WATER QUALITY TARGET REFINEMENT PROJECT

Task 6: Numeric Nutrient Criteria Data Analysis Plan

Interim Report 5

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1.0 Background

The U.S. Environmental Protection Agency (USEPA) is developing numeric nutrient water quality standards for Florida waters, including lakes and flowing waters, and estuaries and coastal waters. The schedule for estuarine and coastal water criteria has been recently modified and requires USEPA to propose estuarine and coastal waters nutrient criteria and downstream protective values in Florida by November 14, 2011 to allow for peer review by the Science Advisory Board (SAB) and to allow for public comment, followed by USEPA revision of the proposed numeric nutrient criteria.

In response to recent discussions with USEPA, this document presents a proposed data analysis plan to use in developing numeric nutrient criteria for the Charlotte Harbor estuary including the estuary bay segments included in the Charlotte Harbor National Estuary Program's jurisdiction (Figure 1). The methods discussed below build on research developed in peer reviewed literature, the many local scientists and natural resource managers studying southwest Florida estuaries, and previous USEPA documents (USEPA, 2009) and reviews by its Science Advisory Board (SAB, 2010) on methods for establishing numeric nutrient criteria.

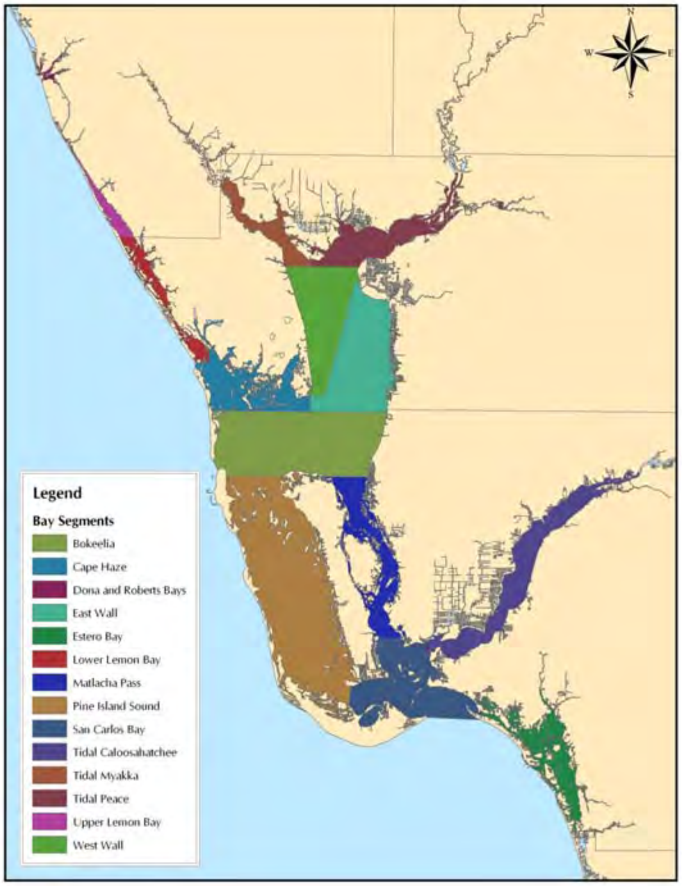

Figure 1. Map of the CHNEP Study Area.

Numeric nutrient water quality criteria define levels of nutrients (i.e., nitrogen and phosphorus) protective of the designated uses of water bodies as prescribed by the Clean Water Act (CWA). Over-enrichment of water bodies by nitrogen and phosphorus typically stimulates plant and microbial growth, and can result in biological and physical responses that adversely affect water quality and aquatic life. The USEPA nutrient criteria guidance recommends development of criteria for both total nitrogen (TN) and total phosphorus (TP), the primary causal constituents, through a stressor response relationship involving the response variables, chlorophyll-a, water clarity, and dissolved oxygen, while not precluding the use of alternative causal or response constituents (USEPA, 2009).

