	-	23.95	-	-	-
2104	1	-	-	-	5.00	-	-	-
2105	2	10.30	-	-	15.35	-	-	20.40
2106	3	6.40	-	-	9.04	-	-	10.40
2107	2	9.06	-	-	20.40	-	-	31.75
2108	1	-	-	-	6.55	-	-	-
2109	2	3.00	-	-	3.00	-	-	3.00
2110	1	-	-	-	3.00	-	-	-
2111	1	-	-	-	3.00	-	-	-
2112	2	2.00	-	-	2.50	-	-	3.00
2113	1	-	-	-	3.00	-	-	-
2114	2	3.00	-	-	3.30	-	-	3.59
2115	0	-	-	-	-	-	-	-
2117	3	3.00	-	-	5.00	-	-	7.64
2202	3	20.10	-	-	33.25	-	-	37.90
2204	2	76.40	-	-	88.20	-	-	100.00
2301	0	-	-	-	-	-	-	-
2302	2	4.70	-	-	5.14	-	-	5.58
2304	4	3.00	-	3.00	3.00	3.00	-	3.00
2305	0	-	-	-	-	-	-	-
2306	4	8.39	-	11.25	16.63	21.69	-	23.60
2307	5	13.95	-	21.90	29.65	33.90	-	56.70
2308	0	-	-	-	-	-	-	-

2309	2	3.00	-	-	3.00	-	-	3.00
2310	2	3.92	-	-	5.81	-	-	7.70
2311	4	5.70	-	7.08	9.08	13.21	-	20.95
2313	0	-	-	-	-	-	-	-
2314	2	14.90	-	-	16.75	-	-	18.60
2431	0	-	-	-	-	-	-	-
2472	0	-	-	-	-	-	-	-
0101A	1	-	-	-	4.78	-	-	-
0101B	0	-	-	-	-	-	-	-
0101C	0	-	-	-	-	-	-	-
0102A	0	-	-	-	-	-	-	-
0103A	0	-	-	-	-	-	-	-
0103C	0	-	-	-	-	-	-	-
0199A	0	-	-	-	-	-	-	-
0201A	0	-	-	-	-	-	-	-
0202A	0	-	-	-	-	-	-	-
0202C	0	-	-	-	-	-	-	-
0202D	0	-	-	-	-	-	-	-
0202E	0	-	-	-	-	-	-	-
0202F	0	-	-	-	-	-	-	-
0202G	0	-	-	-	-	-	-	-
0202H	0	-	-	-	-	-	-	-
0202I	0	-	-	-	-	-	-	-
0202J	0	-	-	-	-	-	-	-
0202K	0	-	-	-	-	-	-	-
0203A	0	-	-	-	-	-	-	-
0203C	0	-	-	-	-	-	-	-
0203D	0	-	-	-	-	-	-	-
0206B	0	-	-	-	-	-	-	-
0207A	0	-	-	-	-	-	-	-
0214A	0	-	-	-	-	-	-	-
0214B	0	-	-	-	-	-	-	-
0218A	0	-	-	-	-	-	-	-
0222A	1	-	-	-	3.00	-	-	-
0224A	0	-	-	-	-	-	-	-
0230A	0	-	-	-	-	-	-	-
0299A	0	-	-	-	-	-	-	-
0302A	0	-	-	-	-	-	-	-
0302B	0	-	-	-	-	-	-	-
0302C	1	-	-	-	3.00	-	-	-

0302D	0	-	-	-	-	-	-	-
0302E	0	-	-	-	-	-	-	-
0302F	0	-	-	-	-	-	-	-
0303B	4	3.00	-	3.00	3.09	3.23	-	3.40
0303D	1	-	-	-	3.00	-	-	-
0303E	0	-	-	-	-	-	-	-
0303F	0	-	-	-	-	-	-	-
0303G	0	-	-	-	-	-	-	-
0303H	0	-	-	-	-	-	-	-
0303I	0	-	-	-	-	-	-	-
0303J	0	-	-	-	-	-	-	-
0303K	0	-	-	-	-	-	-	-
0303L	0	-	-	-	-	-	-	-
0304A	0	-	-	-	-	-	-	-
0304B	0	-	-	-	-	-	-	-
0304C	0	-	-	-	-	-	-	-
0304D	0	-	-	-	-	-	-	-
0305A	0	-	-	-	-	-	-	-
0305B	0	-	-	-	-	-	-	-
0305C	0	-	-	-	-	-	-	-
0305D	0	-	-	-	-	-	-	-
0307A	0	-	-	-	-	-	-	-
0307B	0	-	-	-	-	-	-	-
0307C	0	-	-	-	-	-	-	-
0401A	0	-	-	-	-	-	-	-
0401B	0	-	-	-	-	-	-	-
0402A	3	3.00	-	-	3.00	-	-	3.00
0402B	0	-	-	-	-	-	-	-
0402C	0	-	-	-	-	-	-	-
0402D	0	-	-	-	-	-	-	-
0402E	0	-	-	-	-	-	-	-
0404B	0	-	-	-	-	-	-	-
0404C	0	-	-	-	-	-	-	-
0404I	0	-	-	-	-	-	-	-
0404J	0	-	-	-	-	-	-	-
0404K	0	-	-	-	-	-	-	-
0404O	0	-	-	-	-	-	-	-
0404P	0	-	-	-	-	-	-	-
0404Q	0	-	-	-	-	-	-	-
0404R	0	-	-	-	-	-	-	-

0405A	0	-	-	-	-	-	-	-
0405B	0	-	-	-	-	-	-	-
0405C	0	-	-	-	-	-	-	-
0407A	0	-	-	-	-	-	-	-
0407B	0	-	-	-	-	-	-	-
0408B	0	-	-	-	-	-	-	-
0408C	0	-	-	-	-	-	-	-
0408D	0	-	-	-	-	-	-	-
0409A	1	-	-	-	3.30	-	-	-
0409B	0	-	-	-	-	-	-	-
0409E	0	-	-	-	-	-	-	-
0501B	0	-	-	-	-	-	-	-
0502A	0	-	-	-	-	-	-	-
0502B	0	-	-	-	-	-	-	-
0502D	0	-	-	-	-	-	-	-
0502E	0	-	-	-	-	-	-	-
0504C	0	-	-	-	-	-	-	-
0504D	0	-	-	-	-	-	-	-
0505B	0	-	-	-	-	-	-	-
0505D	0	-	-	-	-	-	-	-
0505G	0	-	-	-	-	-	-	-
0505P	0	-	-	-	-	-	-	-
0506A	0	-	-	-	-	-	-	-
0506C	0	-	-	-	-	-	-	-
0507A	0	-	-	-	-	-	-	-
0507B	0	-	-	-	-	-	-	-
0507D	0	-	-	-	-	-	-	-
0507E	0	-	-	-	-	-	-	-
0507F	0	-	-	-	-	-	-	-
0507G	0	-	-	-	-	-	-	-
0507H	0	-	-	-	-	-	-	-
0508A	0	-	-	-	-	-	-	-
0508C	0	-	-	-	-	-	-	-
0511C	0	-	-	-	-	-	-	-
0511E	0	-	-	-	-	-	-	-
0512A	0	-	-	-	-	-	-	-
0602A	0	-	-	-	-	-	-	-
0602B	0	-	-	-	-	-	-	-
0603A	0	-	-	-	-	-	-	-
0603B	0	-	-	-	-	-	-	-

0604A	0	-	-	-	-	-	-	-
0604B	0	-	-	-	-	-	-	-
0604C	0	-	-	-	-	-	-	-
0604D	0	-	-	-	-	-	-	-
0604M	0	-	-	-	-	-	-	-
0604N	0	-	-	-	-	-	-	-
0605A	0	-	-	-	-	-	-	-
0605E	0	-	-	-	-	-	-	-
0606A	0	-	-	-	-	-	-	-
0606C	0	-	-	-	-	-	-	-
0606D	0	-	-	-	-	-	-	-
0607A	0	-	-	-	-	-	-	-
0607B	0	-	-	-	-	-	-	-
0607C	0	-	-	-	-	-	-	-
0608A	0	-	-	-	-	-	-	-
0608B	0	-	-	-	-	-	-	-
0608C	0	-	-	-	-	-	-	-
0608D	0	-	-	-	-	-	-	-
0608E	0	-	-	-	-	-	-	-
0608F	0	-	-	-	-	-	-	-
0608J	0	-	-	-	-	-	-	-
0610A	0	-	-	-	-	-	-	-
0611A	1	-	-	-	3.00	-	-	-
0611B	0	-	-	-	-	-	-	-
0611C	0	-	-	-	-	-	-	-
0611D	0	-	-	-	-	-	-	-
0612A	0	-	-	-	-	-	-	-
0612B	0	-	-	-	-	-	-	-
0615A	1	-	-	-	3.29	-	-	-
0702A	0	-	-	-	-	-	-	-
0704A	0	-	-	-	-	-	-	-
0801C	0	-	-	-	-	-	-	-
0802B	0	-	-	-	-	-	-	-
0802D	0	-	-	-	-	-	-	-
0803A	0	-	-	-	-	-	-	-
0803B	0	-	-	-	-	-	-	-
0803E	0	-	-	-	-	-	-	-
0803F	0	-	-	-	-	-	-	-
0804F	0	-	-	-	-	-	-	-
0804G	1	-	-	-	3.00	-	-	-

0804H	0	-	-	-	-	-	-	-
0805A	0	-	-	-	-	-	-	-
0805B	0	-	-	-	-	-	-	-
0805D	0	-	-	-	-	-	-	-
0806C	0	-	-	-	-	-	-	-
0806D	0	-	-	-	-	-	-	-
0806E	0	-	-	-	-	-	-	-
0810A	0	-	-	-	-	-	-	-
0810B	0	-	-	-	-	-	-	-
0810C	0	-	-	-	-	-	-	-
0810D	0	-	-	-	-	-	-	-
0814A	0	-	-	-	-	-	-	-
0814B	0	-	-	-	-	-	-	-
0815A	0	-	-	-	-	-	-	-
0816A	0	-	-	-	-	-	-	-
0817A	0	-	-	-	-	-	-	-
0819A	0	-	-	-	-	-	-	-
0819B	0	-	-	-	-	-	-	-
0820B	0	-	-	-	-	-	-	-
0820C	0	-	-	-	-	-	-	-
0821B	0	-	-	-	-	-	-	-
0821C	1	-	-	-	4.00	-	-	-
0821D	1	-	-	-	3.08	-	-	-
0822A	0	-	-	-	-	-	-	-
0822B	0	-	-	-	-	-	-	-
0822C	0	-	-	-	-	-	-	-
0823A	0	-	-	-	-	-	-	-
0823B	0	-	-	-	-	-	-	-
0823C	0	-	-	-	-	-	-	-
0823D	0	-	-	-	-	-	-	-
0826A	0	-	-	-	-	-	-	-
0826C	0	-	-	-	-	-	-	-
0827A	0	-	-	-	-	-	-	-
0828A	0	-	-	-	-	-	-	-
0831A	0	-	-	-	-	-	-	-
0836B	0	-	-	-	-	-	-	-
0836C	0	-	-	-	-	-	-	-
0836D	0	-	-	-	-	-	-	-
0838A	0	-	-	-	-	-	-	-
0838B	0	-	-	-	-	-	-	-

0838C	0	-	-	-	-	-	-	-
0839A	1	-	-	-	3.00	-	-	-
0840A	0	-	-	-	-	-	-	-
0841B	0	-	-	-	-	-	-	-
0841C	0	-	-	-	-	-	-	-
0841D	1	-	-	-	6.81	-	-	-
0841E	0	-	-	-	-	-	-	-
0841F	0	-	-	-	-	-	-	-
0841G	0	-	-	-	-	-	-	-
0841H	0	-	-	-	-	-	-	-
0841I	0	-	-	-	-	-	-	-
0841J	0	-	-	-	-	-	-	-
0841K	0	-	-	-	-	-	-	-
0841L	0	-	-	-	-	-	-	-
0841M	0	-	-	-	-	-	-	-
0841N	0	-	-	-	-	-	-	-
0841O	0	-	-	-	-	-	-	-
0841P	0	-	-	-	-	-	-	-
0841Q	0	-	-	-	-	-	-	-
0841R	0	-	-	-	-	-	-	-
0841T	0	-	-	-	-	-	-	-
0841U	0	-	-	-	-	-	-	-
0841V	0	-	-	-	-	-	-	-
1002A	0	-	-	-	-	-	-	-
1002B	0	-	-	-	-	-	-	-
1004D	0	-	-	-	-	-	-	-
1004E	0	-	-	-	-	-	-	-
1006D	1	-	-	-	3.00	-	-	-
1006F	0	-	-	-	-	-	-	-
1006H	0	-	-	-	-	-	-	-
1006I	0	-	-	-	-	-	-	-
1006J	0	-	-	-	-	-	-	-
1007A	0	-	-	-	-	-	-	-
1007B	1	-	-	-	9.01	-	-	-
1007C	0	-	-	-	-	-	-	-
1007D	1	-	-	-	9.52	-	-	-
1007E	0	-	-	-	-	-	-	-
1007F	0	-	-	-	-	-	-	-
1007G	0	-	-	-	-	-	-	-
1007H	0	-	-	-	-	-	-	-

1007I	0	-	-	-	-	-	-	-
1007K	0	-	-	-	-	-	-	-
1007L	0	-	-	-	-	-	-	-
1007N	0	-	-	-	-	-	-	-
1007O	0	-	-	-	-	-	-	-
1007Q	0	-	-	-	-	-	-	-
1007R	0	-	-	-	-	-	-	-
1008B	0	-	-	-	-	-	-	-
1008C	0	-	-	-	-	-	-	-
1008E	0	-	-	-	-	-	-	-
1008H	0	-	-	-	-	-	-	-
1008J	0	-	-	-	-	-	-	-
1009C	0	-	-	-	-	-	-	-
1009D	0	-	-	-	-	-	-	-
1009E	0	-	-	-	-	-	-	-
1010C	0	-	-	-	-	-	-	-
1013A	0	-	-	-	-	-	-	-
1013C	0	-	-	-	-	-	-	-
1014A	0	-	-	-	-	-	-	-
1014B	0	-	-	-	-	-	-	-
1014C	0	-	-	-	-	-	-	-
1014E	0	-	-	-	-	-	-	-
1014H	0	-	-	-	-	-	-	-
1014K	0	-	-	-	-	-	-	-
1014L	0	-	-	-	-	-	-	-
1014M	0	-	-	-	-	-	-	-
1014N	0	-	-	-	-	-	-	-
1014O	0	-	-	-	-	-	-	-
1015A	0	-	-	-	-	-	-	-
1015B	0	-	-	-	-	-	-	-
1016A	0	-	-	-	-	-	-	-
1016B	0	-	-	-	-	-	-	-
1016C	0	-	-	-	-	-	-	-
1016D	0	-	-	-	-	-	-	-
1017A	0	-	-	-	-	-	-	-
1017B	0	-	-	-	-	-	-	-
1017C	0	-	-	-	-	-	-	-
1017D	0	-	-	-	-	-	-	-
1017E	0	-	-	-	-	-	-	-
1017F	0	-	-	-	-	-	-	-

1101B	0	-	-	-	-	-	-	-
1101F	0	-	-	-	-	-	-	-
1102A	0	-	-	-	-	-	-	-
1102B	0	-	-	-	-	-	-	-
1102C	0	-	-	-	-	-	-	-
1102D	0	-	-	-	-	-	-	-
1102E	0	-	-	-	-	-	-	-
1102F	0	-	-	-	-	-	-	-
1103F	0	-	-	-	-	-	-	-
1104A	0	-	-	-	-	-	-	-
1105A	0	-	-	-	-	-	-	-
1105B	0	-	-	-	-	-	-	-
1105C	0	-	-	-	-	-	-	-
1105D	0	-	-	-	-	-	-	-
1113A	0	-	-	-	-	-	-	-
1202H	1	-	-	-	7.75	-	-	-
1202J	1	-	-	-	5.00	-	-	-
1202K	1	-	-	-	3.25	-	-	-
1202P	0	-	-	-	-	-	-	-
1204A	0	-	-	-	-	-	-	-
1205B	0	-	-	-	-	-	-	-
1205C	0	-	-	-	-	-	-	-
1205D	0	-	-	-	-	-	-	-
1205E	0	-	-	-	-	-	-	-
1205F	0	-	-	-	-	-	-	-
1205G	0	-	-	-	-	-	-	-
1205H	0	-	-	-	-	-	-	-
1206D	0	-	-	-	-	-	-	-
1209C	2	7.97	-	-	10.28	-	-	12.60
1209D	0	-	-	-	-	-	-	-
1209E	0	-	-	-	-	-	-	-
1209G	0	-	-	-	-	-	-	-
1209H	1	-	-	-	3.30	-	-	-
1209I	2	3.10	-	-	6.13	-	-	9.17
1209J	0	-	-	-	-	-	-	-
1209K	0	-	-	-	-	-	-	-
1209L	0	-	-	-	-	-	-	-
1209P	0	-	-	-	-	-	-	-
1210A	0	-	-	-	-	-	-	-
1211A	1	-	-	-	3.94	-	-	-

1212A	0	-	-	-	-	-	-	-
1212B	1	-	-	-	4.69	-	-	-
1213A	1	-	-	-	4.44	-	-	-
1213B	0	-	-	-	-	-	-	-
1213C	0	-	-	-	-	-	-	-
1216A	1	-	-	-	3.00	-	-	-
1216B	0	-	-	-	-	-	-	-
1217A	1	-	-	-	3.00	-	-	-
1217B	6	3.30	-	3.30	3.30	3.30	-	3.30
1217E	0	-	-	-	-	-	-	-
1217F	0	-	-	-	-	-	-	-
1218B	0	-	-	-	-	-	-	-
1220A	2	3.30	-	-	3.30	-	-	3.30
1221A	3	7.06	-	-	9.50	-	-	11.15
1221B	1	-	-	-	3.76	-	-	-
1221C	1	-	-	-	7.94	-	-	-
1221D	2	8.90	-	-	10.60	-	-	12.30
1221E	0	-	-	-	-	-	-	-
1221F	1	-	-	-	5.00	-	-	-
1222A	1	-	-	-	16.00	-	-	-
1222B	1	-	-	-	4.77	-	-	-
1222C	1	-	-	-	4.23	-	-	-
1222D	0	-	-	-	-	-	-	-
1222E	1	-	-	-	3.60	-	-	-
1222F	0	-	-	-	-	-	-	-
1223A	1	-	-	-	9.00	-	-	-
1223B	0	-	-	-	-	-	-	-
1225A	0	-	-	-	-	-	-	-
1226A	1	-	-	-	3.30	-	-	-
1226B	1	-	-	-	8.05	-	-	-
1226C	1	-	-	-	3.00	-	-	-
1226D	1	-	-	-	3.30	-	-	-
1226E	0	-	-	-	-	-	-	-
1226F	0	-	-	-	-	-	-	-
1226G	0	-	-	-	-	-	-	-
1226H	0	-	-	-	-	-	-	-
1226I	0	-	-	-	-	-	-	-
1226J	0	-	-	-	-	-	-	-
1226K	0	-	-	-	-	-	-	-
1226L	0	-	-	-	-	-	-	-

1226M	0	-	-	-	-	-	-	-
1226Q	0	-	-	-	-	-	-	-
1227A	1	-	-	-	3.28	-	-	-
1232A	1	-	-	-	72.20	-	-	-
1232B	1	-	-	-	5.27	-	-	-
1232C	1	-	-	-	11.35	-	-	-
1233A	0	-	-	-	-	-	-	-
1233B	0	-	-	-	-	-	-	-
1236A	0	-	-	-	-	-	-	-
1238A	0	-	-	-	-	-	-	-
1240A	0	-	-	-	-	-	-	-
1241A	3	36.90	-	-	54.80	-	-	55.85
1241D	0	-	-	-	-	-	-	-
1242B	1	-	-	-	3.30	-	-	-
1242C	1	-	-	-	3.30	-	-	-
1242D	1	-	-	-	3.90	-	-	-
1242E	0	-	-	-	-	-	-	-
1242F	0	-	-	-	-	-	-	-
1242I	0	-	-	-	-	-	-	-
1242J	0	-	-	-	-	-	-	-
1242K	0	-	-	-	-	-	-	-
1242L	0	-	-	-	-	-	-	-
1242M	0	-	-	-	-	-	-	-
1242N	2	21.33	-	-	21.52	-	-	21.70
1242O	0	-	-	-	-	-	-	-
1242P	0	-	-	-	-	-	-	-
1242Q	0	-	-	-	-	-	-	-
1244A	1	-	-	-	3.30	-	-	-
1244B	0	-	-	-	-	-	-	-
1244D	0	-	-	-	-	-	-	-
1245B	0	-	-	-	-	-	-	-
1245C	0	-	-	-	-	-	-	-
1245D	0	-	-	-	-	-	-	-
1245I	0	-	-	-	-	-	-	-
1246C	0	-	-	-	-	-	-	-
1246D	0	-	-	-	-	-	-	-
1246E	1	-	-	-	3.00	-	-	-
1247A	2	3.00	-	-	3.15	-	-	3.30
1248A	0	-	-	-	-	-	-	-
1248B	0	-	-	-	-	-	-	-

1248C	1	-	-	-	4.70	-	-	-
1248D	1	-	-	-	3.00	-	-	-
1254A	0	-	-	-	-	-	-	-
1254B	0	-	-	-	-	-	-	-
1255A	0	-	-	-	-	-	-	-
1255B	0	-	-	-	-	-	-	-
1255C	0	-	-	-	-	-	-	-
1255D	0	-	-	-	-	-	-	-
1255E	0	-	-	-	-	-	-	-
1255F	0	-	-	-	-	-	-	-
1255I	0	-	-	-	-	-	-	-
1256A	0	-	-	-	-	-	-	-
1302A	1	-	-	-	3.37	-	-	-
1302B	0	-	-	-	-	-	-	-
1302C	0	-	-	-	-	-	-	-
1402A	1	-	-	-	5.00	-	-	-
1402C	1	-	-	-	76.80	-	-	-
1402H	1	-	-	-	9.62	-	-	-
1403A	1	-	-	-	5.00	-	-	-
1403B	0	-	-	-	-	-	-	-
1403E	0	-	-	-	-	-	-	-
1403F	0	-	-	-	-	-	-	-
1403H	0	-	-	-	-	-	-	-
1403I	0	-	-	-	-	-	-	-
1403J	0	-	-	-	-	-	-	-
1403K	0	-	-	-	-	-	-	-
1403L	0	-	-	-	-	-	-	-
1403M	0	-	-	-	-	-	-	-
1403N	0	-	-	-	-	-	-	-
1403O	0	-	-	-	-	-	-	-
1403P	0	-	-	-	-	-	-	-
1403Q	0	-	-	-	-	-	-	-
1403R	0	-	-	-	-	-	-	-
1404A	1	-	-	-	10.33	-	-	-
1404B	1	-	-	-	3.00	-	-	-
1404C	0	-	-	-	-	-	-	-
1404D	0	-	-	-	-	-	-	-
1406A	1	-	-	-	5.00	-	-	-
1407A	0	-	-	-	-	-	-	-
1409A	0	-	-	-	-	-	-	-

1412B	0	-	-	-	-	-	-	-
1412C	0	-	-	-	-	-	-	-
1414A	0	-	-	-	-	-	-	-
1414B	1	-	-	-	3.00	-	-	-
1414D	0	-	-	-	-	-	-	-
1415A	1	-	-	-	3.00	-	-	-
1415C	0	-	-	-	-	-	-	-
1416A	1	-	-	-	47.20	-	-	-
1416B	0	-	-	-	-	-	-	-
1416C	0	-	-	-	-	-	-	-
1418B	0	-	-	-	-	-	-	-
1421A	0	-	-	-	-	-	-	-
1421B	0	-	-	-	-	-	-	-
1421C	0	-	-	-	-	-	-	-
1423A	0	-	-	-	-	-	-	-
1423B	0	-	-	-	-	-	-	-
1424A	0	-	-	-	-	-	-	-
1424B	0	-	-	-	-	-	-	-
1425A	0	-	-	-	-	-	-	-
1426B	1	-	-	-	10.90	-	-	-
1426C	0	-	-	-	-	-	-	-
1426D	0	-	-	-	-	-	-	-
1427A	1	-	-	-	3.00	-	-	-
1427B	0	-	-	-	-	-	-	-
1427C	1	-	-	-	3.00	-	-	-
1427E	0	-	-	-	-	-	-	-
1427F	0	-	-	-	-	-	-	-
1427G	0	-	-	-	-	-	-	-
1428A	0	-	-	-	-	-	-	-
1428B	0	-	-	-	-	-	-	-
1428C	2	2.00	-	-	2.20	-	-	2.40
1428D	0	-	-	-	-	-	-	-
1428E	0	-	-	-	-	-	-	-
1428F	0	-	-	-	-	-	-	-
1428I	0	-	-	-	-	-	-	-
1428J	0	-	-	-	-	-	-	-
1429A	0	-	-	-	-	-	-	-
1429B	0	-	-	-	-	-	-	-
1429C	0	-	-	-	-	-	-	-
1429D	0	-	-	-	-	-	-	-

1429E	0	-	-	-	-	-	-	-
1429F	0	-	-	-	-	-	-	-
1429G	0	-	-	-	-	-	-	-
1429H	0	-	-	-	-	-	-	-
1430B	0	-	-	-	-	-	-	-
1434B	1	-	-	-	5.10	-	-	-
1601C	0	-	-	-	-	-	-	-
1602B	0	-	-	-	-	-	-	-
1604A	0	-	-	-	-	-	-	-
1604B	0	-	-	-	-	-	-	-
1604C	0	-	-	-	-	-	-	-
1803A	0	-	-	-	-	-	-	-
1803B	0	-	-	-	-	-	-	-
1803C	0	-	-	-	-	-	-	-
1804A	0	-	-	-	-	-	-	-
1806A	0	-	-	-	-	-	-	-
1806D	0	-	-	-	-	-	-	-
1806E	0	-	-	-	-	-	-	-
1806G	0	-	-	-	-	-	-	-
1806H	0	-	-	-	-	-	-	-
1807A	0	-	-	-	-	-	-	-
1811A	0	-	-	-	-	-	-	-
1813A	0	-	-	-	-	-	-	-
1813B	0	-	-	-	-	-	-	-
1813C	0	-	-	-	-	-	-	-
1813D	0	-	-	-	-	-	-	-
1813E	0	-	-	-	-	-	-	-
1813F	0	-	-	-	-	-	-	-
1813G	0	-	-	-	-	-	-	-
1813H	0	-	-	-	-	-	-	-
1813I	0	-	-	-	-	-	-	-
1901A	0	-	-	-	-	-	-	-
1901B	0	-	-	-	-	-	-	-
1901C	0	-	-	-	-	-	-	-
1901D	0	-	-	-	-	-	-	-
1902A	0	-	-	-	-	-	-	-
1902B	0	-	-	-	-	-	-	-
1905A	0	-	-	-	-	-	-	-
1906A	0	-	-	-	-	-	-	-
1910A	0	-	-	-	-	-	-	-

1910B	0	-	-	-	-	-	-	-
1910C	0	-	-	-	-	-	-	-
1910D	0	-	-	-	-	-	-	-
1910E	0	-	-	-	-	-	-	-
1911B	0	-	-	-	-	-	-	-
1911C	0	-	-	-	-	-	-	-
1911D	0	-	-	-	-	-	-	-
1911E	0	-	-	-	-	-	-	-
1911H	0	-	-	-	-	-	-	-
1912A	1	-	-	-	3.00	-	-	-
2004A	0	-	-	-	-	-	-	-
2004B	0	-	-	-	-	-	-	-
2302A	0	-	-	-	-	-	-	-
2304B	0	-	-	-	-	-	-	-
2306A	0	-	-	-	-	-	-	-
2309A	1	-	-	-	3.00	-	-	-
2310A	1	-	-	-	3.00	-	-	-
2422B	0	-	-	-	-	-	-	-
2424A	0	-	-	-	-	-	-	-
2424D	0	-	-	-	-	-	-	-
2424E	0	-	-	-	-	-	-	-
2431A	0	-	-	-	-	-	-	-
2432A	0	-	-	-	-	-	-	-
2432B	0	-	-	-	-	-	-	-
2485B	0	-	-	-	-	-	-	-
2485D	0	-	-	-	-	-	-	-
2492A	0	-	-	-	-	-	-	-

Appendix 1.6. DATA PROCESSING DESCRIPTIONS AND MICROSOFT EXCEL MACRO CODES

Station Sheets

The macro CopyPasteStations was used to take the WQ data from the pivot table and create an individual sheet within the workbook for each station (Station ID). The pivot table has dates as the row labels, parameter codes as the column labels, average of the reported values for each data point, and is filtered by station ID. The macro goes through each station ID, copies the reported data, then pastes it into a new sheet that is named after the station ID number.

(a) CopyPasteStations:

```
Sub CopyPasteStations()
Dim LastRow As Long
LastRow = Cells(Rows.Count, "A").End(xlUp).Row

Dim oItem As Excel.PivotItem
  Dim oField As Excel.PivotField

  Set oField = ThisWorkbook.Worksheets("Pivot").PivotTables("PivotTable2").PivotFields("Station ID")
  For Each oItem In oField.PivotItems
    oField.CurrentPage = oItem.Name

Sheets("Pivot").Select

  Rows("3:3" & LastRow).Select
  Selection.Copy
  Sheets.Add After:=Sheets("Pivot")
  Rows("1:1").Select
  ActiveSheet.Paste
  Rows("3.3").Select
```

```
    Selection.Delete

ActiveSheet.Name = Sheets("Pivot").[B1].Value

DoEvents

Next oItem

Sheets("Pivot").Select
End Sub
```

Parameter Editing

The WQ data had some unwanted parameters (e.g., 00535, 00608, and others) and also needed certain special parameters added. These special parameters essentially synthesize related parameters (for example, two different temperature parameters could be reported) into a single parameter that is consistent across stations. These were added into the data and have associated if-statement formulas that reference the existing parameters. Also, any reported 0 values were replaced with a blank cell. The macro ParametersEdit was used for the task.

(b) ParametersEdit:

```
Option Explicit

Option Compare Text

Option Base 1


Sub ParametersEdit()

'edited by Zach Simpson


    Dim i As Integer

    For i = 1 To ThisWorkbook.Sheets.Count

    Dim ws As Worksheet

    Set ws = Worksheets(i)

    Worksheets(i).Activate


    If Not ws.Name = "Pivot" _

    And Not ws.Name = "Basin 1" _

    And Not ws.Name = "Parameter Code Description" _

    And Not ws.Name = "Raw Data" _

    And Not ws.Name = "Basin" _

    And Not ws.Name = "Dummy Data" Then


        'Deletes Row if Column Labels/Average of Value/ANYTHING is in the first cell of the first row
```

```
If Not IsEmpty(Range("A1")) Then
  Rows(1).Delete
End If

With ActiveSheet
   Dim LastCol As Long
   LastCol = .Cells(1, .Columns.Count).End(xlToLeft).Column
End With
   'Find weird parameters (eg 535) that aren't normally found so that the rest of the code lines up
   'If parameter numbers aren't in this format, then they won't be found correctly (eg, if it's 535 instead of 00535, it won't be deleted)

   Dim iCntr As Long
   For iCntr = 2 To LastCol
   If Cells(1, iCntr) = "00535" Then
   Columns(iCntr).Delete
   End If

   If Cells(1, iCntr) = "00608" Then
   Columns(iCntr).Delete
   End If
   If Cells(1, iCntr) = "00631" Then
   Columns(iCntr).Delete
   End If
   If Cells(1, iCntr) = "00929" Then
   Columns(iCntr).Delete
   End If
   If Cells(1, iCntr) = "00930" Then
   Columns(iCntr).Delete
```

```
    End If
    If Cells(1, iCntr) = "00940" Then
    Columns(iCntr).Delete
    End If
    If Cells(1, iCntr) = "89858" Then
    Columns(iCntr).Delete
    End If

    Next
Columns(4).Insert shift:=xlToRight
Columns(16).Insert shift:=xlToRight
Columns(18).Insert shift:=xlToRight
Columns(19).Insert shift:=xlToRight
Columns(26).Insert shift:=xlToRight
Columns(30).Insert shift:=xlToRight
Columns(33).Insert shift:=xlToRight


  ' Inserts Columns for 00600 group
    Dim colx As Long
    For colx = 59 To 66 Step 1
      Columns(colx).Insert shift:=xlToRight
    Next

 Columns(72).Insert shift:=xlToRight
 Columns(76).Insert shift:=xlToRight
 Columns(77).Insert shift:=xlToRight
 Columns(78).Insert shift:=xlToRight
```

```
Columns(84).Insert shift:=xlToRight
Columns(99).Insert shift:=xlToRight
Columns(107).Insert shift:=xlToRight
Columns(139).Insert shift:=xlToRight
Columns(140).Insert shift:=xlToRight
Columns(143).Insert shift:=xlToRight

'Names inserted Columns
 Cells(1, 4).Value = "00010C"
 Cells(1, 16).Value = "00077m"
 Cells(1, 18).Value = "00078C1"
 Cells(1, 19).Value = "00078C"
 Cells(1, 26).Value = "00210C"
 Cells(1, 30).Value = "00213C"
 Cells(1, 33).Value = "00215C"
 Cells(1, 59).Value = "00593C1"
 Cells(1, 60).Value = "00593C2"
 Cells(1, 61).Value = "00600A"
 Cells(1, 62).Value = "00600B"
 Cells(1, 63).Value = "00600i"
 Cells(1, 64).Value = "00600C1"
 Cells(1, 65).Value = "00600C2"
 Cells(1, 66).Value = "00600C"
 Cells(1, 72).Value = "00620C1"
 Cells(1, 76).Value = "00630C"
 Cells(1, 77).Value = "00630C1"
 Cells(1, 78).Value = "00630C2"
 Cells(1, 84).Value = "00671C"
```

```
  Cells(1, 99).Value = "20389C"
  Cells(1, 107).Value = "20485C"
  Cells(1, 139).Value = "89077m"
  Cells(1, 140).Value = "89077C"
  Cells(1, 143).Value = "89856C"

'Put a placeholder row at the top
Rows(1).Insert shift:=xlDown
      Dim LastRow As Long
      LastRow = Cells(Rows.Count, "A").End(xlUp).Row
        If LastRow < 4 Then On Error Resume Next

       'Runs Equation for Column 00010C
        Range("D3").Select
        'If 0010 is available, use that else use 0011 after converting it to C
        ActiveCell.FormulaR1C1 = "=IF(RC[1]="""",RC[-1],((RC[1]-32)*(5/9)))"
        Range("D3").Select
        Selection.AutoFill Destination:=Range("D3:D" & LastRow)

       'Runs Equation for Column 00077m
        Range("P3").Select
        ActiveCell.FormulaR1C1 = "=IF(RC[-1]="""","""",(RC[-1]/39.700787))"
        Range("P3").Select
        Selection.AutoFill Destination:=Range("P3:P" & LastRow)

       'Runs Equation for Column 00078C1
        Range("R3").Select
        ActiveCell.FormulaR1C1 = "=IF(RC[-1]="""",RC[-2],RC[-1])"
```

```
    Range("R3").Select
    Selection.AutoFill Destination:=Range("R3:R" & LastRow)

'Runs Equation for Column 00078C
    Range("S3").Select
    ActiveCell.FormulaR1C1 = "=IF(RC[-1]="""",RC[120],RC[-1])"
    Range("S3").Select
    Selection.AutoFill Destination:=Range("S3:S" & LastRow)

'Runs Equation for Column 00210C
    Range("Z3").Select
    ActiveCell.FormulaR1C1 = "=IF(AND(RC[-1]>0,RC[1]>0),RC[-1]-RC[1],"""")"
    Range("Z3").Select
    Selection.AutoFill Destination:=Range("Z3:Z" & LastRow)

'Runs Equation for Column 00213C
    Range("AD3").Select
    ActiveCell.FormulaR1C1 = "=IF(AND(RC[-1]>0,RC[1]>0),RC[-1]-RC[1],"""")"
    Range("AD3").Select
    Selection.AutoFill Destination:=Range("AD3:AD" & LastRow)

'Runs Equation for Column 00215C
    Range("AG3").Select
    ActiveCell.FormulaR1C1 = "=IF(AND(RC[-1]>0,RC[1]>0),RC[-1]-RC[1],"""")"
    Range("AG3").Select
    Selection.AutoFill Destination:=Range("AG3:AG" & LastRow)

'Runs Equation for Column 00593C1
```

```
    Range("BG3").Select
    ActiveCell.FormulaR1C1 = "=IF(RC[-1]="""",RC[13],RC[-1])"
    Range("BG3").Select
    Selection.AutoFill Destination:=Range("BG3:BG" & LastRow)

'Runs Equation for Column 00593C2
    Range("BH3").Select
    ActiveCell.FormulaR1C1 = "=IF(RC[-1]="""",RC[12],RC[-1])"
    Range("BH3").Select
    Selection.AutoFill Destination:=Range("BH3:BH" & LastRow)

'Runs Equation for Column 00600A
    Range("BI3").Select
    ActiveCell.FormulaR1C1 = "=IF(AND(RC[13]>0,RC[14]>0),RC[13]+RC[14],"""")"
    Range("BI3").Select
    Selection.AutoFill Destination:=Range("BI3:BI" & LastRow)

'Runs Equation for Column 00600B
    Range("BJ3").Select
    ActiveCell.FormulaR1C1 = "=IF(AND(RC[12]>0,RC[-4]>0),RC[12]+RC[-4],"""")"
    Range("BJ3").Select
    Selection.AutoFill Destination:=Range("BJ3:BJ" & LastRow)

'Runs Equation for Column 00600i
    Range("BK3").Select
    ActiveCell.FormulaR1C1 = "=IF(AND(RC[11]>0,RC[8]>0,RC[7]>0),RC[11]+RC[8]+RC[7],"""")"
    Range("BK3").Select
    Selection.AutoFill Destination:=Range("BK3:BK" & LastRow)
```

```
'Runs Equation for Column 00600C1
  Range("BL3").Select
  ActiveCell.FormulaR1C1 = "=IF(RC[-3]="""",RC[-2],RC[-3])"
  Range("BL3").Select
  Selection.AutoFill Destination:=Range("BL3:BL" & LastRow)

'Runs Equation for Column 00600C2
  Range("BM3").Select
  ActiveCell.FormulaR1C1 = "=IF(RC[-3]="""",RC[-2],RC[-3])"
  Range("BM3").Select
  Selection.AutoFill Destination:=Range("BM3:BM" & LastRow)

'Runs Equation for Column 00600C
  Range("BN3").Select
  ActiveCell.FormulaR1C1 = "=IF(RC[-2]="""",RC[-1],RC[-2])"
  Range("BN3").Select
  Selection.AutoFill Destination:=Range("BN3:BN" & LastRow)

'Runs Equation for Column 00620C1
  Range("BT3").Select
  ActiveCell.FormulaR1C1 = "=IF(AND(RC[-2]>0,RC[-1]>0),RC[-2]+RC[-1],"""")"
  Range("BT3").Select
  Selection.AutoFill Destination:=Range("BT3:BT" & LastRow)

'Runs Equation for Column 00630C
  Range("BX3").Select
  ActiveCell.FormulaR1C1 = "=IF(RC[2]>0,RC[2],RC[-16])"
```

```
  Range("BX3").Select
  Selection.AutoFill Destination:=Range("BX3:BX" & LastRow)

'Runs Equation for Column 00630C1
  Range("BY3").Select
  ActiveCell.FormulaR1C1 = "=IF(RC[-2]="""",RC[-19],RC[-2])"
  Range("BY3").Select
  Selection.AutoFill Destination:=Range("BY3:BY" & LastRow)

'Runs Equation for Column 00630C2
  Range("BZ3").Select
  ActiveCell.FormulaR1C1 = "=IF(RC[-1]="""",RC[-19],RC[-1])"
  Range("BZ3").Select
  Selection.AutoFill Destination:=Range("BZ3:BZ" & LastRow)

'Runs Equation for Column 00671C
  Range("CF3").Select
  ActiveCell.FormulaR1C1 = "=IF(RC[-1]="""",RC[43],RC[-1])"
  Range("CF3").Select
  Selection.AutoFill Destination:=Range("CF3:CF" & LastRow)

'Runs Equation for Column 20389C
  Range("CU3").Select
  ActiveCell.FormulaR1C1 = "=IF(AND(RC[-1]>0,RC[-2]>0),RC[-1]-RC[-2],"""")"
  Range("CU3").Select
  Selection.AutoFill Destination:=Range("CU3:CU" & LastRow)

'Runs Equation for Column 20485C
```

```
    Range("DC3").Select
    ActiveCell.FormulaR1C1 = "=IF(AND(RC[1]>0,RC[-1]>0),RC[1]-RC[-1],"""")"
    Range("DC3").Select
    Selection.AutoFill Destination:=Range("DC3:DC" & LastRow)

  'Runs Equation for Column 89077m
    Range("EI3").Select
    ActiveCell.FormulaR1C1 = "=IF(RC[-1]="""","""",(RC[-1]/3.2808399))"
    Range("EI3").Select
    Selection.AutoFill Destination:=Range("EI3:EI" & LastRow)

  'Runs Equation for Column 89077C
    Range("EJ3").Select
    ActiveCell.FormulaR1C1 = "=IF(RC[-120]="""",RC[-1],RC[-120])"
    Range("EJ3").Select
    Selection.AutoFill Destination:=Range("EJ3:EJ" & LastRow)

  'Runs Equation for Column 89856C
    Range("EM3").Select
    ActiveCell.FormulaR1C1 = "=IF(AND(RC[-1]>0,RC[-2]>0),RC[-1]-RC[-2],"""")"
    Range("EM3").Select
    Selection.AutoFill Destination:=Range("EM3:EM" & LastRow)

    'Replaces all zeros with blank cell
       Dim rng As Range
        For Each rng In Range("B3:EN" & LastRow)
           If rng.Value = 0 Then
             rng.Value = ""
```

```
                End If
              Next

           'Bolds completed parameters
            Range("D2,S2,Z2,AD2,AG2,BI2,BJ2,BK2,BN2,BX2,CF2,CU2,DC2,EJ2,EM2").Font.Bold = True

        Range("A1").EntireColumn.AutoFit
        Range("A1").Select
   End If
  Next

End Sub
```

Median Calculations

With all of the WQ data in place for each station, the yearly median value for each parameter needed to be calculated for each station. The macro used was MedianCalculator. The macro goes through each sheet in the workbook that has WQ data for a station. It finds what years of data are reported and creates a row at the top of the station sheet that is labeled for each year. Then, it steps through each parameter (by column) on the sheet, calculates a median value of that parameter for each reported year, and places the yearly median value in the associated row at the top of the sheet.

(c) MedianCalculator:

```
Option Explicit

Option Compare Text

Option Base 1



Sub MedianCalculator()



Dim i As Integer

    Dim ws As Worksheet

    For i = 1 To ThisWorkbook.Sheets.Count

        Set ws = Worksheets(i)


            Worksheets(i).Activate


            'Exclude these worksheets AND make sure that they are named exactly this way


            If Not ws.Name = "Raw Data" And Not ws.Name = "Basin" And Not ws.Name = "Basin 1" And Not ws.Name = "ParameterCode Description" And Not ws.Name = "Dummy Data" And Not ws.Name = "Pivot" Then
```

```
'Count number of columns or parameters

 Dim LastCol As Long
 Dim LastRow As Long
 LastRow = Cells(Rows.Count, "A").End(xlUp).Row
 LastCol = Cells(2, Columns.Count).End(xlToLeft).Column

 'Assuming the dates are in order (they should be)
 'Find first (earliest) year of data
 Dim BegYear As Integer
 BegYear = Year(Range("A3"))
 'Find last (latest) year of data
 Dim LastYear As Integer
 LastYear = Year((Cells(LastRow, 1)))

 Dim YearsCount As Integer
 YearsCount = (LastYear - BegYear) + 1

 'In the case of there being only one year of data
 If YearsCount = 1 Then
   Rows(1).Insert
   Range("A1").Value = BegYear
   Range("A1").Font.Bold = True
   Dim j As Integer
   For j = 2 To LastCol
     If IsEmpty(Cells(4, j)) Then
       Else
       ActiveSheet.Cells(4, j).Select
```

```
            If Len(Selection.Value) = 0 Then
              Else
              With ActiveSheet
              'Select range to calc median for
              Dim MedRange1 As Range
              'Define last row again since rows were inserted
              Dim LastRow1 As Long
              LastRow1 = Cells(Rows.Count, "A").End(xlUp).Row

              Set MedRange1 = Range(Cells(4, j), Cells(LastRow1, j))
              ActiveSheet.Cells(1, j).Select
              Selection.Value = WorksheetFunction.Median(MedRange1)
              End With
            End If
          End If
        Next

      Else
      'There is more than one year of data
      'Insert a row at top for space
      Rows(1).Insert

      'Insert rows at top
      'Insert year labels
      Dim k As Integer
      Dim YearLabel As Long
      YearLabel = LastYear
      For k = 1 To YearsCount
```

```
        Rows(1).Insert shift:=xlDown
        Range("A1").Value = YearLabel
        Range("A1").Font.Bold = True
        YearLabel = YearLabel - 1
    Next k

    Dim m As Integer
    For m = 1 To YearsCount
        'Set the year in this iteration to the yearlabel we're working in
        Dim YearofInterest As Integer
        YearofInterest = Cells(m, 1).Value
        'Define last row again since rows were inserted
        Dim LastRow2 As Long
        LastRow2 = Cells(Rows.Count, "A").End(xlUp).Row

        With Range("A:A")
        Dim BegofYear As Range
        Set BegofYear = .Find(What:=YearofInterest, LookIn:=xlValues, LookAt:=xlPart, After:=Cells(m, 1), SearchOrder:=xlByRows, SearchDirection:=xlNext)
        Dim EndofYear As Range
        Set EndofYear = .Find(What:=YearofInterest, LookIn:=xlValues, LookAt:=xlPart, After:=Cells(LastRow2, 1).Offset(1, 0), SearchOrder:=xlByRows, SearchDirection:=xlPrevious)
        End With
            Dim n As Integer
            For n = 2 To LastCol
            Dim MedRange As Range
            Set MedRange = Range(Cells(BegofYear.Row, n), Cells(EndofYear.Row, n))

            'Check to see if the median range is empty
```

```
            If IsEmpty(MedRange) Then
            Else
              Dim NuminMedRange As Integer
              NuminMedRange = MedRange.Rows.Count
              Dim p As Integer
              For p = 1 To NuminMedRange
              If Len((Cells(BegofYear.Row, n).Offset(p - 1, 0))) = 0 Then

              Else

                Cells(m, n).Value = WorksheetFunction.Median(MedRange)
              End If
              Next
            End If
            Next
        Next

        End If

      End If
  Next i


End Sub
```

Summary Median Table

The last step in the process gathered all of the yearly median values and organized them into sheets for each year. A macro named SummaryTableMedians was used for this task. A new worksheet was created and labeled for each year to make a table which had parameter codes as the column labels and all of the stations in the workbook as the row labels. The yearly medians calculated in the previous macro were pasted into the tables for the associated year.