2.0 Objective

The objective of this document is to provide a data analysis plan to serve as guidance for the development of numeric nutrient criteria in Charlotte Harbor and associated estuarine waters of the CHNEP. The intention is to use empirically derived, stressor-response relationships whenever possible to derive numeric nutrient criteria that are protective of the full aquatic life support and designated uses of these waterbodies based on scientifically sound and robust methods. The intention is to use empirically derived, stressor-response relationships that are protective of the full aquatic life support and designated uses of these waterbodies based on scientifically sound and robust methods.

3.0 Approach and Rationale

The USEPA has previously furnished guidance for deriving nutrient criteria in the form of peer-reviewed technical approaches and methods (USEPA, 2000a; 2000b; 2001; 2008; 2009). USEPA clearly states their view on development of nutrient criteria in the recent Science Advisory Board Review Draft (USEPA, 2009).

> “USEPA’s view is that the criteria derivation process for the toxic effect of chemical pollutants is not applicable for nutrients because effects, while linked to widespread and significant aquatic degradation, occur through a process of intermediate steps that cannot be easily tested in simple laboratory studies. As a result, nutrient criteria derivation relies in large part on empirical analysis of field data.”

3.1 Approaches

USEPA and others have identified three analytical approaches for the development of nutrient criteria:

- the reference condition approach,

- stressor-response analysis, and
- mechanistic modeling.

The approaches are briefly described below.

3.1.1 Reference Condition Approach

As implied by the name, the reference condition approach is based on determining criteria based on a group of reference waterbodies. The reference waterbodies are selected from among a group of like waterbodies (e.g., the same class of waterbodies) that represent minimally disturbed conditions (Stoddard et al., 2006) and have similar characteristics (e.g., black-water streams). Data from the reference waterbodies are assembled and the distributions of either causal or response variables are analyzed. Because these reference waterbodies typically are intended to represent minimally disturbed conditions (or at least an acceptable level of disturbance), USEPA has used specific percentiles derived from these systems (USEPA, 2009) to develop nutrient criteria. Generally some percentile of the reference stream distribution is chosen to represent the criterion value but caution should be used in selecting the appropriate value to serve as the benchmark criterion value (Rohm et. al., 2002; Suplee et al., 2007).

3.1.2 Stressor-Response Approach

The stressor-response approach consists of developing relationships between nutrient concentrations or loads and biological responses. USEPA (2009) has provided guidance on the development of stressor-response relationships using empirical data analysis approaches and a review of these approaches by the Science Advisory Board (SAB, 2010) has provided additional insights as to how evidence of stressor-response relationships may be used in establishing numeric nutrient criteria.

3.1.3 Mechanistic Modeling Approach

The mechanistic modeling approach is used to predict specific constituents based on a series of equations and algorithms that represent physical, chemical, biological, and ecological processes. Mechanistic models include a wide variety of water quality models, some of which were briefly described in previous USEPA nutrient criteria guidance documents (USEPA 2000a, 2000b). A much more in depth discussion of water quality modeling theory and practice can be found in a wealth of references (e.g., Chapra, 1997; Martin and McCutcheon, 1998; Edinger, 2002). Simple mechanistic models to estimate residence times within the CHNEP estuaries will be employed as part of this study.

3.2 Problem Formulation and Goal Development

The use of a weight of evidence approach will be a critical aspect of our intended development of proposed criteria. Aside from the USEPA guidance on empirical approaches to developing numeric nutrient criteria, there are many peer reviewed articles on the development of criteria that will be utilized as guidance in our efforts. What follows is a detailed description of our proposed analytical approach with citations to documents that were instructive in providing guidance in formulating our proposed approach. It is important to note that we have a variety of analytical tools available to us and that we have demonstrated capability to employ these methods towards this issue.

To a large extent the goals have been defined by the USEPA - to develop numeric criteria for total nitrogen (TN) and total phosphorus (TP) in Charlotte Harbor estuarine waters. The problem formulation is predicated on defining the mechanisms by which the nutrients under consideration affect the estuaries in their ability to fully support their designated aquatic life uses. Therefore, a definition of the appropriate stressor (causal) and response variables is required.

There has been a substantial amount of work in southwest Florida directed towards defining seagrass, water quality, and nutrient loading targets, as well as defining the stressor-response relationships for estuarine waters (Janicki et al., 1994; Janicki and Wade, 1996; Tomasko et al., 2005; Corbett and Hale, 2006; Janicki et al., 2008; Janicki Environmental, 2009; Janicki et al., 2009; Dixon et al., 2010). We intend to utilize existing, technically sound information as a basis from which to identify the response variables of interest corresponding to designated uses as well as the anthropogenically influenced stressor variables that result in adverse effects to estuarine health. We know that the USEPA is interested in chlorophyll *a* concentrations (as a surrogate measure of phytoplankton concentration) as a biological response endpoint. This endpoint is commonly used in a regulatory framework for evaluating water quality and is often used as an index defining the trophic state of waterbodies. Chlorophyll *a* concentrations are also used by the FDEP as a primary criterion for determining impairment of waterbodies in both freshwaters and estuaries. Chlorophyll *a* not only affects light penetration through the water column but the degradation and decay of phytoplankton can also affect water column dissolved oxygen concentrations. FDEP also uses standards for DO to determine impairment. The value of using these parameters as response variables is in their more direct linkage to nutrient enrichment in the causal pathway as described above. Therefore, chlorophyll *a* will be used as the primary response variables of interest. However, if through analysis it is demonstrated that chlorophyll concentrations do not contribute to deleterious effects on light penetration in these estuaries, the relationship between chlorophyll and DO will be explored. The response variable of interest may become DO using the conceptual model that increased phytoplankton production from nutrient enrichment can reduce bottom DO levels leading to deleterious effects on estuarine health.

The methodology presented in this document is intended to be used to develop numeric nutrient criteria for total nitrogen (TN) and total phosphorus (TP). These constituents are defined as the stressor variables of interest. Relationships between nutrient enrichment and estuarine eutrophication are well-known and accepted; however, there are many factors such as hydrologic retention times and seasonality that influence the ability of phytoplankton to take up nutrients. Further complications arise when trying to assess stressor-response relationships between nutrients and response when the limiting nutrient is not considered or when co-limitation may occur over the range of the relationship. Therefore, we intend to consider how covariates such as residence times, seasonality, colored dissolved organic matter and other potential confounding factors influence the relationship between nutrients and phytoplankton responses in southwest Florida estuaries. We intend to document the physical, chemical and biological variables comprising the morphological relationships (e.g., habitat, spatial, and temporal) that define the aquatic system of interest, and which may be important in modifying the relationship between nutrient concentrations (both nitrogen and phosphorus) and observed endpoints as recommended by the SAB (2010). Conceptual models are a valuable tool to visualize and refine the conceptual framework under which subsequent data analysis will take place.

Charlotte Harbor is a data rich estuary, including many years of discrete water quality sampling in both the estuaries and their watersheds, nutrient loading estimates, and many other studies including seagrass coverage and routine fisheries monitoring are available. The forethought and insight of local scientists and resource managers in these estuaries has allowed for analysts to have available to them a wealth of empirical information from which to consider stressor-response relationship as part of the development process for numeric nutrient criteria.

3.3 Analytical Framework

There are several principles that we intend to follow with respect to data analysis. A primary consideration is that analysis should follow the design used to generate the data. For example, analysis of data collected using a fixed station sampling design should be conducted differently than analysis conducted on data from probabilistic designs. There are advantages and compromises associated with both designs but recognition of the design allows for the proper analytical tool to be chosen. We intend to characterize the sampling design from which the data were derived for each analytical component in the development of the numeric nutrient criteria and state the assumptions and limitations of the sampling design as it pertains to any outcomes derived from an analysis. Another important component of the preliminary evaluation is the visualization of the data using exploratory data analysis methods. Exploratory data analysis methods will be based on the conceptual models developed in the previous step. Scatterplots will be generated to visually explore relationships among potential stressor and response variables. Maps can be generated that display the spatial variability for particular stressor and response variables of interest within an estuary. Univariate summary statistics will be generated as an initial exploratory data analysis step as well as Cumulative Frequency Diagrams (Cumulative Distribution Function) plots, and timeseries plots. Inter and intra-annual box plots are valuable tools to explore the temporal variability in the metric of interest.   Simple correlation metrics such as Pearsons correlation coefficient (Rho), and Spearmans rank correlation coefficient (Rho S) will also be utilized in the exploratory data analysis phase.