(d) SummaryTableMedians

```
Option Explicit

Option Compare Text

Option Base 1


'last edit by Zach Simpson 4/10/15


Sub SummaryTableMedians()


'look for the raw data sheet

'newer data calls it 'Raw Data' while older data calls it 'Basin'

Dim wsSheet As Worksheet

Dim refsheet As Worksheet

On Error Resume Next

Set wsSheet = Sheets("Raw Data")

On Error GoTo 0

If Not wsSheet Is Nothing Then

Set refsheet = Sheets("Raw Data")

Else

Set refsheet = Sheets("Basin")

End If
```

```
refsheet.Activate


'Finding the columnn labelled "End Date", should be column F but just in case...

With Range("1:1")

Dim EndDate As Range

Set EndDate = .Find(What:="End Date", LookIn:=xlValues, LookAt:=xlWhole, After:=Cells(1, 1),
SearchOrder:=xlByColumns, SearchDirection:=xlNext)

End With


'Finding the last row in the sheet

With Range("A:A")

Dim LastRow As Long

LastRow = Cells(Rows.Count, "A").End(xlUp).Row

End With


'finding the earliest (beginning) year mentioned in the raw data

Dim j As Integer

'assuming the data starts after 1990, this can be changed if need be

'you can change these years if need be

j = 1990

   Dim BegYear As Long

   Do Until BegYear = j


   With Range(Cells(1, EndDate.Column), Cells(LastRow, EndDate.Column))

   Dim RealBegYear As Range

   Set RealBegYear = .Find(What:=j, LookIn:=xlValues, LookAt:=xlPart, After:=Cells(1,
EndDate.Column).Offset(1, 0), SearchOrder:=xlByRows, SearchDirection:=xlNext)

   End With

   If Not RealBegYear Is Nothing Then
```

```
      BegYear = j
      If Not RealBegYear Is Nothing Then Exit Do
   Else
   j = j + 1
   End If

   Loop

'Finding the last (end or latest) year in the raw data
'once again, if you're using this macro in 2027 AD, you may want to update k

Dim k As Integer
k = 2015
   Dim EndYear As Long
   Do Until EndYear = k

   With Range(Cells(1, EndDate.Column), Cells(LastRow, EndDate.Column))
   Dim RealEndYear As Range
   Set RealEndYear = .Find(What:=k, LookIn:=xlValues, LookAt:=xlPart, After:=Cells(1,
EndDate.Column).Offset(1, 0), SearchOrder:=xlByRows, SearchDirection:=xlNext)
   End With
   If Not RealEndYear Is Nothing Then
      EndYear = k
      If Not RealEndYear Is Nothing Then Exit Do
   Else
   'this time we're stepping backwards through time
   k = k - 1
```

```
    End If

    Loop

'Need to find list of parameters to paste into each new sheet (when we get to that step)

refsheet.Activate
Dim StationRef As String
'I'm just picking any station as a reference
'Each station sheet should have all the parameter codes used
StationRef = Cells(2, 5).Value
'Picks first station listed so we can go to that sheet
Dim StationRefSheet As Worksheet
Set StationRefSheet = Sheets(StationRef)

'Get the parameter code labels

With StationRefSheet
    StationRefSheet.Activate
    With Range("A:A")
    Dim RowLabels As Range
    'find the row of parameter labels
    Set RowLabels = .Find(What:="Row Labels", LookIn:=xlValues, LookAt:=xlWhole, After:=Cells(1, 1),
SearchOrder:=xlByRows, SearchDirection:=xlNext)
    End With

    Dim ParamRange As Range
    If IsEmpty(RowLabels.Offset(-1, 1)) Then
```

```
    'the row of parameters should be around 142 but varying datasets (between timesets) may have extra parameters.
    'Thus, I'm letting it go to 145 just in case
    Set ParamRange = Range(RowLabels.Offset(0, 1), RowLabels.Offset(0, 145))
    Else
    Set ParamRange = Range(RowLabels.Offset(-1, 1), RowLabels.Offset(-1, 145))
    End If


    ParamRange.Select


End With


refsheet.Activate
'this with statement finds all the unique station id's and pastes them into Column V to use as the row labels for each of the year tabs
With Range("E:E")
    Dim d As Object, c As Variant, m As Long, lr As Long
    Set d = CreateObject("Scripting.Dictionary")
    lr = Cells(Rows.Count, 5).End(xlUp).Row
    c = Range("E2:E" & lr)
    For m = 1 To UBound(c, 1)
        d(c(m, 1)) = 1
    Next m
    Range("V2").Resize(d.Count) = Application.Transpose(d.keys)
    Dim StationRange As Range
    Dim lvr As Long
    lvr = Cells(Rows.Count, "V").End(xlUp).Row
    Set StationRange = Range("V2:V" & lvr)
```

```
End With


'Create a sheet for each year

'This is where the median summary table (for each year) will go

Dim SheetLabel As Long

For SheetLabel = BegYear To EndYear


    Sheets.Add.Name = SheetLabel

    Dim sheetlabeltext As String

    sheetlabeltext = SheetLabel

    Worksheets(sheetlabeltext).Activate

    Range("B1:EP1").Value = ParamRange.Value

    Range("B1:EP1").Font.Bold = True

    Range("A2:A" & lvr).Value = StationRange.Value

    Range("A2:A" & lvr).Font.Bold = True

    'bolding label row/column for effect


    Next


'now we've made our tables for each year with station id's on row labels and parameters as column labels

'next step is to fill in the appropriate median data


Dim n As Integer

For n = BegYear To EndYear

    'n is the year of interest


    Dim o As Long

    Dim stationsheet
```

```
For o = 1 To ThisWorkbook.Sheets.Count
    Set stationsheet = Worksheets(o)
    Worksheets(o).Activate
    'Exclude these worksheets AND make sure that they are named exactly this way
    If Not stationsheet.Name = "Raw Data" And Not stationsheet.Name = "All Data" And Not stationsheet.Name = "All Station List" And Not stationsheet.Name = "TCEQ Station List" And Not stationsheet.Name = "All Median" And Not stationsheet.Name = "All Count" And Not stationsheet.Name = "Cen 1 Count" And Not stationsheet.Name = "Basin" And Not stationsheet.Name = "Basin 1" And Not stationsheet.Name = "Parameter Description" And Not stationsheet.Name = "ParameterCode Description" And Not stationsheet.Name = "Dummy Data" And Not stationsheet.Name = "Pivot" Then
        With Range("A:A")
        Dim CopyYear As Range
        Set CopyYear = .Find(What:=n, LookIn:=xlValues, LookAt:=xlWhole, SearchOrder:=xlByRows, SearchDirection:=xlNext)
        If Not CopyYear Is Nothing Then
            Dim CopyYearRange As Range
            'again, using 145 for possible number of parameters
            Set CopyYearRange = Range(Cells(CopyYear.Row, 2), Cells(CopyYear.Row, 145))


            Dim stationsheetname As Long
            stationsheetname = ActiveSheet.Name



            'go to the summary table sheet for the nth year
            Sheets(CStr(n)).Activate
            With Range("A:A")
            Dim PasteDestination As Range
            Set PasteDestination = .Find(What:=stationsheetname, LookIn:=xlValues, LookAt:=xlWhole, SearchOrder:=xlByRows, SearchDirection:=xlNext)
            Range(Cells(PasteDestination.Row, 2), Cells(PasteDestination.Row, 145)).Value = CopyYearRange.Value
```

```
            End With
          Else
          'year isn't found so do nothing

          End If

          End With
        End If

    'next sheet
    Next

'next year
Next


End Sub
```

Appendix 1.7. Maps of GIS analysis to target drought and non-drought basin-ecoregion union areas

January 2004

February 2004

March 2004

April 2004

Figure A1.7.1. For the months January – April 2004, Texas basin-ecoregion III union areas with severe to exceptional drought zones at the centroid are shown in gray (DM ≥ 2; United States Drought Monitor classifications; droughtmonitor.unl.edu), while non-drought areas are shown in white. Annual medians from union areas determined to be in drought for at least four months of the year in 2004 were excluded from targeted drought analyses, in order to focus on areas with normal to above average precipitation.

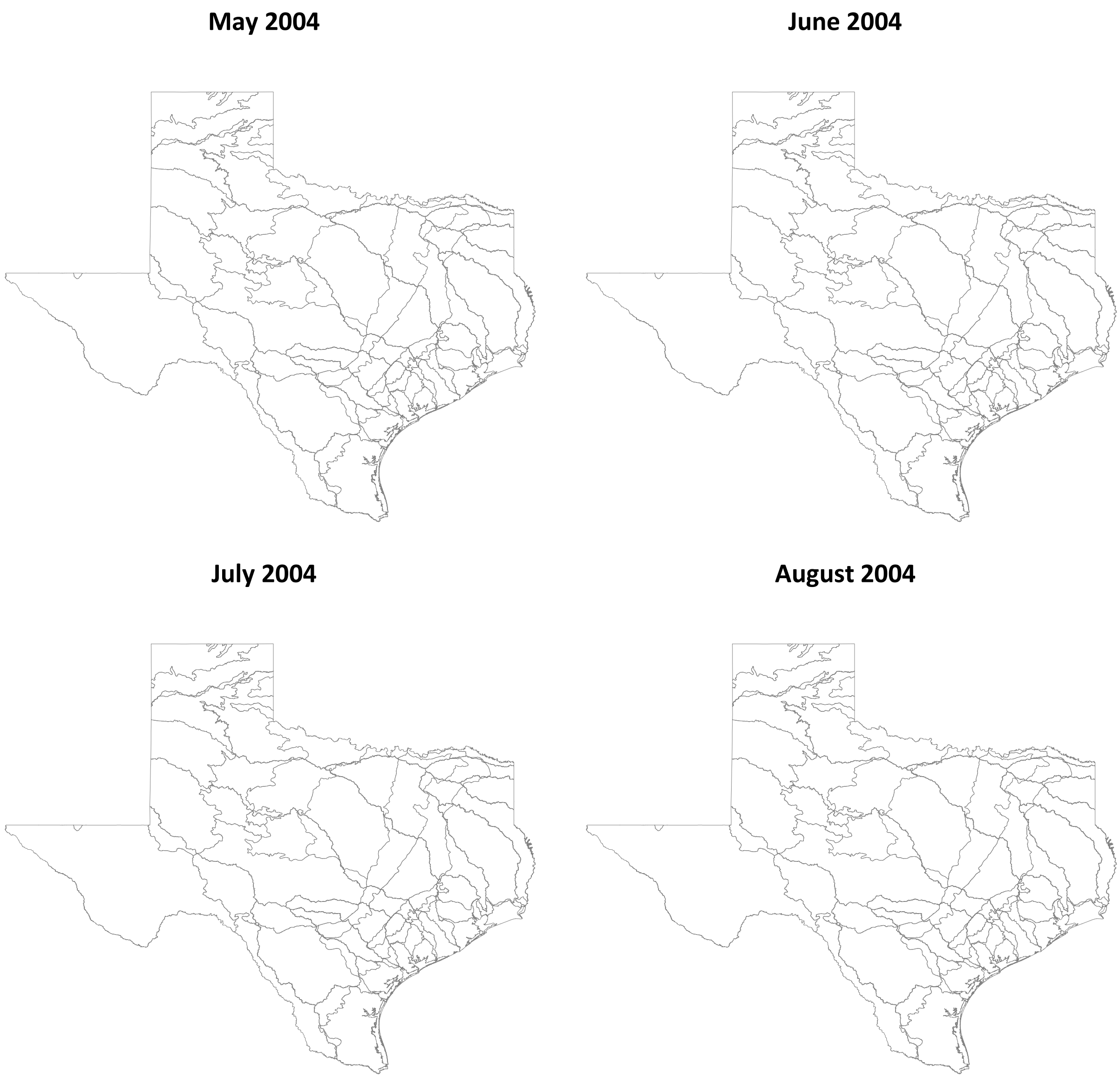


Figure A1.7.2. For the months May – August 2004, no Texas basin-ecoregion III union areas were identified with severe to exceptional drought zones at the centroid (DM ≥ 2; United States Drought Monitor classifications; droughtmonitor.unl.edu). Therefore all union areas are shown in white, indicating non-drought status. Annual medians from union areas determined to be in drought for at least four months of the year in 2004 were excluded from targeted drought analyses, in order to focus on areas with normal to above average precipitation.

September 2004

October 2004

November 2004

December 2004

Figure A1.7.3. For the months September – December 2004, no Texas basin-ecoregion III union areas were identified with severe to exceptional drought zones at the centroid (DM ≥ 2; United States Drought Monitor classifications; droughtmonitor.unl.edu). Therefore all union areas are shown in white, indicating non-drought status. Annual medians from union areas determined to be in drought for at least four months of the year in 2004 were excluded from targeted drought analyses, in order to focus on areas with normal to above average precipitation.

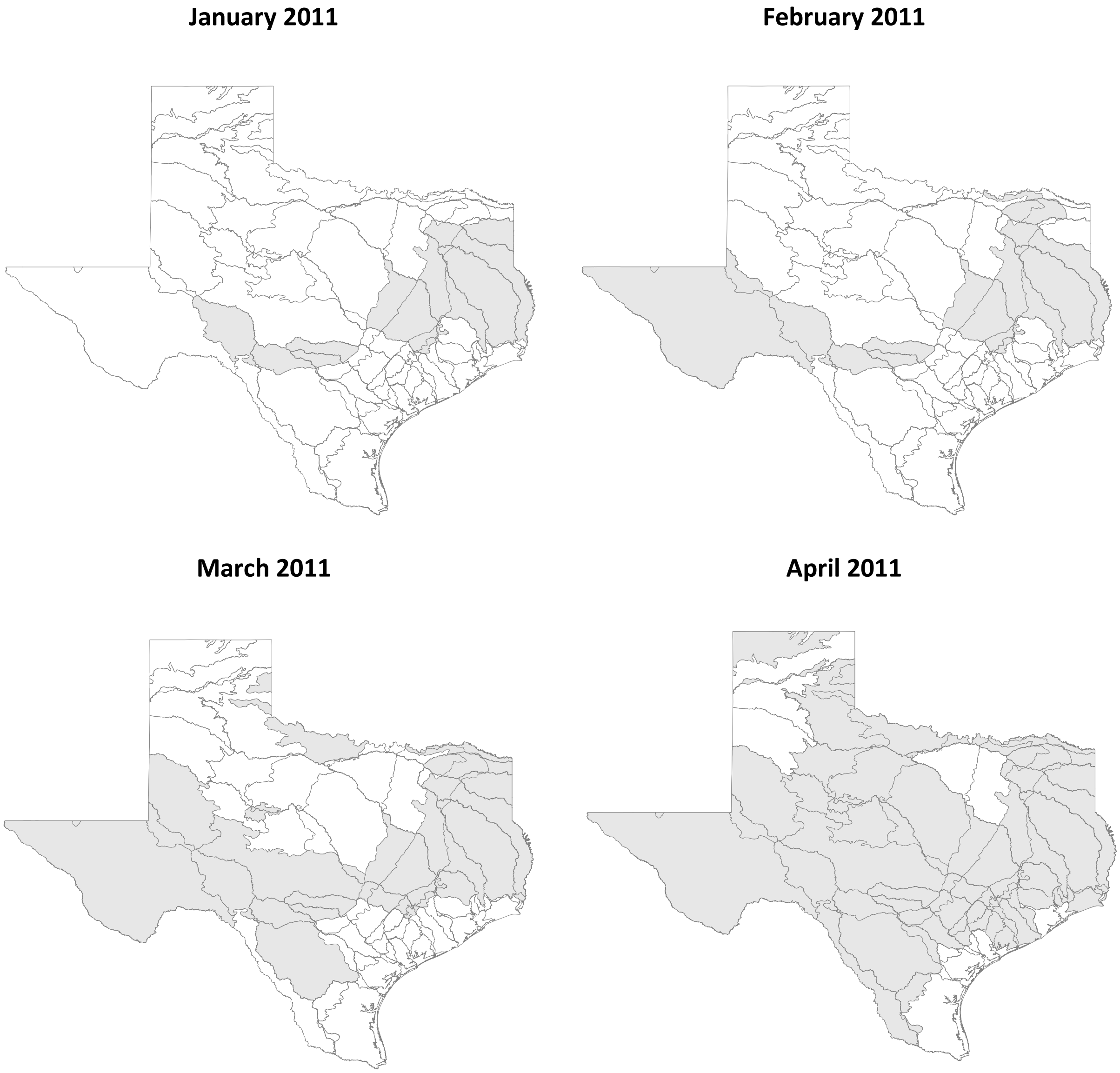


Figure A1.7.4. For the months January – April 2011, Texas basin-ecoregion III union areas with severe to exceptional drought zones at the centroid are shown in gray (DM ≥ 2; United States Drought Monitor classifications; droughtmonitor.unl.edu), while non-drought areas are shown in white. Only annual medians from union areas determined to be in drought for at least eight months of the year in 2011 were included in drought analysis, in order to focus on areas with the most severe and established drought conditions.

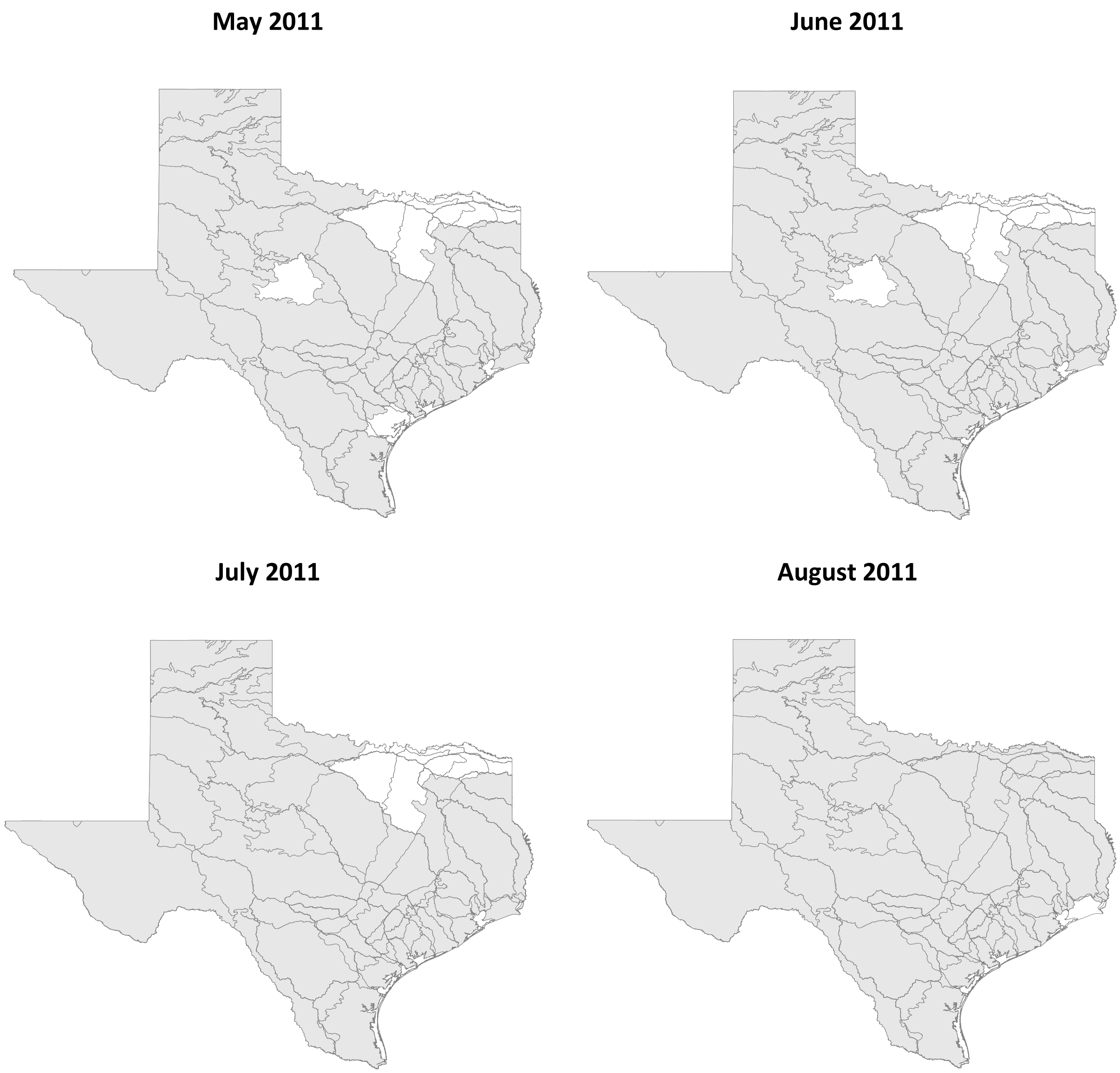


Figure A1.7.5. For the months May – August 2011, Texas basin-ecoregion III union areas with severe to exceptional drought zones at the centroid are shown in gray (DM ≥ 2; United States Drought Monitor classifications; droughtmonitor.unl.edu), while non-drought areas are shown in white. Only annual medians from union areas determined to be in drought for at least eight months of the year in 2011 were included in drought analysis, in order to focus on areas with the most severe and established drought conditions.

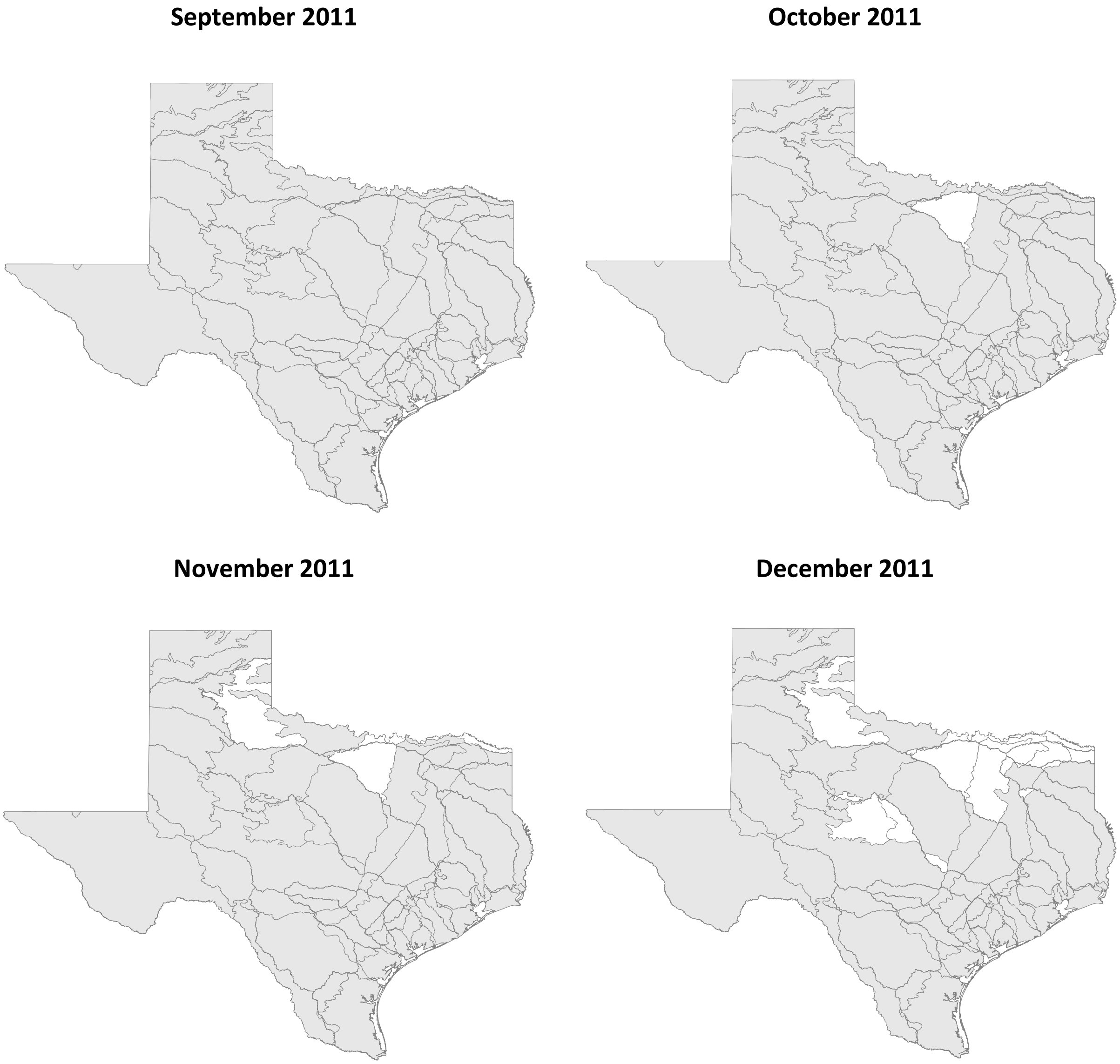


Figure A1.7.6. For the months September – December 2011, Texas basin-ecoregion III union areas with severe to exceptional drought zones at the centroid are shown in gray (DM ≥ 2; United States Drought Monitor classifications; droughtmonitor.unl.edu), while non-drought areas are shown in white. Only annual medians from union areas determined to be in drought for at least eight months of the year in 2011 were included in drought analysis, in order to focus on areas with the most severe and established drought conditions.

Appendix 1.8 Boxplots of parameters of interest for the drought comparisons with targeted groups

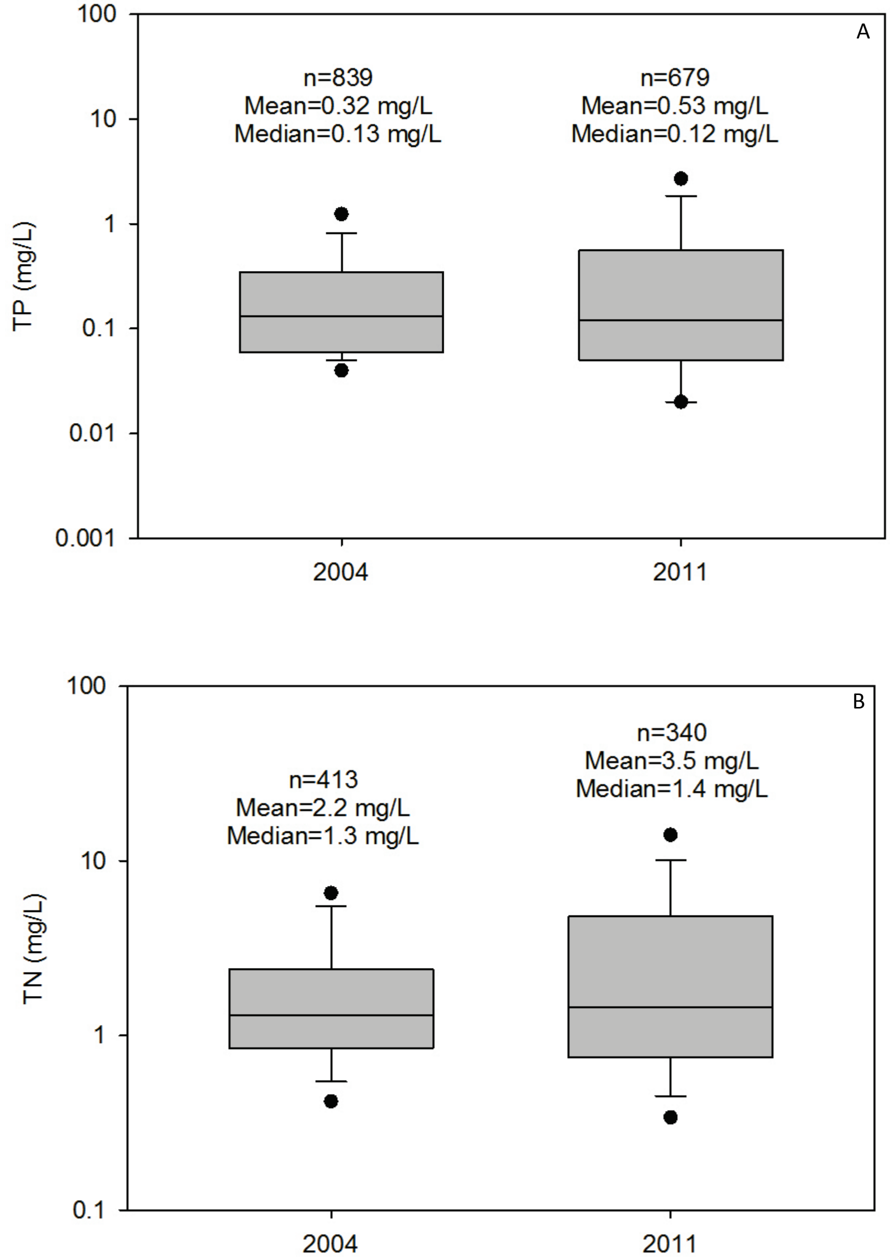


Figure A1.8.1. Data distributions for statewide station annual medians of A) total phosphorus (TP) and B) total nitrogen (TN) after removing medians from basin-ecoregion III union areas determined to be not representative of the target wet and dry conditions in 2004 and 2011, respectively. The shaded area represents data falling between the 25th and 75th percentiles, while error bars indicate the 10th and 90th percentiles and outlier icons represent 5th and 95th percentiles.

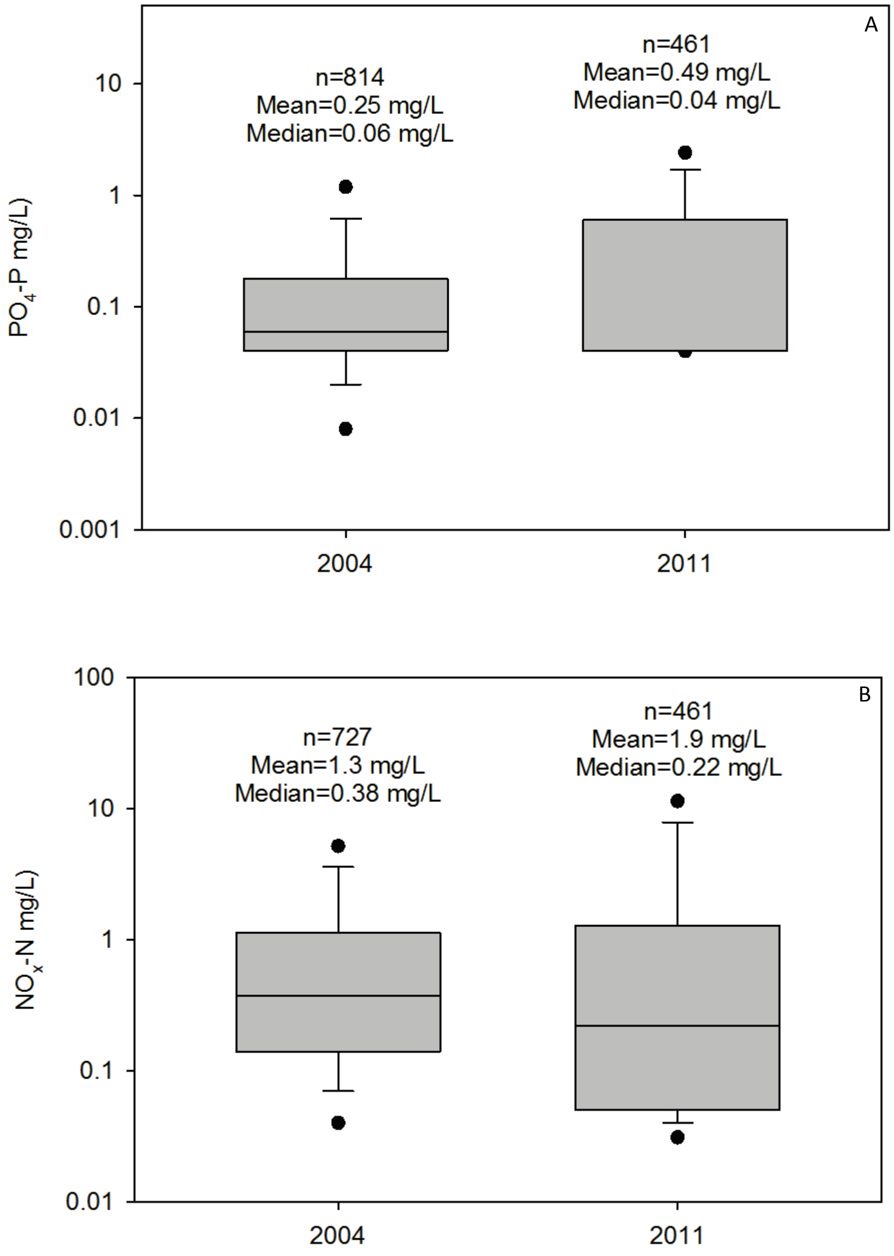


Figure A1.8.2. Data distributions for statewide station annual medians of A) phosphate-phosphorus (PO_4-P) and B) nitrate+nitrite-nitrogen (NO_x-N) after removing medians from basin-ecoregion III union areas determined to be not representative of the target wet and dry conditions in 2004 and 2011, respectively. The shaded area represents data falling between the 25th and 75th percentiles, while error bars indicate the 10th and 90th percentiles and outlier icons represent 5th and 95th percentiles.

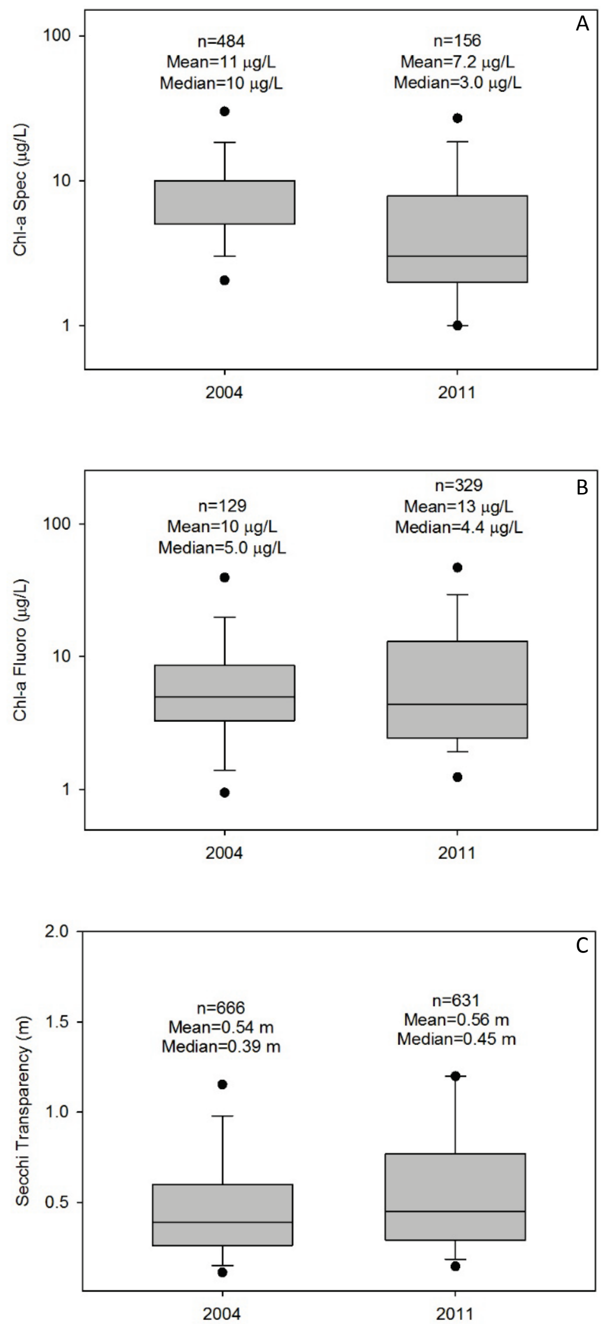


Figure A1.8.3. Data distributions for statewide station annual medians of chlorophyll-a measured A) spectrophotometrically or B) fluorometrically and Secchi transparency after removing medians from basin-ecoregion III union areas determined to be not representative of the target wet and dry conditions in 2004 and 2011, respectively. The shaded area represents data falling between the 25th and 75th percentiles, while error bars indicate the 10th and 90th percentiles and outlier icons represent 5th and 95th percentiles.

Section 2: Reservoirs

E.M. Grantz, J.T. Scott, and B.E. Haggard

EXECUTIVE SUMMARY

The Clean Water Action Plan, released in 1998 by the United States Environmental Protection Agency (USEPA), established a national set of nutrient targets for 14 aggregate ecoregions across the United States, directing states and tribes to adopt these targets or pursue development of scientifically defensible targets at the state level. For reservoirs, the two main approaches for target development focus on the frequency distribution of median concentrations and statistical analysis of stressor-response relationships between nutrients and biological response variables. Predictive approaches have focused on establishing relationships between nutrient concentrations and sestonic algae.

The objective of Section 2 was to provide statistical support to the Texas Commission on Environmental Quality (TCEQ) to assist in the development of numeric nutrient or biological response targets for Texas reservoirs. The USEPA recommends that statistical approaches that evaluate stressor-response relationships in aquatic systems and frequency distribution analysis should be used in conjunction for developing numeric targets for lakes and reservoirs. Further, questions remain regarding the legitimacy of promulgating a single numeric target for a parameter across areas that may contain multiple basins, ecoregions, and land uses. Finally, censored datasets present a challenge to states, tribes, and others in progressing toward statistically-based numeric criteria development. Analyses in Sections 2.1 – 2.3 provide analyses that aid in addressing these concerns through multiple lines of inquiry. These analyses were based upon data provided by the TCEQ for the period 2000 – 2010 and that were organized by the Arkansas Water Resources Center (AWRC) under a prior study (FY2012-2013). The data compiled water quality parameters from 764 stations and were collected under non-biased flow conditions. To explore potential censored data effects, data were processed into five median datasets with variable correction for censoring.

In Section 2.1, prior changepoint analysis of stressor-response relationships in Texas reservoirs were expanded by "flipping" the traditional configuration of the analysis to place the stressor and response parameters on the y-axis and x-axis, respectively. The study objective was to thresholds in biological variables. Potential censored data effects were explored by repeating analyses on three of the five datasets with variable correction for censoring. Thresholds were identified in spectrophotometric chlorophyll-a (chl-a spec; 21.6 – 26.1 ug/L) and Secchi transparency (0.42 – 0.87) for both TP and TN gradients, but analyses appeared to be strongly affected by outlier chl-a values. After these values were removed, lower chl-a thresholds were identified (12.5 – 16.8 ug/L), while Secchi thresholds were unchanged, though model explanatory power increased. The chl-a spec thresholds identified after removing outliers greatly exceeded chl-a targets recommended by the USEPA (2000), but were mid-range between mean chl-a concentrations associated with low and high nutrient stations that had median TP and TN concentrations that were either below and above nutrient thresholds identified in prior

changepoint analysis. The transparency thresholds identified in "flipped" changepoint analysis were, in contrast, consistently, in range with average transparency associated with high nutrient groups, thereby representing a less conservative potential target.

Prior changepoint analysis of stressor-response relationships in Texas reservoirs at the statewide level was refined in Section 2.2 by conducting these analyses on water quality data specific to major river basins and Omnerik Level III ecoregions. Potential geographic variability was further explored by conducting frequency distribution analysis of water quality parameters within reservoir segments in Section 2.3. The parameters of primary concern were total phosphorus (TP), ortho-phosphate (PO_4-P; SRP), total nitrogen (TN), nitrate plus nitrite N (NO_x-N), and sestonic chlorophyll-a (chl-a). Frequency distributions, including the minimum, 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentiles, and maximum values of these parameters, were calculated for the general population within each segment. Both sets of regional analyses indicated significant variability in potential nutrient and biological response target values for different geographic areas, and model strength associated with nutrient thresholds was often much greater for basins or level III ecoregions than was observed for reservoirs at the statewide-scale. Potential censored data effects were evident for regional-scale analyses as well, with different TP thresholds observed between the three datasets with variable correction for censoring in a number of Texas basins and level III ecoregions.

During 2011 – 2014, Texas was in extreme to exceptional drought, most notably in 2011. In Section 2.4, potential shifts in data distributions for groups of annual water quality medians during drought years were explored through comparisons with data collected during periods of normal to above average precipitation in Texas (2001 – 2004). Analyses were conducted at the statewide level and after targeting non-drought and drought conditions in 2004 and 2011, respectively, by removing data from geographical areas with precipitation regimes that were not representative of the rest of the state in those years. Among these subgroups of annual medians, differences between wet and dry years were typically small, though notably, means consistently exhibited the greatest differences and medians the smallest, supporting the idea that medians are a more robust choice for use in setting water quality standards.

INTRODUCTION

The Clean Water Action Plan, released in 1998 by the United States Environmental Protection Agency (USEPA), established a national set of water quality target standards for 14 regions across the United States aggregating geographically similar Omnerik Level III Ecoregions. These numeric values were a function of frequency distributions of national lakes and reservoirs datasets, and targets were established for both causative variables, such as nutrients, and response variables, such as chlorophyll-a or transparency, that are associated with the prevention and assessment of eutrophic conditions in streams and rivers. In lieu of adopting USEPA recommended targets, states, tribes, and others were provided the option to establish scientifically defensible targets for lakes and reservoirs at reduced spatial scales that are specific to an area of concern. States have overwhelmingly opted for this option, as the proposed USEPA targets did not account for local and regional influences that can affect water quality. Subsequent analysis has indicated that aggregate ecoregions likely represent too coarse a geographical scale for establishing water quality standards, and the basin or individual ecoregion level may be more appropriate (Rohm et al. 2002). Variability in water quality metrics across geographical scales and locations has been shown to result in nutrient and biological data frequency distributions that deviate from nationwide datasets and therefore from USEPA recommendations (e.g., Ice et al., 2003; Smith et al. 2003; Binkley 2004, Longing and Haggard 2010; Evans-White et al. 2013). For example, nutrient levels in Pacific Northwest lakes are strongly related to typology defined by turbidity and conductivity, as well as geospatial variability (Vaga et al. 2006).

Commonly accepted statistical approaches to developing nutrient targets available to states, tribes, and others include percentile analysis of data frequency distributions and stressor-response relationships. The frequency distribution method does not require prior knowledge of individual stream conditions. Criteria are instead developed relative to values observed for a specific population of water bodies. The USEPA (2000) suggested two statistical methods to identify nutrient targets based on percentile analysis of data frequency distributions. The first establishes the 75th percentile of a distribution of a reference or minimally impacted population as a criterion. The second focuses on the 25th percentile of the general population. The USEPA (2000) suggested that both approaches should result in similar values; however, comparisons between approaches show that these values can be highly variable in lakes and reservoirs (Herlihy et al. 2013). There are many additional concerns with this approach, such as limited data availability representing reference, or even general populations, from targeted areas. Frequency distributions from the recent National Lakes Assessment survey, which used probability-based experimental design to randomly select 1028 lakes and reservoirs across the conterminous U.S. for detailed water quality analysis, also differed from previous USEPA recommendations based on found data (Herlihy et al. 2013). Furthermore, a percentile selected may not be tied to water-quality impairments or protection of a designated us.

The USEPA has recommended that states and tribes use stressor-response studies to develop nutrient targets. In these analyses, biological conditions are evaluated over a gradient of nutrient concentrations. Classification and regression tree (CART) analysis is an empirical modeling technique that is useful for identifying ecological thresholds and hierarchical structure in predictor variables (De'ath and Fabricius 2000). CART uses recursive partitioning to divide data into subsets that are increasingly homogeneous, invoking a tree-like classification that can explain relationships that may be difficult to reconcile with conventional linear models (Urban 2002). CART and other similar methods have been used to identify thresholds and hierarchical structure in environmental correlates of various biological processes in aquatic ecosystems (King et al. 2005, East and Sharfstein 2006). King et al. (2005) used CART to identify thresholds in nutrient concentrations which resulted in shifts in ecological structure and function.

Censored datasets present a significant challenge to states, tribes, and others in progressing toward statistically-based numeric nutrient target development because censored observations can affect analyses such as distribution fitting or stressor-response. The true value of a censored observation is unknown, except that it falls within a range of values. Left-censored observations are bounded by zero and an analytical detection limit, and are the most common type of censored data in environmental datasets. Some environmental metrics, such as Secchi depth, can also be associated with right-censored observations. The value of right-censored observations is known only to exceed a detection limit. Common approaches for handling censored observations include deletion or substitution with either zero, the detection limit, or half the detection limit. These approaches are not statistically rigorous and can obscure existing patterns or introduce patterns to datasets that do not reflect real-world conditions. Though less commonly employed, statistically rigorous methods for analyzing censored data do exist. Methods for calculating summary statistics, such as means, medians, standard deviations, and percentiles are well-developed (Helsel 2012). These methods extract known information, such as the frequency at which censored observations occur in the dataset relative to uncensored observations.

The State of Texas and Texas Commission on Environmental Quality (TCEQ) has contracted with the Arkansas Water Resources Center (AWRC) since 2011 to analyze the state's long-term water quality datasets. A median database (2000-2010) for reservoirs was developed as part of the FY2012-2013 contract. This database has served as the foundation for previous and the present analyses on Texas reservoirs and is comprised of data provided by TCEQ that were collected from 1968 to 2012 from reservoirs throughout Texas. Data were collected from 764 reservoir stations spanning 14 watersheds. The data describe 116 reservoir characteristics and water quality parameters including nutrient and sediment concentrations, transparency, a range of physico-chemical parameters, and others. These data were subject to quality control measures outlined in project QAPP's. After organization into a workable database, data were analyzed for frequency distributions and stressor-response relationships. This process is described in detail in the final report of the FY2012-2013 contract (AWRC 2013).

Present project tasks for Texas reservoirs focus on refining the analytical goals set out in FY2012-2013. Stressor-response relationships were explored using changepoint analysis in a way that would result in potential chl-a or Secchi transparency threshold values. Potential biological and nutrient target values relevant at the regional, or even segment-specific, scale were explored using frequency distribution and changepoint analysis of data collected specifically within these various geographic areas. Finally, because Texas experienced widespread severe to exceptional drought from 2011-2014 (United States Drought

Monitor; droughtmonitor.unl.edu), potential drought-related trends in the values of key biological and nutrient parameters were explored, as these trends could affect nutrient target development.

Therefore, the objectives of this chapter for Texas reservoirs are:

1) to explore whether changepoint analysis of stressor-response relationships can identify meaningful thresholds in median biological parameters (focusing on Secchi transparency and chlorophyll-a) relative to a gradient of median nutrient stressor values (focusing on TP and TN) by "flipping" traditional stressor and response variables;
2) to identify nutrient thresholds values associated with changes in the magnitude or variability of commonly measured biological parameters within Texas basins and Omnerik level III ecoregions;
3) to assess the frequency distribution of median nutrient concentrations and response variables at the segment scale for Texas reservoirs, based on Segment ID's acquired from the Texas Commission of Environmental Quality (TCEQ).
4) and to calculate a time-series of station medians and determine if a shift in the median values of key water quality parameters has occurred in tandem with drought onset and persistence.

2.1 CHANGEPOINT ANALYSIS TO IDENTIFY THRESHOLDS IN BIOLOGICAL PARAMETERS

Methods

We used a novel application of non-parametric changepoint analysis (nCPA; Qian et al. 2003, King and Richardson 2003), a stressor-response analysis related to CART, to identify thresholds in common biological response variables relative to gradients of nutrient stressor variables. This approach reverses the traditional stressor-response relationship, placing biological variables on the x-axis as the independent variable and nutrient variables on the y-axis as the dependent variable. These analyses were carried out on the median database for streams and rivers developed in FY2012-2013. The biological variables included in the analyses were median Secchi transparency (m; parameter code 00078C) and median chlorophyll-a chl-a measured with spectrophotometry (chl-a spec; µg/L; 32211. The nutrient variables were total phosphorus (TP; mg/L; 00665) and total nitrogen (TN; mg/L; 00600C). Medians for TP and chl-a were calculated using five approaches to handling censored data: 1) substituting the value of the quantification limit (QL) or 2) 1/2QL for censored observations, 3) deleting censored observations, 4) statistically based calculations of measures of central tendency in censored datasets, and 5) a hybrid statistical-substitution method. Data censorship of TN and Secchi transparency was minor, and medians for these parameters were calculated using only approaches 1-3, which were treatments of the raw dataset. For the current analyses, only medians from Datasets 1, 2, and 4, which are described in detail below, were used. For TN and Secchi transparency, medians from Dataset 1 were also used in Dataset 4.

Dataset 1 – This dataset contains medians for all stations with n ≥ 12 observations. Medians were calculated after substituting the QL for censored observations in the raw data. Substitution with the QL is a common approach to handling censored data, but is not considered statistically rigorous.

Dataset 2 – This dataset contains medians for all stations with n ≥ 12 observations. Medians were calculated after substituting 1/2QL for censored observations in the raw data. Substitution with 1/2QL is a common approach to handling censored data, but is not considered statistically rigorous.

Dataset 4 – This dataset contains medians generated using statistical methods that consider known information about censored observations, such as frequency of occurrence relative to uncensored observations, in calculating measures of central tendency. The statistical methods used to estimate these methods are peer-reviewed and published approaches to analyzing censored datasets, but have an important limitation in that they not appropriate for estimating measures of central tendency if the censored data exceeds 80%. Therefore, this dataset only includes stations with 0-80% censored data.

CART analysis is a means to reduce data, based on quantifying thresholds in independent variables that are correlated with shifts in the magnitude and/or variability of dependent variables. This statistical procedure can also provide hierarchical structure in independent variables, showing multiple thresholds from the same or different independent variables. CART analysis is very useful for resolving nonlinear, hierarchical, and high-order interactions among predictor variables (De'Ath and Fabricius 2000) and for detecting numerical values that lead to ecological changes (Qian and others 2003). CART models use recursive partitioning to separate data into subsets that are increasingly homogeneous; for example, subsets of data representing similar nutrient conditions. This iterative process invokes a tree-like classification that can reveal relationships that are often difficult to reconcile with conventional linear models (Urban 2002). We "pruned" CART models to generate final models that balanced accuracy within the available dataset with robustness to novel data (Urban 2002). CART models were cross-validated to determine "pruning size" (i.e., the number of predictor variables included in the model). Model cross-validations were conducted using 10 random and similarly sized subsets of our data according to the method detailed by De'ath and Fabricius (2000). The optimum tree size for each model was selected using the minimum cross-validated error rule (De'ath and Fabricius 2000).

CART and nCPA analyses were performed using the MVPART library in R 2.9.1 (http://www.r-project.org/). Non-parametric changepoint analysis was used to determine model statistical significance (p_{perm}<0.05) and 95% confidence interval about the threshold estimate (Qian et al. 2003, King and Richardson 2003). This analysis uses random permutations to estimate a p value that can be used to determine Type I and II error associated with the threshold and simultaneously uses bootstrapping to calculate cumulative probability to estimate uncertainty and provide confidence estimates for the threshold. We required a minimum of 10 observations to be used in any single split in the CART model and that each terminal node in the model had a minimum of 5 observations. CART analysis is insensitive to missing data. Therefore, we did not remove observations from the data set due to missing values. We required that all calculated medians have a minimum of 10 observations used in calculating the median value.

A user's guide to interpreting CART and nCPA models and associated summary statistics is available in Appendix 1.1. In Appendix 2.1, the statistical code and raw output generated for each CART and nCPA analysis conducted for this study on stressor-response relationships in the Texas reservoirs database has been compiled.

Results of changepoint analysis on the reservoir datasets suggested that 1 – 4 data points were potentially affecting analytical outcomes for each of the possible nutrient stressor-biological response pairs. Therefore, changepoint analyses were repeated for each of these pairs after removing potential outlier values. For TP, analyses were repeated twice to screen for potential outlier effects after 1) removing a single value > 1 mg TP/L and 2) two additional values >0.40 mg TP/L. For TN, analyses were repeated twice after 1) removing a single value > 4 mg TN/L and 2) removing three additional values > 2 mg TN/L.

The chl-a and Secchi transparency thresholds identified through "flipped" changepoint analysis were compared to other potential biological response targets to determine whether this exploratory method yielded values that were relatively more or less conservative of water quality (Table 2.1.1). The sources of other potential targets available to TCEQ included recommendations by USEPA (2000) for lakes and reservoirs within aggregate ecoregions, 25th percentiles of Texas reservoir station medians, and mean chl-a or transparency for station medians assigned to low and high nutrient groups. The latter two sources were derived from results of analyses carried out during FY2012-2013 contract (AWRC 2013). Low and high nutrient groups directly corresponded to changes in biological response and consisted of stations with median TP or TN that was either less than a relevant TP or TN threshold for low nutrient groups, or exceeded a relevant TP or TN threshold for high nutrient groups. Characteristics of these low and high nutrient station groups, including the mean, maximum, minimum, and relevant threshold for TP or TN, are summarized in Table 2.1.2.

Table 2.1.1. Summary of potential response variable targets for chlorophyll-a measured spectropotometrically (chl-a spec) and Secchi transparency. Sources include the present "flipped" changepoint analysis and USEPA (2000), and values drawn from the FY2012 – 2013 contract, including 25th percentile estimates for Texas reservoirs and the average value of the response variable associated with high and low TP and TN groups of reservoirs determined using changepoint analysis of the cumulative reservoirs median dataset. A dash indicates that a given estimate of a possible criterion was not available. The letters "NO" indicate the threshold estimate generated after removing outliers, or data points that were disproportionally affecting analytical outcomes, such as the changepoint or model explanatory power.

	Potential Targets						
Parameter	CP Flip TP Models	CP Flip TN Models	USEPA (2000)	Low TP	High TP	Low TN	High TN
Chl-a Spec (µg/L)	21.7 – 24.4 15 – 16.8^{NO}	21.6 – 26.1 12.5^{NO}	2.0 – 8.6	8.5 – 12	19 – 22	7.8 – 10	22 – 24
Secchi (m)	0.42 0.42^{NO}	0.87 0.87^{NO}	-	1.1 – 1.6	0.54 – 0.70	2.3 – 2.6	0.78 – 0.84

Results and Discussion

Sestonic Chlorophyll-a

For models relating TP and sestonic chl-a in Texas reservoirs, thresholds in chl-a spec = 24.4 µg/L and = 21.7 µg/L were identified for Datasets 1-2 and Dataset 4, respectively (Fig. 2.1.1A-C). In these analyses, only a very small difference in threshold values was observed between the datasets generated using different approaches to handling censored data, and no difference was observed between substituting the QL or 1/2QL. On average, TP concentration was more than 2x greater when chl-a exceeded the identified thresholds. These thresholds were approximately 2x greater than the chl-a concentrations representative of average chl-a for low TP reservoirs groups (i.e. stations with median TP less than TP thresholds; see Table 2.1.2), as identified by changepoint analyses relating chl-a and TP in FY2012-2013 (Table 2.1.1). These thresholds were also substantially higher than percentile-based criteria recommended by the USEPA for Texas aggregate ecoregions (2.00 – 8.59 µg/L). Therefore, the chl-a thresholds identified in the current analyses are less conservative than these other potential targets.

Table 1.1.2. Nutrient concentration mean and range for stations categorized as “low” and “high” nutrient based on thresholds identified in changepooint analysis of stressor-response relationships as part of the FY2012-13 contract (AWRC 2013). The count of stations classified as “low” nutrient, or having a nutrient median below a nutrient threshold, or “high” nutrient, or having a nutrient median above a nutrient threshold are also provided for each stressor-response pair with a statistically significant threshold. For stressor-response pairs that did not have a statistically significant threshold, low and high nutrient groups could not be identified and no summary characteristics of groups were provided, as indicate by a dash.

				Total Nutrient Concentration (mg/L)			
Response parameter	Nutrient parameter	Dataset	Thresholds	Low Nutrient Means (Count)	Low Nutrient Range	High Nutrient Means	High Nutrient Range
Chl-a spec	TP	1	0.063	0.055 (99)	0.020 – 0.063	0.14 (63)	0.064 – 1.1
		2	0.039	0.029 (73)	0.020 – 0.038	0.11 (86)	0.040 – 1.1
		3	0.060	0.039 (16)	0.020 – 0. 060	0.12 (85)	0.060 – 1.1
		4	0.063	0.040 (66)	0.007 – 0.063	0.14 (58)	0.064 – 1.1
		5	0.049	0.022 (76)	0.006 – 0.048	0.11 (86)	0.049 – 1.1
	TN	1	0.90	0.65 (72)	0.38 – 0.90	1.3 (61)	0.91 – 8.9
Secchi	TP	1	0.061	0.056 (129)	0.020 – 0.060	0.13 (74)	0.063 – 1.1
		2	0.039	0.029 (99)	0.020 – 0.038	0.11 (106)	0.040 – 1.1
		3	0.054	0.039 (19)	0.020 – 0.050	0.12 (122)	0.057 – 1.1
		4	0.049	0.032 (55)	0.007 – 0.048	0.11 (106)	0.049 – 1.1
		5	0.025	0.014 (57)	0.006 – 0.022	0.090 (146)	0.028 – 1.1
	TN	1	0.60	0.52 (41)	0.38 – 0.60	1.1 (141)	0.60 – 8.9

The results of analyses conducted to screen for potential outlier effects in modeling the TP vs. chl-a relationship indicated that a single high TP value > 1 mg/L was disproportionally affecting the value of the thresholds identified in nCPA and skewing these values upward. After excluding this observation and repeating changepoint analysis, chl-a spec thresholds for all datasets were reduced by approximately one third to 16.8 and 15.0 µg/L for Datasets 1-2 and Dataset 4, respectively (Fig. 2.1.2A-C). These values were mid-range compared to the chl-a concentrations representative of average chl-a for low and high TP reservoir groups (i.e. groups of stations with median TP less or greater than TP thresholds for low and high groups, respectively). Model predictive power (r^2) was also slightly improved by removing this outlier value (r^2 = 0.12 – 0.18 vs. r^2= 0.08 – 0.12). Removing additional potential TP outlier values >0.40 mg/L and repeating changepoint analyses a second time did not change the value of chl-a thresholds or significantly improve model predictive power (results not shown). Therefore, our interpretation was that these remaining data points had very little effect on analytical outcomes and therefore should not be treated as outliers or excluded from analysis.

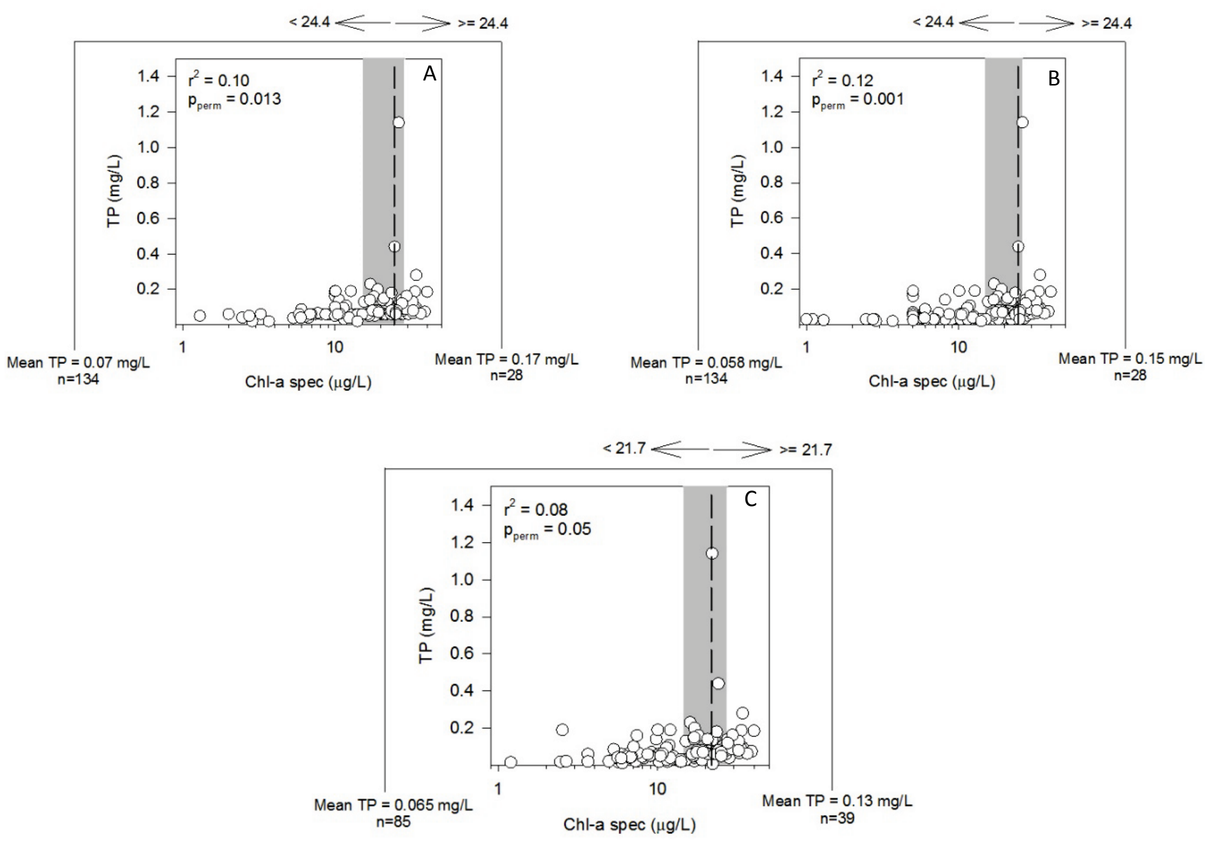


Figure 2.1.1. The "flipped" relationship between chlorophyll-a measured spectrophotometrically (chl-a spec) and total phosphorus for Datasets (A) 1, (B) 2, and (C) 4. For statistically significant models (p<0.05), the chl-a threshold and confidence interval are shown as a dashed line and shaded area, respectively.

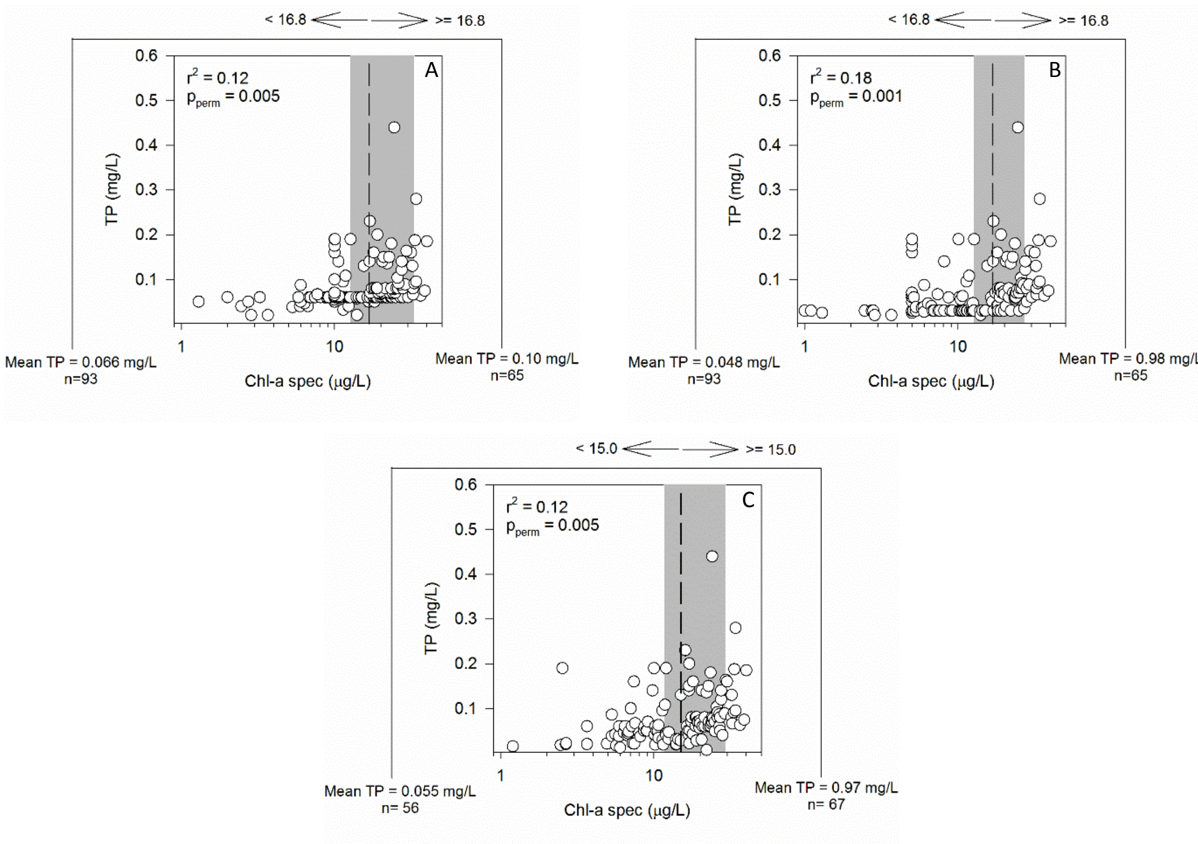


Figure 2.1.2. The "flipped" relationship between chlorophyll-a measured spectrophotometrically (chl-a spec) and total phosphorus for Datasets (A) 1, (B) 2, and (C) 4 after removing a single outlier value exceeding 1 mg TP/L. For statistically significant models (p<0.05), the chl-a threshold and confidence interval are shown as a dashed line and shaded area, respectively.

For models relating TN and chl-a in Texas reservoirs, thresholds in chl-a spec = 26.1 µg/L and = 21.6 µg/L were identified for Datasets 1-2 and Dataset 4, respectively (Fig. 2.1.3A-C). As with TP, in these analyses, only a very small difference in threshold values was observed between the datasets generated using different approaches to handling censored data, and no difference was observed between substituting the QL or 1/2QL. On average, TN concentration was 2x greater when chl-a spec exceeded the identified thresholds. These threshold were at least 2 – 3x greater than chl-a concentrations representative of average chl-a for low TN reservoir groups (see Table 2.1.2). Therefore, these thresholds represent less conservative potential chl-a targets (Table 2.1.1). These thresholds were also substantially higher than percentile-based criteria recommended by the USEPA for Texas aggregate ecoregions (2.00 – 8.59 µg/L). Therefore, the chl-a thresholds identified in the current analyses are less conservative than these other potential targets.

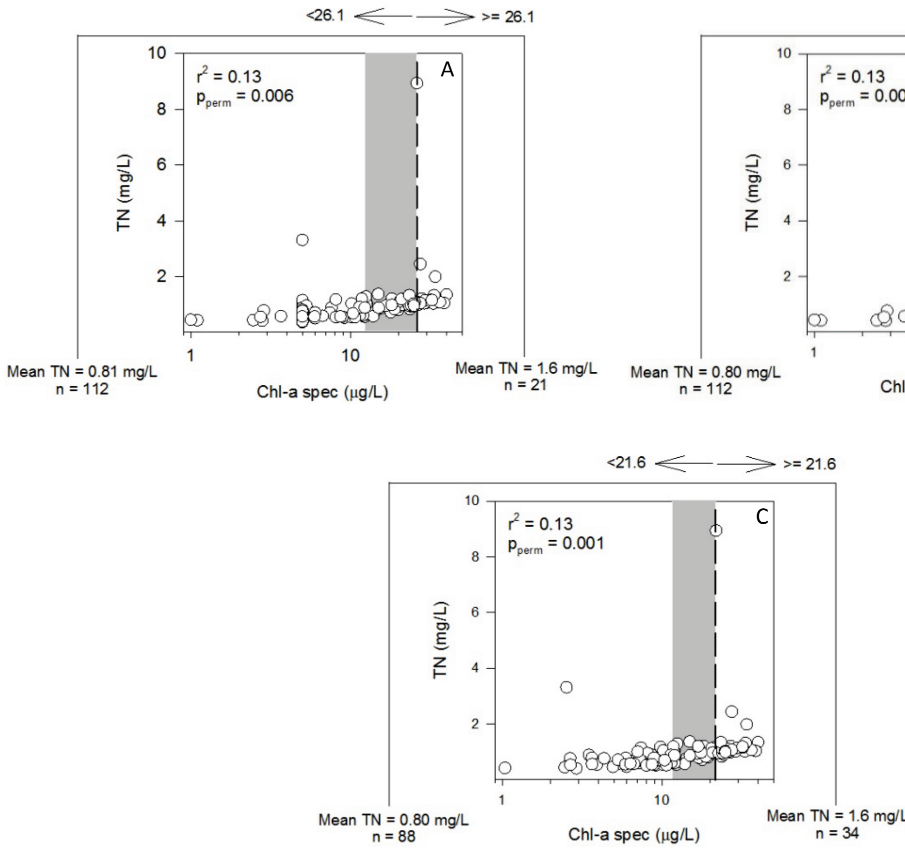


Figure 2.1.3. The "flipped" relationship between chlorophyll-a measured spectrophotometrically (chl-a spec) and total nitrogen for Datasets (A) 1, (B) 2, and (C) 4. For statistically significant models (p<0.05), the chl-a threshold and confidence interval are shown as a dashed line and shaded area, respectively.

The results of analyses conducted to screen for potential outlier effects in modeling the TN vs. chl-a relationship indicated that a single high TN value > 4 mg/L was disproportionally affecting the value of the thresholds identified in nCPA and skewing these values upward. A second round of outlier screening excluded three additional high TN observations > 2 mg/L. Model explanatory power was approximately 3x higher when these points were excluded compared to when no outlier values were excluded, indicating that these data points deviated from an otherwise strong pattern in the data. After removing these four outlier values and repeating changepoint analysis, chl-a thresholds for all datasets were reduced by more than half to 12.5 µg/L (Fig. 2.1.4A-C). After removing outlier values, no differences in the chl-a thresholds were found between datasets generated using different approaches to handling censored data. Model predictive power (r^2) increased from 13% with outliers included to 42 – 48% without outliers, which was in range with the explanatory power for nCPA models from FY2012-2013 that related chl-a and TN in the traditional configuration for stressor and response variables.

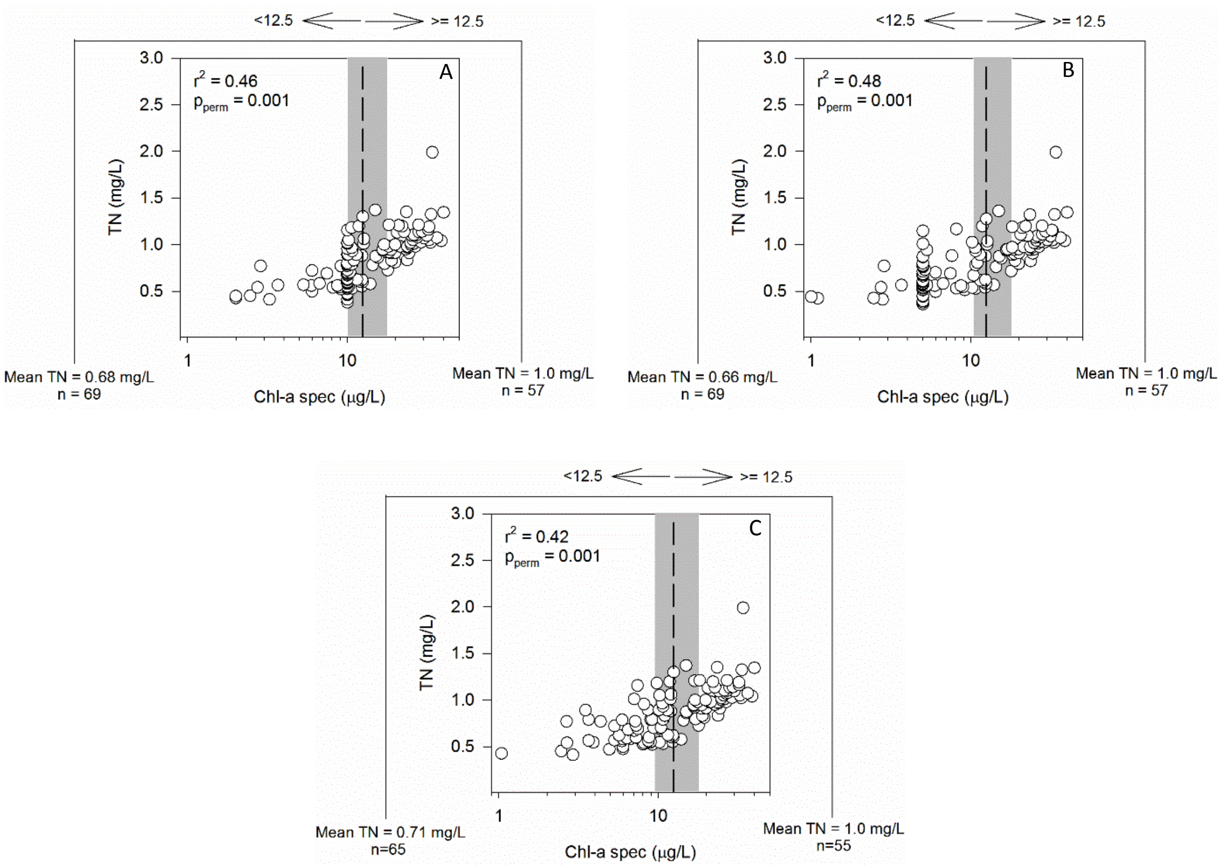


Figure 2.1.4. The "flipped" relationship between chlorophyll-a measured spectrophotometrically (chl-a spec) and total nitrogen for Datasets (A) 1, (B) 2, and (C) 4 after removing 3 outlier values exceeding 2 mg TP/L. For statistically significant models (p<0.05), the chl-a threshold and confidence interval are shown as a dashed line and shaded area, respectively.

Secchi transparency

For models relating TP and Secchi transparency, a threshold = 0.42 m was identified for all datasets (Fig. 2.1.5A-C). For these analyses, no difference in Secchi thresholds was observed between approaches to handling censored data. On average, TP concentration was at least 2x lower when Secchi transparency exceeded 0.42 m. This threshold was close to the range of Secchi transparencies representative of average transparency in high TP reservoir groups (Table 2.1.1). However, this threshold was 2 – 3x less than average transparency in corresponding low TP reservoir groups, and therefore, represented a considerably less conservative potential target.

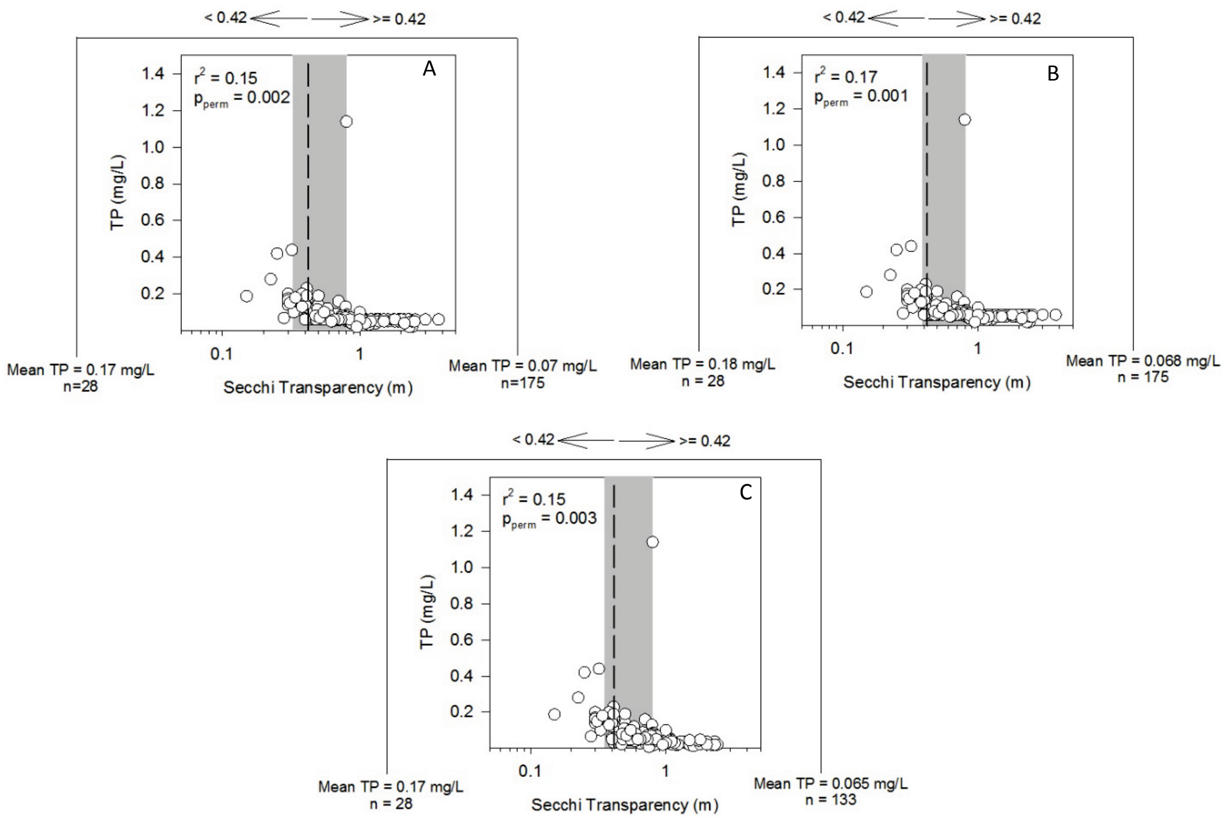


Figure 2.1.5. The "flipped" relationship between Secchi transparency and total phosphorus for Datasets (A) 1, (B) 2, and (C) 4. For statistically significant models (p<0.05), the transparency threshold and confidence interval are shown as a dashed line and shaded area, respectively.

The results of analyses conducted to screen for potential outlier effects in modeling the TP vs. Secchi transparency relationship indicated that no single observation was skewing the value of the identified threshold, which remained unchanged after removing a high TP value > 1 mg/L (Fig. 2.1.6A-C). However, treating this high TP observations as an outlier and excluding it from analysis approximately tripled model explanatory power (r^2 = 0.48 – 0.51 vs. r^2 = 0.15 – 0.17), indicating that this data point deviated from an otherwise strong pattern in the data. Excluding additional high TP values > 0.40 mg/L in a second round of outlier analysis (data not shown) also did not affect the value of the identified TP threshold and did not substantially increase model explanatory power from analyses excluding only the value > 1 mg/L. Therefore, our interpretation was that these data points had very little effect on analytical outcomes and therefore should not be treated as outliers or excluded from analysis.

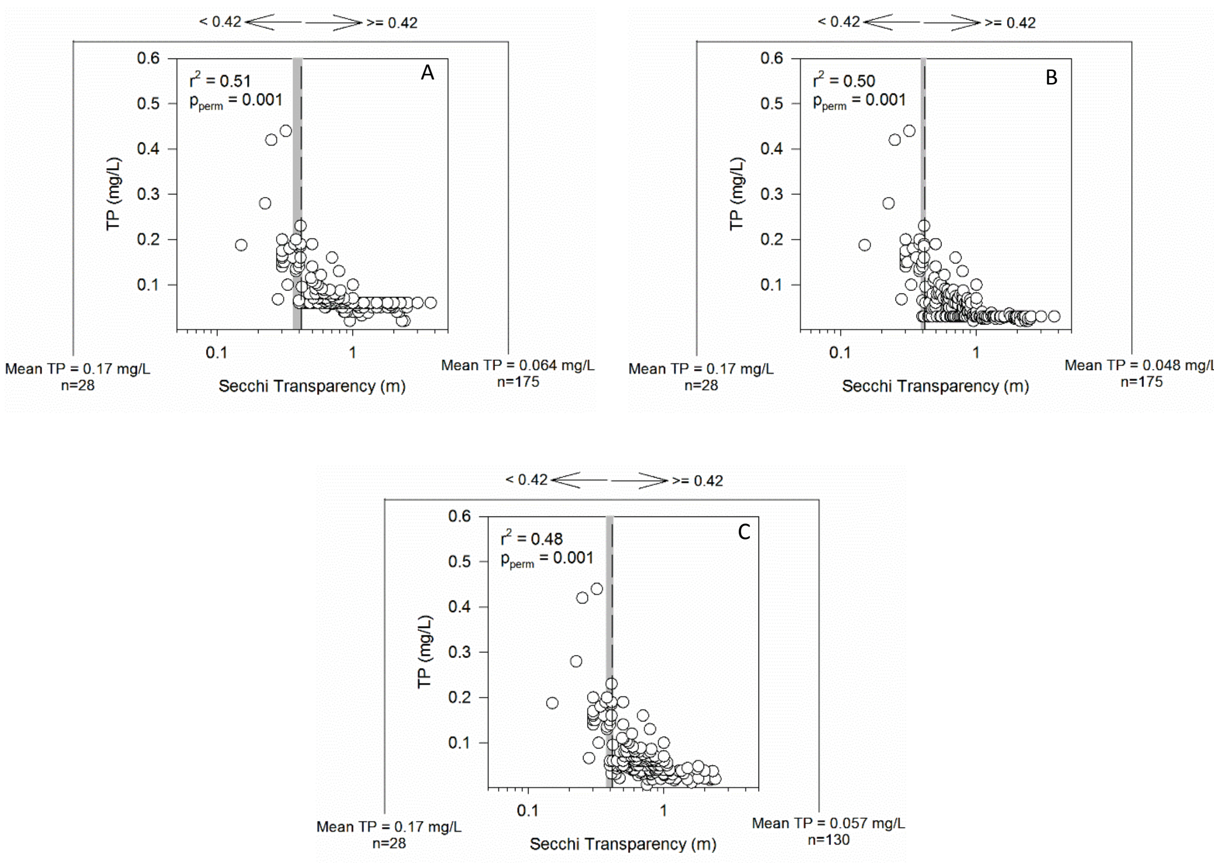


Figure 2.1.6. The "flipped" relationship between Secchi transparency and total phosphorus for Datasets (A) 1, (B) 2, and (C) 4 after removing a single outlier exceeding 1 mg TP/L. For statistically significant models (p<0.05), the transparency threshold and confidence interval are shown as a dashed line and shaded area, respectively.

For models relating TN and Secchi transparency, a threshold in Secchi transparency = 0.87 m was identified for both datasets (Fig. 2.1.7A-B). For these analyses, no difference in Secchi thresholds was observed between approaches to handling censored data. On average, TN concentration was approximately 2x lower when Secchi transparency exceeded 0.87 m. This threshold was in range with Secchi transparency representative of average transparency in high TN reservoir groups, as identified through changepoint analysis of the Secchi transparency and TN relationship in FY2012-2013 (Table 2.1.1). However, this threshold was at least 2x less than average transparency in corresponding low TN reservoir groups. Therefore, the Secchi transparency threshold identified in the current analyses is less conservative estimate when compared to other possible target values for transparency in Texas reservoirs.

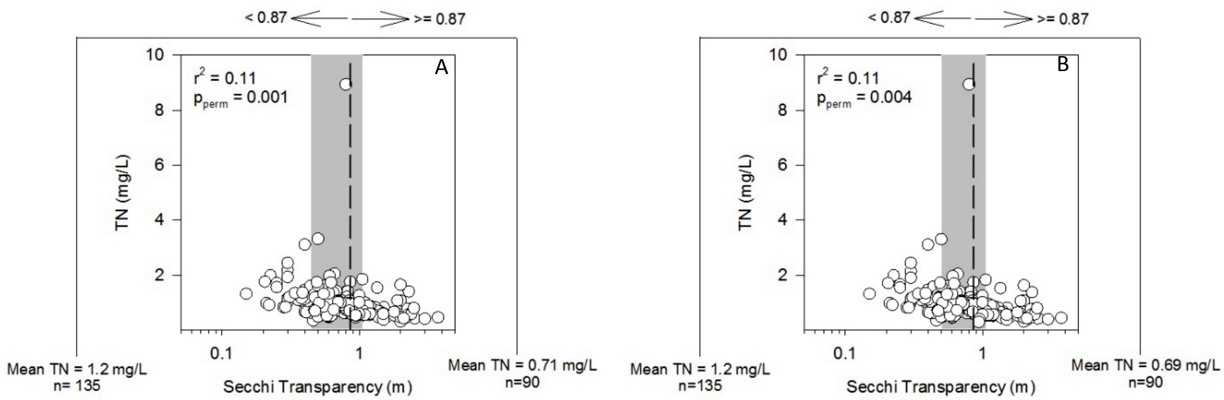


Figure 2.1.7. The "flipped" relationship between Secchi transparency and total nitrogen for Datasets (A) 1 and (B) 2. For statistically significant models (p<0.05), the transparency threshold and confidence interval are shown as a dashed line and shaded area, respectively.

The results of analyses conducted to screen for potential outlier effects in modeling the TN vs. Secchi transparency relationship indicated that no single observation was skewing the value of the identified threshold, which remained unchanged after removing a high TN value > 4 mg/L (Fig. 2.1.8A-B). However, treating this high TN observations as an outlier and excluding it from analysis approximately doubled model explanatory power (r^2 = 0.21 vs. r^2 = 0.11), indicating that this data point deviated from an otherwise strong pattern in the data. Excluding additional high TN values > 2 mg/L in a second round of outlier analysis also did not affect the value of the identified TN threshold and did not substantially increase model explanatory power (data not shown). Therefore, our interpretation was that these data points had very little effect on analytical outcomes and therefore should not be treated as outliers and excluded from analysis.

Summary of "flipped" stressor-response analysis for Texas reservoirs

For all biological and nutrient parameter pairs considered in these analyses, potential biological thresholds provided moderate to strong explanatory power for stressor-response relationships in the Texas reservoirs dataset, especially once outlier values were excluded. This finding contrasts with findings from "flipping" stressor-response relationships to analyze the Texas streams and rivers database for biological thresholds (Section 1.1). Stronger results for "flipped" analyses in Texas reservoirs relative to streams and rivers likely reflects the fact that models relating biological and nutrient parameters in the traditional configuration with the biological and nutrient parameter on the y- and x-axes, respectively, were also stronger for reservoirs than for streams and rivers. It is also possible that Texas reservoirs exhibit less variability in nutrient dynamics than Texas streams and rivers.

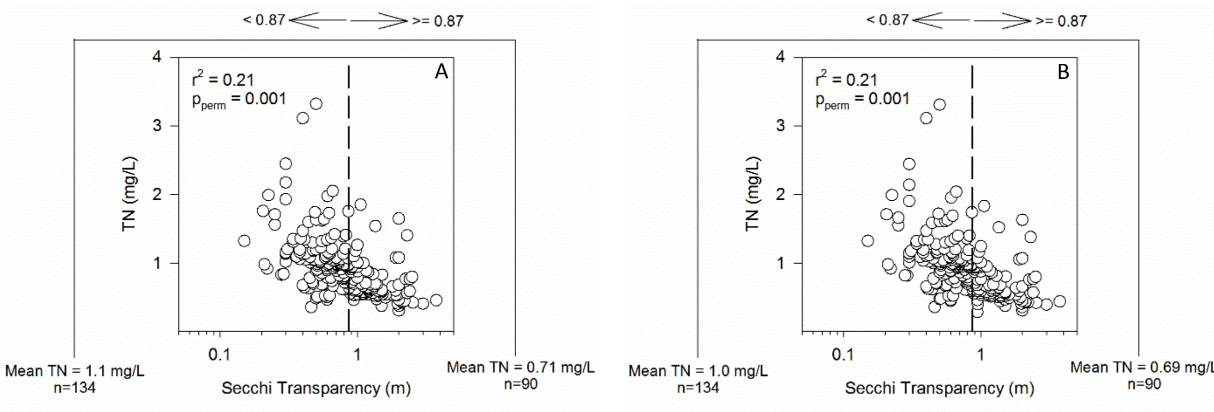


Figure 2.1.8. The "flipped" relationship between Secchi transparency and total nitrogen for Datasets (A) 1 and (B) 2 after removing a single outlier exceeding 4 mg TN/L. For statistically significant models (p<0.05), the transparency threshold and confidence interval are shown as a dashed line and shaded area, respectively.

For the Texas reservoirs dataset, we observed evidence of substantial outlier effects in analyses relating TP and TN to biological parameters. This finding contrasts with outcomes from the traditional stressor-response models developed for Texas reservoirs in FY2012-2013, for which no outlier effects were observed. This difference may have occurred because changepoint analyses appear to be especially sensitive to outlier values associated with the variable on the y-axis. In the Texas reservoirs dataset, outlier values were observed in TP and TN, but not chl-a or Secchi, and total nutrient parameters were oriented to the y-axis in the present analyses, rather than to the x-axis, as in traditional models.

Also in contrast to findings from FY2012-2013, the approach to handling censored data appeared to have little or no effect on the value of thresholds identified by changepoint analysis. A possible reason for this difference is that "flipped" analyses were not carried out on Dataset 5, the dataset that underwent the most complete correction for censored data. In FY2012 – 2013, the largest differences between datasets often were observed when comparing this dataset to Dataset 1. However, differences between Dataset 1 and 2 were also often large in FY2012 – 2013 analyses, which contrasts with current findings.

Another explanation for the relatively minor effects of censored data on "flipped" changepoint analysis is that a large number of censored data in the x-axis variable may more strongly affect results of this type of analysis than a large number of censored data in the y-axis variable. For examining biological response to TP in Texas reservoirs, TP was the most highly censored parameter. In the present analyses, TP was oriented to the y-axis, but was oriented to the x-axis in the traditional models, for which large differences in TP thresholds between datasets were common. Scatterplots of these variables in traditional and "flipped" configurations (Figs. 2.1.9A-B) provide a visual demonstration of why changepoint analysis would likely respond more greatly to censored data on the x-axis compared to on the y-axis.

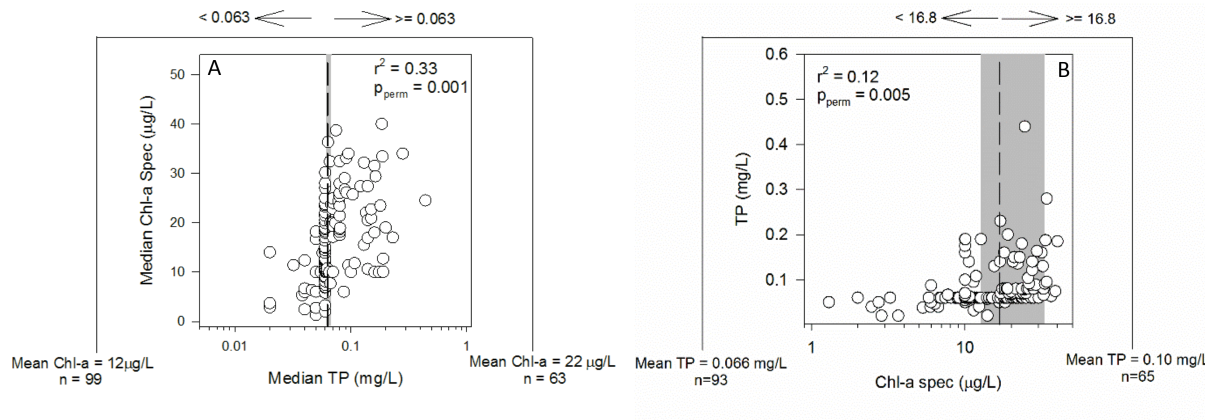


Figure 2.1.9. The relationship between chlorophyll-a measured spectrophotometrically (chl-a spec) and TP in Dataset 1 in the (A) traditional stressor-response and (B) "flipped configurations analyzed in FY12-13 and present analyses, respectively.

When a single value is substituted for a large number of the x-axis variable data, as in Dataset 1, a vertical line forms in the plot. Because TP is highly censored for Texas reservoirs, we see this trend in the traditional models relating biological variables, here chl-a, to TP (Fig. 2.1.9A). The analysis interprets vertical lines in the scatterplot as meaningful threshold trends in how the response variable interacts with the stressor variable. These lines convey that a large degree of variance in the stressor-response relationship occurs at the substituted value, and the analysis therefore identifies a threshold near this value. Similarly, a horizontal line forms when a single value is substituted for a large number of the y-axis variable data. Again, because TP is highly censored in this dataset, we see this trend in the "flipped models" (Fig. 2.1.9B). In contrast to vertical lines, however, changepoint analysis is unlikely to interpret horizontal lines as a meaningful in identifying a threshold. Horizontal lines corresponding to the substituted value convey similarity in the y-axis variable values across a gradient of x-axis variable values. Substituting values in this way therefore reduces the variance on either side of the threshold, which could theoretically affect analysis, but the magnitude of this reduction in variance is likely often minor relative to the variance present in the remaining uncensored data.