Our proposed method of using stressor-response relationships to develop numeric nutrient criteria is conceptualized in the illustration provided in Figure 2. At this point the determination has been made that a stressor-response model is the preferred method for assessment. The problem has been formulated and a conceptual "model construct" has been developed that describes the hypothesized cause and effect relationship. Once the model construct has been established, empirical analysis approaches will be developed from which analytical outcomes will be generated.

As illustrated in Figure 2, analytical outcomes will be generated from the data analysis and these analytical outcomes will be evaluated as to their relevance to the conceptual model construct. If the analytical result does not agree with the model construct, then the model construct will be revisited. If the outcome supports the model construct, then the outcome will be compared as to its relevance to existing information. Since there is a wealth of information established in the stewardship of these estuarine systems, the analytical outcome will be weighed against this existing information. If the analytical outcome supports existing information and the conceptual model construct, then an assessment will be conducted as to the appropriate mechanism to implement the analytical outcome as a potential numeric nutrient criterion.

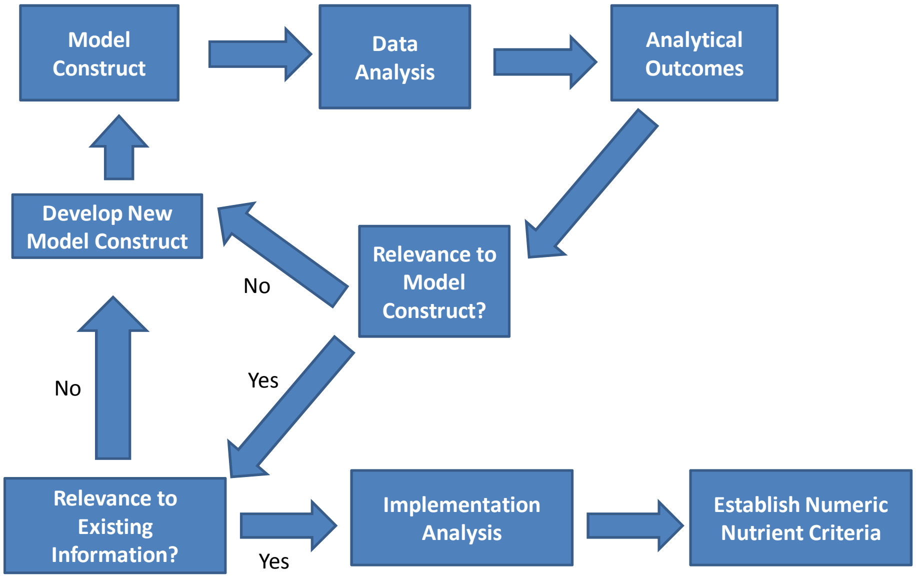

Figure 2. Analytical flow path to development of Estuarine Numeric Nutrient Criteria.

3.4 Data Analysis Plan

The USEPA guidance on the use of empirical approaches to establishing numeric nutrient criteria has detailed several analytical tools which we intend to employ as part of our analytical approach. Linear regression, logistic regression, and quantile regression are all useful tools that are commonly used in assessing stressor-response relationships. In the USEPA Guidance document, USEPA characterizes these tools as appropriate for use when response thresholds have been previously established. The rate of change estimates provided by the slope coefficient in these relationships can be used to predict the criterion value that results in the established threshold. Changepoint methods are valuable tools to identify thresholds indicating where a rate of change in response to a stressor may change dramatically indicating a nonlinear threshold value such as the assimilative capacity of a system under study. Changepoint methods are rapidly evolving from simple data mining tools to predictive models using advanced statistical algorithms to evaluate conditional probabilities in the stressor-response relationships. These methods are therefore useful to evaluate the stressor-response relationship whether or not a threshold value has been established. Several novel techniques are available to quantify the spatial relationships with the estuary such as generalized additive models (GAM), spatial interpolation methods and artificial neural networks that we intend to explore as potentially useful tools to understand how hydrology, residence times, nutrient loads and concentrations and primary productivity inter-relate. What follows is a brief description of each method with specific examples provided to convey the analytical path we intend to follow.