The results of these analyses indicated strong biological response thresholds relative to nutrient gradients in Texas reservoirs. However, "flipping" the traditional configuration of stressor and response variables in changepoint analysis to find biological response thresholds is a novel use of the analysis that has not been peer-reviewed or published. Therefore, the findings of these analyses should be interpreted with caution for use in setting numeric chl-a or transparency targets for Texas reservoirs. Table 2.1.1 provides a summary of potential biological response criteria values for Texas reservoirs drawn from present and previous changepoint analyses, as well as USEPA recommendations.

2.2 NUTRIENT THRESHOLDS SPECIFIC TO TEXAS BASINS AND OMNERIK LEVEL III ECOREGIONS

Methods

We conducted CART analyses on the median database for reservoirs to identify thresholds in nutrient concentrations that resulted in measurable changes in common biological responses within Texas basins (Appendix 1.3) and Omnerik level III ecoregions (Appendix 1.4). The biological (dependent) variables included in the analyses were median Secchi depth (m; parameter code 00078C) and median chlorophyll-a measured with spectrophotometry (chl-a spec; 32211). The nutrient (independent) variables included in the analysis were total phosphorus (TP; 00665) and total nitrogen (TN; 00600C). We required a minimum of 20 paired medians within a basin or ecoregion for the analysis. Medians for TP and chl-a were calculated using five approaches to handling censored data: 1) substituting the value of the quantification limit (QL) or 2) 1/2QL for censored observations, 3) deleting censored observations, 4) statistically based calculations of measures of central tendency in censored datasets, and 5) a hybrid statistical-substitution method. Data censorship of TN and Secchi transparency was considered minor, and medians for these parameters were calculated using only approaches 1-3, which were treatments of the raw dataset. For the current analyses, only medians from Datasets 1, 2, and 4 were used, which are described in detail below. For TN and Secchi transparency, medians from Dataset 1 were also used in Dataset 4.

Dataset 1 – This dataset contains medians for all stations with $n \geq 12$ observations. Medians were calculated after substituting the QL for censored observations in the raw data. Substitution with the QL is a common approach to handling censored data, but is not considered statistically rigorous.

Dataset 2 – This dataset contains medians for all stations with $n \geq 12$ observations. Medians were calculated after substituting 1/2QL for censored observations in the raw data. Substitution with 1/2QL is a common approach to handling censored data, but is not considered statistically rigorous.

Dataset 4 – This dataset contains medians generated using statistical methods that consider known information about censored observations, such as frequency of occurrence relative to uncensored observations, in calculating measures of central tendency. The statistical methods used to estimate these medians are peer-reviewed, published approaches to analyzing censored datasets. These methods have an important limitation, however, and are not appropriate for estimating measures of central tendency if the percentage of censored data exceeds 80%. Therefore, in this dataset, medians were only included for stations with 0-80% censored data.

CART analysis is a means to reduce data, based on quantifying thresholds in independent variables that are correlated with shifts in the magnitude and/or variability of dependent variables. This statistical procedure can also provide hierarchical structure in independent variables, showing multiple thresholds from the same or different independent variables. CART analysis is very useful for resolving nonlinear, hierarchical, and high-order interactions among predictor variables (De'Ath and Fabricius 2000) and for detecting numerical values that lead to ecological changes (Qian and others 2003). CART models use recursive partitioning to separate data into subsets that are increasingly homogeneous; for example, subsets of data representing similar nutrient conditions. This iterative process invokes a tree-like classification that can reveal relationships that are often difficult to reconcile with conventional linear models (Urban 2002). We "pruned" CART models to generate final models that balanced accuracy within the available dataset with robustness to novel data (Urban 2002). CART models were cross-validated to determine "pruning size" (i.e., the number of predictor variables included in the model). Model cross-validations were conducted using 10 random and similarly sized subsets of our data according to the method detailed by De'ath and Fabricius (2000). The optimum tree size for each model was selected using the minimum cross-validated error rule (De'ath and Fabricius 2000).

CART analyses were performed using the MVPART library in R 2.9.1 (http://www.r-project.org/). Non-parametric changepoint analysis was used to determine model statistical significance ($p_{perm}<0.05$) and 95% confidence interval about the threshold estimate (Qian et al. 2003, King and Richardson 2003). This analysis uses random permutations to estimate a p value that can be used to determine Type I and II error associated with the threshold and simultaneously uses bootstrapping to calculate cumulative probability to estimate uncertainty and provide confidence estimates for the threshold. We required a minimum of 10 observations to be used in any single split in the CART model and that each terminal node in the model had a minimum of 5 observations. CART analysis is insensitive to missing data. Therefore, we did not remove observations from the data set due to missing values. We required that all calculated medians have a minimum of 10 observations used in calculating the median value.

A user's guide to interpreting CART and nCPA models and associated summary statistics is available in Appendix 1.1. In Appendix 2.1, the statistical code and raw output generated for each CART and nCPA analysis conducted for this study on stressor-response relationships in the Texas reservoirs database has been compiled.

Results and Discussion

Nutrient thresholds by basin

Texas reservoir stations with sufficient data for these analyses (n ≥ 12 observations per station) were concentrated in 2 major river basins. Changepoint analysis of at least one stressor-response pair was possible for 4 of the 14 basins (Basins 6, 8, 12, and 14), but the majority of statistically significant models were found within a single basin (Basin 8). The remaining 8 basins had fewer than 20 paired station medians for all possible stressor-response pairs and were therefore not eligible for analysis.

For models relating Secchi transparency to TP, statistically significant TP thresholds were found for at least one of the three datasets for each of these four basins (Tables 2.2.1-2.2.4). Across basins, these thresholds indicated that Secchi transparency decreased with increasing TP concentration and were in range with thresholds identified for Secchi transparency using combined data from all the basins (0.025 – 0.063 mg/L) in FY2012-2013. Thresholds ranged from 0.060 – 0.079 mg/L for Dataset 1, 0.035 – 0.079 mg/L for Dataset 2, and 0.025 – 0.079 mg/L for Dataset 4. For Basin 8, the TP threshold was the same for all datasets, indicating no censored data effects. The TP threshold was highest for this basin and exceeded common

QL values (0.079 mg/L vs. 0.050 or 0.060 mg/L). In contrast, For Basins 6 and 12, lower TP thresholds were identified using Datasets 2 and 4 compared to Dataset 1. For Basin 12, Dataset 2 and 4 thresholds were close in range compared to the threshold for Dataset 1 (0.035 – 0.041 mg/L vs. 0.063 mg/L), suggesting that censored data had a strong effect on the analyses and that substituting the QL for censored observations overestimated the true value of the threshold for reservoirs in Basin 12. For Basin 6, the model relating Secchi transparency and TP had ~5x greater explanatory power for Dataset 2 than for Dataset 1 (r^2 = 0.53 vs. r^2 = 0.11), but insufficient medians (n<20) were available for analysis in Dataset 4 due to the removal of stations with >80% censored data. Therefore, it was impossible to determine if the difference in model strength between Datasets 1 and 2 was the result of more accurate estimation of median values for stations with a higher percentage of censored data or a false trend introduced by substituting ½QL for censored observations. Finally, for Basin 14, censored data were clearly a problem for the changepoint analysis. Due to substitution of a single value for censored observations in the raw data and a high percentage of censored observations, all but a few medians were equal to a single value for reservoirs stations in this basin, resulting in analysis error. However, a threshold was identified for Dataset 4 for Basin 14 that was among the lowest in the study (0.025 mg/L).

Model explanatory power (r^2) for TP thresholds relative to Secchi transparency within basins was usually in range with that of the combined data model (r^2 = 0.22 – 0.44). However, model explanatory power was less than 22% for Basin 6 Dataset 1 and Basin 12 Dataset 1. For both Basins 6 and 12, model explanatory power improved when other approaches to handling censored data were used than substituting the QL, and, for Basin 12, this included when statistical methods were used (Dataset 4). For other basin and dataset combinations, model r^2 often exceeded or was at the upper end of the range for combined data models. For some basin and dataset combinations, the value of model TP thresholds were likely influenced by the high frequency of censored observations, as indicated by TP thresholds that were approximately equal to the most common quantification limit of 0.060 mg/L or half that value. These basin and dataset combinations included Basin 6 Dataset 1, Basin 12 Dataset 1, and Basin 12 Dataset 2.

For models relating chl-a and TP, statistically significant thresholds were less common than for Secchi transparency. Thresholds were identified only for reservoirs in Basin 8 and indicated that chl-a concentration increased with increasing TP concentration. The same TP threshold was identified for all datasets (0.063 mg/L) and was in range with thresholds identified in models using data across basins (0.049 – 0.063 mg/L) in FY2012-2013. The approach to handling censored data did not affect the threshold value. Despite the fact that the threshold was close in value to that of the most common QL, these findings indicated, as with Secchi transparency, that the level of censoring in Basin 8 reservoirs was not sufficient to affect changepoint analysis. Model explanatory power for Basin 8 datasets exceeded that of the chl-a vs. TP models generated using combined data (r^2 = 0.27 – 0.34).

Statistically significant TN thresholds were only found for reservoirs in Basins 8 and 14. For models relating Secchi transparency and TN, thresholds indicated that Secchi transparency decreased as TN concentration increased and were similar between Datasets 1 and 2 for both basins (~0.70 mg/L). For models relating chl-a and TN, the same thresholds was identified for all datasets (0.95 mg/L) and indicated that chl-a increased as TN concentrations increased. Model explanatory power within basins for both response variables was within range of r^2 for models using cumulative data across basins (0.32 – 0.54 mg/L).

Nutrient thresholds by level III ecoregion

Texas reservoir stations with sufficient data for these analyses (n ≥ 12 observations per station) were concentrated in 2 level III ecoregions. Changepoint analysis of at least one stressor-response pair was possible for 4 ecoregions (Ecoregions 29, 30, 33, and 35), but the majority of statistically significant models were within Ecoregions 29 and 35. The remaining level III ecoregions within Texas had fewer than 20 paired station medians for all possible stressor-response pairs and were therefore not eligible for analysis.

For models relating Secchi transparency and TP, statistically significant TP thresholds were found for at least one of the three datasets for 3 level III ecoregions, including Ecoregions 29, 33, and 35 (Tables 2.2.5-2.2.8). These threshold indicated that Secchi transparency decreased with increasing TP concentration. Thresholds in TP ranged from 0.061 – 0.074 mg/L for Dataset 1, 0.045 – 0.046 for Dataset 2, and 0.041 – 0.079 for Dataset 4. These values were typically in range with the TP threshold identified for Secchi transparency using combined data from all the ecoregions (0.025 – 0.063 mg/L). For each of these ecoregions, lower TP thresholds were identified using Dataset 2. For Ecoregions 29 and 35, TP thresholds for Dataset 4 were closer in range with those from Dataset 2 than Dataset 1, indicating that substituting 1/2QL resulted in a better approximation of median values than substituting the QL. This finding was reversed, however, for Ecoregion 33, where the TP threshold from Dataset 4 was the highest of the three datasets. Model explanatory power (r^2) for TP thresholds relative to Secchi transparency within ecoregions was usually in range with that of the combined data models (r^2 = 0.22 – 0.44) identified in FY2012-2013. However, model explanatory power was less than 22% for Ecoregion 29 Dataset 1. For some ecoregion and dataset combinations, the value of model TP thresholds were likely influenced by the high frequency of censored observations, as indicated by TP thresholds that were approximately equal to the most common quantification limit of 0.060 mg/L or half that value. These basin and dataset combinations included Ecoregion 29 Dataset 1 and Ecoregion 35 Dataset 1.

For models relating chl-a and TP, statistically significant thresholds were identified for at least one data set from three level III ecoregions, including Ecoregions 29, 33, and 35. These thresholds ranged from 0.063 – 0.068 mg/L for Dataset 1, 0.051 – 0.068 mg/L for Dataset 2, and 0.060 for Dataset 4 and indicated that chl-a increased with increasing TP concentrations. These thresholds were in range with TP thresholds identified for chl-a using combined data from all the ecoregions (0.049 – 0.063 mg/L). The approach to handling censored data had less effect on the threshold value for models relating chl-a to TP than Secchi transparency. Model explanatory power within ecoregions was in range with that of combined data models (r^2 = 0.27 – 0.34), except for Ecoregion 29 where r^2 = 0.38 – 0.47.

For models relating Secchi transparency and TN, statistically significant TN thresholds were identified for at least one dataset from three level III ecoregions, including Ecoregions 30, 33, and 35. These thresholds indicated that Secchi transparency decreased as TN concentration increased and were similar between Datasets 1 and 2 for all ecoregions. For models relating chl-a and TN, statistically significant TN thresholds were identified for three level III ecoregions, including Ecoregions 29, 33, and 35, and indicated that chl-a increased as TN concentrations increased. For Ecoregions 29 and 33, TN thresholds were identical or close in range across datasets, indicating minimal effects of censored data on analyses. For Ecoregion 35, however, TN thresholds for Datasets 2 and 4 were approximately 30% lower than for Dataset 1. Model explanatory power within basins for both response variables was within range of r^2 for models using cumulative data across basins (0.32 – 0.54 mg/L).

Summary of regional stressor-response analysis for Texas reservoirs

Regional analysis of stressor-response relationships in Texas reservoirs indicated relatively small differences in total nutrient thresholds between basins and level III ecoregions, especially when compared to findings from streams and rivers. Most regionally-specific TP and TN thresholds were in range with the thresholds identified using the Texas-wide median datasets in FY2012 – 2013. However, for TP, thresholds identified both for specific regions and in the cumulative datasets could differ by up to 3x (~ 0.025 – 0.075 mg/L), depending upon the dataset and the region. This range of thresholds spans TP concentrations representative of mesotrophic to nearing hypereutrophic conditions in lakes and reservoirs, and this variability may indicate that relevant differences exist in trophic state and nutrient dynamics between reservoirs in different basins or level III ecoregions. In contrast, TN thresholds were less variable both between datasets and regions.

Model explanatory power was also similar between regional and cumulative dataset models for all stressor-response combinations. Paired with similarities in nutrient thresholds between regional and Texas-wide datasets, these findings indicate that cumulative Texas reservoir models from FY2012-2013 effectively captured stressor-response relationships for Texas reservoirs. Though we observed some regional variability in nutrient thresholds, especially for TP, this variability was relatively minor in scale and did not create noise in analyses of the Texas-wide datasets, as was the case for Texas streams and rivers.

Table 2.2.1. Summary of TP and TN thresholds (CP) with confidence intervals (CI) for Texas river basin 6. Thresholds were identified using non-parametric changepoint analysis, where Secchi transparency and chl-a measured spectrophotometrically (chl-a spec) were potential response variables. Model summary statistics, including r^2, p_{perm}, average value of the response variable above and below the nutrient threshold (M_R and M_L, respectively), and number of observations above and below the nutrient threshold (n_R and n_L, respectively) are included for all possible stressor-response models where n>20. All values for CP are in mg/L. Values for M_R and M_L are in meters or µg/L, where nutrient thresholds are relative to responses in Secchi transparency or chl-a, respectively. Models indicating relationships between nutrient stressors and response variables that were not congruent with ecological theory or not statistically significant (p>0.05) are shown in gray italics. Dataset 4 did not contain unique median estimates for TN or Secchi transparency, but rather included medians for these variables from Dataset 1. Therefore, Secchi vs. TN models were not applicable (NA) for Dataset 4.

		vs. TP (mg/L)							vs. TN (mg/L)						
Dataset	Variable	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L
Dataset 1	Secchi	0.060↓ (0.060-0.065)	0.11	0.003	1.3	0.56	5	16	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dataset 2	Secchi	0.048↓ (0.030-0.063)	0.53	0.002	1.4	0.63	13	8	-	-	-	-	-	-	-
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dataset 4	Secchi	-	-	-	-	-	-	-	NA	NA	NA	NA	NA	NA	NA
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-

↓ The value of the response variable decreases with increasing predictor variable values, and vice versa
↑The value of the response variable increases with increasing predictor variable values, and vice versa

Table 2.2.2. Summary of TP and TN thresholds (CP) with confidence intervals (CI) for Texas reservoirs in river basin 8. Thresholds were identified using non-parametric changepoint analysis, where Secchi transparency and chl-a measured spectrophotometrically (chl-a spec) were potential response variables. Model summary statistics, including r^2, p_{perm}, average value of the response variable above and below the nutrient threshold (M_R and M_L, respectively), and number of observations above and below the nutrient threshold (n_R and n_L, respectively) are included for all possible stressor-response models where n>20. All values for CP are in mg/L. Values for M_R and M_L are in meters or µg/L, where nutrient thresholds are relative to responses in Secchi transparency or chl-a, respectively. Models indicating relationships between nutrient stressors and response variables that were not congruent with ecological theory or not statistically significant (p>0.05) are shown in gray italics. Dataset 4 did not contain unique median estimates for TN or Secchi transparency, but rather included medians for these variables from Dataset 1. Therefore, Secchi vs. TN models were not applicable (NA) for Dataset 4.

		vs. TP (mg/L)							vs. TN (mg/L)						
Dataset	Variable	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L
Dataset 1	Secchi	0.079↓ (0.061-0.085)	0.41	0.001	0.90	0.47	31	19	0.74↓ (0.69-1.1)	0.39	0.001	1.3	0.64	6	37
	Chl-a spec	0.063↑ (0.060-0.070)	0.48	0.001	13.0	26.3	19	26	0.95↑ (0.90-0.96)	0.60	0.001	13.8	28.3	21	22
Dataset 2	Secchi	0.079↓ (0.039-0.083)	0.41	0.001	0.90	0.47	31	19	0.72↓ (0.69-1.1)	0.39	0.003	1.3	0.64	6	37
	Chl-a spec	0.063↑ (0.048-0.066)	0.49	0.001	12.3	26.3	19	26	0.95↑ (0.90-0.96)	0.60	0.001	13.2	28.3	23	20
Dataset 4	Secchi	0.079↓ (0.039-0.083)	0.54	0.001	0.045	0.13	28	19	NA	NA	NA	NA	NA	NA	NA
	Chl-a spec	0.063↑ (0.053-0.070)	0.46	0.001	12.9	26.2	17	26	0.95↑ (0.90-0.96)	0.60	0.001	13.3	28.2	21	22

↓ The value of the response variable decreases with increasing predictor variable values, and vice versa
↑The value of the response variable increases with increasing predictor variable values, and vice versa

Table 2.2.3. Summary of TP and TN thresholds (CP) with confidence intervals (CI) for Texas reservoirs in river basin 12. Thresholds were identified using non-parametric changepoint analysis, where Secchi transparency and chl-a measured spectrophotometrically (chl-a spec) were potential response variables. Model summary statistics, including r^2, p_{perm}, average value of the response variable above and below the nutrient threshold (M_R and M_L, respectively), and number of observations above and below the nutrient threshold (n_R and n_L, respectively) are included for all possible stressor-response models where n>20. All values for CP are in mg/L. Values for M_R and M_L are in meters or µg/L, where nutrient thresholds are relative to responses in Secchi transparency or chl-a, respectively. Models indicating relationships between nutrient stressors and response variables that were not congruent with ecological theory or not statistically significant (p>0.05) are shown in gray italics. Dataset 4 did not contain unique median estimates for TN or Secchi transparency, but rather included medians for these variables from Dataset 1. Therefore, Secchi vs. TN models were not applicable (NA) for Dataset 4.

		vs. TP (mg/L)							vs. TN (mg/L)						
Dataset	Variable	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L
Dataset 1	Secchi	0.063↓ (0.037-0.070)	0.14	0.037	1.0	0.61	30	11	*-*	*0.09*	*0.41*	*-*	*-*	*-*	*-*
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dataset 2	Secchi	0.035↓ (0.035-0.045)	0.26	0.003	1.1	0.64	22	19	*-*	*0.07*	*0.50*	*-*	*-*	*-*	*-*
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dataset 4	Secchi	0.041↓ (0.040-0.046)	0.37	0.005	1.2	0.63	11	24	NA	NA	NA	NA	NA	NA	NA
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-

↓ The value of the response variable decreases with increasing predictor variable values, and vice versa

↑The value of the response variable increases with increasing predictor variable values, and vice versa

Table 2.2.4. Summary of TP and TN thresholds (CP) with confidence intervals (CI) for Texas reservoirs in river basin 14. Thresholds were identified using non-parametric changepoint analysis, where Secchi transparency and chl-a measured spectrophotometrically (chl-a spec) were potential response variables. Model summary statistics, including r^2, p_{perm}, average value of the response variable above and below the nutrient threshold (M_R and M_L, respectively), and number of observations above and below the nutrient threshold (n_R and n_L, respectively) are included for all possible stressor-response models where n≥20. All values for CP are in mg/L. Values for M_R and M_L are in meters or µg/L, where nutrient thresholds are relative to responses in Secchi transparency or chl-a, respectively. Models indicating relationships between nutrient stressors and response variables that were not congruent with ecological theory or not statistically significant (p>0.05) are shown in gray italics. Dataset 4 did not contain unique median estimates for TN or Secchi transparency, but rather included medians for these variables from Dataset 1. Therefore, Secchi vs. TN models were not applicable (NA) for Dataset 4.

		vs. TP (mg/L)							vs. TN (mg/L)						
Dataset	Variable	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L
Dataset 1	Secchi	-	-	-	-	-	-	-	0.59↓ (0.49-0.80)	0.40	0.003	1.8	0.86	14	18
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dataset 2	Secchi	-	-	-	-	-	-	-	0.58↓ (0.47-0.86)	0.40	0.002	1.8	0.86	14	18
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dataset 4	Secchi	0.025↓ (0.021-0.030)	0.47	0.007	1.4	0.51	11	10	NA	NA	NA	NA	NA	NA	NA
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-

↓ The value of the response variable decreases with increasing predictor variable values, and vice versa
↑The value of the response variable increases with increasing predictor variable values, and vice versa

Table 2.2.5. Summary of TP and TN thresholds (CP) with confidence intervals (CI) for Texas reservoirs in level III ecoregion 29. Thresholds were identified using non-parametric changepoint analysis, where Secchi transparency and chl-a measured spectrophotometrically (chl-a spec) were potential response variables. Model summary statistics, including r^2, p_{perm}, average value of the response variable above and below the nutrient threshold (M_R and M_L, respectively), and number of observations above and below the nutrient threshold (n_R and n_L, respectively) are included for all possible stressor-response models where n>20. All values for CP are in mg/L. Values for M_R and M_L are in meters or µg/L, where nutrient thresholds are relative to responses in Secchi transparency or chl-a, respectively. Models indicating relationships between nutrient stressors and response variables that were not congruent with ecological theory or not statistically significant (p>0.05) are shown in gray italics. Dataset 4 did not contain unique median estimates for TN or Secchi transparency, but rather included medians for these variables from Dataset 1. Therefore, Secchi vs. TN models were not applicable (NA) for Dataset 4.

		vs. TP (mg/L)							vs. TN (mg/L)						
Dataset	Variable	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L
Dataset 1	Secchi	0.061↓ (0.061-0.085)	0.19	0.007	1.0	0.64	40	23	*-*	*0.10*	*0.12*	*-*	*-*	*-*	*-*
	Chl-a spec	0.063↑ (0.060-0.065)	0.44	0.001	12.3	23.7	19	19	0.97↑ (0.71-0.1.0)	0.52	0.001	12.5	25.8	17	13
Dataset 2	Secchi	0.045↓ (0.035-0.069)	0.23	0.003	1.1	0.66	34	29	*-*	*0.10*	*0.10*	*-*	*-*	*-*	*-*
	Chl-a spec	0.051↑ (0.039-0.64)	0.47	0.001	9.1	22.2	14	24	0.97↑ (0.71-1.0)	0.53	0.001	11.2	25.8	17	13
Dataset 4	Secchi	0.041↓ (0.039-0.083)	0.25	0.004	1.0	0.66	19	36	NA	NA	NA	NA	NA	NA	NA
	Chl-a spec	0.060↑ (0.047-0.064)	0.38	0.002	11.9	22.7	14	22	0.97↑ (0.71-1.0)	0.49	0.001	12.7	25.8	17	13

↓ The value of the response variable decreases with increasing predictor variable values, and vice versa
↑The value of the response variable increases with increasing predictor variable values, and vice versa

Table 2.2.6. Summary of TP and TN thresholds (CP) with confidence intervals (CI) for Texas reservoirs in level III ecoregion 30. Thresholds were identified using non-parametric changepoint analysis, where Secchi transparency and chl-a measured spectrophotometrically (chl-a spec) were potential response variables. Model summary statistics, including r^2, p_{perm}, average value of the response variable above and below the nutrient threshold (M_R and M_L, respectively), and number of observations above and below the nutrient threshold (n_R and n_L, respectively) are included for all possible stressor-response models where n>20. All values for CP are in mg/L. Values for M_R and M_L are in meters or µg/L, where nutrient thresholds are relative to responses in Secchi transparency or chl-a, respectively. Models indicating relationships between nutrient stressors and response variables that were not congruent with ecological theory or not statistically significant (p>0.05) are shown in gray italics. Dataset 4 did not contain unique median estimates for TN or Secchi transparency, but rather included medians for these variables from Dataset 1. Therefore, Secchi vs. TN models were not applicable (NA) for Dataset 4.

		vs. TP (mg/L)							vs. TN (mg/L)						
Dataset	Variable	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L
Dataset 1	Secchi	-	-	-	-	-	-	-	0.49↓ (0.48-0.55)	0.66	0.001	2.3	1.1	6	14
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dataset 2	Secchi	-	-	-	-	-	-	-	0.48↓ (0.47-0.55)	0.66	0.001	2.3	1.1	6	14
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dataset 4	Secchi	-	-	-	-	-	-	-	NA	NA	NA	NA	NA	NA	NA
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-

↓ The value of the response variable decreases with increasing predictor variable values, and vice versa

↑The value of the response variable increases with increasing predictor variable values, and vice versa

Table 2.2.7. Summary of TP and TN thresholds (CP) with confidence intervals (CI) for Texas reservoirs in level III ecoregion 33 Thresholds were identified using non-parametric changepoint analysis, where Secchi transparency and chl-a measured spectrophotometrically (chl-a spec) were potential response variables. Model summary statistics, including r^2, p_{perm}, average value of the response variable above and below the nutrient threshold (M_R and M_L, respectively), and number of observations above and below the nutrient threshold (n_R and n_L, respectively) are included for all possible stressor-response models where n>20. All values for CP are in mg/L. Values for M_R and M_L are in meters or µg/L, where nutrient thresholds are relative to responses in Secchi transparency or chl-a, respectively. Models indicating relationships between nutrient stressors and response variables that were not congruent with ecological theory or not statistically significant (p>0.05) are shown in gray italics. Dataset 4 did not contain unique median estimates for TN or Secchi transparency, but rather included medians for these variables from Dataset 1. Therefore, Secchi vs. TN models were not applicable (NA) for Dataset 4.

		vs. TP (mg/L)							vs. TN (mg/L)						
Dataset	Variable	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L
Dataset 1	Secchi	0.074↓ (0.060-0.088)	0.48	0.001	0.98	0.56	15	9	1.1↓ (0.88-1.1)	0.44	0.003	0.98	0.55	15	7
	Chl-a spec	0.068↑ (0.055-0.080)	0.32	0.028	16.2	25.5			-	-	-	-	-	-	-
Dataset 2	Secchi	0.045↓ (0.033-0.080)	0.59	0.001	1.2	0.68	7	17	0.97↓ (0.88-1.1)	0.46	0.002	1.0	0.64	11	11
	Chl-a spec	0.068↑ (0.045-0.079)	0.29	0.045	15.3	25.2			-	-	-	-	-	-	-
Dataset 4	Secchi	0.079↓ (0.055-0.089)	0.59	0.001	0.89	0.53	14	8	NA	NA	NA	NA	NA	NA	NA
	Chl-a spec	-	-	-	-	-	-	-	-	-	-	-	-	-	-

↓ The value of the response variable decreases with increasing predictor variable values, and vice versa
↑The value of the response variable increases with increasing predictor variable values, and vice versa

Table 2.2.8. Summary of TP and TN thresholds (CP) with confidence intervals (CI) for Texas reservoirs in level III ecoregion 35. Thresholds were identified using non-parametric changepoint analysis, where Secchi transparency and chl-a measured spectrophotometrically (chl-a spec) were potential response variables. Model summary statistics, including r^2, p_{perm}, average value of the response variable above and below the nutrient threshold (M_R and M_L, respectively), and number of observations above and below the nutrient threshold (n_R and n_L, respectively) are included for all possible stressor-response models where n>20. All values for CP are in mg/L. Values for M_R and M_L are in meters or µg/L, where nutrient thresholds are relative to responses in Secchi transparency or chl-a, respectively. Models indicating relationships between nutrient stressors and response variables that were not congruent with ecological theory or not statistically significant (p>0.05) are shown in gray italics. Dataset 4 did not contain unique median estimates for TN or Secchi transparency, but rather included medians for these variables from Dataset 1. Therefore, Secchi vs. TN models were not applicable (NA) for Dataset 4.

		vs. TP (mg/L)							vs. TN (mg/L)						
Dataset	Variable	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L	CP (CI)	r^2	p_{perm}	M_R	M_L	n_R	n_L
Dataset 1	Secchi	0.063↓ (0.063-0.075)	0.56	0.001	1.2	0.48	26	28	0.68↓ (0.64-1.0)	0.65	0.001	1.4	0.61	13	29
	Chl-a spec	0.068↑ (0.058-0.16)	0.22	0.010	12.3	20.2	25	22	1.1↑ (0.89-1.1)	0.54	0.001	11.8	25.7	25	12
Dataset 2	Secchi	0.046↓ (0.043-0.075)	0.60	0.001	1.3	0.54	20	34	0.62↓ (0.57-0.91)	0.63	0.001	1.4	0.63	8	44
	Chl-a spec	0.058↑ (0.028-0.10)	0.25	0.004	8.0	18.2	19	28	0.81↑ (0.78-1.0)	0.53	0.001	6.2	22.0	19	18
Dataset 4	Secchi	0.049↓ (0.047-0.11)	0.62	0.001	1.5	0.55	7	36	NA	NA	NA	NA	NA	NA	NA
	Chl-a spec	*-*	*0.15*	*0.14*	*-*	*-*	*-*	*-*	0.83↑ (0.83-1.1)	0.46	0.001	7.7	21.2	17	18

↓ The value of the response variable decreases with increasing predictor variable values, and vice versa
↑The value of the response variable increases with increasing predictor variable values, and vice versa

2.3 FREQUENCY DISTRIBUTION ANALYSIS FOR TEXAS RESERVOIR SEGMENTS

Methods

For this study, frequency distribution analyses were conducted on station medians within Texas reservoir segments defined by TCEQ (https://gisweb.tceq.texas.gov/segments/default.htm). Because each reservoir station within a segment was not equally represented in the raw water quality dataset, frequency distributions were calculated using medians to remove potential site-specific bias for sites that were over- or under-represented in the raw dataset. Furthermore, biological response and nutrient stressor data did not always overlap in the raw data. Conducting analyses with median values allowed comparison of long-term trends in biological and nutrient data for these stations.

Frequency distributions (minimum value, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} percentiles and maximum value) were calculated using Microsoft Excel for water quality parameters total phosphorus (TP; TCEQ parameter code 00665), total nitrogen (TN; calculated parameter code 00600C; TCEQ parameter code 00625 + 00630, 00625 + 00593 or 00625 + 00615 + 00620), nitrate+nitrite-nitrogen (NO_x-N; calculated parameter 00630C; TCEQ parameter code 00630, 00593 or 00615 + 00620), orthophosphate-phosphorus (PO_4-P ; TCEQ calculated parameter code 00671C; TCEQ parameter code 00671 or 70507), and sestonic chlorophyll-a measured fluorometrically (chl-a fluoro; TCEQ parameter code 70953). For this study, a parameter combining chl-a measured spectrophotometrically and fluorometrically measured chlorophyll-a was not created due differences between the methods (Laurie Eng, personal communication). Because data were more complete and censorship was less of a concern than for spectrophotometric chl-a, frequency distributions for sestonic chl-a were only calculated for the fluorometric method.

Results and Discussion

For Texas reservoirs, 102 unique segment codes were identified. For all parameters of interest, the majority of these segments contained fewer than 4 station medians and were therefore not eligible for calculation of 25^{th} percentile estimates. None of the segments contained 30 or more stations medians, which is the minimum number of data points recommended by the USEPA for frequency distribution analysis.

Significant variability in 25^{th} percentiles among segments with n ≥4 station medians was observed however (see Appendix 2.2, Table A2.2.1). For TP, 24 segments had ≥4 medians, and 25^{th} percentiles ranged from 0.020 – 0.16 mg/L. For TN, 18 segments had ≥4 medians, and 25^{th} percentiles ranged from 0.42 – 1.4 mg/L. For NO_x-N, 17 segments had ≥4 medians, and 25^{th} percentiles ranged from 0.010 – 0.20 mg/L. For PO_4-P, 26 segments had ≥4 medians, and 25^{th} percentiles ranged from 0.003-0.070 mg/L. For chl-a fluoro, 11 segments had ≥4 medians, and 25^{th} percentiles ranged from 5.00 – 31.4 µg/L.

Summary of frequency distributions by segment for Texas reservoirs

Significant variability in 25th percentiles among segments with n ≥4 station medians was observed in these analyses. While no Texas reservoir segments included 30 or more station medians, these percentile estimates may be a useful tool for identifying reservoir segments that would be in or out of compliance with proposed nutrient and biological response criteria or as part of a weight of evidence approach to setting segment-specific criteria. Furthermore, we recommend that TCEQ review whether combining segments with overlapping designations would be appropriate for calculating segment-specific frequency distributions. If appropriate, combining segments with overlapping designations would increase the number of medians per segment for some Texas reservoirs segments.

2.4 EXPLORING POTENTIAL EFFECTS OF DROUGHT ON VALUES OF WATER QUALITY PARAMETERS

Methods

Data organization and compilation for annual medians database

Comparing water quality data collected under drought and non-drought conditions required that the FY2012-2013 Texas reservoirs water quality database be expanded to include the years 2011-2014. During this period, Texas experienced wide-spread historic drought (United States Drought Monitor, droughtmonitor.unl.edu). To expand the database, TCEQ provided a data comprised of 116 water quality parameters with data collected from January 1, 2011 – December 31, 2014 from reservoirs throughout Texas. The collected data was received in two installments: 1) in October 2013, spanning January 1, 2011-October 2013 and 2) in May 2015, spanning January 1, 2013-December 31, 2014. Only the complete 2013 data provided through the second installment were used in subsequent analyses.

Data from 2011 – 2014 were received in a format in which data for all parameters were stored in a single column. The data were therefore processed into a usable format identical to the FY2012-2013 water quality database. Data received as part of the present contract were organized through the same process and identical quality assurance requirements as applied to organize 2000 – 2010 data into the FY2012-2013 water quality database. Data collected under the monitoring type “Biased Flow” were removed by sorting the data by monitoring type code and deleting all biased flow observations. Although monitoring identified as “Biased Flow” may be planned to target either low or high flow conditions, typically this monitoring is planned to target storm events. Since these data were removed, samples collected during wet weather events may be under-represented in the dataset. Data points that were considered to be censored were replaced in the rearranged data with the value of the quantification limit. Data were then reorganized using a pivot table function in Microsoft Excel to rearrange the single column output from SWQMIS into a format with a column assigned to each unique parameter code and associated data. The reorganization process was accomplished using Microsoft Excel Macros (see Appendix 1.6 for code).

Several additional parameters were calculated. Nitrate plus nitrite-nitrogen (NO_x-N) and total nitrogen (TN) were calculated if the necessary N species were provided by TCEQ in the original data file. In addition, diel change (i.e., 24 hour maximum minus 24 hour minimum) was calculated for dissolved oxygen, temperature, conductivity, pH, and turbidity. The additional parameters were added to each station worksheet using a Microsoft Excel Macro (Appendix 1.6). Due to the volume of data provided, several parameters were removed because of lack of data and duplication of parameters, or because TCEQ indicated that the parameter could be removed from the database.

Once the 2011 – 2014 were formatted identically to 2000 – 2010 data in the FY2012-2013 water quality database, an annual median was calculated for all parameters for all years for which data were present for all stream and river stations during the period 2000 – 2014. Annual medians were then automatically transferred to a summary tab for each year. This series of actions was carried out using a Microsoft Excel Macro (see Appendix 1.6 for code).

Initial analysis of statewide drought conditions in Texas by year from 2000 – 2014 was provided by TCEQ. These data and data used subsequently to assess the timing and extent of drought in Texas were acquired from the United States Drought Monitor (droughtmonitor.unl.edu). Initial analyses indicated that 2004 and 2011 represented extremes of wet and dry years, respectively, for a large proportion of the state, while the periods of 2001-2005 and 2011-2014 represented extended periods of wet and dry, respectively.

Data were fit to boxplots to illustrate frequency distributions for the different groups of annual medians for target water quality variables. These parameters of interest were total phosphorus (TP; parameter 00665), total nitrogen (TN; parameter 00600C), phosphate-phosphorus (SRP; parameter 00671C), nitrate+nitrite-nitrogen (NOx-N; parameter 00630), chlorophyll-a (chl-a) measured spectrophometrically (chl-a spec; parameter 32211) and fluorometrically (chl-a fluoro; parameter 79753), and Secchi transparency (parameter 00078C).

These analyses were conducted at the statewide scale, but data were also divided into subgroups in order to reduce variability in the data known to originate from sources other than variability in precipitation. Statewide analyses did not reveal differences between groups of annual medians representing single or multiple years of wet or dry conditions; therefore, subgroups were created for 2004 and 2011 only. Subgroups were intended to remove regions where drought conditions diverged from conditions that were representative of a large proportion of the state (i.e. drought in 2004 or non-drought in 2011).

In order to exclude areas of Texas where drought conditions diverged from the norm, the areal extent of drought in Texas for each month in 2004 and 2011 was assessed. Data illustrating the areal extent of drought on a weekly basis were downloaded from the United States Drought Monitor website for both years. For each month in 2004, all land area in Texas under severe to exceptional drought (DM = 2 – 4) for at least one week in a given month was identified and joined using the union tool in ArcMap 10.2.2. For each month in 2011, all land area in Texas classified as DM = 2 – 4, for all weeks within the given month was identified and separated from areas not classified as DM = 2 – 4 using the clip tool in ArcMap 10.2.2. For every month in both 2004 and 2010, Texas basin-ecoregion areas under severe to exceptional drought were identified by overlaying a GIS layer created and provided by TCEQ that was comprised of shapes representing unique unions of major Texas basins and Omnerik Level III ecoregions. Basin-ecoregion areas experiencing severe to exceptional drought were identified as the unions with drought area overlapping the centroid of the union. Finally, basin-ecoregion areas were selected for exclusion from the study for 2004 by eliminating areas that had drought area at the centroid for 4 or more months of the year, while basin-ecoregion areas were selected exclusion for 2011 by eliminating areas that experienced no drought or drought designated DM <2 for four or more months of the year. Maps showing the basin-ecoregion union areas that were experienced drought vs. non-drought conditions for each month in 2004 and 2011 are included in this report in Appendix 1.7.

Results and Discussion

Results for drought comparisons for the statewide and targeted drought areas data subgroups were very similar. Therefore, only the results for the statewide annual medians groups are presented graphically in the body of the report. Results of analyses on the targeted drought subgroup of annual medians are presented in Appendix 2.3. No basin-ecoregion union areas were actually eliminated from the 2004 dataset for severe to exceptional drought (DM = 2 – 4) conditions for four or more months out of the year. In 2011, 26 basin-ecoregion areas were identified as diverging from the statewide trend with conditions with no drought or a DM < 2 for four months or more out of the year. The basin-ecoregion unions that were excluded from the targeted analysis for 2011 are 1-26, 2-25, 2-26, 2-29, 2-32, 2-33, 2-35, 3-32, 3-33, 3-35, 4-33, 5-32, 8-27, 829, 8-32, 11-34, 12-25, 14-27, 14-29, 17-34, 18-34, 19-34, 20-33, 20-34, 21-34, and 22-34. Of these basin-ecoregion unions, 14 were not represented in the reservoirs water quality database: 2-32, 2-35, 3-32, 3-33, 5-32, 8-27, 11-34, 17-34, 18-34, 19-34, 20-33, 20-34, 21-34, and 22-34. Data belonging to the remaining basin-ecoregion unions were removed from the 2011 targeted drought subgroup, but comprised a relatively small percentage of the cumulative annual medians. In short, the original assessment that 2004 and 2011 were excellent candidate years for representing statewide extreme wet and extreme drought conditions, respectively, was correct.

For the statewide and targeted drought annual medians groups, few or minor differences were identified between drought and non-drought years. The few noteworthy potential differences in the distributions are discussed subsequently, but advanced analysis would be required to determine whether these data populations are statistically different.

Nutrients

Frequency distributions indicated little or no difference between medians in wet vs. drought years for TP or TN (Fig. 2.4.1A-B). For TP, medians across annual medians groups were approximately 0.05 – 0.06 mg/L. For TN, medians ranged between 0.83 and 0.85 mg/L. Both TP and TN means were higher and more variable than medians (mean TP = 0.10 – 0.20 mg/L, mean TN = 1.1 – 1.7 mg/L). The TP mean for 2011 was approximately 2x higher than for 2004 or the series of wet years, while the series of drought years had a mid-range mean. For TN, means were identical across annual median groups, except for the series of drought years (1.1. mg/L vs. 1.7 mg/L). The TP distributions for drought years also differed from wet years in the range of data falling between the 25th and 75th percentiles, which was driven by lower 25th and 10th percentiles in 2011-2014. These differences in lower percentiles could be attributable to drought, but may also reflect lower quantification limits for TP analytical methods for a greater number of reservoir stations. However, TP medians were equal to two common quantification limits in the TCEQ water quality database for all annual median subgroups, indicating that these analyses were affected by the prevalence of censored data. These effects likely obscured any potential differences due to drought.

As with TP and TN, differences between wet and drought years observed for PO_4-P and NO_x-N annual median groups were minor, but a few trends emerged (Fig. 2.4.2A-B). Distributions of both variables showed signs of being limited by the prevalence of censored data, most notably in drought years. Across groups, PO_4-P medians were consistently equal to the most common QL (0.04 mg/L), but for drought years all annual medians within the interquartile range (25 – 75th percentile) were equal to this value, suggesting even greater prevalence of censored data in 2011-2014. For NO_x-N, the spread of the interquartile range was more limited in drought years as well, with both 25th percentiles and medians equal to the common QL (0.04 mg/L). These differences between wet and dry years could be attributable to drought effects, suggesting dry conditions reduced both the magnitude and variability of dissolved inorganic nutrient concentrations in reservoirs, but could also reflect increases in QL's after 2010.

In contrast to medians, for PO_4-P, means differed more greatly between wet and dry years. Mean PO_4-P was 2x greater in the drought year of 2011 than in the wet year of 2004 (0.10 mg/L vs. 0.05 mg/L). This difference was erased when the groups representing series of wet and dry years were considered, as both series of years had mean PO_4-P = 0.06 mg/L. Differences in means between 2011 and the other annual median subgroups likely reflect increases in the value of the lower percentile estimates for these years, though differences in the sample size between groups representing a single year vs. a series of years could also skew results. For NO_x-N, in contrast, means were similar across annual median groups (0.20 – 0.23 mg/L).

The percentage of TN comprised by NO_x-N was higher in wet years than in dry years in Texas reservoirs (~20% and 14%, respectively). This difference was small, however, and may be due to error associated with measurement of these parameters, such as changes in QL, or inconsistent representation of stations between groups of annual medians. If this difference reflected a real trend, however, it would be consistent with scientific understanding of nitrogen dynamics in lakes and reservoirs. Nitrogen removal processes, such as denitrification, become more efficient as water residence time increases in aquatic systems (Seitzinger et al. 2006), which would be a likely consequence of a more restricted flow regime due to drought conditions.

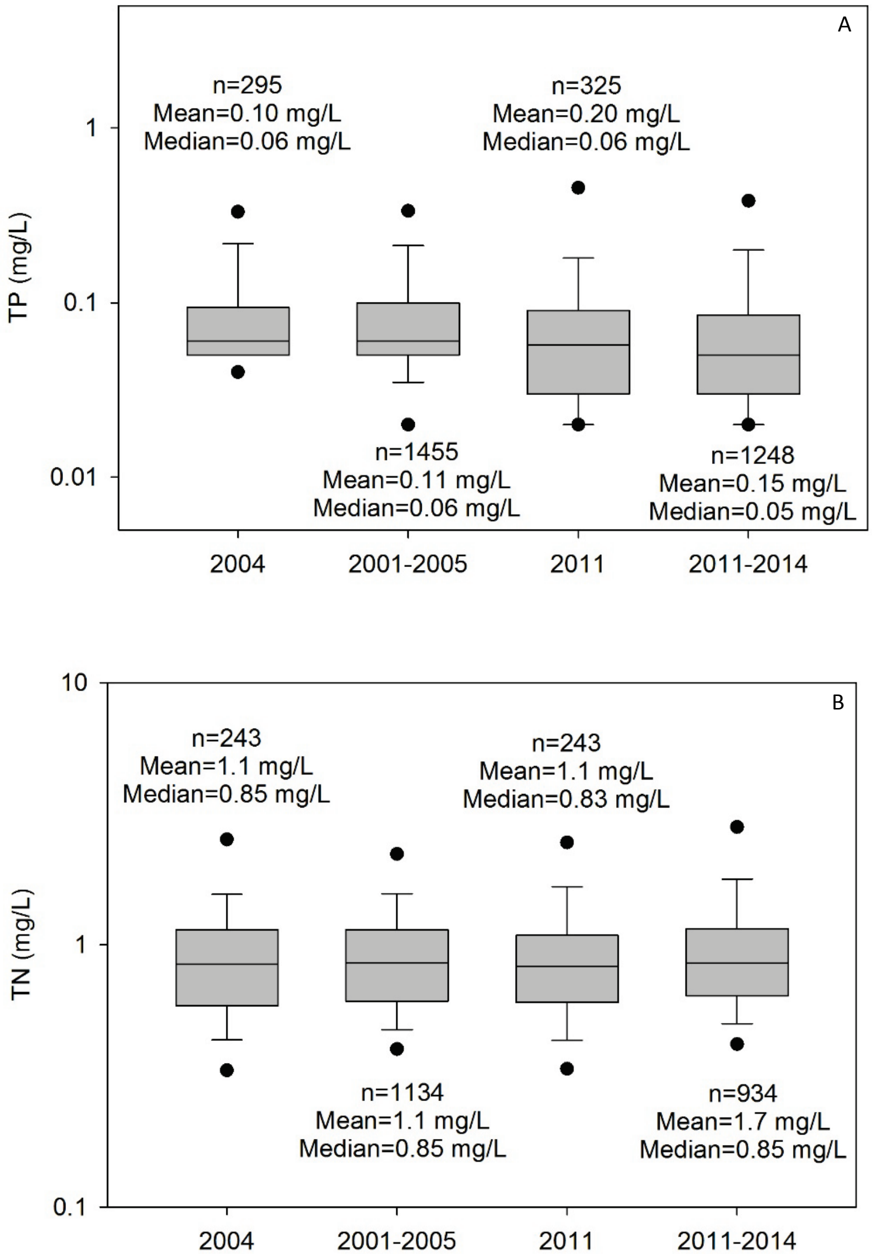


Figure 2.4.1. Data distributions for statewide station annual medians of A) total phosphorus (TP) and B) total nitrogen (TN) grouped by single or a series of wet (2004, 2001-2005) and drought (2011, 2011-2014) years in Texas. The shaded area represents data falling between the 25th and 75th percentiles, while error bars indicate the 10th and 90th percentiles and outlier icons represent 5th and 95th percentiles.

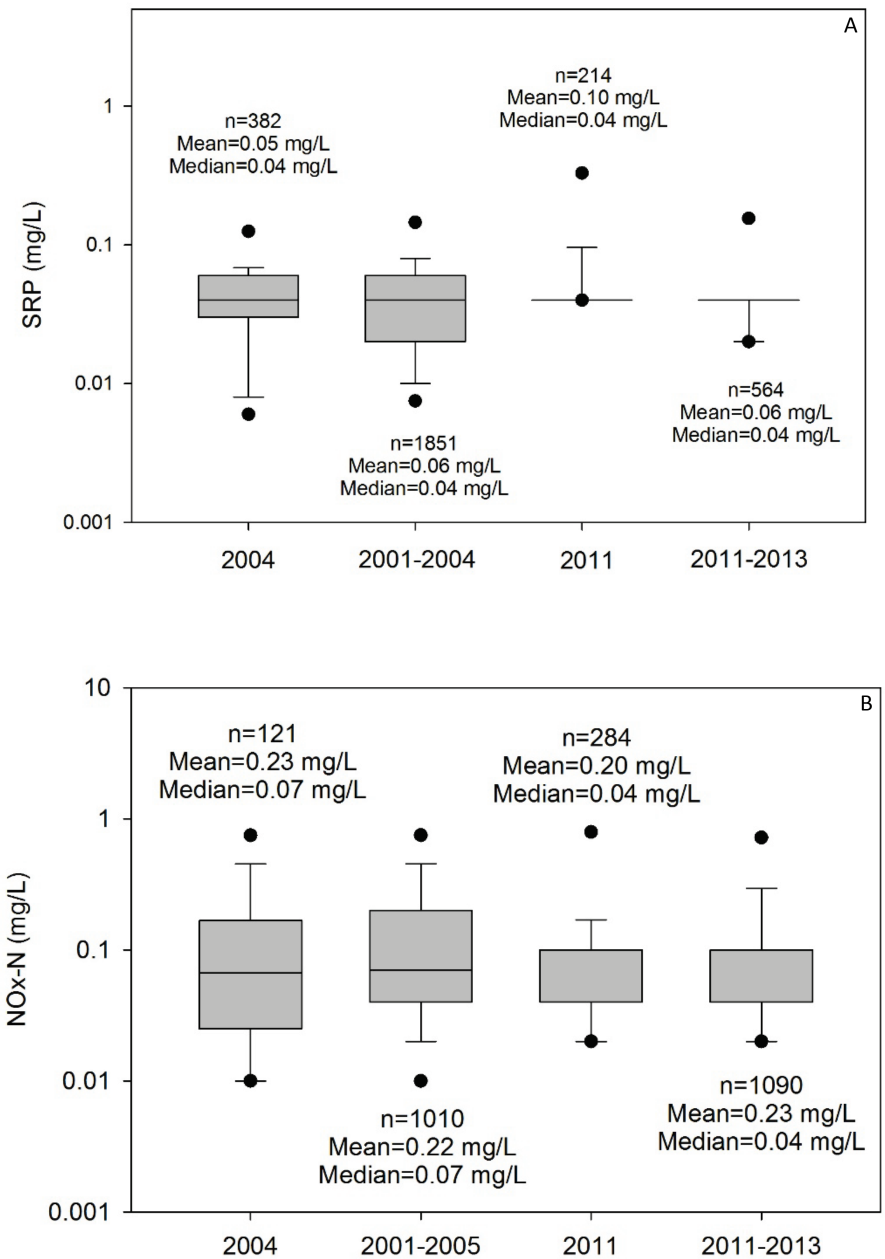


Fig. 2.4.2. Data distributions for statewide station annual medians of A) phosphate-phosphorus (PO_4-P) and B) nitrate+nitrite-nitrogen (NO_x-N) grouped by single or a series of wet (2004, 2001-2005) and drought (2011, 2011-2014) years in Texas. The shaded area represents data falling between the 25th and 75th percentiles, while error bars indicate the 10th and 90th percentiles and outlier icons represent 5th and 95th percentiles. Where indicators different percentiles overlap are not visible, the values of these percentiles were equal, indicating that a single value was common in the dataset, likely the quantification limit (QL).

The proportion of TN composed of NO_x-N in reservoirs (< 20%) was small compared to the proportion in streams and rivers (~60 – 80%), reflecting a fundamental difference between lotic and lentic systems. In lotic systems, nitrogen primarily moves as NO_x-N at base flow and is measurable year-round. In contrast, for reservoirs, especially productive warm-water systems, NO_x-N is often not detectable throughout the growing season (Scott et al. 2008; Scott and Grantz 2013), which comprises the majority of the year at latitudes within Texas. Though NO_x-N concentrations may be quite high in reservoirs during mixing and when temperature limits algal growth, elevated concentrations would not be reflected in median estimates if the number of measurements collected during the growing season represented ≥50% of all measurements. Therefore, setting nutrient targets for NO_x-N in reservoirs may not be practical if observations are not weighted to account for seasonal variability. Accounting for seasonal variability in NO_x-N in Texas reservoirs was beyond the scope of the present study.

For all the nutrient parameters of interest, differences in measures of central tendency were consistently seen for means, but rarely for medians, with the exception of NO_x-N. In general, the spread of data distributions, especially data between the 25^{th} and 75^{th} percentiles, encompassed a wider range of values in drought years than in wet years, which may account for the differences in means. As the 50^{th} percentile, however, medians were less likely to be strongly affected by changes to lower and higher percentiles, especially in cases where values in the interquartile range spread wider in both directions from the median. Therefore, findings from these comparisons support the idea that medians are a more robust choice for setting water quality targets.

Sestonic chlorophyll-a and Secchi transparency

For chl-a spec, medians and means ranged narrowly across groups of annual medians, between 13 – 14 µg/L and 17 – 19 µg/L, respectively (Fig. 2.4.3A). The spread of data falling between the 25^{th} and 75^{th} percentiles was greater for drought years, but most data (5^{th}-95^{th}) fell within a similar range across groups. Medians for chl-a fluoro were similar to those for chl-a spec, ranging from 11 – 15 ug/L, but fluorometric means were higher than for chl-a spec, ranging from 22 – 32 ug/L (Fig. 2.4.3B). Across groups of annual medians, mean chl-a fluoro was approximately 50% greater for drought years than for wet years.

Changes in the prevalence of use of the different methods of chl-a analysis between the early 2000's and post 2010 make comparison of drought and non-drought group problematic. The sample size of annual medians for chl-a spec was much larger for 2004 than for chl-a fluoro the same year or for chl-a spec for 2011 (n = 247, 86, and 95, respectively), while the sample size for chl-a fluoro approximately tripled between 2004 and 2011. These large changes in sample size between the periods entail that the stations represented by annual medians differ greatly between the drought and non-drought periods and to an extent that is likely not true for other parameters. These fundamental differences in the data population for chl-a parameters between the early 2000's and post 2010 make it difficult to determine whether trends identified between the annual median groups can be attributed to the effects of drought.

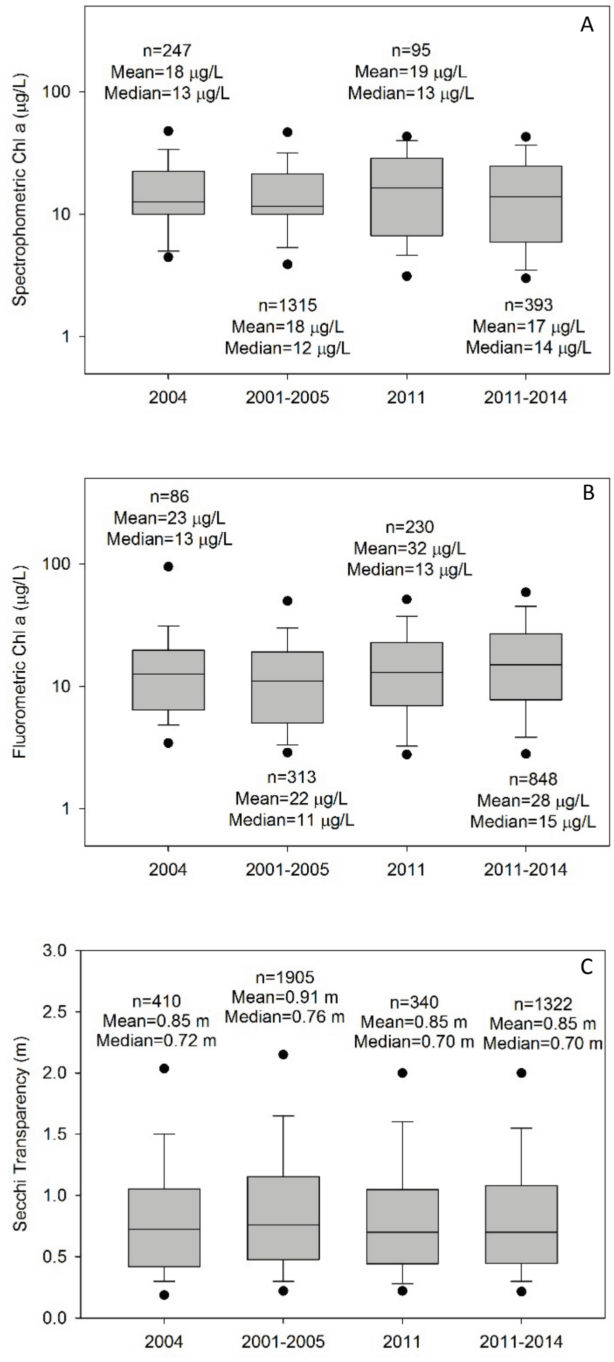


Figure 2.4.3. Data distributions for statewide station annual medians of chlorophyll-a measured A) spectrophotometrically (chl-a spec) and B) fluorometrically (chl-a fluoro) and C) Secchi transparency grouped by single or a series of wet (2004, 2001-2005) and drought (2011, 2011-2014) years in Texas. The shaded area represents data falling between the 25th and 75th percentiles, while error bars indicate the 10th and 90th percentiles and outlier icons represent 5th and 95th percentiles.

For Secchi transparency, the estimated measures of central tendency and the shape of distributions were almost identical across the 4 groups (Fig. 2.4.3C). Median Secchi transparency was 0.70 – 0. 76 m across groups, while mean transparency varied by approximately 0.06 m between 0.85 and 0.91 m. In general, Secchi transparency appeared highly immune to potential drought effects.

Summary of drought effects on water quality parameters

Drought conditions had few, if any, effects on distributions of annual medians for water quality parameters of interest at the statewide scale in Texas reservoirs. As with streams and rivers, targeting drought effects by eliminating basin-ecoregion union areas not in drought (DM < 2) for at least a third of the year in 2011 did not reduce variability or refine analyses. A highly significant threshold in municipal discharge congruent to that found for streams was not available for reservoirs. Therefore drought comparisons on subgroups of stations receiving low and high municipal discharges relative to watershed area was not relevant for reservoirs. It may still be possible to identify drought effects on Texas reservoirs at smaller scales, however, such as the segment level. The few observed differences between wet and dry years were consistently associated with group means, most notably for mean TP, which doubled between 2004 and 2011. Medians were relatively insensitive to variability between wet and dry years, and therefore may be considered more resilient to drought effects.

These findings have implications for the process of setting nutrient criteria. When all reservoirs were considered together at the statewide scale, water quality data distributions in drought years did not deviate strongly or consistently from wet years. Therefore, data collected during drought years would likely not be out of compliance with criteria established using data from years with normal or high precipitation. This assessment however, depends upon how conservative a target was put in place, the selected measure of central tendency for setting standards, and the parameter of interest, among other considerations.

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Appendix 2.1 Statistical code from "flipped" changepoint analysis and regional threshold analysis

Flipped Changepoint Analysis

ANALYSIS: TP vs. CHL-A SPEC Dataset 1

```
      cp     r2  mean left mean right pperm    5%   25%    50%    75% 95%
[1,] 24.425 0.10127 0.07297015  0.1549821 0.013 15.275 23.35 24.425 26.125  28.48625
```

ANALYSIS: TP vs. CHLA Dataset 2

```
      cp       r2 mean left mean right pperm    5%   25%   50%    75%       95%
[1,] 24.425 0.1224717 0.0581145  0.1526607 0.001 14.95 18.95 24.25 26.075  26.125
```

ANALYSIS: TP vs. CHLA Dataset 4

```
     cp        r2  mean left mean right pperm   5%   25%   50%   75%  95%
[1,] 21.65 0.08172485 0.06465294  0.1341026  0.05 14.5 16.95 21.65 21.65 27.2
```

ANALYSIS: TP vs. SECCHI Dataset 1

```
     cp       r2 mean left mean right pperm    5%  25%   50%   75%   95%
[1,] 0.415 0.1530506 0.1739107 0.07025143 0.002 0.325 0.39 0.415 0.415 0.805
```

ANALYSIS: TP vs. SECCHI Dataset 2

```
     cp       r2 mean left mean right pperm   5%   25%   50%   75%    95%
[1,] 0.415 0.1697624 0.1794947 0.06794359 0.001 0.39 0.415 0.415 0.805 0.8125
```

ANALYSIS: TP vs. SECCHI – Dataset 4

```
    cp       r2 mean left mean right pperm    5%  25%   50%   75%   95%
[1,] 0.415 0.1509968  0.172125 0.06487218 0.003 0.355 0.39 0.415 0.415 0.805
```

ANALYSIS: TN vs. CHLA Dataset 1

```
   r2 mean left mean right pperm   5%    25%    50%    75%       95%
[1,] 26.125 0.1345559 0.8122531   1.620675 0.006 11.4 14.675 26.075 26.125   26.125
```

ANALYSIS: TN vs. CHLA Dataset 2

```
   r2 mean left mean right pperm     5%    25%    50%    75%    95%
[1,] 26.125 0.1344696 0.8010624   1.611275 0.001 12.425 14.675 26.075 26.125   26.125
```

ANALYSIS: TN vs. CHLA Dataset 4

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 21.65 0.1017624 0.8040466 1.382706 0.027 11.65 14.675 21.35 21.65 21.65

ANALYSIS: TN vs. SECCHI Dataset 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.865 0.1093751 1.168308 0.7055606 0.001 0.445 0.805 0.8525 0.865 1.0625

ANALYSIS: TN vs. SECCHI Dataset 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.865 0.1101847 1.153386 0.6862837 0.004 0.505 0.82 0.865 0.865 1.05775

ANALYSIS: Dataset 1 TP vs. CHLA minus 1 outlier

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 16.8 0.1222955 0.06604811 0.1026693 0.006 12.675 16.8 20.475 24.425 33.12

ANALYSIS: Dataset 1 TP vs. CHLA minus 2 outliers

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 16.8 0.1274908 0.06604811 0.09731481 0.005 12.525 16.65 18.95 29.2 33.26

ANALYSIS: Dataset 2 TP vs. CHLA minus 1 outlier

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 16.8 0.1753645 0.04815071 0.09827513 0.001 12.675 15.275 16.85 20.675 27.2

ANALYSIS: Dataset 2 TP vs. CHLA minus 2 outliers

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 15.275 0.189461 0.04688095 0.09153535 0.001 12.6 15.275 16.8 20.475 29.2

ANALYSIS: Dataset 4 TP vs. CHLA minus 1 outlier

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 14.975 0.1201991 0.05476786 0.09729104 0.005 11.65 14.975 21.7 23.85 29.2

ANALYSIS: Dataset 4 TP vs. CHLA minus 2 outliers

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 29.2 0.1292494 0.06881818 0.1312917 0.003 9.055 14.975 20.475 27.2 29.2

ANALYSIS: Dataset 1 TP vs. SECCHI minus 1 outlier

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.415 0.5056225 0.1739107 0.06410345 0.001 0.36 0.39375 0.415 0.415 0.425

ANALYSIS: Dataset 1 TP vs. SECCHi minus 3 outliers

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.415 0.5624195 0.1542115 0.06410345 0.001 0.39 0.415 0.415 0.415 0.425

ANALYSIS: Dataset 2 TP vs. SECCHI minus 1 outlier

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.415 0.5025735 0.1717679 0.0483892 0.001 0.39 0.40875 0.415 0.415 0.425

ANALYSIS: Dataset2 TP vs. SECCHI minus 3 outliers

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.415 0.5244218 0.1519038 0.0483892 0.001 0.39 0.415 0.415 0.415 0.505

ANALYSIS: Dataset 4 TP vs. SECCHI minus 1 outlier

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.415 0.4802563 0.172125 0.05686923 0.001 0.375 0.39 0.415 0.415 0.425

ANALYSIS: Dataset 4 TP vs. SECCHI minus 3 outliers

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.415 0.5123422 0.1522885 0.05686923 0.001 0.39 0.415 0.415 0.415 0.425

ANALYSIS: Dataset 1 TN vs. CHLA minus 1 outlier

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 12.475 0.2296264 0.7143096 1.06972 0.001 10.05 12.425 12.475 18.025 24.95875

ANALYSIS: Dataset 1 TN vs. CHLA minus 3 outliers (all TN >2 mg/L)

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 12.475 0.4641358 0.6781194 1.046009 0.001 10.05 11.65 12.475 12.55 17.66875

ANALYSIS: Dataset 2 TN vs. CHLA minus 1 outlier

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 12.475 0.23191 0.7006864 1.061263 0.001 11.59 12.475 12.55 16.1 26.7025

ANALYSIS: Dataset 2 TN vs. CHLA minus 3 outliers

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	12.475	0.4752926	0.6629065	1.037031	0.001	10.425	12.425	12.475	14.425	18.025

ANALYSIS: Dataset 4 TN vs. CHLA minus 1 outlier

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	14.675	0.1945035	0.7528597	1.081231	0.001	8.84625	12.425	14.675	18.05	26.85

ANALYSIS: Dataset 4 CHLA vs. TN minus 3 outliers

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	12.45	0.4196699	0.7057873	1.046402	0.001	9.5715	11.65	12.45	14.675	18.05

ANALYSIS: Dataset 1 SECCHI vs. TN minus 1 outlier

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	0.865	0.2093619	1.11031	0.7055606	0.001	0.405	0.575	0.7925	0.865	1.065

ANALYSIS: Dataset1 SECCHI vs. TN minus 3-4 outliers

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	0.865	0.2394652	1.051788	0.7055606	0.001	0.6225	0.8525	0.865	1.0625	1.065

ANALYSIS: Dataset 2 SECCHI vs. TN minus 1 outlier

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	0.865	0.2111264	1.095276	0.6862837	0.001	0.405	0.611875	0.795	0.865	1.062625

ANALYSIS: Dataset 2 SECCHI vs. TN minus 3-4 outliers

	cp	r2	mean left	mean right	pperm	5%	25%	50%	75%	95%
[1,]	0.865	0.2421971	1.036636	0.6862837	0.001	0.6475	0.8525	0.865	0.9222	1.065

Regional threshold analysis

ANALYSIS: BASIN 6 SECCHI VS. TP DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.06 0.1095129 1.316667 0.5583333 0.003 0.06 0.06 0.06 0.0625 0.065

ANALYSIS: BASIN 6 SECCHI vs. TP DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.048 0.5265044 1.388462 0.63125 0.002 0.03 0.045 0.048 0.048 0.0625\

ANALYSIS: BASIN 8 SECCHI vs. TP DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.079 0.4112346 0.9006258 0.4710632 0.001 0.06125 0.073875 0.079 0.079 0.0847625

ANALYSIS: BASIN 8 SECCHI vs. TP DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.079 0.412481 0.9006258 0.4700105 0.001 0.039 0.05975 0.07725 0.079 0.0834

ANALYSIS: BASIN 8 SECCHi vs. TP DATASET 4

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.079 0.5358484 0.8492643 0.4710632 0.001 0.045 0.07725 0.079 0.079 0.13275

ANALYSIS – BASIN 8 CHLA vs. TP DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.063 0.4760686 12.98632 26.25269 0.001 0.05975 0.06175 0.063 0.06425 0.0695

ANALYSIS: BASIN 8 CHLA v. TP DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.063 0.4862859 12.32842 26.25269 0.001 0.048 0.05975 0.063 0.063 0.0663

ANALYSIS: BASIN 8 CHLA vs. TP DATASET 4

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.06275 0.458093 12.91235 26.15462 0.001 0.053 0.0615 0.06275 0.063 0.0695

ANALYSIS: BASIN 8 TN vs. SECCHI DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.735 0.3901717 1.269167 0.6447189 0.001 0.6925 0.735 0.9175 1.084 1.1045

ANALYSIS: BASIN 8 TN vs. SECCHI DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.7175 0.3901167 1.269167 0.6441784 0.003 0.688125 0.7175 0.87775 1.06875 1.084

ANALYSIS: BASIN 8 CHLA vs. TN DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.948 0.6003352 13.79 28.27364 0.001 0.89875 0.94225 0.948 0.9575 0.963

ANALYSIS: BASIN 8 CHLA vs. TN DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.94725 0.5978093 13.19476 28.27364 0.001 0.885 0.8975 0.94725 0.95575 0.97625

ANALYSIS: BASIN 8 CHLA vs. TN DATASET 4

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.948 0.6034362 13.33095 28.17364 0.001 0.89875 0.90875 0.948 0.957 0.9631

ANALYSIS: BASIN 12 SECCHI vs. TP DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0625 0.1363615 1.0145 0.6086364 0.037 0.06 0.0625 0.0625 0.065 0.07

ANALYSIS: BASIN 12 SECCHI VS. TP DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.035 0.2599875 1.136364 0.6384211 0.003 0.035 0.035 0.035 0.045 0.045

ANALYSIS: BASIN 12 SECCHI vs. TP DATASET 4

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0405 0.369384 1.154091 0.625625 0.005 0.04 0.0405 0.0405 0.0415 0.0455

ANALYSIS: BASIN 12 SECCHI vs. TN DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.7 0.08972622 1.275 0.8682258 0.406 0.665 0.711875 0.99375 1.14 1.57

ANALYSIS: BASIN 12 SECCHI vs. TN DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.7 0.07454509 1.275 0.8682258 0.5 0.68 0.715 1.04125 1.288125 1.5525

ANALYSIS: BASIN 14 SECCHI vs. TP DATASET 4

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.025 0.4726763 1.44 0.5075 0.007 0.0205 0.0215 0.025 0.025 0.0295

ANALYSIS: BASIN 14 SECCHI vs. TN DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.5885 0.4049269 1.754643 0.8583333 0.003 0.48575 0.54725 0.5885 0.65825 0.801

ANALYSIS: BASIN 14 SECCHI vs. TN DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.581 0.4049269 1.754643 0.8583333 0.002 0.46825 0.58 0.581 0.692675 0.855

ANALYSIS: ECOREGION 29 SECCHI vs. TP DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.06125 0.1851752 1.015 0.6352174 0.007 0.06125 0.06125 0.06125 0.0685 0.07225

ANALYSIS: ECOREGION 29 SECCHI vs. TP DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.045 0.2286918 1.063824 0.6558621 0.003 0.035 0.039 0.045 0.045 0.0685

ANALYSIS: ECOREGION 29 SECCHI vs. TP DATASET 4

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0405 0.2520981 1.029737 0.6609722 0.004 0.039 0.0405 0.0405 0.0415 0.07535

ANALYSIS: ECOREGION 29 SECCHI vs. TN DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.39 0.104551 0.8361957 1.355833 0.117 0.6325 0.6975 0.9165 1.36625 1.3975

ANALYSIS: ECOREGION 29 SECCHi vs. TN DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.36 0.1046104 0.8357609 1.355833 0.101 0.615 0.7 0.924375 1.295 1.37

ANALYSIS: ECOREGION 29 CHLA vs. TP DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.063 0.443031 12.26789 23.65895 0.001 0.05975 0.06175 0.063 0.0635 0.06475

ANALYSIS: ECOREGION 29 CHLA vs. TP DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.051 0.4670431 9.135 22.18833 0.001 0.039 0.048 0.051 0.05975 0.06425ANALYSIS: ECOREGION 29 CHLA vs. TP DATASET 4

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.05975 0.3820025 11.89714 22.71682 0.002 0.0465 0.0525 0.05975 0.06275 0.06425

ANALYSIS: ECOREGION 29 CHLA vs. TN DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.96525 0.5189344 12.48471 25.84385 0.001 0.71 0.9375 0.96525 0.9675 1.01625

ANALYSIS: ECOREGION 29 CHLA vs. TN DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.96525 0.5303562 11.17882 25.84385 0.001 0.71 0.90375 0.96525 0.9675 1.015

ANALYSIS: ECOREGION 29 CHLA vs. TN DATASET 4

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.96525 0.4929777 12.66 25.77462 0.001 0.71 0.95275 0.96525 0.9675 1.01625

ANALYSIS: ECOREGION 30 SECCHI vs. TN DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.48575 0.6624116 2.3175 1.1175 0.001 0.48375 0.48575 0.493 0.5215 0.54735

ANALYSIS: ECOREGION 30 SECCHI vs. TN DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.47575 0.6624116 2.3175 1.1175 0.001 0.47075 0.47575 0.48 0.49 0.55225

ANALYSIS: ECOREGION 33 SECCHI vs. TP DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.074 0.4806204 0.9846267 0.5578 0.001 0.06 0.065 0.074 0.079 0.0875

ANALYSIS: ECOREGION 33 SECCHI vs. TP DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.045 0.592617 1.182143 0.6773294 0.001 0.0325 0.0375 0.045 0.06 0.08

ANALYSIS: ECOREGION 33 SECCHI vs. TP DATASET 4

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.079 0.5936827 0.8942429 0.532525 0.001 0.055 0.07 0.078 0.0794375 0.0885

ANALYSIS: ECOREGION 33 SECCHI vs. TN DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.1375 0.4445856 0.98064 0.5535714 0.003 0.88 0.918 1.0125 1.12 1.1375

ANALYSIS: ECOREGION 33 SECCHI vs. TN DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.96825 0.4564586 1.046309 0.6432 0.002 0.8775 0.9295625 0.96825 1.0925 1.125

ANALYSIS: ECOREGION 33 CHLA vs. TP DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.06833335 0.3164909 16.19292 25.50556 0.028 0.055 0.06333335 0.06833335 0.07 0.08

ANALYSIS: ECOREGION 33 CHLA vs. TP DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.06833335 0.29323 15.32958 25.22778 0.045 0.0325 0.05 0.06333335 0.06833335 0.079

ANALYSIS: ECOREGION 35 SECCHI vs. TP DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0625 0.5631507 1.184423 0.4814286 0.001 0.0625 0.0625 0.0625 0.065 0.075

ANALYSIS: ECOREGION 35 SECCHI vs. TP DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0455 0.5988226 1.292 0.5422059 0.001 0.0425 0.0455 0.0455 0.0625 0.075

ANALYSIS: ECOREGION 35 SECCHI vs. TP DATASET 4

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0485 0.6172736 1.465714 0.5518056 0.001 0.0465 0.0485 0.0485 0.052 0.11

ANALYSIS: ECOREGION 35 SECCHI vs. TN DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.675 0.6472588 1.381667 0.6115517 0.001 0.635 0.64 0.675 0.7025 1.015

ANALYSIS: ECOREGION 35 SECCHI vs. TN DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.62 0.629429 1.407273 0.6278333 0.001 0.56875 0.62 0.62 0.665 0.90875

ANALYSIS: ECOREGION 35 CHLA vs. TP DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0675 0.2163973 12.2878 20.17045 0.01 0.0575 0.0675 0.075 0.08075 0.15575

ANALYSIS: ECOREGION 35 CHLA vs. TP DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0575 0.2495449 7.994474 18.18571 0.004 0.0275 0.0575 0.0675 0.075 0.10425

ANALYSIS: ECOREGION 35 CHLA vs. TP DATASET 4

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0485 0.1471733 8.417143 17.785 0.139 0.047 0.0545 0.065 0.0885 0.1725

ANALYSIS: ECOREGION 35 CHLA vs. TN DATASET 1

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.065 0.5356378 11.81 25.69583 0.001 0.885 0.9275 1.045 1.065 1.0775

ANALYSIS: ECOREGION 35 CHLA vs. TN DATASET 2

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.81 0.5340741 6.231579 21.96389 0.001 0.7755 0.81 0.8975 1.01975 1.0425

ANALYSIS: ECOREGION 35 CHLA vs. TN DATASET 4

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.825 0.4597672 7.709412 21.23667 0.001 0.825 0.8325 0.9375 1.065 1.077

Appendix 2.2 Data frequency distributions for water quality parameters for Texas reservoir segments

Table A2.2.1. Frequency distribution of median nutrient and chlorophyll-a concentrations for reservoir segments in Texas, using data from 2000-2010 and the median dataset generated in FY2012-2013.

Total Phosphorus (TP; mg/L)

SEG_ID	n	Min	10th	25th	Median	75th	90th	Max
0102	2	0.050	-	-	0.055	-	-	0.060
0203	3	0.067	-	-	0.073	-	-	0.080
0207	0	-	-	-	-	-	-	-
0208	0	-	-	-	-	-	-	-
0209	1	-	-	-	0.060	-	-	-
0210	1	-	-	-	0.060	-	-	-
0212	1	-	-	-	0.160	-	-	-
0213	0	-	-	-	-	-	-	-
0215	1	-	-	-	0.050	-	-	-
0217	1	-	-	-	0.055	-	-	-
0219	1	-	-	-	0.200	-	-	-
0223	1	-	-	-	0.060	-	-	-
0228	1	-	-	-	0.060	-	-	-
0302	6	0.080	-	0.099	0.131	0.148	-	0.190
0401	3	0.060	-	-	0.060	-	-	0.087
0403	4	0.050	-	0.054	0.058	0.070	-	0.100
0405	1	-	-	-	0.060	-	-	-
0408	2	0.050	-	-	0.050	-	-	0.050
0504	1	-	-	-	0.060	-	-	-
0507	4	0.060	-	0.060	0.065	0.076	-	0.095
0509	2	0.060	-	-	0.070	-	-	0.080
0510	1	-	-	-	0.050	-	-	-
0512	4	0.060	-	0.060	0.060	0.065	-	0.080
0603	1	-	-	-	0.065	-	-	-
0605	6	0.060	-	0.060	0.080	0.100	-	0.190
0610	8	0.060	0.060	0.060	0.060	0.063	0.070	0.070
0613	4	0.050	-	0.050	0.050	0.053	-	0.060
0614	2	0.050	-	-	0.050	-	-	0.050
0615	1	-	-	-	0.175	-	-	-
0803	4	0.130	-	0.153	0.173	0.209	-	0.280
0807	3	0.069	-	-	0.080	-	-	0.081
0809	6	0.060	-	0.068	0.079	0.100	-	0.150
0811	7	0.038	0.039	0.040	0.046	0.061	0.076	0.095

0813	1	-	-	-	0.060	-	-	-
0815	1	-	-	-	0.060	-	-	-
0816	1	-	-	-	0.060	-	-	-
0817	1	-	-	-	0.060	-	-	-
0818	7	0.060	0.066	0.074	0.089	0.147	0.188	0.225
0823	3	0.040	-	-	0.050	-	-	0.080
0826	6	0.040	-	0.040	0.045	0.058	-	0.155
0827	0	-	-	-	-	-	-	-
0828	4	0.064	-	0.065	0.070	0.083	-	0.108
0830	5	0.060	-	0.060	0.080	0.082	-	0.091
0832	1	-	-	-	0.060	-	-	-
0834	1	-	-	-	0.060	-	-	-
0836	6	0.032	-	0.043	0.050	0.114	-	0.188
0838	0	-	-	-	-	-	-	-
1002	10	0.100	0.145	0.160	0.195	0.305	0.422	0.440
1012	0	-	-	-	-	-	-	-
1203	3	0.060	-	-	0.060	-	-	0.060
1205	4	0.050	-	0.058	0.065	0.070	-	0.070
1207	4	0.060	-	0.060	0.060	0.060	-	0.060
1210	3	0.180	-	-	0.210	-	-	0.270
1212	1	-	-	-	0.080	-	-	-
1216	0	-	-	-	-	-	-	-
1220	2	0.060	-	-	0.060	-	-	0.060
1222	1	-	-	-	0.070	-	-	-
1224	2	0.060	-	-	0.070	-	-	0.080
1225	6	0.020	-	0.060	0.060	0.075	-	0.080
1228	2	0.060	-	-	0.060	-	-	0.060
1230	0	-	-	-	-	-	-	-
1231	1	-	-	-	0.060	-	-	-
1233	1	-	-	-	0.060	-	-	-
1234	1	-	-	-	0.050	-	-	-
1236	0	-	-	-	-	-	-	-
1237	0	-	-	-	-	-	-	-
1240	1	-	-	-	0.060	-	-	-
1247	1	-	-	-	0.060	-	-	-
1249	2	0.060	-	-	0.060	-	-	0.060
1252	4	0.060	-	0.060	0.070	0.089	-	0.115
1254	3	0.060	-	-	0.060	-	-	0.060
1403	4	0.040	-	0.055	0.060	0.060	-	0.060
1404	0	-	-	-	-	-	-	-

1405	0	-	-	-	-	-	-	-
1406	4	0.060	-	0.060	0.060	0.060	-	0.060
1407	2	0.060	-	-	0.060	-	-	0.060
1408	5	0.060	-	0.060	0.060	0.060	-	0.068
1411	2	0.060	-	-	0.060	-	-	0.060
1418	3	0.060	-	-	0.060	-	-	0.060
1419	1	-	-	-	0.060	-	-	-
1422	2	0.060	-	-	0.060	-	-	0.060
1423	2	0.060	-	-	0.060	-	-	0.060
1425	1	-	-	-	0.140	-	-	-
1429	5	0.020	-	0.020	0.040	0.050	-	0.050
1433	3	0.060	-	-	0.060	-	-	0.060
1805	1	-	-	-	0.050	-	-	-
1904	1	-	-	-	0.060	-	-	-
2103	2	0.140	-	-	0.174	-	-	0.208
2116	2	0.057	-	-	0.064	-	-	0.070
2303	1	-	-	-	0.060	-	-	-
2305	3	0.050	-	-	0.050	-	-	0.060
2312	2	0.050	-	-	0.055	-	-	0.060
0229A	1	-	-	-	1.140	-	-	-
0404A	0	-	-	-	-	-	-	-
1208A	0	-	-	-	-	-	-	-
1209A	1	-	-	-	0.355	-	-	-
1209B	1	-	-	-	0.140	-	-	-
1241A	0	-	-	-	-	-	-	-
1241C	1	-	-	-	0.065	-	-	-
1412A	0	-	-	-	-	-	-	-
1416B	1	-	-	-	0.060	-	-	-
1426A	1	-	-	-	0.060	-	-	-

Total Nitrogen (TN; mg/L)

SEG_ID	n	Min	10th	25th	Median	75th	90th	Max
0102	2	0.505	-	-	0.568	-	-	0.630
0203	0	-	-	-	-	-	-	-
0207	0	-	-	-	-	-	-	-
0208	0	-	-	-	-	-	-	-
0209	1	-	-	-	0.790	-	-	-
0210	1	-	-	-	0.665	-	-	-
0212	1	-	-	-	0.890	-	-	-

0213	0	-	-	-	-	-	-	-
0215	1	-	-	-	0.710	-	-	-
0217	1	-	-	-	0.540	-	-	-
0219	1	-	-	-	2.175	-	-	-
0223	1	-	-	-	0.530	-	-	-
0228	1	-	-	-	0.620	-	-	-
0302	6	1.060	-	1.084	1.100	1.124	-	1.205
0401	3	0.705	-	-	0.720	-	-	0.771
0403	4	0.670	-	0.693	0.745	0.845	-	1.010
0405	1	-	-	-	0.780	-	-	-
0408	2	0.590	-	-	0.595	-	-	0.600
0504	1	-	-	-	1.000	-	-	-
0507	2	1.100	-	-	1.118	-	-	1.135
0509	2	1.070	-	-	1.130	-	-	1.190
0510	1	-	-	-	0.475	-	-	-
0512	4	0.830	-	0.943	0.990	1.000	-	1.000
0603	1	-	-	-	0.680	-	-	-
0605	5	0.875	-	0.980	1.020	1.320	-	3.320
0610	3	0.470	-	-	0.600	-	-	0.790
0613	4	0.545	-	0.549	0.565	0.583	-	0.590
0614	2	0.380	-	-	0.380	-	-	0.380
0615	1	-	-	-	1.020	-	-	-
0803	4	0.860	-	1.036	1.220	1.506	-	1.990
0807	3	0.810	-	-	0.829	-	-	0.908
0809	6	0.913	-	0.954	1.000	1.043	-	1.136
0811	7	0.465	0.503	0.545	0.560	0.575	0.624	0.685
0813	1	-	-	-	0.595	-	-	-
0815	1	-	-	-	0.920	-	-	-
0816	1	-	-	-	0.790	-	-	-
0817	1	-	-	-	0.785	-	-	-
0818	7	0.910	0.934	0.960	1.025	1.150	1.400	1.760
0823	0	-	-	-	-	-	-	-
0826	0	-	-	-	-	-	-	-
0827	0	-	-	-	-	-	-	-
0828	4	1.039	-	1.047	1.062	1.104	-	1.198
0830	5	0.976	-	0.980	1.010	1.023	-	1.160
0832	1	-	-	-	0.895	-	-	-
0834	1	-	-	-	0.685	-	-	-
0836	6	0.880	-	0.901	0.940	1.134	-	1.324
0838	0	-	-	-	-	-	-	-

1002	1	-	-	-	1.155	-	-	-
1012	0	-	-	-	-	-	-	-
1203	3	0.695	-	-	0.700	-	-	0.740
1205	3	1.640	-	-	1.755	-	-	1.850
1207	4	1.390	-	1.401	1.473	1.568	-	1.650
1210	3	1.350	-	-	1.560	-	-	1.760
1212	1	-	-	-	1.210	-	-	-
1216	0	-	-	-	-	-	-	-
1220	2	1.080	-	-	1.155	-	-	1.230
1222	1	-	-	-	1.135	-	-	-
1224	2	0.840	-	-	0.943	-	-	1.045
1225	2	0.725	-	-	0.790	-	-	0.855
1228	2	1.140	-	-	1.160	-	-	1.180
1230	0	-	-	-	-	-	-	-
1231	1	-	-	-	0.620	-	-	-
1233	1	-	-	-	0.630	-	-	-
1234	1	-	-	-	0.600	-	-	-
1236	0	-	-	-	-	-	-	-
1237	0	-	-	-	-	-	-	-
1240	1	-	-	-	0.895	-	-	-
1247	1	-	-	-	1.600	-	-	-
1249	2	1.080	-	-	1.173	-	-	1.265
1252	4	1.410	-	1.418	1.520	1.650	-	1.740
1254	3	0.930	-	-	0.955	-	-	1.010
1403	4	0.410	-	0.421	0.428	0.434	-	0.446
1404	0	-	-	-	-	-	-	-
1405	0	-	-	-	-	-	-	-
1406	4	0.522	-	0.540	0.548	0.568	-	0.620
1407	2	0.577	-	-	0.634	-	-	0.690
1408	5	0.540	-	0.545	0.602	0.624	-	0.832
1411	0	-	-	-	-	-	-	-
1418	3	0.600	-	-	0.635	-	-	0.650
1419	1	-	-	-	0.700	-	-	-
1422	2	0.965	-	-	1.008	-	-	1.050
1423	2	0.725	-	-	1.013	-	-	1.300
1425	1	-	-	-	2.445	-	-	-
1429	5	0.450	-	0.498	0.540	0.565	-	0.770
1433	1	-	-	-	0.770	-	-	-
1805	0	-	-	-	-	-	-	-
1904	1	-	-	-	0.410	-	-	-

2103	0	-	-	-	-	-	-	-
2116	0	-	-	-	-	-	-	-
2303	0	-	-	-	-	-	-	-
2305	3	0.460	-	-	0.590	-	-	0.800
2312	2	1.210	-	-	1.420	-	-	1.630
0229A	1	-	-	-	8.940	-	-	-
0404A	0	-	-	-	-	-	-	-
1208A	0	-	-	-	-	-	-	-
1209A	1	-	-	-	1.470	-	-	-
1209B	1	-	-	-	1.180	-	-	-
1241A	0	-	-	-	-	-	-	-
1241C	1	-	-	-	2.050	-	-	-
1412A	0	-	-	-	-	-	-	-
1416B	1	-	-	-	1.370	-	-	-
1426A	1	-	-	-	0.960	-	-	-

Nitrate+Nitrite-Nitrogen (NOx-N; mg/L)

SEG_ID	n	Min	10th	25th	Median	75th	90th	Max
0102	1	-	-	-	0.040	-	-	-
0203	3	0.040	-	-	0.060	-	-	0.120
0207	0	-	-	-	-	-	-	-
0208	0	-	-	-	-	-	-	-
0209	1	-	-	-	0.050	-	-	-
0210	1	-	-	-	0.040	-	-	-
0212	1	-	-	-	0.040	-	-	-
0213	0	-	-	-	-	-	-	-
0215	1	-	-	-	0.040	-	-	-
0217	1	-	-	-	0.040	-	-	-
0219	1	-	-	-	0.040	-	-	-
0223	1	-	-	-	0.040	-	-	-
0228	1	-	-	-	0.050	-	-	-
0302	6	0.040	-	0.050	0.050	0.050	-	0.050
0401	1	-	-	-	0.040	-	-	-
0403	4	0.040	-	0.040	0.040	0.043	-	0.050
0405	1	-	-	-	0.045	-	-	-
0408	2	0.050	-	-	0.050	-	-	0.050
0504	0	-	-	-	-	-	-	-
0507	2	0.040	-	-	0.093	-	-	0.145
0509	2	0.040	-	-	0.045	-	-	0.050

0510	1	-	-	-	0.040	-	-	-
0512	4	0.040	-	0.040	0.043	0.049	-	0.060
0603	1	-	-	-	0.050	-	-	-
0605	6	0.040	-	0.040	0.045	0.163	-	1.935
0610	8	0.040	0.047	0.054	0.074	0.093	0.102	0.105
0613	4	0.040	-	0.040	0.045	0.050	-	0.050
0614	2	0.050	-	-	0.050	-	-	0.050
0615	1	-	-	-	0.320	-	-	-
0803	4	0.050	-	0.118	0.208	0.368	-	0.645
0807	3	0.010	-	-	0.012	-	-	0.014
0809	6	0.010	-	0.010	0.013	0.019	-	0.035
0811	7	0.009	0.010	0.011	0.027	0.029	0.034	0.040
0813	1	-	-	-	0.040	-	-	-
0815	1	-	-	-	0.100	-	-	-
0816	1	-	-	-	0.110	-	-	-
0817	1	-	-	-	0.080	-	-	-
0818	7	0.010	0.010	0.010	0.030	0.035	0.100	0.190
0823	0	-	-	-	-	-	-	-
0826	3	0.040	-	-	0.040	-	-	0.055
0827	0	-	-	-	-	-	-	-
0828	4	0.025	-	0.030	0.040	0.102	-	0.265
0830	5	0.010	-	0.027	0.038	0.040	-	0.090
0832	1	-	-	-	0.050	-	-	-
0834	1	-	-	-	0.040	-	-	-
0836	6	0.078	-	0.085	0.129	0.175	-	0.204
0838	0	-	-	-	-	-	-	-
1002	1	-	-	-	0.190	-	-	-
1012	0	-	-	-	-	-	-	-
1203	3	0.040	-	-	0.040	-	-	0.040
1205	0	-	-	-	-	-	-	-
1207	0	-	-	-	-	-	-	-
1210	1	-	-	-	0.040	-	-	-
1212	1	-	-	-	0.040	-	-	-
1216	0	-	-	-	-	-	-	-
1220	0	-	-	-	-	-	-	-
1222	1	-	-	-	0.050	-	-	-
1224	2	0.040	-	-	0.045	-	-	0.050
1225	2	0.060	-	-	0.070	-	-	0.080
1228	2	0.060	-	-	0.065	-	-	0.070
1230	0	-	-	-	-	-	-	-

1231	1	-	-	-	0.040	-	-	-
1233	1	-	-	-	0.040	-	-	-
1234	1	-	-	-	0.070	-	-	-
1236	0	-	-	-	-	-	-	-
1237	0	-	-	-	-	-	-	-
1240	1	-	-	-	0.040	-	-	-
1247	0	-	-	-	-	-	-	-
1249	0	-	-	-	-	-	-	-
1252	0	-	-	-	-	-	-	-
1254	3	0.120	-	-	0.245	-	-	0.330
1403	4	0.100	-	0.108	0.123	0.145	-	0.175
1404	0	-	-	-	-	-	-	-
1405	0	-	-	-	-	-	-	-
1406	4	0.020	-	0.024	0.028	0.031	-	0.035
1407	2	0.020	-	-	0.050	-	-	0.080
1408	5	0.020	-	0.020	0.025	0.050	-	0.069
1411	2	0.020	-	-	0.020	-	-	0.020
1418	3	0.040	-	-	0.050	-	-	0.055
1419	1	-	-	-	0.070	-	-	-
1422	2	0.040	-	-	0.043	-	-	0.045
1423	2	0.050	-	-	0.105	-	-	0.160
1425	1	-	-	-	0.045	-	-	-
1429	5	0.140	-	0.195	0.200	0.235	-	0.320
1433	3	0.045	-	-	0.050	-	-	0.055
1805	1	-	-	-	0.100	-	-	-
1904	1	-	-	-	0.065	-	-	-
2103	2	0.020	-	-	0.023	-	-	0.027
2116	2	0.020	-	-	0.020	-	-	0.020
2303	1	-	-	-	0.050	-	-	-
2305	3	0.140	-	-	0.240	-	-	0.440
2312	2	0.040	-	-	0.093	-	-	0.145
0229A	1	-	-	-	5.695	-	-	-
0404A	0	-	-	-	-	-	-	-
1208A	0	-	-	-	-	-	-	-
1209A	0	-	-	-	-	-	-	-
1209B	0	-	-	-	-	-	-	-
1241A	0	-	-	-	-	-	-	-
1241C	1	-	-	-	0.505	-	-	-
1412A	1	-	-	-	0.020	-	-	-
1416B	1	-	-	-	0.020	-	-	-

1426A	1	-	-	-	0.040	-	-	-

Orthophosphate-Phosphorus (PO_4-P; mg/L)

SEG_ID	n	Min	10th	25th	Median	75th	90th	Max
0102	2	0.040	-	-	0.050	-	-	0.060
0203	3	0.040	-	-	0.040	-	-	0.040
0207	0	-	-	-	-	-	-	-
0208	0	-	-	-	-	-	-	-
0209	1	-	-	-	0.060	-	-	-
0210	1	-	-	-	0.040	-	-	-
0212	1	-	-	-	0.095	-	-	-
0213	0	-	-	-	-	-	-	-
0215	1	-	-	-	0.040	-	-	-
0217	1	-	-	-	0.040	-	-	-
0219	1	-	-	-	0.060	-	-	-
0223	1	-	-	-	0.040	-	-	-
0228	1	-	-	-	0.060	-	-	-
0302	7	0.020	0.032	0.050	0.060	0.060	0.060	0.060
0401	3	0.010	-	-	0.040	-	-	0.040
0403	8	0.020	0.020	0.020	0.030	0.060	0.060	0.060
0405	1	-	-	-	0.060	-	-	-
0408	2	0.040	-	-	0.045	-	-	0.050
0504	1	-	-	-	0.040	-	-	-
0507	4	0.010	-	0.033	0.040	0.040	-	0.040
0509	2	0.040	-	-	0.040	-	-	0.040
0510	1	-	-	-	0.040	-	-	-
0512	4	0.040	-	0.040	0.040	0.043	-	0.050
0603	1	-	-	-	0.060	-	-	-
0605	6	0.040	-	0.040	0.045	0.058	-	0.060
0610	8	0.040	0.040	0.040	0.040	0.040	0.040	0.040
0613	4	0.040	-	0.040	0.040	0.045	-	0.060
0614	2	0.040	-	-	0.040	-	-	0.040
0615	1	-	-	-	0.060	-	-	-
0803	9	0.040	0.056	0.070	0.080	0.090	0.118	0.130
0807	3	0.008	-	-	0.008	-	-	0.010
0809	6	0.010	-	0.010	0.010	0.010	-	0.020
0811	6	0.005	-	0.005	0.006	0.008	-	0.011
0813	1	-	-	-	0.040	-	-	-
0815	3	0.020	-	-	0.020	-	-	0.040

0816	1	-	-	-	0.040	-	-	-
0817	3	0.013	-	-	0.020	-	-	0.060
0818	7	0.008	0.009	0.010	0.010	0.020	0.042	0.060
0823	3	0.010	-	-	0.020	-	-	0.030
0826	7	0.010	0.016	0.020	0.020	0.020	0.024	0.030
0827	0	-	-	-	-	-	-	-
0828	4	0.005	-	0.007	0.009	0.013	-	0.020
0830	5	0.005	-	0.005	0.007	0.008	-	0.009
0832	1	-	-	-	0.040	-	-	-
0834	1	-	-	-	0.040	-	-	-
0836	6	0.008	-	0.010	0.010	0.013	-	0.019
0838	5	0.006	-	0.006	0.006	0.010	-	0.010
1002	10	0.040	0.040	0.046	0.070	0.110	0.251	0.345
1012	0	-	-	-	-	-	-	-
1203	8	0.013	0.013	0.017	0.020	0.040	0.040	0.040
1205	9	0.040	0.040	0.040	0.040	0.040	0.040	0.040
1207	4	0.040	-	0.040	0.040	0.040	-	0.040
1210	3	0.063	-	-	0.110	-	-	0.120
1212	1	-	-	-	0.040	-	-	-
1216	0	-	-	-	-	-	-	-
1220	2	0.040	-	-	0.040	-	-	0.040
1222	1	-	-	-	0.050	-	-	-
1224	2	0.040	-	-	0.040	-	-	0.040
1225	9	0.002	0.003	0.003	0.006	0.006	0.013	0.040
1228	2	0.040	-	-	0.040	-	-	0.040
1230	0	-	-	-	-	-	-	-
1231	1	-	-	-	0.040	-	-	-
1233	3	0.020	-	-	0.020	-	-	0.040
1234	1	-	-	-	0.060	-	-	-
1236	0	-	-	-	-	-	-	-
1237	0	-	-	-	-	-	-	-
1240	1	-	-	-	0.050	-	-	-
1247	1	-	-	-	0.040	-	-	-
1249	2	0.040	-	-	0.040	-	-	0.040
1252	4	0.040	-	0.040	0.040	0.040	-	0.040
1254	3	0.040	-	-	0.040	-	-	0.040
1403	4	0.020	-	0.020	0.028	0.036	-	0.040
1404	0	-	-	-	-	-	-	-
1405	0	-	-	-	-	-	-	-
1406	4	0.020	-	0.020	0.030	0.040	-	0.040

1407	2	0.040	-	-	0.040	-	-	0.040
1408	5	0.030	-	0.040	0.040	0.040	-	0.040
1411	2	0.020	-	-	0.020	-	-	0.020
1418	3	0.040	-	-	0.040	-	-	0.040
1419	1	-	-	-	0.040	-	-	-
1422	2	0.060	-	-	0.060	-	-	0.060
1423	2	0.060	-	-	0.060	-	-	0.060
1425	1	-	-	-	0.060	-	-	-
1429	5	0.020	-	0.020	0.020	0.020	-	0.020
1433	3	0.040	-	-	0.040	-	-	0.040
1805	0	-	-	-	-	-	-	-
1904	1	-	-	-	0.040	-	-	-
2103	2	0.072	-	-	0.078	-	-	0.083
2116	1	-	-	-	0.010	-	-	-
2303	1	-	-	-	0.040	-	-	-
2305	3	0.040	-	-	0.040	-	-	0.040
2312	2	0.040	-	-	0.045	-	-	0.050
0229A	1	-	-	-	0.910	-	-	-
0404A	0	-	-	-	-	-	-	-
1208A	0	-	-	-	-	-	-	-
1209A	1	-	-	-	0.205	-	-	-
1209B	1	-	-	-	0.060	-	-	-
1241A	0	-	-	-	-	-	-	-
1241C	1	-	-	-	0.040	-	-	-
1412A	0	-	-	-	-	-	-	-
1416B	1	-	-	-	0.040	-	-	-
1426A	1	-	-	-	0.040	-	-	-

Fluorometric Chlorophyll-a (Chl-a; µg/L)

SEG_ID	n	Min	10th	25th	Median	75th	90th	Max
0102	1	-	-	-	5.30	-	-	-
0203	0	-	-	-	-	-	-	-
0207	0	-	-	-	-	-	-	-
0208	0	-	-	-	-	-	-	-
0209	1	-	-	-	25.90	-	-	-
0210	0	-	-	-	-	-	-	-
0212	0	-	-	-	-	-	-	-
0213	0	-	-	-	-	-	-	-

0215	0	-	-	-	-	-	-	-
0217	0	-	-	-	-	-	-	-
0219	0	-	-	-	-	-	-	-
0223	1	-	-	-	3.68	-	-	-
0228	0	-	-	-	-	-	-	-
0302	5	20.00	-	29.20	29.80	34.00	-	34.60
0401	2	5.60	-	-	6.54	-	-	7.47
0403	4	16.90	-	17.80	19.10	20.18	-	20.40
0405	1	-	-	-	28.90	-	-	-
0408	2	5.97	-	-	7.56	-	-	9.15
0504	0	-	-	-	-	-	-	-
0507	0	-	-	-	-	-	-	-
0509	2	44.50	-	-	47.05	-	-	49.60
0510	0	-	-	-	-	-	-	-
0512	1	-	-	-	25.90	-	-	-
0603	1	-	-	-	11.10	-	-	-
0605	4	26.40	-	31.35	38.20	45.64	-	52.35
0610	3	5.75	-	-	11.60	-	-	18.55
0613	4	9.26	-	11.54	12.55	12.85	-	13.00
0614	2	3.11	-	-	3.62	-	-	4.12
0615	1	-	-	-	4.35	-	-	-
0803	0	-	-	-	-	-	-	-
0807	0	-	-	-	-	-	-	-
0809	0	-	-	-	-	-	-	-
0811	0	-	-	-	-	-	-	-
0813	1	-	-	-	8.95	-	-	-
0815	1	-	-	-	15.90	-	-	-
0816	1	-	-	-	17.60	-	-	-
0817	1	-	-	-	10.45	-	-	-
0818	0	-	-	-	-	-	-	-
0823	0	-	-	-	-	-	-	-
0826	0	-	-	-	-	-	-	-
0827	0	-	-	-	-	-	-	-
0828	0	-	-	-	-	-	-	-
0830	0	-	-	-	-	-	-	-
0832	1	-	-	-	29.65	-	-	-
0834	0	-	-	-	-	-	-	-
0836	0	-	-	-	-	-	-	-
0838	0	-	-	-	-	-	-	-
1002	4	6.78	-	9.08	13.12	20.69	-	16.40

1012	0	-	-	-	-	-	-	-
1203	3	11.09	-	-	15.90	-	-	22.10
1205	4	18.20	-	21.35	24.05	26.65	-	29.50
1207	4	7.20	-	9.59	11.87	14.76	-	18.95
1210	1	-	-	-	38.20	-	-	-
1212	1	-	-	-	39.13	-	-	-
1216	0	-	-	-	-	-	-	-
1220	2	4.26	-	-	9.58	-	-	14.90
1222	1	-	-	-	29.47	-	-	-
1224	0	-	-	-	-	-	-	-
1225	2	15.50	-	-	18.60	-	-	21.70
1228	2	17.16	-	-	18.61	-	-	20.05
1230	0	-	-	-	-	-	-	-
1231	1	-	-	-	6.90	-	-	-
1233	1	-	-	-	3.76	-	-	-
1234	0	-	-	-	-	-	-	-
1236	0	-	-	-	-	-	-	-
1237	0	-	-	-	-	-	-	-
1240	1	-	-	-	13.60	-	-	-
1247	1	-	-	-	9.10	-	-	-
1249	2	3.50	-	-	4.55	-	-	5.60
1252	4	14.73	-	19.10	20.88	21.71	-	23.23
1254	3	12.20	-	-	16.60	-	-	17.10
1403	4	5.00	-	5.00	5.00	5.00	-	5.00
1404	0	-	-	-	-	-	-	-
1405	0	-	-	-	-	-	-	-
1406	4	7.65	-	8.14	8.55	9.73	-	12.50
1407	2	5.45	-	-	9.30	-	-	13.15
1408	4	7.65	-	7.80	10.00	13.03	-	15.65
1411	0	-	-	-	-	-	-	-
1418	0	-	-	-	-	-	-	-
1419	0	-	-	-	-	-	-	-
1422	1	-	-	-	10.03	-	-	-
1423	2	6.79	-	-	7.62	-	-	8.45
1425	1	-	-	-	53.25	-	-	-
1429	3	2.30	-	-	2.75	-	-	7.68
1433	0	-	-	-	-	-	-	-
1805	0	-	-	-	-	-	-	-
1904	1	-	-	-	3.00	-	-	-
2103	1	-	-	-	5.35	-	-	-

2116	1	-	-	-	14.15	-	-	-
2303	0	-	-	-	-	-	-	-
2305	3	3.00	-	-	3.00	-	-	3.05
2312	0	-	-	-	-	-	-	-
0229A	1	-	-	-	65.25	-	-	-
0404A	0	-	-	-	-	-	-	-
1208A	0	-	-	-	-	-	-	-
1209A	0	-	-	-	-	-	-	-
1209B	0	-	-	-	-	-	-	-
1241A	0	-	-	-	-	-	-	-
1241C	0	-	-	-	-	-	-	-
1412A	0	-	-	-	-	-	-	-
1416B	1	-	-	-	18.00	-	-	-
1426A	0	-	-	-	-	-	-	-

Appendix 2.3 Boxplots of water quality annual medians for targeted groups

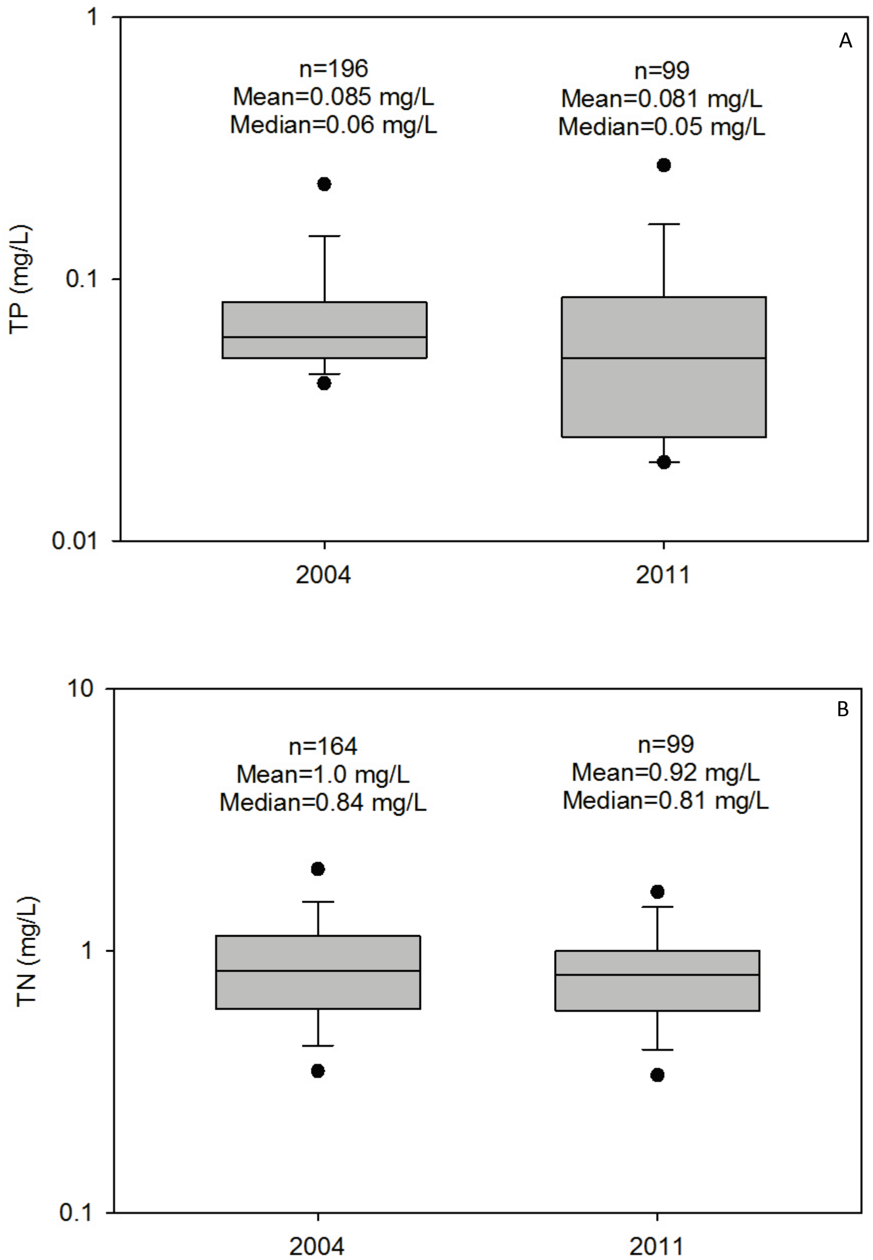

Figure A2.3.1. Data distributions for statewide station annual medians of A) total phosphorus (TP) and B) total nitrogen (TN) after removing medians from basin-ecoregion III union areas determined to be not representative of the target wet and dry conditions in 2004 and 2011, respectively. The shaded area represents data falling between the 25th and 75th percentiles, while error bars indicate the 10th and 90th percentiles and outlier icons represent 5th and 95th percentiles.

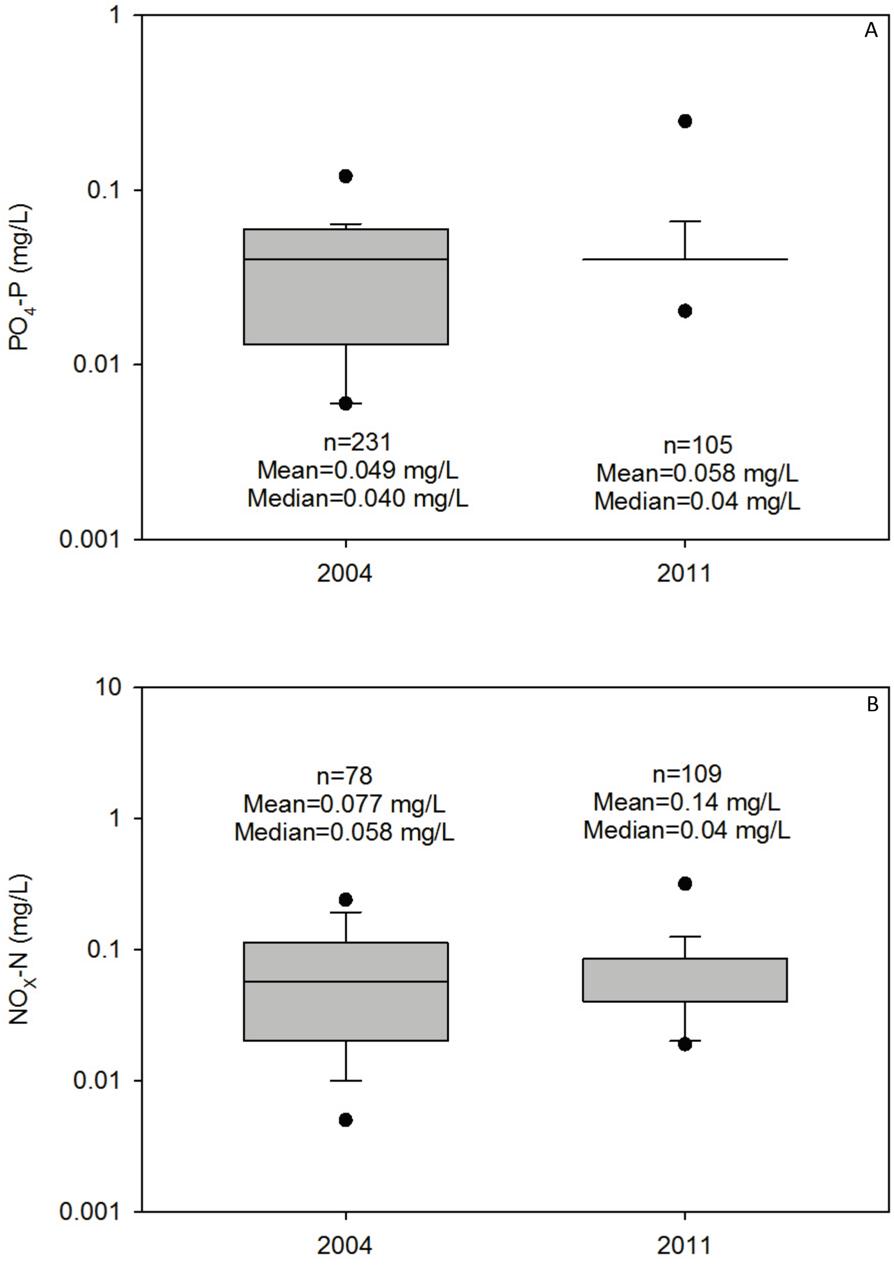

Figure A2.3.2. Data distributions for statewide station annual medians of A) phosphate-phosphorus (PO_4-P) and B) nitrate-nitrogen (NO_x-N) after removing medians from basin-ecoregion III union areas determined to be not representative of the target wet and dry conditions in 2004 and 2011, respectively. The shaded area represents data falling between the 25th and 75th percentiles, while error bars indicate the 10th and 90th percentiles and outlier icons represent 5th and 95th percentiles.

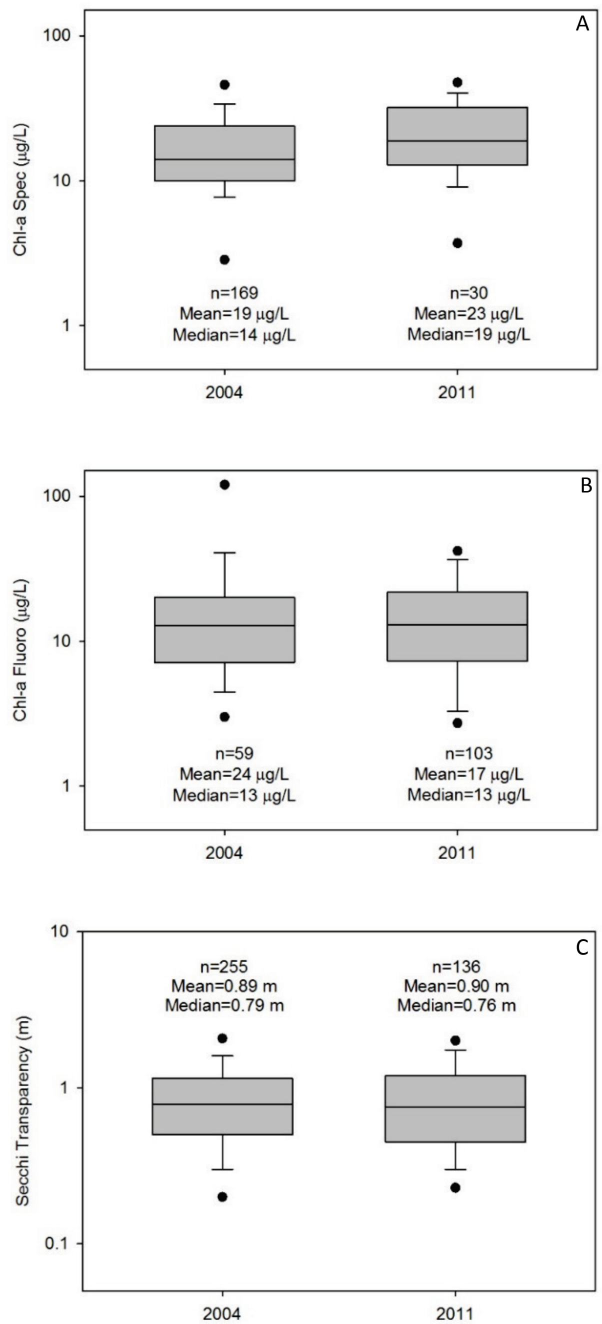

Figure A2.3.3. Data distributions for statewide station annual medians of chlorophyll-a measured A) spectrophotometrically (chl-a spec) and B) fluorometrically (chl-a fluoro) and C) Secchi transparency after removing medians from basin-ecoregion III union areas determined to be not representative of the target wet and dry conditions in 2004 and 2011, respectively. The shaded area represents data falling between the 25th and 75th percentiles, while error bars indicate the 10th and 90th percentiles and outlier icons represent 5th and 95th percentiles.

Section 3: Estuaries

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EXECUTIVE SUMMARY

The Clean Water Act directs states to adopt water-quality standards for all water bodies, including estuaries. The push in water-quality standards over the last decade or more has been for the development of numeric nutrient targets applicable to all water bodies, and protective of designated beneficial uses. The USEPA has published a series of guidance documents detailing technical approaches that can be used to develop numeric nutrient targets, including frequency distribution of nutrient concentration data and stressor-response studies. There is a growing wealth of information on streams, rivers, lakes and reservoirs, although the literature available on nutrient criteria for estuaries is much more limited because this water body type is more complex, both in hydrology and nutrient dynamics. The USEPA has released guidance for the development of estuarine nutrient targets for stressor and response, based on classification by physical characteristics, analyses of historical data, reference site approach, stressor-response relationships. However, the USEPA has not provided numerical guidance (based on frequency distribution of existing nutrient and biological conditions) for estuaries like that provided for lakes and reservoirs or streams and rivers. Nonetheless, states are directed to develop numeric nutrient targets for estuaries and coastal water protective of beneficial uses, as defined by each state's regulatory agency. The development of numeric nutrient targets will allow the states to manage nutrient enrichment of coastal waters and the associated effects on recreation and biological conditions.

The objective of Section 3 was to provide statistical support to the Texas Commission on Environmental Quality (TCEQ) to assist in the development of numeric nutrient or biological response targets for Texas estuaries. The USEPA recommends that statistical approaches that evaluate stressor-response relationships in aquatic systems and frequency distribution analysis should be used in conjunction for developing numeric targets. Further, questions remain regarding the legitimacy of promulgating a single numeric target for a parameter across areas that may contain multiple contributing basins and ecoregions. Sections 3.1 – 3.3 provide analyses that aid in addressing these concerns through multiple lines of inquiry. These analyses were based upon data provided by TCEQ for the period 2000 – 2010 that were organized by the Arkansas Water Resources Center (AWRC) under a prior contract (FY2012-2013). These data compiled water quality parameters from 860 stations within 38 estuaries across Texas and were collected under non-biased flow conditions.

In Section 3.1, prior changepoint analysis of stressor-response relationships in Texas estuaries were expanded by "flipping" the traditional configuration of the analysis to place the stressor and response parameters on the y-axis and x-axis, respectively. The study objective was to predict thresholds in biological variables. For these analyses, thresholds were identified in chlorophyll-a measured spectrophotometrically (chl-a spec = 13.8 µg/L) and fluorometrically (chl-a fluoro = 10.7 µg/L) relative to TP and TN gradients, as well as Secchi transparency. Analyses with TP as a variable appeared to be strongly affected by potential nutrient outlier values, however. After removing outlier TP values, the threshold in chl-a spec was reduced to 10.7 µg/L, while threshold chl-a fluoro was unchanged and Secchi transparency remained approximately 0.60 m. Thresholds for chl-a were mid-range between mean chl-a concentrations associated with low and high nutrient stations with median TP or TN concentration either below or above previously identified (FY2012-2013) nutrient thresholds.

Prior changepoint analysis of stressor-response relationships in Texas estuaries at the statewide level was refined in Section 3.2 by conducting these analyses on water quality data specific to two groups of basins contributing flow to the estuaries. Potential geographic variability was further explored by conducting frequency distribution analysis of water quality parameters within stream and river segments assigned by TCEQ in Section 3.3. The parameters of primary concern were total phosphorus (TP), ortho-phosphate (PO_4-P; SRP), total nitrogen (TN), nitrate plus nitrite N (NO_x-N), and sestonic chlorophyll-a (chl-a). Frequency distributions, including the minimum, 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentiles, and maximum values of these parameters, were calculated for the general population within each segment. Both sets of regional analyses indicated significant variability in potential nutrient and biological response target values for different geographic areas, with TP thresholds ranging from 0.065 – 0.93 mg/L and TN thresholds ranging from 0.72 – 1.1 mg/L for the two groups of estuaries with different contributing basins.

Total nutrient concentrations in Texas estuaries exhibit a threshold response to salinity. In Section 3.4, the potential mechanism for this relationship was explored by calculating monthly freshwater inflows to Texas estuaries and comparing inflows to salinity, nutrient concentrations, and biological response variables. Changepoint analysis indicated a threshold in freshwater inflow = 76,000 acft per month that was associated with an approximately 40% reduction in salinity on average. However, no quantifiable relationship was identified between nutrient or biological parameters and freshwater inflows. Variability in these parameters at low levels of freshwater inflow was high and may have obscured potential trends.

During 2011 – 2014, Texas experienced extreme drought conditions at the statewide level, most notably in 2011. In Section 3.5, potential shifts in data distributions and measures of central tendency for annual medians of water quality parameters during these drought years were explored through comparisons with data collected during periods of normal to above average precipitation in Texas (2001 – 2004). The most compelling evidence of drought effects was found for Texas estuaries among any of the water body types considered. For nitrogen parameters TN and NO_x-N, overlap in data distributions was minimal when annual medians from 2004 and 2011 were compared, while means and medians were up to 10x higher for wet years than for drought years. Differences were also observed in chl-a spec and PO_4-P between wet and drought years, but these differences were most likely attributable to changes in quantification limits (QL) and sampling protocols between the two periods.

INTRODUCTION

The Clean Water Act (CWA) directs states to adopt water-quality standards for all water bodies, including estuaries. The push in water-quality standards over the last decade or more has been for the development of numeric nutrient criteria applicable to all water bodies, and protective of designated beneficial uses, primarily, aquatic life and recreation. The United States Environmental Protection Agency (USEPA) has published a series of guidance documents detailing technical approaches that can be used to develop numeric nutrient targets, including frequency distributions of nutrient or biological data (USEPA, 2000) and the preferred stressor-response studies (USEPA, 2010). There is a growing wealth of information on streams, rivers, lakes and reservoirs, although the literature available on nutrient criteria development for estuaries is more limited because this water body type is more complex in nature, both in hydrology and in nutrient dynamics.

The complex hydrology of estuaries results from the mixing and density stratification of fresh and marine waters, and variation in mixing plays a role in nutrient dynamics and biological response. The sources of nutrients to estuaries are the surrounding landscape, tidal streams, large inland rivers draining to marine systems, ground water, and even atmospheric deposition. These external sources may lead to accumulation within estuarine systems that fuel internal cycling of nutrients and oxygen demand. However, nutrient inputs to estuaries are closely linked to freshwater inputs, including tidal streams and larger inland rivers draining into these systems. These interactions and a myriad of processes make establishing a link between stressors (e.g., nutrients) and response variables (e.g., oxygen concentration, sestonic or benthic algae, water clarity, etc.) difficult.

The USEPA has released guidance for the development of estuarine nutrient targets (USEPA, 2001), based on these selected elements: classification by physical characteristics (i.e., possible grouping of estuaries), analyses of historical data, reference site approach, and stressor-response relationships (i.e., modeling approaches). Guidance also focuses on examination of the information and proposed nutrient criteria by a panel of regional, federal, state and tribal experts and on determining the consequences of the criteria both upstream and downstream. However, the USEPA has not provided numerical guidance (based on frequency distribution of existing nutrient and biological conditions) for estuaries, as was provided for lakes and reservoirs (EPA 2000b) or streams and rivers (EPA 2000a). Nonetheless, states are directed to develop numeric nutrient targets for estuaries and coastal waters protective of beneficial uses, as defined by each state’s regulatory agency. The development of numeric nutrient targets will allow the states to manage nutrient enrichment of coastal waters and the associated effects on recreation and biological conditions.

The effects of nutrient enrichment in estuaries share some similarities with freshwaters, but the considerations generally focus on the development of harmful algal blooms (i.e., algal toxins), hypoxic conditions in coastal waters, and the impact on marine biology (i.e., accelerated eutrophication and oxygen demand), loss of submerged and shore-line vegetation native to coastal waters. Estuaries might also not show an increase in primary productivity (carbon fixation) with increased nutrient enrichment, because the productivity shifts from benthic algae to sestonic organisms (McGlathery et al. 2007). However, nutrient loads are positively correlated with the anoxic volume in coastal waters (Kemp et al. 2005, Conley et al. 2009, Breitburg et al. 2009), showing the nutrient enrichment reduces oxygen concentrations in overlying water especially when density stratification occurs (Stow et al. 2005). The literature on estuaries has generally focused on the relationship between dissolved oxygen, nutrients and biological conditions, and few studies have employed threshold analysis, and even fewer have identified nutrient thresholds. The associated effects of nutrient enrichment also influence the social and economic values, such as recreational opportunities, cultural uses, and marine fisheries.

The State of Texas has contracted with the Arkansas Water Resources Center since 2011 to analyze the state’s long-term water quality datasets. A median database for estuaries was developed as part of the FY2012-2013 contract and has served as the foundation for previous and the present analyses on Texas estuaries. This database is comprised of data provided by TCEQ that were collected from 1968 to 2012 from estuaries throughout Texas. Data were collected from 860 stations from 34 estuaries. The data describe 116 estuary characteristics and water quality parameters including nutrient and sediment concentrations, transparency, a range of physico-chemical parameters, and others. These data were subject to quality control measures outlined in the project QAPP. After organization into a workable database, data were analyzed for frequency distributions and stressor-response relationships. This process in described in detail in the final report of the FY2012-2013 contract (AWRC 2013).

Present project tasks focus on refining analytical goals set out in FY2012-2013. Stressor-response relationships were explored using changepoint analysis in a way that would result in potential chl-a or Secchi threshold values. Potential biological and nutrient target values relevant at the regional, or even segment-specific, scale were explored using frequency distribution and changepoint analysis of data collected specifically within these various geographic areas. For Texas estuaries, this objective involved separating estuaries into groups based on contributing basins. Finally, because Texas experienced widespread severe to exceptional drought from 2011-2014 (United States Drought Monitor; droughtmonitor.unl.edu), potential drought-related trends in the values of key biological and nutrient parameters were explored, as these trends could affect nutrient target development.

The objectives of this chapter for Texas estuaries are:

1) to explore whether changepoint analysis of stressor-response relationships can identify meaningful thresholds in median biological parameters (focusing on Secchi transparency and chlorophyll-a) relative to a gradient of median nutrient stressor values (focusing on TP and TN) by “flipping” traditional stressor and response variables;
2) to identify nutrient thresholds values associated with changes in the magnitude or variability of commonly measured biological parameters associated with contributing basins or groups of contributing basins;

3) to discuss the frequency distribution of median nutrient concentrations and response variables at the segment scale for Texas streams and rivers acquired from the Texas Commission of Environmental Quality (TCEQ);
4) to quantify potential relationships between freshwater inflows to estuaries, water chemistry, and biological response variables;
5) and to calculate a time-series of annual station medians and determine if a shift in the median values of key water quality parameters occurred in tandem with drought onset and persistence.

3.1 CHANGEPOINT ANALYSIS TO IDENTIFY THRESHOLDS IN BIOLOGICAL PARAMETERS

Methods

We used a novel application non-parametric changepoint analysis (nCPA; Qian et al. 2003, King and Richardson 2003), a stressor-response analysis related to CART, to identify thresholds in common biological response variables relative to gradients of nutrient stressor variables. This approach reverses the traditional stressor-response relationship, placing biological variables on the x-axis as the independent variable and nutrient variables on the y-axis as the dependent variable. These analyses were carried out on the median database for streams and rivers developed in FY2012-2013. The biological variables included in the analyses were median Secchi transparency (m; parameter code 00078C), median chlorophyll-a chl-a measured with spectrophotometry (chl-a spec; µg/L; 32211), and median chlorophhyll-a measured with fluorometry (chl-a fluoro; µg/L 70953). The nutrient variables included in the analysis were total phosphorus (TP; mg/L; 00665) and total nitrogen (TN; mg/L; 00600C).

CART analysis is a means to reduce data, based on quantifying thresholds in independent variables that are correlated with shifts in the magnitude and/or variability of dependent variables. This statistical procedure can also provide hierarchical structure in independent variables, showing multiple thresholds from the same or different independent variables. CART analysis is very useful for resolving nonlinear, hierarchical, and high-order interactions among predictor variables (De'Ath and Fabricius 2000) and for detecting numerical values that lead to ecological changes (Qian and others 2003). CART models use recursive partitioning to separate data into subsets that are increasingly homogeneous; for example, subsets of data representing similar nutrient conditions. This iterative process invokes a tree-like classification that can reveal relationships that are often difficult to reconcile with conventional linear models (Urban 2002). We "pruned" CART models to generate final models that balanced accuracy within the available dataset with robustness to novel data (Urban 2002). CART models were cross-validated to determine "pruning size" (i.e., the number of predictor variables included in the model). Model cross-validations were conducted using 10 random and similarly sized subsets of our data according to the method detailed by De'ath and Fabricius (2000). The optimum tree size for each model was selected using the minimum cross-validated error rule (De'ath and Fabricius 2000).

CART and nCPA analyses were performed using the MVPART library in R 2.9.1 (http://www.r-project.org/). Non-parametric changepoint analysis (nCPA) was used to determine model statistical significance ($p_{perm}<0.05$) and 95% confidence interval about the threshold estimate (Qian et al. 2003, King and Richardson 2003). This analysis uses random permutations to estimate a p value that can be used to determine Type I and II error associated with the threshold and simultaneously uses bootstrapping to calculate cumulative probability to estimate uncertainty and provide confidence estimates for the threshold. We required a minimum of 10 observations to be used in any single split in the CART model and that each terminal node in the model had a minimum of 5 observations. CART analysis is insensitive to missing data. Therefore, we did not remove observations from the data set due to missing values. We did required that all medians have a minimum of 10 observations used in calculation.

Results of changepoint analysis on the estuaries datasets suggested that 1 – 2 data points were potentially affecting the analyses as outlier values for each of the possible nutrient stressor-biological response pairs. Therefore, changepoint analyses were repeated for each of these pairs after removing potential outlier values. For TP, analyses were repeated once to screen for potential outlier effects after removing values >0.40 mg TP/L. No potential outliers were identified for TN.

A user's guide to interpreting CART and nCPA models and associated summary statistics is available in Appendix 1.1. In Appendix 3.1, the statistical code and raw output generated for each CART and nCPA analysis conducted for this study on stressor-response relationships in the Texas streams and rivers bioassessment database has been compiled.

The chl-a and Secchi transparency thresholds identified through "flipped" changepoint anlaysis were compared to other potential biological response targets to determine whether this exploratory method yielded values that were relatively more or less conservative of water quality (Table 3.1.1). The sources of other potential targets available to TCEQ included recommendations by USEPA (2000) for streams and rivers within aggregate ecoregions, 25^{th} percentiles of Texas estuary station medians, and mean chl-a or transparency for station medians assigned to low and high nutrient groups. The latter two sources were derived from results of analyses carried out during FY2012-2013 contract (AWRC 2013). Low and high nutrient groups directly corresponded to changes in biological response and consisted of stations with median TP or TN that was either less than a relevant TP or TN threshold for low nutrient groups, or exceeded a relevant TP or TN threshold for high nutrient groups. Characteristics of these low and high nutrient station groups, including the mean, maximum, minimum, and relevant threshold for TP or TN are summarized in Table 3.1.2.

Results and Discussion

Sestonic Chlorophyll-a

For models relating TP and chl-a in Texas estuaries, thresholds were identified in chl-a = 10.7 – 13.8 µg/L (Fig. 3.1.1A, C). On average, TP concentration was more than 2x greater when chl-a exceeded the identified thresholds. These thresholds were close in range with chl-a concentrations representative of the relatively narrow range of mean chl-a spec for low and high TP estuary groups (i.e. stations with median TP below TP thresholds for low nutrient groups and above the TP thresholds for high nutrient groups; see Table 3.1.2), as identified by changepoint analyses relating chl-a and TP in FY2012-2013 (Table 3.1.1). The difference between mean chl-a associated with low and high TP estuary groups (6.5 and 14 µg/L, respectively) was greater for the fluorometric method, and the chl-a threshold = 11 µg/L from the present "flipped" analysis was mid-range between these means.

For chl-a spec, predictive power (r^2) for the "flipped" model was approximately 2x greater than for the traditional chl-a spec vs. TP stressor response model (r^2= 0.20 – 0.35 vs. r^2 = 0.13), which is in contrast to findings from streams and rivers and reservoirs, where "flipped" model strength was either less than or comparable to strength of traditional changepoint models. For chl-a fluoro, model r^2 was close in range for both "flipped" and traditional models (r^2 = 0.24 – 0.25).

Table 3.1.1. Summary of potential response variable targets for Secchi transparency and chlorophyll-a measured spectropotometrically (chl-a spec) and fluorometrically (chl-a fluoro). Sources of potential response variable targets include the present "flipped" changepoint analysis and USEPA (2000), as well as values drawn from the FY2012 – 2013 contract, including 25th percentile estimates for Texas and the average value of the response variable associated with high and low TP and TN groups of estuaries determined using changepoint analysis of the cumulative estuaries median dataset. A dash indicates that a given estimate of a possible target was not available. The letters "NO" indicate the threshold estimate generated after removing outliers, or data points that were disproportionally affecting analytical outcomes, such as the changepoint or model explanatory power.

	Potential criterion					
Parameter	CP Flip TP Models	CP Flip TN Models	Low TP	High TP	Low TN	High TN
Secchi (m)	0.58-0.63	0.64	0.85	0.54	0.71	0.56
Chl-a Spec (µg/L)	11-14	-	9.9	13	10	14
Chl-a Fluoro (µg/L)	11	12	6.5	14	6.4	18

Table 3.1.2. Nutrient concentration mean and range for stations categorized as "low" and "high" nutrient based on thresholds identified in changepooint analysis of stressor-response relationships as part of the FY2012-13 contract (AWRC 2013). The count of stations classified as "low" nutrient, or having a nutrient median below a nutrient threshold, or "high" nutrient, or having a nutrient median above a nutrient threshold are also provided for each stressor-response pair with a statistically significant threshold. For stressor-response pairs that did not have a statistically significant threshold, low and high nutrient groups could not be identified and no summary characteristics of groups were provided, as indicate by a dash.

			Total Nutrient Concentration (mg/L)			
Response parameter	Nutrient parameter	Threshold	Low Nutrient Mean (Count)	Low Nutrient Range	High Nutrient Mean	High Nutrient Range
Chl-a spec	TP	0.25	0.094 (76)	0.50 – 0.23	0.35 (14)	0.25 – 0.76
	TN	1.3	0.88 (53)	0.55 – 1.3	1.7 (12)	1.3 – 2.0
Chl-a fluoro	TP	0.11	0.071 (52)	0.060 – 0.11	0.18 (20)	0.11 – 0.76
	TN	1.1	0.81 (52)	0.55 – 1.1	1.6 (13)	1.1 – 2.0
Secchi	TP	0.068	0.060 (35)	0.050 – 0.065	0.16 (171)	0.070 – 0.76
	TN	0.85	0.70 (54)	0.55 – 0.85	1.1 (104)	0.85 – 2.0

The results of analyses conducted to screen for potential outlier effects indicated that high TP values >0.40 mg TP/L were skewing the threshold value for chl-a spec upward. After excluding two observations and repeating changepoint analysis, the chl-a spec threshold was lowered to 10.7 µg/L from 13.8 µg/L (Fig. 3.1.1B). In contrast, no change was observed in chl-a fluoro thresholds when high TP values were removed (Fig. 3.1.1D). For chl-a spec, model predictive power was reduced by removing high TP values (r^2 = 0.24 vs. r^2=0.35), suggesting that these values disproportionately inflated model r^2. In contrast, for chl-a fluoro, model predictive power increased after removing high TP values (r^2 = 0.25 vs. r^2=0.20).

For Texas estuaries, censored data clearly affected the results of changepoint analysis for models with chl-a spec as a variable. After removing the strong trend related to outliers, the chl-a spec threshold was adjusted to a value that was approximately equal to the common QL of 10 µg/L. This trend was almost certainly driven by the large number of stations with medians equal to 10 µg/L, indicating that these stations likely had > 50% censored chl-a spec data. However, in the case of Texas estuaries, it is possible that a real chl-a threshold exists in this range. The threshold for chl-a fluoro, which was not subject to a QL = 10 µg/L, was also 10.7 µg/L. Without advanced statistical analysis, it is not possible to determine with greater certainty, however, exactly how censored data affected these analyses.

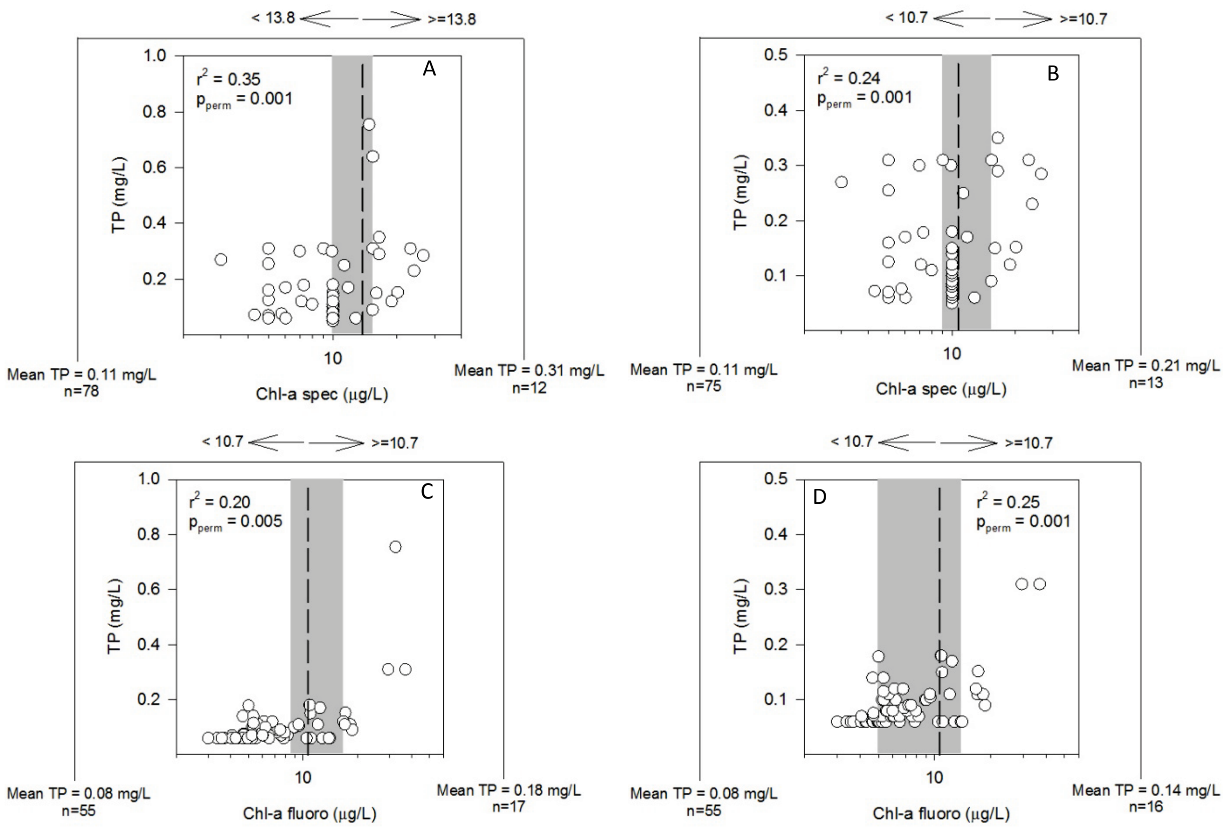


Figure 3.1.1. The "flipped" relationship between (A-B) chlorophyll-a measured spectrophotometrically (chl-a spec) or (C-D) fluorometrically and total phosphorus (A,C) with and (B,D) without possible outlier values. For statistically significant models (p<0.05), the chl-a threshold and confidence interval are shown as a dashed line and shaded area, respectively.

For Texas estuaries, the majority of chl-a spec station medians paired with TN medians were equal to 10 µg/L, or the common QL. Fewer than 10 of these chl-a spec medians were equal to values other than 10 µg/L. Because the analysis required that no fewer than 10 medians be partitioned on either side of a threshold, this analysis could not be completed (Fig. 3.1.2A) and was therefore limited by the prevalence of censoring in the chl-a spec data. For models relating TN and chl-a fluoro, a threshold was identified in chl-a fluoro = 11.6 µg/L (Fig. 3.1.2B). On average, TN concentration was almost 2x greater when chl-a fluoro exceeded this threshold. This threshold was mid-range among the chl-a concentrations representative of mean chl-a for low and high TN station groupings (see Table 3.1.2), as identified by changepoint analyses relating chl-a and TN in FY2012-2013 (Table 3.1.1). Therefore, these thresholds represent moderately conservative potential chl-a targets.

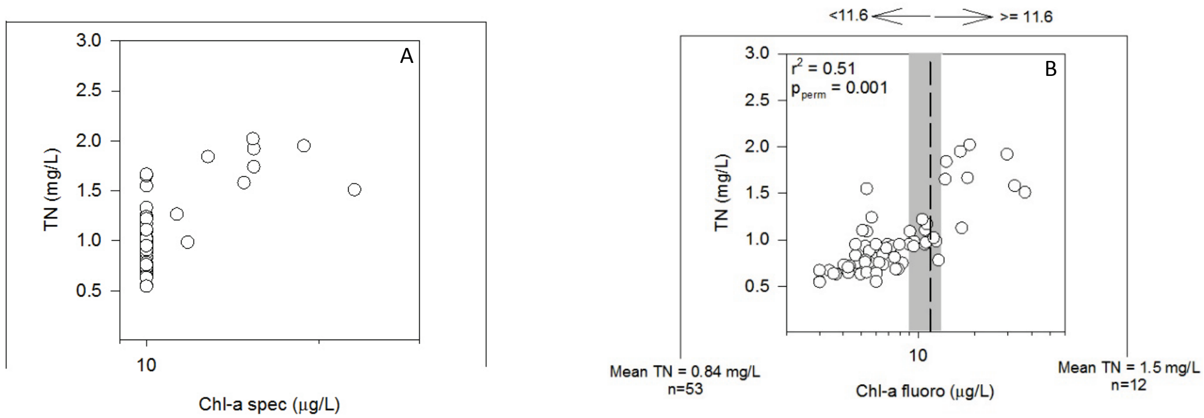


Figure 3.1.2. The "flipped" relationship between chlorophyll-a measured (A) spectrophotometrically (chl-a spec) or (B) fluorometrically (chl-a fluoro) and total nitrogen. For statistically significant models ($p<0.05$), the chl-a threshold and confidence interval are shown as a dashed line and shaded area, respectively. For stressor-response pairs that did not yield statistically significant, only the scatterplot is shown.

Secchi transparency

For models relating TP and Secchi transparency, a threshold in Secchi transparency = 0.58 m (Fig. 3.1.3A) was identified. On average, TP concentration was almost 2x lower when Secchi transparency exceeded this threshold. This threshold was in range with Secchi transparency representative of average transparency in high TP station groups (see Table 3.1.2), as identified through changepoint analysis of the Secchi transparency and TP relationship in FY2012-2013 (Table 3.1.1). However, this threshold was 35% less than the average transparency in corresponding low TP estuary groups. Therefore, the Secchi transparency threshold identified in the current analyses is less conservative than other potential target values derived from the Texas estuary dataset using changepoint analysis.

The results of analyses conducted to screen for potential outlier effects indicated that high TP values >0.40 mg TP/L were affecting the value of the threshold identified in changepoint analysis. However, the difference between thresholds with and without these high values was minor. After excluding high TP observations and repeating changepoint analysis, the Secchi transparency threshold increased from 0.58 m to 0.63 m (Fig. 3.1.3B). Model predictive power was improved by removing high TP values ($r^2 = 0.21$ vs. $r^2=0.15$), but was still lower than that of the traditional stressor-response model relating transparency and TP in FY 2012-2013 ($r^2 = 0.29$).

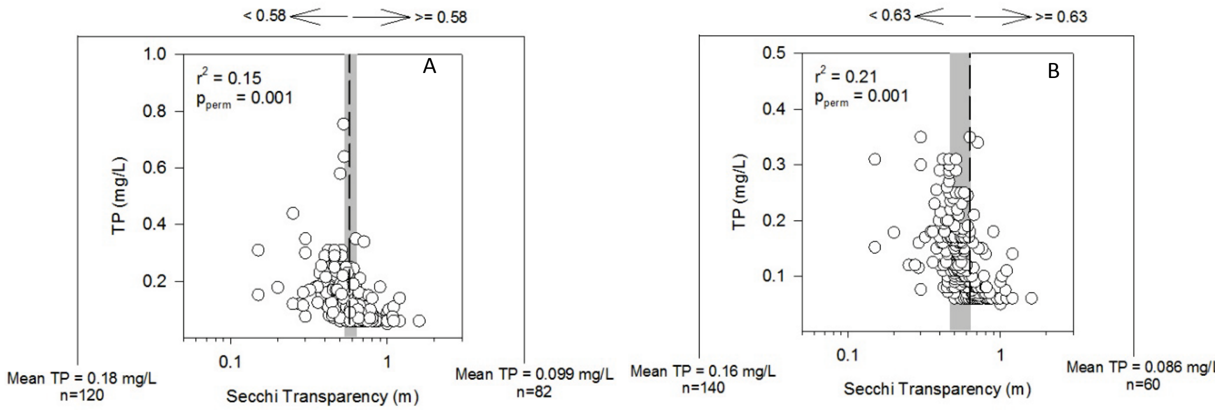


Figure 3.1.3. The "flipped" relationship between Secchi transparency and total phosphorus (A) with and (B) without potential outlier TP values > 0.40 mg/L. For statistically significant models (p<0.05), the transparency threshold and confidence interval are shown as a dashed line and shaded area, respectively.

For models relating TN and Secchi transparency, a threshold in Secchi transparency = 0.64 m was identified for Texas estuaries (Fig. 3.1.4). On average, TN concentration was approximately 15% lower when Secchi transparency exceeded 0.64 m. This threshold was mid-range with Secchi transparencies representative of average transparency in low and high TN estuary groups (see Table 3.1.2), as identified through changepoint analysis of the Secchi transparency and TN relationship in FY2012-2013 (Table 3.1.1). Therefore, the Secchi transparency threshold identified in the current analyses is moderately conservative when compared with other potential criteria values derived from the Texas estuary dataset using changepoint analysis. Model explanatory power was 50% less for the "flipped" model compared to the traditional stressor response model ($r^2 = 0.07$ vs. $r^2 = 0.14$). This threshold would be considered statistically weak and should be used with caution in setting Secchi transparency criteria for Texas estuaries.

Summary of "Flipped" Stressor-Response Analysis for Texas Estuaries

For the biological and nutrient parameter pairs considered in these analyses, potential biological thresholds provided a wide range of explanatory power for stressor-response relationships in the Texas estuaries dataset. The strongest relationships were between TN and chl-a fluoro, followed by TP and both biological variables. This finding contrasts with findings from "flipping" stressor-response relationships to analyze the Texas streams and rivers database for biological thresholds. Stronger results for "flipped" analyses in Texas estuaries relative to streams and rivers likely reflects the fact that the traditional stressor-response models were also stronger for estuaries.

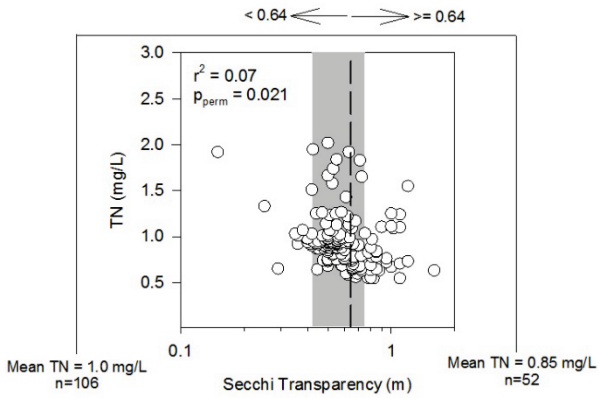


Figure 3.1.4. The "flipped" relationship between Secchi transparency and total nitrogen. For statistically significant models (p<0.05), the transparency threshold and confidence interval are shown as a dashed line and shaded area, respectively.

For the Texas estuaries dataset, we observed some evidence of outlier effects in analyses relating TP to biological parameters. These effects were not as pronounced as what was observed for Texas reservoirs, but the range of TP values for estuaries was more narrowly constrained with TP always less than 1 mg/L. Removing medians pairs where TP > 0.40 mg/L may be necessary to more clearly understand "flipped" stressor-response relationships in Texas estuaries. This finding contrasts with findings from the traditional stressor-response models developed for Texas estuaries in FY2012-2013. No outlier effects were observed in these analyses. These differences may have occurred, however, because outlier values were in TP only and on the y-axis in "flipped" analyses, making changepoint analysis more sensitive to them.

The results of these analyses indicated several strong biological response thresholds relative to nutrient gradients in Texas estuaries. However, "flipping" the traditional configuration of stressor and response variables in changepoint analysis to find biological response thresholds is a novel use of the analysis that has not been peer-reviewed or published. Therefore, the findings of these analyses should be interpreted with caution for use in setting numeric chl-a or transparency targets for Texas estuaries.

3.2 NUTRIENT THRESHOLDS SPECIFIC TO CONTRIBUTING BASINS TO TEXAS ESTUARIES

Methods

We conducted CART analyses on the median database for estuaries to identify thresholds in nutrient concentrations that resulted in measurable changes in common biological responses within groups of basins contributing flow to Texas estuaries. Data were too limited to conduct analyses for each basin contributing flow to Texas estuaries. Therefore, estuaries were divided into 2 groups based on the latitudinal gradient of contributing basins. The northern group consisted of estuaries receiving flow from

Basins 5-11. The southern groups consisted of estuaries receiving flow from Basins 13-23. No medians with n≥10 observations were available for estuaries receiving flow from Basin 12. The bays and estuaries included in this group are listed in Table 3.2.1. The biological (dependent) variables included in the analyses were median Secchi depth (m; parameter code 00078C), median chlorophyll-a measured with spectrophotometry (chl-a spec; 32211), and median chlorophyll-a measured with fluorometry (chl-a fluoro; 70953). The nutrient (independent) variables included in the analysis were total phosphorus (TP; 00665) and total nitrogen (TN; 00600C). We required a minimum of 20 paired medians within groups of contributing basins for the analysis.

CART analysis is a means to reduce data, based on quantifying thresholds in independent variables that are correlated with shifts in the magnitude and/or variability of dependent variables. This statistical procedure can also provide hierarchical structure in independent variables, showing multiple thresholds from the same or different independent variables. CART analysis is very useful for resolving nonlinear, hierarchical, and high-order interactions among predictor variables (De'Ath and Fabricius 2000) and for detecting numerical values that lead to ecological changes (Qian and others 2003). CART models use recursive partitioning to separate data into subsets that are increasingly homogeneous; for example, subsets of data representing similar nutrient conditions. This iterative process invokes a tree-like classification that can reveal relationships that are often difficult to reconcile with conventional linear models (Urban 2002). We "pruned" CAμRT models to generate final models that balanced accuracy within the available dataset with robustness to novel data (Urban 2002). CART models were cross-validated to determine "pruning size" (i.e., the number of predictor variables included in the model). Model cross-validations were conducted using 10 random and similarly sized subsets of our data according to the method detailed by De'ath and Fabricius (2000). The optimum tree size for each model was selected using the minimum cross-validated error rule (De'ath and Fabricius 2000).

Table 3.2.1. Names and ID's of Texas estuaries included in each of the contributing basin groups. Estuaries not included in these lists did not have stations with medians with n≥10 observations.

Estuaries with Contributing Basins 5 – 11		Estuaries with Contributing Basins 13 - 23	
ID	Name	ID	Name
3	Bastrop Bay/Oyster Lake/Christmas Bay/Drum Bay	1	Aransas Bay
4	Burnett Bay/Black Duck Bay/San Jacinto/Scott Bay	2	Baffin Bay/Alazan Bay/Cayo Del Grullo/Laguna Salada
7	Chocolate Bay	8	Copano Bay/Port Bay/Mission Bay
11	East Bay	9	Corpus Christi Bay
19	Lower Galveston Bay	14	Espiritu Santo Bay
22	Moses Lake	16	Laguna Madre
27	Sabine Lake	21	Mesquite Bay/Carlos Bay/Ayres Bay
31	Tabbs Bay	23	Nueces Bay
33	Trinity Bay	25	Oso Bay
34	Upper Galveston Bay	26	Redfish Bay
35	West Bay	28	San Antonio Bay/Hynes Bay/Guadalupe Bay
36	Clear Lake	29	South Bay/Brownsville Ship Channel
		30	St Charles Bay

CART analyses were performed using the MVPART library in R 2.9.1 (http://www.r-project.org/). Non-parametric changepoint analysis was used to determine model statistical significance (p_{perm}<0.05) and 95% confidence interval about the threshold estimate (Qian et al. 2003, King and Richardson 2003). This analysis uses random permutations to estimate a p value that can be used to determine Type I and II error associated with the threshold and simultaneously uses bootstrapping to calculate cumulative probability to estimate uncertainty and provide confidence estimates for the threshold. We required a minimum of 5 observations to be used in any single split in the CART model and that each terminal node in the model had a minimum of ten observations. CART analysis is insensitive to missing data. Therefore, we did not remove observations from the data set due to missing values. We required that all calculated medians have a minimum of 10 observations used in calculating the median value.

Results and Discussion

Thresholds within contributing basins group 5-11

For estuaries in the contributing basins group 5-11, analyses were somewhat limited by the number of station medians available, especially for chl-a. However, models relating Secchi transparency and total nutrient concentrations were statistically significant and indicated that transparency decreased with increasing nutrient concentrations. Changepoint analyses identified a TP threshold = 0.093 mg/L (Fig. 3.2.1A). On average, Secchi transparency was approximately 30% lower when TP concentrations exceeded 0.093 mg/L. This threshold was higher than the TP threshold (0.068 mg/L) identified for Secchi transparency using the cumulative estuaries dataset in FY2012-2013 analyses. Model explanatory power was similar between the models, but also somewhat reduced from cumulative dataset analyses (r^2 = 0.23 vs. r^2 = 0.29), though both models exhibited good explanatory power.

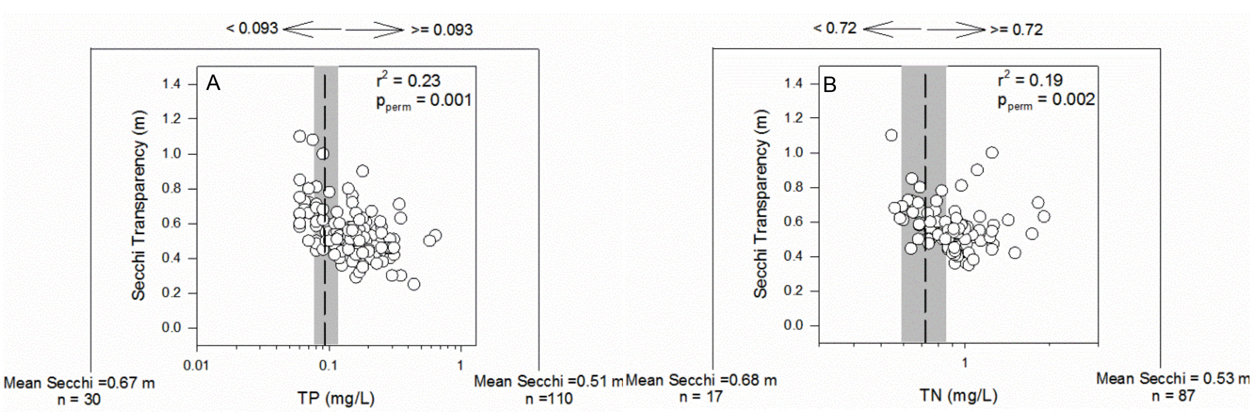


Fig. 3.2.1. The relationship between Secchi transparency and (A) TP and (B) TN within the contributing basins group 5-11 for Texas estuaries. For statistically significant models (p<0.05), the nutrient threshold and confidence interval are shown as a dashed line and shaded area, respectively.

Changepoint analysis also identified a TN threshold = 0.72 mg/L relative to Secchi transparency (Fig. 3.2.1B). On average, transparency was approximately 30% lower when TN concentrations exceeded 0.72 mg/L. This threshold was close in range with the TN threshold (0.85 mg/L) identified for Secchi transparency using the cumulative estuaries dataset in FY2012-2013. Explanatory power was also similar between the models, but slightly higher for the contributing basin-specific model (r^2 = 0.19 vs. r^2 =0.14).

For estuaries in the contributing basins group 5-11, no statistically significant models (p>0.05) relating chl-a and total nutrients were found. The possible model relating chl-a spec to TP did not meet requirements for statistical significance. The scatterplot for this stressor-response relationship is shown in Fig. 3.2.2A. The number of station medians available for analyses was n<20 for possible models relating chl-a spec to TN, and chl-a fluoro to both TP and TN (Fig. 3.2.2B-D).

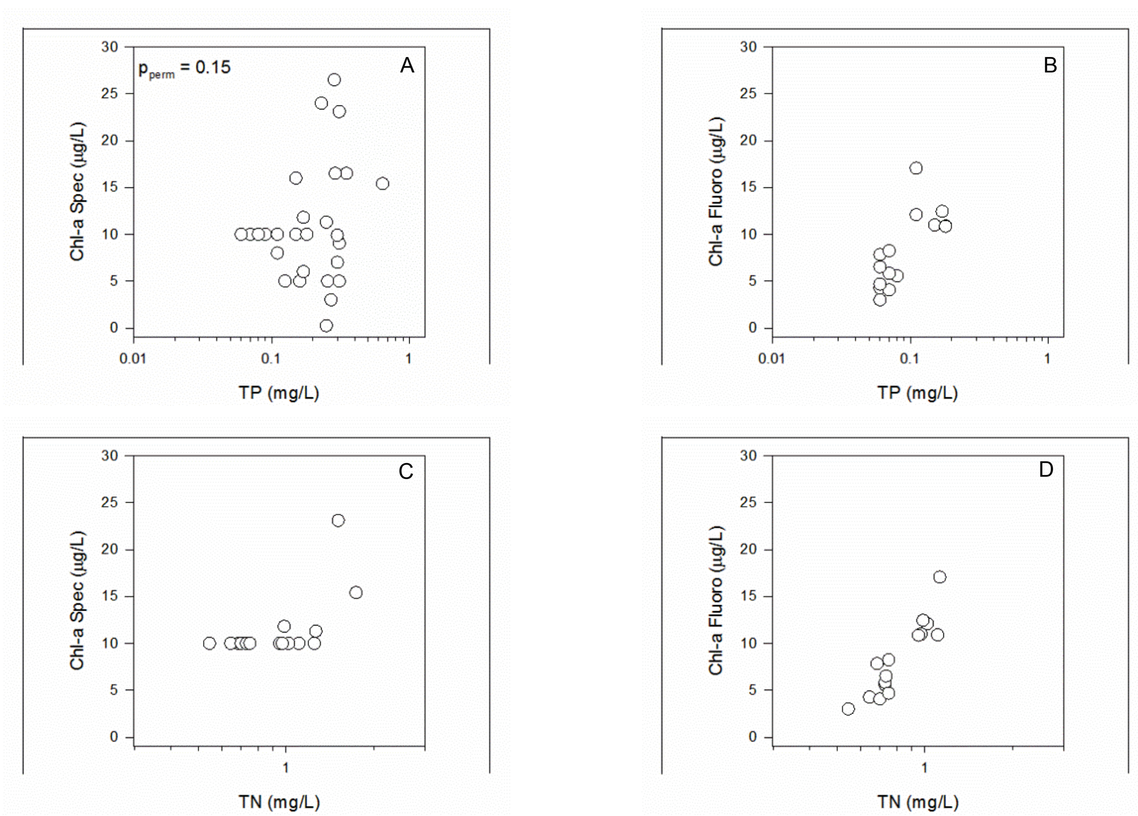


Fig. 3.2.2. The relationship between chl-a spec or chl-a fluoro and (A-B) TP and (C-D) TN within the contributing basins group 5-11 for Texas estuaries. For stressor-response pairs that did not yield statistically significant thresholds, only the scatterplot is shown.

Thresholds within contributing basins group 13-23

For estuaries in the contributing basins group 13-23, all models relating Secchi transparency and total nutrient concentrations were statistically significant and indicated that transparency decreased with increasing nutrient concentrations. Changepoint analyses identified a TP threshold = 0.065 mg/L (Fig. 3.2.3A) that was close in range with the TP threshold (0.068 mg/L) identified for Secchi transparency using the cumulative estuaries dataset in FY2012-2013 analyses. On average, Secchi transparency was more than 30% lower when TP concentrations exceeded 0.065 mg/L. Model explanatory power was good and also identical between the models (r^2 = 0.29). This finding suggests that the larger data pool in this group of contributing basins dominated analyses of the cumulative dataset in FY2012-2013. In both cases, the value of the TP threshold, which was close in range with that of the most common QL, may also have been influenced by the prevalence of censored data.

Changepoint analysis of the transparency and TN relationship identified a TN threshold = 0.74 mg/L (Fig. 3.2.3B). On average, transparencies were approximately 30% lower when TN concentrations exceeded 0.74 mg/L. This threshold was close in range with the TN threshold (0.85 mg/L) identified for Secchi transparency using the cumulative estuaries dataset in FY2012-2013. Explanatory power was also similar between the models, though slightly higher for the contributing basin-specific model (r^2 = 0.20 vs. 0.14).

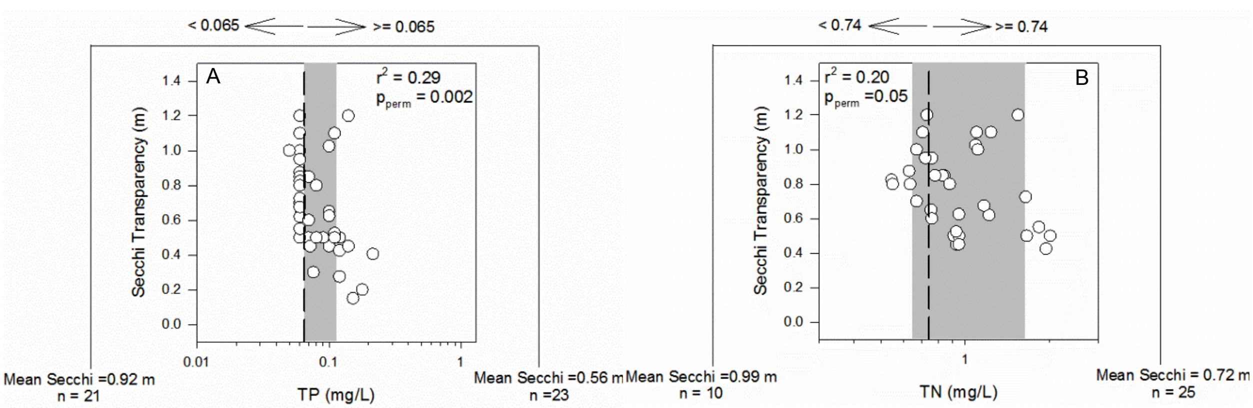


Fig. 3.2.3. The relationship between Secchi transparency and (A) TP and (B) TN within the contributing basins group 13-23 for Texas estuaries. For statistically significant models (p<0.05), the nutrient threshold and confidence interval are shown as a dashed line and shaded area, respectively.

Models relating chl-a and TP did not identify a statistically significant TP threshold ($p<0.05$) for chl-a spec (Fig. 3.2.4A), but were successful in identifying a TP threshold for chl-a fluoro (3.2.4B). For chl-a fluoro, a threshold in TP = 0.085 mg/L was identified and indicated that chl-a fluoro concentrations increased with increasing TP. On average, chl-a fluoro concentrations were approximately 40% higher when TP concentrations exceeded 0.085 mg/L. This threshold was approximately 20% lower than the threshold identified for chl-a fluoro using the cumulative estuaries dataset in FY2012-2013 analyses. Model explanatory power was lower for the model relating chl-a fluoro to TP in the contributing basins 13-23 dataset than in the cumulative dataset ($r^2 = 0.15$ vs. $r^2 = 0.25$).

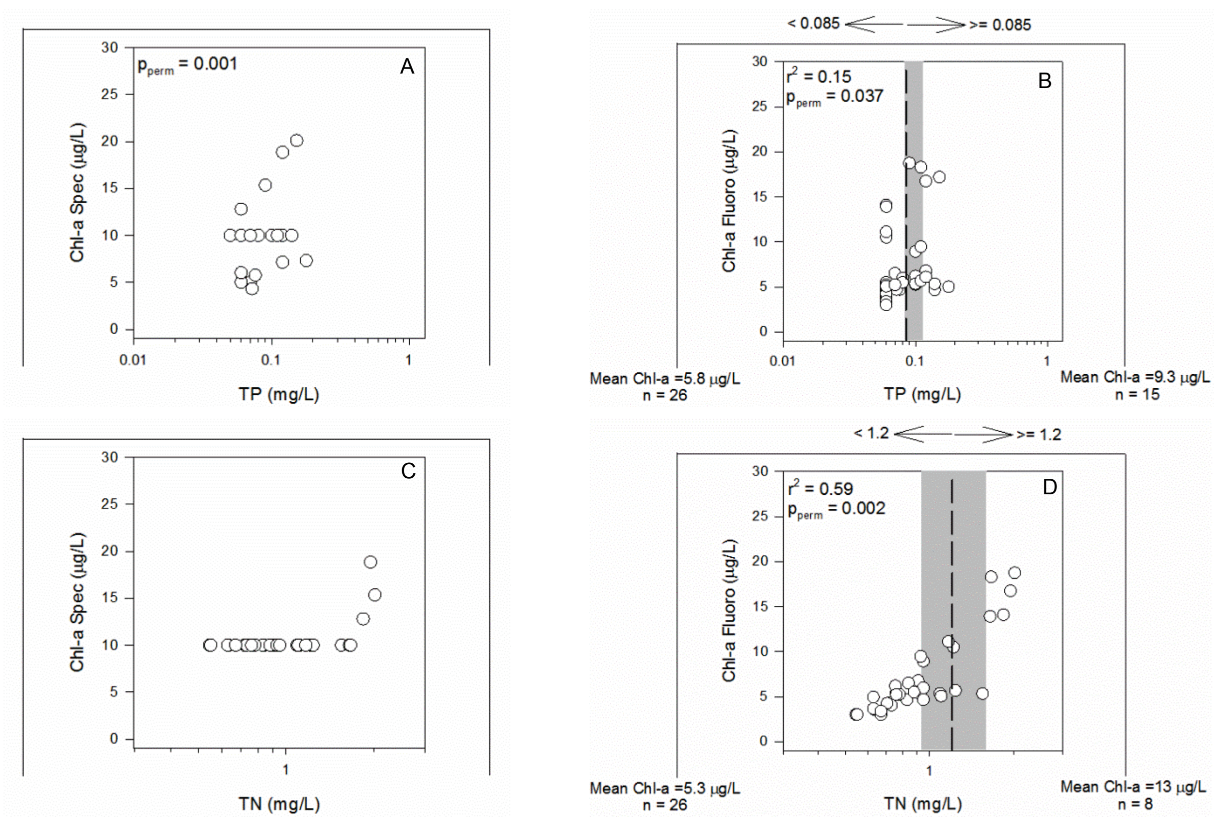


Fig. 3.2.4. The relationship between chl-a spec or chl-a fluoro and (A-B) TP and (C-D) TN within the contributing basins group 13-23 for Texas estuaries. For statistically significant models ($p<0.05$), the nutrient threshold and confidence interval are shown as a dashed line and shaded area, respectively. For stressor-response pairs that did not yield statistically significant results, only the scatterplot is shown.

Attempted analyses of the potential relationship between chl-a spec and TN (Fig. 3.2.4C) were limited by the prevalence of censored chl-a spec data and resulted in error because only 3 stations chl-a spec station medians were not equal to 10 µg/L, the value of the most common chl-a spec QL. However, models relating chl-a fluoro and TN did identify a statistically significant TN threshold = 1.2 mg/L (Fig. 3.2.4D). This threshold was close in range with the TN threshold identified for chl-a fluoro using the cumulative estuaries dataset in FY2012-2013 analyses. On average, when TN concentration exceeded 1.2 mg/L, chl-a fluoro concentrations were approximately 60% higher in Texas estuaries. This division was the most significant difference between high and low nutrient groups observed in the present analyses. Model explanatory power was also high (r^2=0.59) relative to all other models in the present analyses and also relative to the cumulative dataset model (r^2=0.47). Together, these findings suggest that setting targets for TN in this group of estuaries may be especially useful to maintaining water quality.

Summary of stressor-response analysis for Texas estuaries grouped by contributing basins

In the regional analysis of stressor-response relationships, we observed differences in nutrient thresholds between the two groups of basins contributing flow to Texas estuaries. These differences were most pronounced for the Secchi transparency and TP relationship. Analysis of chl-a and total nutrient stressor-response pairs was often limited by data availability. The TP threshold identified for Secchi transparency for estuaries in the contributing basins 5-11 group was approximately 30% higher than for estuaries in the contributing basins 13-23 group. The TP threshold for the contributing basins 3-23 group was also closer in range with the threshold identified in the cumulative dataset in FY2012-2013 analyses. These findings suggest that potentially important regional differences exist between Texas estuaries based on factors associated with different contributing basins, and that data from the basins 13-23 were dominant in analyses of the cumulative dataset. Therefore, it may be important to separate estuaries geographically, or by inflow, to fully capture stressor-response relationships. Texas estuaries were grouped by geographically proximate basins with a natural division between groups occurring to the north and south of Basin 12. More appropriate and precise grouping schemes may exist for Texas estuaries that capture differences in topography and climate between estuaries. However, data availability is somewhat limited for this water body type, particularly for chl-a. Therefore, data may not currently be sufficient for further division of estuaries into groups and more elaborate geographical grouping schemes.

3.3 FREQUENCY DISTRIBUTION ANALYSIS FOR TEXAS ESTUARY SEGMENTS

Methods

For this study, frequency distribution analyses were conducted on station medians within Texas estuary segments defined by TCEQ (https://gisweb.tceq.texas.gov/segments/default.htm). Because each estuary station within a segment was not equally represented in the raw water quality dataset, frequency distributions were calculated for medians to remove potential site-specific bias for sites that are over- or under-represented in the raw dataset. Furthermore, biological response and nutrient stressor data did not always overlap in the raw data. Conducting analyses with median values allowed comparison of long-term trends in biological and nutrient data for these stations.

Frequency distributions (minimum value, 10th, 25th, 50th, 75th, 90th percentiles and maximum value) were calculated using Microsoft Excel for water quality parameters total phosphorus (TP; TCEQ parameter code 00665), total nitrogen (TN; calculated parameter code 00600C; TCEQ parameter code 00625 + 00630, 00625 + 00593 or 00625 + 00615 + 00620), nitrate+nitrite-nitrogen (NO_x-N; calculated parameter 00630C; TCEQ parameter code 00630, 00593 or 00615 + 00620), orthophosphate-phosphorus (PO_4-P; TCEQ calculated parameter code 00671C; TCEQ parameter code 00671 or 70507), and sestonic chlorophyll-a measured fluorometrically (chl-a fluoro; TCEQ parameter code 70953). For this study, a parameter combining chl-a measured spectrophotometrically and fluorometrically measured chlorophyll-a was not created due differences between the methods (Laurie Eng, personal communication). Because data were more complete and censorship was less of a concern than for spectrophotometric chl-a, frequency distributions for sestonic chl-a were only calculated for the fluorometric method.

Results and Discussion

For Texas estuaries, 60 unique segment codes were identified. For all parameters of interest, the majority of these segments contained fewer than 4 station medians and were therefore not eligible for calculation of 25th percentile estimates. One estuary segment contained 30 or more station medians for each of the parameters of interest, except chl-a fluoro. Thirty data points is the minimum number recommended by the EPA for frequency distribution analysis.

Significant variability in 25th percentiles among segments with n ≥4 station medians was observed for some of the parameters of interest (Appendix 1.2, Table A1.2.1), most notably for TP and PO_4-P. For TP, 10 segments had ≥4 medians, and 25th percentiles ranged from 0.060 – 0.17 mg/L. For TN, 8 segments had ≥4 medians, and 25th percentiles ranged from 0.65 – 0.95 mg/L. For NO_x-N, 9 segments had ≥4 medians, and 25th percentiles ranged from 0.040 – 0.070 mg/L. For PO_4-P, 9 segments had ≥4 medians, and 25th percentiles ranged from 0.040 – 0.11 mg/L. For chl-a fluoro, 3 segments had ≥4 medians, and 25th percentiles ranged from 3.4 – 5.4 µg/L.

Summary of frequency distributions by segment for Texas estuaries

Significant variability in 25th percentiles among segments with n ≥4 station medians was observed in these analyses for TP and PO_4-P. While only one estuary segment included 30 or more station medians, these percentile estimates may be a useful tool for identifying estuary segments that would be in or out of compliance with proposed nutrient and biological response criteria or as part of a weight of evidence approach to setting segment-specific criteria. Furthermore, we recommend that TCEQ review whether combining segments with overlapping designations would be appropriate for calculating segment-specific frequency distributions. If appropriate, combining segments with overlapping designations would increase the number of medians per segment for some Texas estuary segments.

3.4 ESTUARY FLOW-DRIVEN NUTRIENT CONCENTRATIONS AND BIOLOGICAL RESPONSE

Methods

Freshwater inflow records

Long-term records (1977-2014) of freshwater inputs to Texas estuaries were developed by obtaining estimates of daily freshwater inflows from the Texas Water Development Board (TWDB). These estimates included in-stream flow calculated from gage data from United States Geological Service (USGS) or from models using information like precipitation and relief for ungaged coastal subwatersheds with tidal influence on flow regimes. Freshwater inflow estimates with modeled in-stream flow also accounted for point-source return minus diversions. For all coastal subwatersheds defined by TWDB and for all major river basins upstream of tidal influence, daily freshwater inflows were aggregated over a monthly time step by summing all daily flows within the period of interest.

Freshwater inflows were estimated by the TWDB for groups of estuaries, comprised of a major estuary and associated smaller estuaries. Major estuaries, as defined by TWDB, are Sabine Lake (Sabine-Neches), Galveston Bay (Trinity-San Jacinto), East Matagorda Bay, Matagorda Bay (Colorado-Lavaca), San Antonio Bay (Guadalupe), Aransas Bay (Mission-Aransas), Corpus Christi Bay (Nueces), and Laguna Madre Estuary. Freshwater inflows were also available for two minor estuaries, the Brazos River Estuary and the San Bernard River Estuary, but no water quality data were present in the FY2012-2013 estuaries median water quality database for these waterbodies. Freshwater inflows to other minor estuaries have not been estimated by the TWDB. Estuaries for which no data were present for either the water quality or freshwater inflow component could not be included in subsequent analyses of the potential effects of freshwater inflows on common water quality metrics.

Texas estuaries have been assigned numeric Estuary ID's by TCEQ that identify estuaries at a smaller scale than the major estuary complexes defined by TWDB. Therefore, TWDB cumulative freshwater inflow estimates had to be broken up by individual river basins and coastal subwatersheds to accurately reflect freshwater inflows to all but the largest and most downstream estuaries under the TCEQ identification system. Some TCEQ Estuary ID's covered multiple small estuaries that needed to be assigned different contributing subwatersheds. Therefore, a new Estuary ID, combining the numeric TCEQ Estuary ID with a letter (a, b, c, etc.) was assigned to these estuaries. Coastal subwatersheds and major river basins were assigned as contributing areas to each Texas estuary with a unique Estuary ID in Arc GIS 10.2.2 by overlaying TWDB subwatersheds layers with corresponding HUC 10 shapes and stream layers to identify connectivity and the direction of flow within each coastal subwatershed. For some Texas estuaries, determining areas contributing flow specifically to that estuary was not possible (e.g. Redfish Bay), therefore these estuaries were not included in subsequent analyses.

Once all areas contributing flow to Texas estuaries were identified, cumulative freshwater inflow to each estuary was calculated for a monthly time-step by summing freshwater inflows for every major river basins or coastal subwatersheds contributing flow to an estuary. These monthly freshwater inflow estimates were then joined to raw water quality observations for parameters of interest, which included total phosphorus (TP; parameter 00665), total nitrogen (TN; parameter 00600C), salinity (parameter 00480), Secchi transparency (parameter 00078C), and chorophyll-a measured spectrophotometrically (chl-a spec; parameter 32211) and fluorometrically (chl-a fluoro; parameter 70953). Monthly freshwater inflow estimates for the period of 2000 – 2010 were matched with raw water quality data observations organized during the FY2012-2013 contract for the above-defined parameters of interest from all stations located within a given estuary. For months where more than one sample was collected at one or more stations within an estuary, raw values were averaged across estuary stations so that only a single value for a parameter of interest would be matched to a monthly freshwater inflow estimate.

Freshwater inflow, nutrient, and biological response comparisons

We conducted CART analyses of relationships between water quality parameters of interest and monthly freshwater inflow estimates. Potential flow-driven water chemistry was explored through variables including salinity (00480), total phosphorus (TP; 00665), and total nitrogen (TN; 00600C). Potential flow-driven biological response was explored through variables including Secchi depth and chlorophyll-a measured with spectrophotometry and with fluorometry.

CART analysis is a means to reduce data, based on quantifying thresholds in independent variables that are correlated with shifts in the magnitude and/or variability of dependent variables. This statistical procedure can also provide hierarchical structure in independent variables, showing multiple thresholds from the same or different independent variables. CART analysis is very useful for resolving nonlinear, hierarchical, and high-order interactions among predictor variables (De'Ath and Fabricius 2000) and for detecting numerical values that lead to ecological changes (Qian and others 2003). CART models use recursive partitioning to separate data into subsets that are increasingly homogeneous; for example, subsets of data representing similar nutrient conditions. This iterative process invokes a tree-like classification that can reveal relationships that are often difficult to reconcile with conventional linear models (Urban 2002). We "pruned" CART models to generate final models that balanced accuracy within the available dataset with robustness to novel data (Urban 2002). CART models were cross-validated to determine "pruning size" (i.e., the number of predictor variables included in the model). Model cross-validations were conducted using 10 random and similarly sized subsets of our data according to the method detailed by De'ath and Fabricius (2000). The optimum tree size for each model was selected using the minimum cross-validated error rule (De'ath and Fabricius 2000).

CART analyses were performed using the MVPART library in R 2.9.1 (http://www.r-project.org/). Non-parametric changepoint analysis was used to determine model statistical significance ($p_{perm}<0.05$) and 95% confidence interval about the threshold estimate (Qian et al. 2003, King and Richardson 2003). This analysis uses random permutations to estimate a p value that can be used to determine Type I and II error associated with the threshold and simultaneously uses bootstrapping to calculate cumulative probability to estimate uncertainty and provide confidence estimates for the threshold. We required a minimum of 10 observations to be used in any single split in the CART model and that each terminal node in the model had a minimum of ten observations. CART analysis is insensitive to missing data. Therefore, we did not remove observations from the data set due to missing values. We required that all calculated medians have a minimum of 10 observations used in calculating the median value.

Results and Discussion

Salinity was inversely related to freshwater inflow across Texas estuaries. This relationship was congruent with expectations that salinity would be higher for estuaries that receive lower freshwater inputs and that elevated flows related to storm events in contributing basins would result in reduced salinity through dilution. Changepoint analysis of the variables indicated a statistically significant threshold of 76,000 acft per month (Figure 3.4.1). For estuaries receiving freshwater inflows above this threshold within a month, salinity was approximately 40% lower on average. This threshold accounted for a relatively low percentage of variability in salinity in Texas estuaries, approximately 15% (r^2 = 0.15).

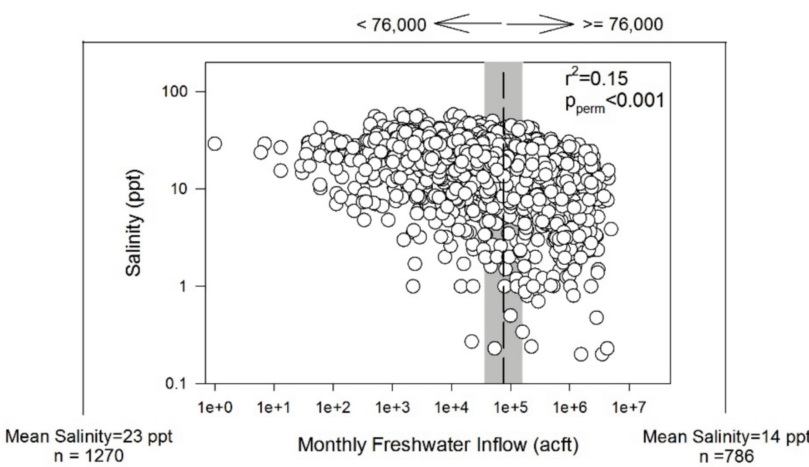
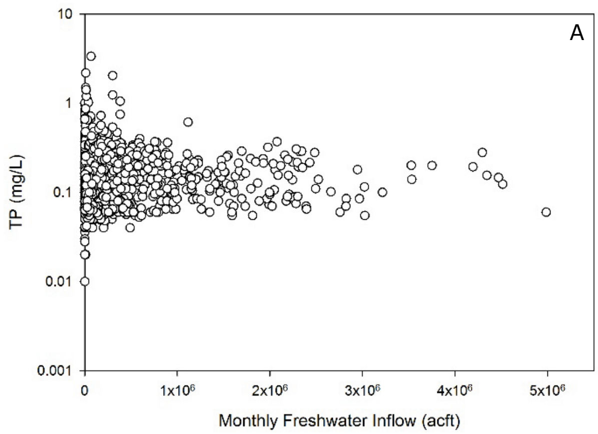


Figure 3.4.1. The relationship between salinity and freshwater inflows to Texas estuaries on a monthly timestep. Salinity values represent the mean of all observations within a month for all stations located within an estuary. Salinity and freshwater inflow variables are shown on the log10 scale.



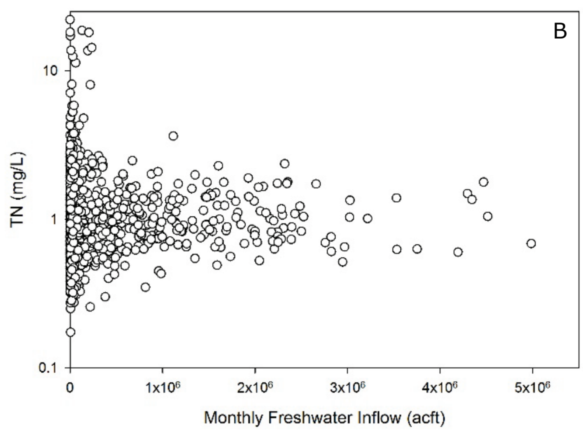


Figure 3.4.2. The relationship between A) TP and B) TN and freshwater inflows to Texas estuaries on a monthly timestep. Nutrient values represent the mean of all observations within a month for all stations located within an estuary. Nutrient concentrations are shown on the log10 scale in all plots.

Other sources of variability in salinity include differences between estuaries such as estuary type (e.g. hypersaline), level of connectivity with the openocean, evapotranspiration rates, and estuary surface area. However, a clear relationship between freshwater inputs and salinity was observed in this analysis that was potentially applicable to other water chemistry parameters, such as nutrient concentrations, as well as biological variables.

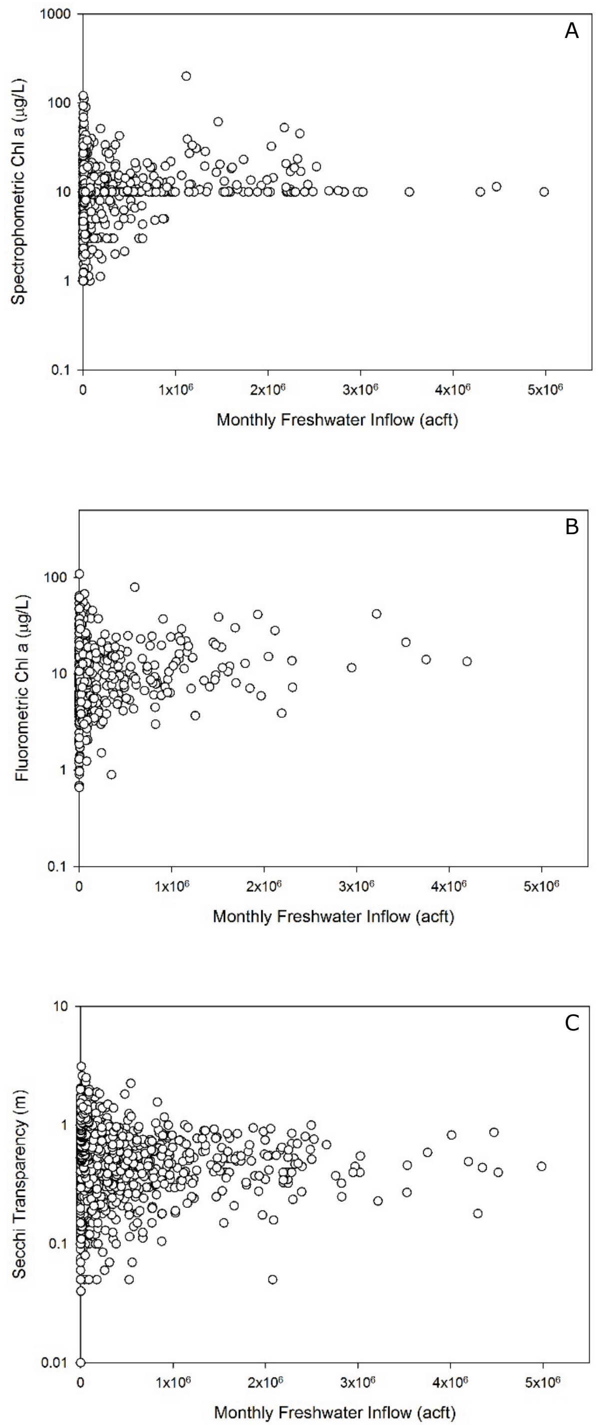


Figure 3.4.3. The relationship between (A) chl-a measured spectrophotometrically, (B) chl-a measured fluorometrically, and C) Secchi transparency and freshwater inflows to Texas estuaries on a monthly timestep. Salinity and nutrient values represent the mean of all observations within a month for all stations located within an estuary. Response variables are shown on the log10 scale in all plots.

However, this was not the case, likely due to the even more complex biogeochemical factors acting on nitrogen and phosphorus, and, thereby, biological responses to these nutrients. Due to the extremely large sample size, changepoint analyses indicated statistically significant relationships between freshwater inflows and Secchi transparency, TP, and chl-a spec. These thresholds were nonetheless statistically weak and explained < 2% of variability in these variables. Therefore, these thresholds were not presented in the results. For all parameters of interest, variability was so high at low-range freshwater inflow values that any potential flow-driven response at high flows was masked (Figs. 3.4.2A-B and 3.4.3A-C). Meaningful relationships between freshwater inflows and water chemistry or biological response variables might still be found in the Texas estuaries dataset, but subsequent analysis would need to address sources of variability at low freshwater inflow.

3.5 EXPLORING POTENTIAL EFFECTS OF DROUGHT ON VALUES OF WATER QUALITY PARAMETERS

Methods

Data organization and compilation for annual medians database

Comparing water quality data collected under drought and non-drought conditions required that the FY2012-2013 Texas estuaries water quality database be expanded to include the years 2011-2014. During this period, Texas experienced wide-spread historic drought (United States Drought Monitor, droughtmonitor.unl.edu). To expand the database, TCEQ provided data comprised of 116 water quality parameters with data collected from January 1, 2011 – December 31, 2014 from estuaries throughout Texas. The collected data was received in two installments: 1) in October 2013, spanning January 1, 2011-October 2013 and 2) in May 2015, spanning January 1, 2013-December 31, 2014. Only the complete 2013 data provided through only the second installment were used in subsequent analyses.

Data from 2011 – 2014 were received in a format in which data for all parameters were stored in a single column. The data were therefore processed into a usable format identical to the FY2012-2013 water quality database. Data received as part of the present contract were organized through same process and undergoing identical quality assurance requirements as applied to organize 2000 – 2010 data into the FY2012-2013 water quality database. Data collected under the monitoring type “Biased Flow” were removed by sorting the data by monitoring type code and deleting all biased flow observations. Although monitoring identified as “Biased Flow” may be planned to target either low or high flow conditions, typically this monitoring is planned to target storm events. Since these data were removed, samples collected during wet weather events may be under-represented in the dataset. Data points that were considered to be censored were replaced in the rearranged data with the value of the quantification limit. Data were then reorganized using a pivot table function in Microsoft Excel to rearrange the single column output from SWQMIS into a format with a column assigned to each unique parameter code and associated data. The reorganization process was accomplished using Microsoft Excel Macros (see Appendix 1.6 for code).

Several additional parameters were calculated. Nitrate plus nitrite-nitrogen (NO_x-N) and total nitrogen (TN) were calculated if the necessary N species were provided by TCEQ in the original data file. In addition, diel change (i.e., 24 hour maximum minus 24 hour minimum) was calculated for dissolved oxygen, temperature, conductivity, pH, and turbidity. The additional parameters were added to each station worksheet using a Microsoft Excel Macro (Appendix 1.6). Due to the volume of data provided, several parameters were removed because of lack of data and duplication of parameters, or because TCEQ indicated that the parameter could be removed from the database.

Once the 2011 – 2014 were formatted identically to 2000 – 2010 data in the FY2012-2013 water quality database, an annual median was calculated for all parameters for all years for which data were present for all stream and river stations during the period 2000 – 2014. Annual medians were then automatically transferred to a summary tab for each year. This series of actions was carried out using a Microsoft Excel Macro (see Appendix 1.6 for code).

Initial analysis of statewide drought conditions in Texas by year from 2000 – 2014 was provided by TCEQ. These data and data used subsequently to assess the timing and extent of drought in Texas were acquired from the United States Drought Monitor (droughtmonitor.unl.edu). Initial analyses indicated that 2004 and 2011 represented extremes of wet and dry years, respectively, for a large proportion of the state, while the periods of 2001-2005 and 2011-2014 represented extended periods of wet and dry, respectively.

Data were fit to boxplots to illustrate frequency distributions for the different groups of annual medians for target water quality variables. These parameters of interest were total phosphorus (TP; parameter 00665), total nitrogen (TN; parameter 00600C), phosphate-phosphorus (SRP; parameter 00671C), nitrate+nitrite-nitrogen (NOx-N; parameter 00630), chlorophyll-a (chl-a) measured spectrophotometrically (chl-a spec; parameter 32211) and fluorometrically (chl-a fluoro; parameter 79753), and Secchi transparency (parameter 00078C).

Results and Discussion

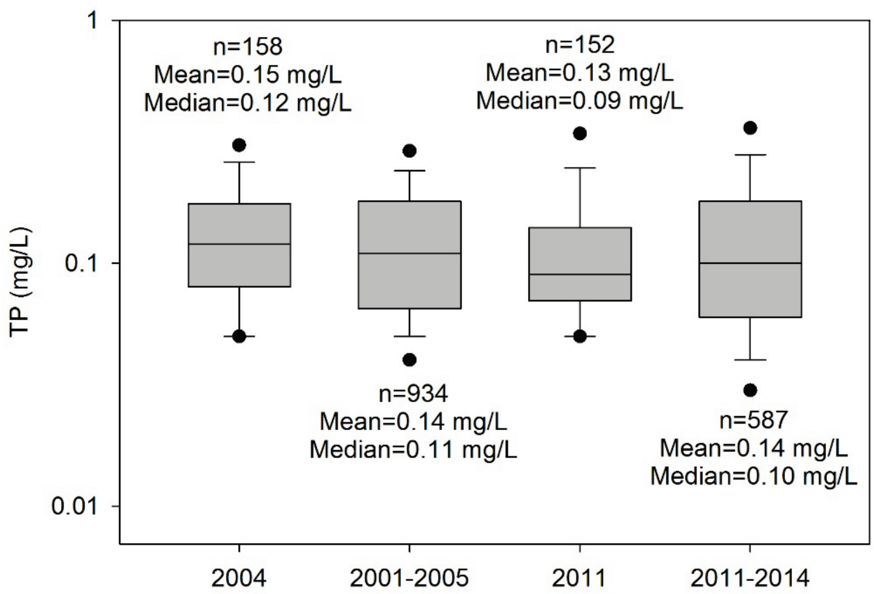
Nutrients

For TP, frequency distributions indicated little or no difference between annual medians associated with wet and drought years (Fig. 3.5.1A). Median TP across groups was approximately 0.09 – 0.12 mg/L, while means ranged from 0.13 – 0.14 mg/L. The data spread between the 5th and 75th percentiles, was more constrained for 2011 than for any other group of annual medians, but 90th and 95th percentiles were in range with the other groups.

In contrast, TN exhibited a probable drought response, most notably between the single wet and drought years of 2004 and 2011. Across all groups, TN measures of central tendency varied by 2-3x, with medians ranging between 0.75 and 2.0 mg/L, while means ranged between 0.88 and 2.4 mg/L (Fig. 3.5.1B). For the 2004 and 2011 groups, medians were 0.79 and 2.0 mg/L, respectively, and means were 0.88 and 2.0 mg/L respectively. These were not the largest differences in measures of central tendency between groups, but both 2004 and 2011 annual medians exhibited a reduced spread of data falling between the 25th and 50th percentiles, though some overlap in the data distributions was observed. Values for TN concentrations observed in both groups fell only within the uppermost percentiles for 2011 and lowest percentiles for 2004. Advanced analysis would be required to confirm whether these groups represent statistically different populations, but this potential difference is among the most notable potential drought effects observed for any parameter in any of the Texas waterbodies. Conclusions remained similar when results from the series of wet and dry years were also considered, but greater overlap in the distributions was associated with these groups.

In contrast to TP, measures of central tendency in annual median PO_4-P concentrations differed between wet and drought years (Fig. 3.5.2A). In drought years, PO_4-P medians and means, as well as lower percentiles (≤25th) were consistently at or near common quantification limits (0.04 – 0.06 mg/L). In wet years, means and medians were an order of magnitude greater (median PO_4-P = 0.18-0.69 mg/L; mean PO_4-P = 0.27 – 0.68 mg/L).

These findings are consistent with the hypothesis that high flow may be associated with elevated nutrient concentrations in Texas estuaries, but this trend is likely spurious. It is not be possible for PO_4-P concentrations to exceed TP concentrations, since PO_4-P is a component of the TP pool. But, since medians, means, and, indeed, most percentiles in the data distributions were higher for PO_4-P than for TP, it is clear that PO_4-P concentrations commonly exceeded TP concentrations in the raw database. Close examination of PO_4-P data from the two time periods indicated that increased rigor of quality assurance/quality control measures for sample handling since 2001-2005 was likely responsible for the observed differences, rather than drought. These analyses used the calculated PO_4-P parameter 00671C for comparisons, which combined two TCEQ PO_4-P parameters (00671 and 70507). Parameter 00671 stored data from PO_4-P samples that were filtered within 15 minutes of collection, while parameter 70507 stored data from samples that were filtered more than 15 minutes after collection. Priority was given in calculating parameter to data stored as the parameter 00671, but, for 2001-2005, all almost all avabilable PO_4-P data were from samples with less rigorous handling requirements that were filtered after > 15 minutes and stored as 70507. In contrast, for 2011-2014, all samples were stored as 00671. Such large discrepancies between parameter codes for PO_4-P were not observed for other water body types, but, in this case, the clear difference in handling requirements between 2001-2005 and 2011-2014 is a likely culprit for the differences in PO_4-P distributions observed in the current drought analysis.



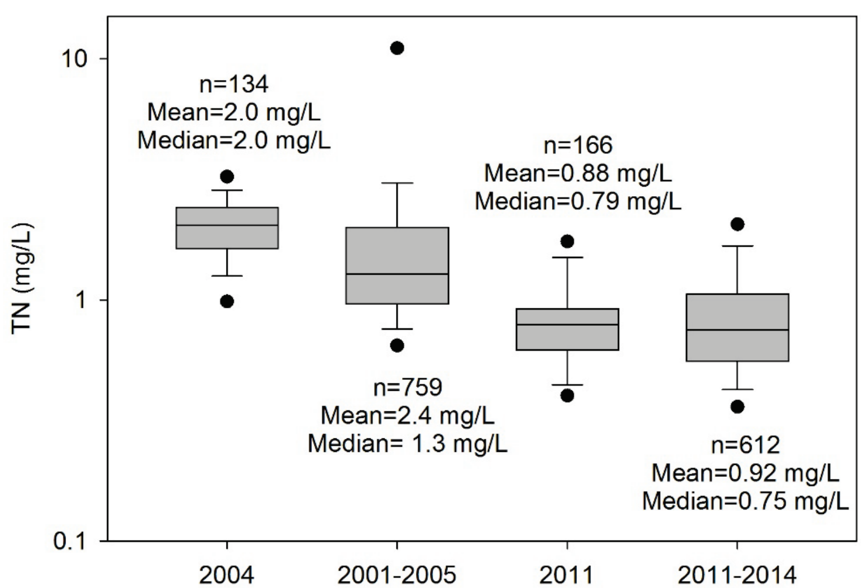
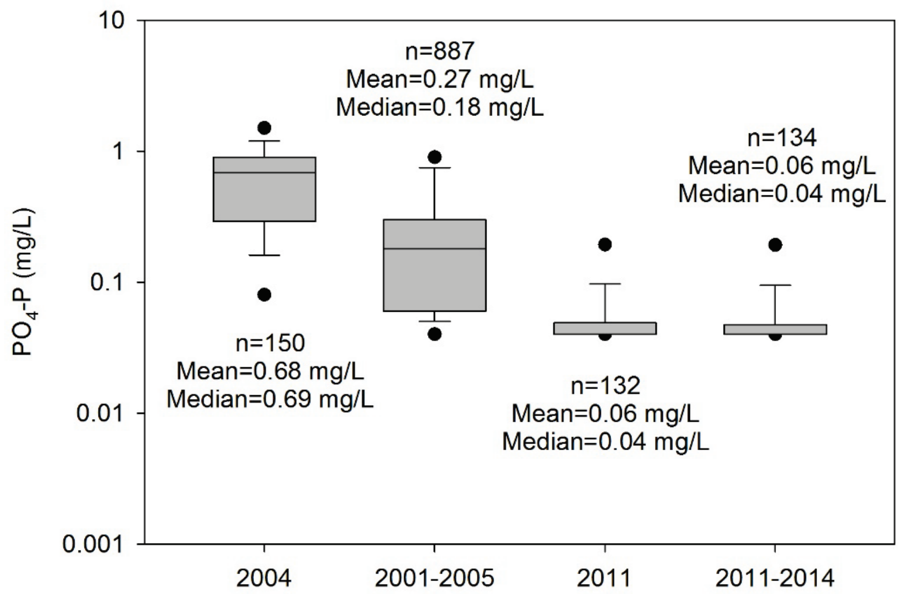


Figure 3.5.1. Distributions of A) total phosphorus (TP) and B) total nitrogen (TN) annual medians for all Texas estuaries from wet (2004, 2001-2005) and drought years (2011, 2011-2014).



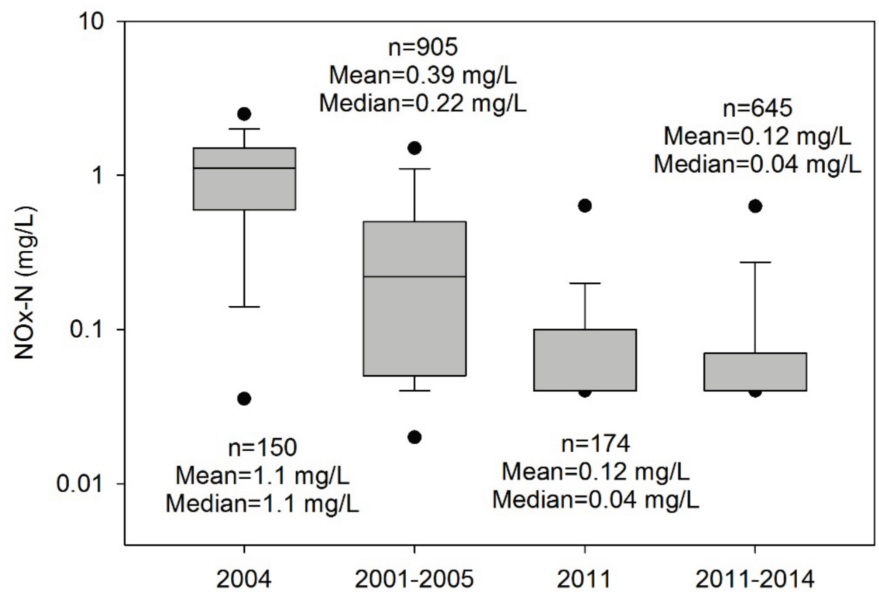


Figure 3.5.2. Distributions of A) phosphate-phosphorus (PO4-P) and B) nitrate+nitrite-nitrogen (NOx-N) annual medians for all Texas estuaries from wet (2004, 2001-2005) and drought years (2011, 2011-2014).

Annual median groups for NO_x-N followed similar trends to those observed for TN, exhibiting a probable drought response in Texas estuaries. Across all groups, measures of central tendency for NO_x-N varied by up to two orders of magnitude, with medians ranging between 0.04 and 1.1 mg/L, while means ranged between 0.12 and 1.1 mg/L (Fig. 3.5.2B). For the 2004 and 2011 groups, medians were 0.04 and 1.1 mg/L, respectively, and means were 0.12 and 1.1 mg/L respectively. These were the largest differences in measures of central tendency between groups, and both 2004 and 2011 groups also exhibited reduced spread compared to series of wet and dry years, especially between the 5th and 75th percentiles. Lower percentiles for both 2011 and 2011-2014 were clearly constrained by the value of a common quantification limit (0.04 mg/L). Advanced analysis would be required to confirm whether these groups represent statistically different populations, but this difference is among the most notable potential drought effects observed for any parameter in any of the Texas waterbodies in the study. Conclusions remained similar when results from the series of wet and dry years were also considered, but greater overlap in the distributions was associated these groups.

Sestonic chlorophyll-a and Secchi transparency

For chl-a spec, medians were up to 3x higher in wet years compared to drought years, and the values of data falling between the 25th and 75th percentile were considerably more constrained in wet years than dry years (Fig. 3.5.3A). These trends, however, are most likely spurious and were introduced when censored observations were replaced in the dataset with the value of the common quantification limit. During 2001-2005, this value was 10 µg/L, but was reduced to 3 µg/L during 2011-2014. The medians for 2004, 2001-2005, and 2011-2014 correspond exactly to the value of the common quantification limit in effect at that time. Since a wider range of values was possible for chl-a spec in years in when quantification limits were lower, differences in the spread of distributions between the two periods can also likely be attributed to the effects of replacing censored data with the quantification limit.

For chl-a fluoro, medians ranged from 5.2 – 11 µg/L, but differences between years was not consistently associated with wet vs. dry years (Fig. 3.5.3B). The groups with the highest and lowest median were the single wet year 2004 and the series of wet years 2001-2005, respectively. Medians associated with drought years fell between wet year values. Mean chl-a fluoro ranged from ~ 8 – 11 mg/L and similarly showed no consistent potentially drought-related trends.

In addition to changes in QL, changes in the prevalence of the use of the different methods of chl-a analysis between the early 2000's and post 2010 make comparison of drought and non-drought groups of chl-a data problematic. The sample size of annual medians for chl-a spec was much larger for 2004 than for chl-a fluoro the same year or for chl-a spec for 2011 (n = 148, 7, and 16, respectively), while the sample size for chl-a fluoro was more than 20x greater in 2011 than in 2004. These large increases and reductions in sample size between the periods entail that the stations represented by annual medians differ greatly between the drought and non-drought periods and to an extent that is likely not true for other parameters. These fundamental differences in the data population for chl-a parameters between the early

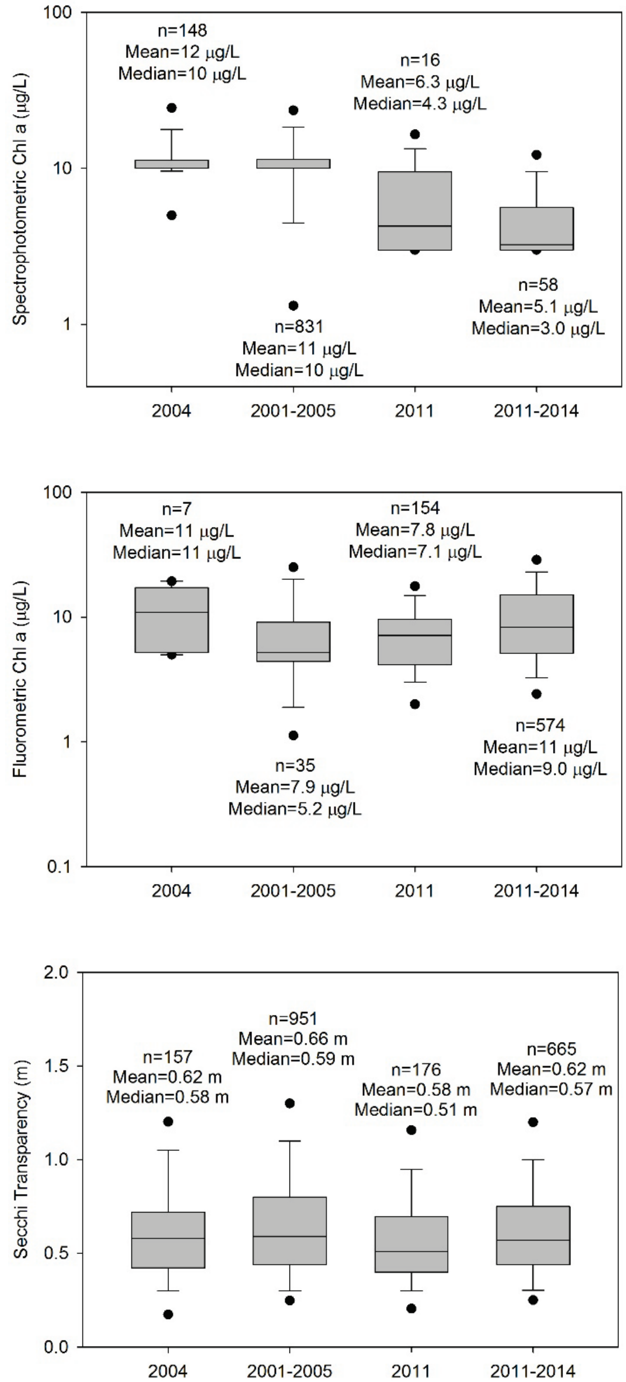


Fig. 3.5.3. Distributions of A) chlorophyll-a measured spectrophotometrically, B) chlorophyll-a measured fluorometrically, and C) Secchi transparency annual medians for all Texas estuaries from wet (2004, 2001-2005) and extreme drought (2011, 2011-2013) years.

2000's and post 2010 make it difficult to determine whether trends identified between the annual median groups can be attributed to the effects of drought.

For Secchi transparency, the estimated measures of central tendency and the shape of distributions were similar across the 4 groups (Fig. 3.5.3C). Median Secchi transparency was approximately 0.50 – 0.60 m across groups, while mean transparency varied by approximately 0.08 m between 0.58 and 0.66 m. In general, Secchi transparency appeared highly immune to potential drought effects.

Summary of drought effects on water quality parameters

Frequency distributions for groups of estuary annual medians representing drought and non-drought conditions indicated likely drought effects on several water quality parameters, even at the statewide scale. This was in contrast to findings for streams and rivers and reservoirs, but may have been true for estuaries because they are the end-point of all flows and associated nutrient transport in the state. Differences in measures of central tendency for these groups were seen for nitrogen parameters, TN and NO_x-N, which were 1 – 2 orders of magnitude lower in 2011 than in 2004, especially for NO_x-N. Enhanced nutrient transport from the landscape to adjacent water bodies has been strongly linked with precipitation and related storm events and is likely responsible for high TN and NO_x-N concentrations during wet years.

Potential drought effects were also observed for PO_4-P, but were most likely an artifact of improved sample handling and reduced holding time post 2010. No drought effects were observed for TP. The different response by N species and TP to hydrologic differences between wet and dry years may be attributable to differences in N and P biogeochemistry. In flowing freshwater systems, highly mobile NO_x-N often comprises a high proportion of TN, while TP is often largely comprised of particulates that quickly become immobilized as high flows recede. At this scale, it may be impossible to capture the potential signal of elevated TP in estuaries associated with high flow events.

These findings have implications for the process of setting nutrient criteria. Annual medians of N species collected during drought periods exhibit a low likelihood of being out of compliance with targets established using data from periods of high or average precipitation. In contrast, if data collected largely during drought years were used to develop targets for N species, annual medians for years with average or above average precipitation might be at risk for non-compliance.

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Appendix 3.1 Statistical code and output for analyses on estuaries

Flipped analyses

ANALYSIS: TP vs. CHLASPEC (nCPA)

```
     cp       r2 mean left mean right pperm   5%   25%  50%  75%    95%
[1,] 13.8 0.3454318 0.1073269  0.3068333 0.001 9.95 10.65 12.3 13.8 15.375
```

ANALYSIS: TP vs. CHLAFlUORO (nCPA)

```
       cp       r2  mean left mean right pperm    5%  25%   50%     75%   95%
[1,] 10.675 0.1961456 0.08020909  0.1757059 0.005 8.585 10.5 10.75 12.53125 16.75
```

ANALYSIS: TP vs. SECCHI (nCPA)

```
      cp      r2 mean left mean right pperm      5%    25%    50%    75%  95%
[1,] 0.575 0.154163 0.1764132 0.09891566 0.001 0.534875 0.5475 0.5825 0.6325 0.64
```

ANALYSIS: TN vs. CHLASPEC

```
   cp r2 mean left mean right pperm 5% 25% 50%      75%  95%
[1,] 10  0 0.9217857   1.645556 0.001 10  10  10 10.01413 11.8
```

ANALYSIS: TN vs. CHLAFLUORO

```
     cp      r2 mean left mean right pperm   5%    25%  50%  75%   95%
[1,] 11.6 0.512576 0.8383019    1.50375 0.001 8.98 10.675 11.5 12.8 13.35
```

ANALYSIS: TP vs. SECCHI values > 0.40 removed

```
       cp       r2 mean left mean right pperm     5%    25%   50%    75%  95%
[1,] 0.6325 0.2074273 0.1568643 0.08633333 0.001 0.4725 0.5475 0.585 0.6325 0.64
```

ANALYSIS: TP vs. CHLASPEC values >0.040 mg TP/L removed

```
      cp      r2 mean left mean right pperm 5% 25%   50%    75%    95%
[1,] 10.65 0.236754   0.10522  0.2128462 0.001  9  10 10.65 12.675 15.375
```

ANALYSI: TP vs. CHLA FLUORO values > 0.40 mg TP/L removed

```
       cp       r2  mean left mean right pperm    5%     25%    50%  75%  95%
[1,] 10.675 0.2527834 0.08020909     0.1395 0.001 4.975 9.48625 10.675 10.7 13.9
```

Regional CP

ANALYSIS: BASINS 5-11 SECCHI vs. TP

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.0925 0.2337402 0.6723333 0.5096818 0.001 0.0775 0.085 0.0925 0.105 0.1175

ANALYSIS: BASINS 5-11 CHL-A SPEC vs. TP

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.2775 0.1594896 9.426923 14.32778 0.147 0.1375 0.205 0.2675 0.2775 0.3

ANALYSIS: BASINS 5-11 SECCHI vs. TN

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.715 0.1881846 0.6814706 0.5344253 0.002 0.595 0.67 0.715 0.795 0.86

ANALYSIS: BASINS 13-23 SECCHI vs. TP

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.065 0.2934329 0.917619 0.5643478 0.002 0.065 0.065 0.065 0.071 0.115

ANALYSIS: BASINS 13-23 CHLAS vs. TP

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.085 0.1208217 9.187885 11.33857 0.119 0.076 0.083 0.085 0.11 0.12

ANALYSIS: BASINS 13-23 CHLAF vs. TP

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.085 0.1549982 5.761923 9.314667 0.037 0.083 0.085 0.085 0.105 0.115

ANALYSIS: BASINS 13-23 SECCHI vs. TN

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 0.7425 0.2027241 0.985 0.7208 0.05 0.65 0.7425 0.745 0.9975 1.65

ANALYSIS: BASINS 13-23 CHLAF vs. TN
cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1.205 0.593035 5.328077 12.9125 0.002 0.94 1.13 1.16 1.445 1.6

Monthly Freshwater Inflows

ANALYSIS: SECCHI VS. FRESHWATER INFLOWS

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 313141.5 0.008370033 0.6170722 0.5346197 0.006 897 7190.375 155728.8 313141.5 572002

ANALYSIS: SALINITY VS. FRESHWATER INFLOWS

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 75718 0.1502022 23.10643 14.4756 0.001 36304.5 65628 78758.5 91342.5 158614.5

ANALYSIS: TN VS. FRESHWATER INFLOWS

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 242483.5 0.009820274 1.377281 1.050265 0.078 518.5 148676.5 237757 252833 355128.5

ANALYSIS: TP VS. FRESHWATER INFLOWS

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 65984 0.02003535 0.1375459 0.1856864 0.015 1898.5 34172.5 50737.5 65592.5 81316.22

ANALYSIS: CHL-A SPEC VS. FRESHWATER INFLOWS

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 1091371 0.01673741 12.27613 18.55914 0.032 572 6467 947519.5 1091371 1091371

ANALYSIS: CHL-A FLUORO VS. FRESHWATER INFLOWS

cp r2 mean left mean right pperm 5% 25% 50% 75% 95%

[1,] 987169.5 0.00956758 11.91257 16.49442 0.271 345.525 1052.5 513164 888047.5 1648130

Appendix 3.2 Frequency distributions of water quality parameters for Texas estuary segments

Table 3.2.1. Frequency distribution of median nutrient and chlorophyll-a concentrations for estuary segments in Texas, using data from 2000-2010 and the median dataset generated in FY2012-2013.

Total Phosphorus (TP; mg/L)

SEG_ID	n	Min	10th	25th	50th	75th	90th	Max
0703	1	-	-	-	0.08	-	-	-
1111	1	-	-	-	0.06	-	-	-
1304	0	-	-	-	-	-	-	-
2411	0	-	-	-	-	-	-	-
2412	2	0.07	-	-	0.07	-	-	0.07
2421	23	0.06	0.16	0.165	0.18	0.215	0.25	0.29
2422	21	0.07	0.14	0.15	0.17	0.2	0.34	0.58
2423	12	0.06	0.062	0.0875	0.1225	0.1825	0.199	0.235
2424	15	0.06	0.065	0.0775	0.09	0.12	0.219	0.35
2425	3	0.07	-	-	0.26	-	-	0.29
2426	2	0.255	-	-	0.2825	-	-	0.31
2427	3	0.15	-	-	0.3	-	-	0.31
2428	1	-	-	-	0.27	-	-	-
2429	2	0.23	-	-	0.265	-	-	0.3
2430	1	-	-	-	0.285	-	-	-
2431	2	0.17	-	-	0.24	-	-	0.31
2432	2	0.125	-	-	0.1425	-	-	0.16
2433	1	-	-	-	0.15	-	-	-
2434	2	0.07	-	-	0.09	-	-	0.11
2435	1	-	-	-	0.06	-	-	-
2436	1	-	-	-	0.25	-	-	-
2437	1	-	-	-	0.14	-	-	-
2438	3	0.11	-	-	0.18	-	-	0.23
2439	37	0.05	0.08	0.1	0.12	0.165	0.18	0.64
2441	1	-	-	-	0.115	-	-	-
2451	6	0.07	-	0.07	0.075	0.08	-	0.12
2452	2	0.065	-	-	0.0775	-	-	0.09
2453	4	0.1	-	0.10375	0.15	0.335	-	0.755
2454	2	0.08	-	-	0.085	-	-	0.09
2455	1	-	-	-	0.09	-	-	-
2456	2	0.07	-	-	0.19	-	-	0.31
2461	0	-	-	-	-	-	-	-
2462	1	-	-	-	0.06	-	-	-
2463	1	-	-	-	0.1	-	-	-
2471	1	-	-	-	0.1	-	-	-
2472	4	0.06	-	0.0675	0.085	0.105	-	0.12
2473	1	-	-	-	0.076	-	-	-
2481	9	0.06	0.06	0.06	0.06	0.072	0.0997	0.1785
2482	2	0.08	-	-	0.095	-	-	0.11
2483	2	0.05	-	-	0.095	-	-	0.14
2484	3	0.06	-	-	0.1	-	-	0.11
2485	2	0.14	-	-	0.146	-	-	0.152
2491	8	0.06	0.06	0.06	0.06	0.0625	0.082	0.11
2492	2	0.06	-	-	0.075	-	-	0.09
2493	1	-	-	-	0.12	-	-	-
2494	3	0.06	-	-	0.06	-	-	0.06

2421A	1	-	-	-	0.075	-	-	-
2424B	0	-	-	-	-	-	-	-
2424D	2	0.06	-	-	0.0925	-	-	0.125
2424F	1	-	-	-	0.11	-	-	-
2426C	1	-	-	-	0.44	-	-	-
2431B	0	-	-	-	-	-	-	-
2435A	1	-	-	-	0.06	-	-	-
2441A	0	-	-	-	-	-	-	-
2452A	1	-	-	-	0.09	-	-	-
2453D	1	-	-	-	0.085	-	-	-
2471A	1	-	-	-	0.215	-	-	-
2483A	2	0.06	-	-	0.06	-	-	0.06
2485A	1	-	-	-	0.12	-	-	-
2494A	0	-	-	-	-	-	-	-

Total Nitrogen (TN; mg/L)

SEG_ID	n	Min	10th	25th	50th	75th	90th	Max
703	1	-	-	-	0.73	-	-	-
1111	1	-	-	-	0.78	-	-	-
1304	0	-	-	-	-	-	-	-
2411	0	-	-	-	-	-	-	-
2412	2	0.73	-	-	0.74	-	-	0.75
2421	20	0.75	0.915	0.9375	1.005	1.085	1.232	1.265
2422	19	0.68	0.866	0.8775	0.92	1.05	1.51	1.92
2423	9	0.65	0.718	0.95	0.955	0.98	1.036	1.26
2424	10	0.6	0.6225	0.645	0.7175	0.81375	1.106	1.25
2425	1	-	-	-	0.7	-	-	-
2426	1	-	-	-	1.51	-	-	-
2427	1	-	-	-	0.91	-	-	-
2428	0	-	-	-	-	-	-	-
2429	0	-	-	-	-	-	-	-
2430	0	-	-	-	-	-	-	-
2431	0	-	-	-	-	-	-	-
2432	0	-	-	-	-	-	-	-
2433	1	-	-	-	0.97	-	-	-
2434	1	-	-	-	0.645	-	-	-
2435	1	-	-	-	0.685	-	-	-
2436	0	-	-	-	-	-	-	-
2437	0	-	-	-	-	-	-	-
2438	2	1.02	-	-	1.0625	-	-	1.105
2439	34	0.545	0.624	0.79	0.88	0.93	0.97	1.74
2441	1	-	-	-	0.65	-	-	-
2451	6	0.55	-	0.65125	0.8175	1.01375	-	1.33
2452	2	0.81	-	-	0.8575	-	-	0.905
2453	3	0.98	-	-	1.09	-	-	1.58
2454	2	0.9	-	-	0.915	-	-	0.93
2455	1	-	-	-	0.93	-	-	-
2456	2	0.92	-	-	1.42	-	-	1.92
2461	0	-	-	-	-	-	-	-
2462	1	-	-	-	0.63	-	-	-

2463	1	-	-	-	0.95	-	-	-
2471	1	-	-	-	0.93	-	-	-
2472	3	0.755	-	-	0.76	-	-	0.91
2473	0	-	-	-	-	-	-	-
2481	7	0.705	0.714	0.725	0.78	0.835	0.884	0.95
2482	2	0.88	-	-	0.905	-	-	0.93
2483	2	0.95	-	-	1.03	-	-	1.11
2484	2	1.09	-	-	1.165	-	-	1.24
2485	1	-	-	-	1.55	-	-	-
2491	8	0.545	0.5485	0.7075	1.135	1.65375	1.7175	1.84
2492	2	1.22	-	-	1.62	-	-	2.02
2493	1	-	-	-	1.95	-	-	-
2494	3	0.63	-	-	0.635	-	-	0.67
2421A	0	-	-	-	-	-	-	-
2424B	0	-	-	-	-	-	-	-
2424D	1	-	-	-	0.545	-	-	-
2424F	1	-	-	-	1.125	-	-	-
2426C	0	-	-	-	-	-	-	-
2431B	0	-	-	-	-	-	-	-
2435A	1	-	-	-	0.645	-	-	-
2441A	0	-	-	-	-	-	-	-
2452A	1	-	-	-	0.99	-	-	-
2453D	1	-	-	-	0.95	-	-	-
2471A	0	-	-	-	-	-	-	-
2483A	1	-	-	-	0.67	-	-	-
2485A	0	-	-	-	-	-	-	-
2494A	0	-	-	-	-	-	-	-

Nitrate+Nitrite-Nitrogen (NO_x-N; mg/L)

SEG_ID	n	Min	10th	25th	50th	75th	90th	Max
703	0	-	-	-	-	-	-	-
1111	0	-	-	-	-	-	-	-
1304	1	-	-	-	0.04	-	-	-
2411	0	-	-	-	-	-	-	-
2412	2	0.06	-	-	0.075	-	-	0.09
2421	21	0.04	0.05	0.07	0.15	0.25	0.31	0.46
2422	25	0.03	0.04	0.045	0.14	0.25	0.25	0.85
2423	11	0.04	0.04	0.04	0.045	0.1325	0.2	0.345
2424	17	0.03	0.04	0.04	0.06	0.15	0.15	0.155
2425	3	0.02	-	-	0.04	-	-	0.065
2426	3	0.365	-	-	0.645	-	-	0.83
2427	2	0.2	-	-	0.52	-	-	0.84
2428	0	-	-	-	-	-	-	-
2429	2	0.04	-	-	0.295	-	-	0.55
2430	1	-	-	-	0.085	-	-	-
2431	1	-	-	-	0.096	-	-	-
2432	0	-	-	-	-	-	-	-
2433	2	0.04	-	-	0.3625	-	-	0.685
2434	3	0.04	-	-	0.05	-	-	0.145

2435	1	-	-	-	0.935	-	-	-
2436	3	0.06	-	-	0.25	-	-	0.25
2437	3	0.115	-	-	0.25	-	-	0.25
2438	2	0.12	-	-	0.135	-	-	0.15
2439	37	0.02	0.04	0.04	0.09	0.15	0.274	0.69
2441	1	-	-	-	0.29	-	-	-
2451	4	0.04	-	0.055	0.155	0.325	-	0.55
2452	3	0.04	-	-	0.25	-	-	0.25
2453	3	0.135	-	-	0.14	-	-	0.69
2454	3	0.105	-	-	0.13	-	-	0.15
2455	3	0.045	-	-	0.13	-	-	0.15
2456	2	0.05	-	-	0.11	-	-	0.17
2461	0	-	-	-	-	-	-	-
2462	0	-	-	-	-	-	-	-
2463	1	-	-	-	0.04	-	-	-
2471	3	0.04	-	-	0.1	-	-	0.11
2472	4	0.04	-	0.04375	0.0675	0.0925	-	0.1
2473	2	0.02	-	-	0.02	-	-	0.02
2481	8	0.02	0.034	0.04	0.07	0.12375	0.177	0.24
2482	2	0.05	-	-	0.05	-	-	0.05
2483	3	0.08	-	-	0.08	-	-	0.25
2484	3	0.02	-	-	0.33	-	-	0.41
2485	2	0.02	-	-	0.2625	-	-	0.505
2491	10	0.04	0.04	0.04	0.04	0.09125	0.165	0.3
2492	1	-	-	-	0.04	-	-	-
2493	1	-	-	-	0.04	-	-	-
2494	0	-	-	-	-	-	-	-
2421A	1	-	-	-	0.14	-	-	-
2424B	0	-	-	-	-	-	-	-
2424D	2	0.02	-	-	0.03	-	-	0.04
2424F	2	0.18	-	-	0.365	-	-	0.55
2426C	1	-	-	-	0.07	-	-	-
2431B	0	-	-	-	-	-	-	-
2435A	1	-	-	-	0.04	-	-	-
2441A	0	-	-	-	-	-	-	-
2452A	1	-	-	-	0.15	-	-	-
2453D	1	-	-	-	0.02	-	-	-
2471A	0	-	-	-	-	-	-	-
2483A	1	-	-	-	0.17	-	-	-
2485A	0	-	-	-	-	-	-	-
2494A	0	-	-	-	-	-	-	-

Ortho-Phosphate (PO_4-P; mg/L)

SEG_ID	n	Min	10th	25th	50th	75th	90th	Max
0703	0	-	-	-	-	-	-	-
1111	0	-	-	-	-	-	-	-
1304	1	-	-	-	0.04	-	-	-
2411	0	-	-	-	-	-	-	-
2412	2	0.06	-	-	0.075	-	-	0.09

2421	21	0.04	0.05	0.07	0.15	0.25	0.31	0.46
2422	25	0.03	0.04	0.045	0.14	0.25	0.25	0.85
2423	11	0.04	0.04	0.04	0.045	0.1325	0.2	0.345
2424	17	0.03	0.04	0.04	0.06	0.15	0.15	0.155
2425	3	0.02	-	-	0.04	-	-	0.065
2426	3	0.365	-	-	0.645	-	-	0.83
2427	2	0.2	-	-	0.52	-	-	0.84
2428	0	-	-	-	-	-	-	-
2429	2	0.04	-	-	0.295	-	-	0.55
2430	1	-	-	-	0.085	-	-	-
2431	1	-	-	-	0.096	-	-	-
2432	0	-	-	-	-	-	-	-
2433	2	0.04	-	-	0.3625	-	-	0.685
2434	3	0.04	-	-	0.05	-	-	0.145
2435	1	-	-	-	0.935	-	-	-
2436	3	0.06	-	-	0.25	-	-	0.25
2437	3	0.115	-	-	0.25	-	-	0.25
2438	2	0.12	-	-	0.135	-	-	0.15
2439	37	0.02	0.04	0.04	0.09	0.15	0.274	0.69
2441	1	-	-	-	0.29	-	-	-
2451	4	0.04	-	0.055	0.155	0.325	-	0.55
2452	3	0.04	-	-	0.25	-	-	0.25
2453	3	0.135	-	-	0.14	-	-	0.69
2454	3	0.105	-	-	0.13	-	-	0.15
2455	3	0.045	-	-	0.13	-	-	0.15
2456	2	0.05	-	-	0.11	-	-	0.17
2461	0	-	-	-	-	-	-	-
2462	0	-	-	-	-	-	-	-
2463	1	-	-	-	0.04	-	-	-
2471	3	0.04	-	-	0.1	-	-	0.11
2472	4	0.04	-	0.04375	0.0675	0.0925	-	0.1
2473	2	0.02	-	-	0.02	-	-	0.02
2481	8	0.02	0.034	0.04	0.07	0.12375	0.177	0.24
2482	2	0.05	-	-	0.05	-	-	0.05
2483	3	0.08	-	-	0.08	-	-	0.25
2484	3	0.02	-	-	0.33	-	-	0.41
2485	2	0.02	-	-	0.2625	-	-	0.505
2491	10	0.04	0.04	0.04	0.04	0.09125	0.165	0.3
2492	1	-	-	-	0.04	-	-	-
2493	1	-	-	-	0.04	-	-	-
2494	0	-	-	-	-	-	-	-
2421A	1	-	-	-	0.14	-	-	-
2424B	0	-	-	-	-	-	-	-
2424D	2	0.02	-	-	0.03	-	-	0.04
2424F	2	0.18	-	-	0.365	-	-	0.55
2426C	1	-	-	-	0.07	-	-	-
2431B	0	-	-	-	-	-	-	-
2435A	1	-	-	-	0.04	-	-	-
2441A	0	-	-	-	-	-	-	-
2452A	1	-	-	-	0.15	-	-	-

2453D	1	-	-	-	0.02	-	-	-
2471A	0	-	-	-	-	-	-	-
2483A	1	-	-	-	0.17	-	-	-
2485A	0	-	-	-	-	-	-	-
2494A	0	-	-	-	-	-	-	-

Fluorometric Chlorophyll-a (Chl-a; µg/L)

SEG_ID	n	Min	10th	25th	50th	75th	90th	Max
0703	0	-	-	-	-	-	-	-
1111	0	-	-	-	-	-	-	-
1304	1	-	-	-	3.37	-	-	-
2411	0	-	-	-	-	-	-	-
2412	2	5.825	-	-	7.0325	-	-	8.24
2421	1	-	-	-	4.69	-	-	-
2422	1	-	-	-	5.245	-	-	-
2423	1	-	-	-	6.51	-	-	-
2424	0	-	-	-	-	-	-	-
2425	1	-	-	-	4.06	-	-	-
2426	0	-	-	-	-	-	-	-
2427	1	-	-	-	36.85	-	-	-
2428	0	-	-	-	-	-	-	-
2429	1	-	-	-	3	-	-	-
2430	0	-	-	-	-	-	-	-
2431	1	-	-	-	5	-	-	-
2432	0	-	-	-	-	-	-	-
2433	0	-	-	-	-	-	-	-
2434	1	-	-	-	11	-	-	-
2435	0	-	-	-	-	-	-	-
2435A	1	-	-	-	7.6	-	-	-
2436	1	-	-	-	7.835	-	-	-
2437	1	-	-	-	4.27	-	-	-
2438	1	-	-	-	10.9	-	-	-
2439	3	3	-	-	7.49	-	-	12.45
2441	0	-	-	-	-	-	-	-
2451	2	5.33	-	-	6.64	-	-	7.95
2452	1	-	-	-	6.01	-	-	-
2453	3	3.56	-	-	9.49	-	-	12.1
2454	2	6.875	-	-	7.0025	-	-	7.13
2455	2	7.13	-	-	7.2	-	-	7.27
2456	2	6.055	-	-	17.8275	-	-	29.6
2461	0	-	-	-	-	-	-	-
2462	0	-	-	-	-	-	-	-
2463	1	-	-	-	3.67	-	-	-
2471	3	5.57	-	-	8.93	-	-	17.05
2472	4	5.245	-	5.42875	5.845	6.345	-	6.78
2473	2	4.7	-	-	4.85	-	-	5
2481	8	4.035	4.189	4.31125	4.675	6.1025	14.3	32.5
2482	2	5.5	-	-	7.48	-	-	9.46
2483	1	-	-	-	4.655	-	-	-

2484	3	5	-	-	5.35	-	-	5.67
2485	2	5.33	-	-	11.265	-	-	17.2
2491	10	3	3	3.4875	5.1425	13.2	14.52	18.3
2492	1	-	-	-	10.5	-	-	-
2493	1	-	-	-	18.75	-	-	-
2494	0	-	-	-	-	-	-	-
2421A	1	-	-	-	10.85	-	-	-
2424B	0	-	-	-	-	-	-	-
2424D	0	-	-	-	-	-	-	-
2424F	0	-	-	-	-	-	-	-
2426C	1	-	-	-	16.75	-	-	-
2431B	0	-	-	-	-	-	-	-
2441A	0	-	-	-	-	-	-	-
2452A	1	-	-	-	9.03	-	-	-
2453D	1	-	-	-	6.1	-	-	-
2471A	0	-	-	-	-	-	-	-
2483A	1	-	-	-	12.8	-	-	-
2485A	0	-	-	-	-	-	-	-
2494A	0	-	-	-	-	-	-	-

Appendix 3.3 Maps of contributing subwatersheds to Texas estuaries

Chocolate Bay

East Bay

Trinity Bay

Clear Lake

Moses Lake

West Bay

Scott/Black Duck/ San Jacinto/ Burnett

Upper Galveston

Lower Galveston

Mission Bay

Copano Bay

St. Charles Bay

Port Bay

Aransas Bay

Espiritu Santo Bay

Gaudalupe Bay

Hynes Bay

San Antonio Bay

Tres Palicios Bay

Turtle Bay

Carancahua Bay

Cox

Lavaca Bay

Powderhorn Lake

Matagorda Bay

Laguna Salada

Cayo del Grullo

Alazan Bay

Baffin Bay

South Bay

Laguna Madre

Nueces Bay

Oso Bay

Corpus Christi Bay