3.4.1 Regression Approaches

Linear regression is a common statistical technique used to explore the relationship between two or more variables. The relationship between the dependent variable (y-axis) and independent variable (x-axis) is developed. This is done by fitting a straight line through the set of points that minimizes the sum of squared residuals (i.e. the difference between observed and model predicted values). Assumptions of linear regression include independence, homoscedasticity (equality of variance) and normal errors.

An example of a linear regression applied to the relationship between chlorophyll *a* and TN in Upper Lemon Bay is provided in Figure 3. There is a statistically significant relationship between these two variables.

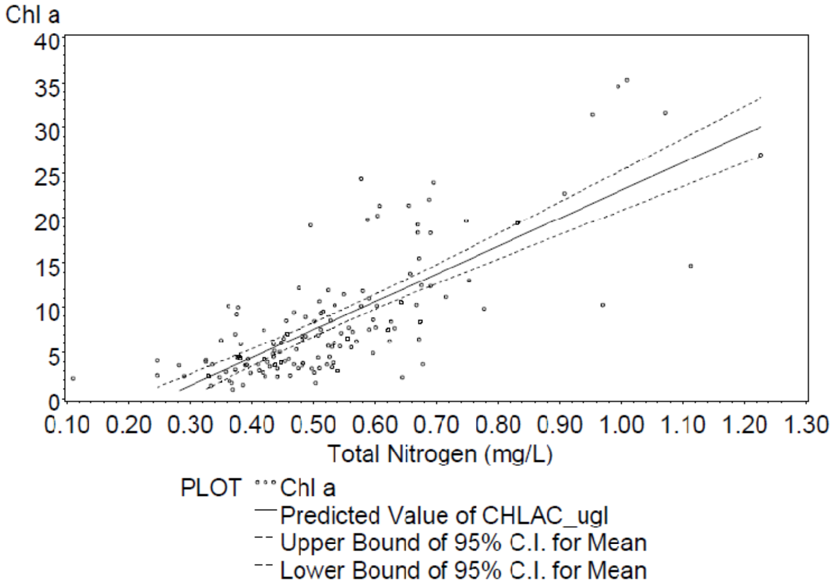

Figure 3. Linear regression of monthly average TN and chlorophyll a concentrations in Upper Lemon Bay.

Often times, water quality data are not normally distributed and exhibit a non-linear relationship with other variables. While there are non-linear regression techniques that can be employed, one should try transforming the data. Often times, ordinary linear regressions can be developed using a natural log transformation of the data and these model will satisfy the assumptions of linear regression. Sometimes specific transformations such as the natural log are insufficient to satisfy the assumptions of normality of the error structure. In these cases the Box-Cox method (Box and Cox, 1964) will be used. The Box-Cox method considers a family of power transformations of the exponential distribution:

$$\frac{y^{\lambda}-1}{\lambda}$$

This transformation is sometimes helpful in normalizing the error term and more satisfactorily modeling the observed relationship.

Analysis of covariance is an extension of linear regression that allows for the incorporation of discrete categorical variables into these relationships. For example, in Upper Lemon Bay the sampling design is stratified such that a single sample is collected in month in each of 5 strata (i.e., LB1-LB5; Figure 4). nstead of estimating the relationship of the monthly average values across all strata, a “stratum” variable can be incorporated into the analysis to test for potential differences among strata with Upper Lemon Bay. Analysis of covariance is a powerful tool to incorporate covariates and account for potential confounding in the stressor-response relationship.

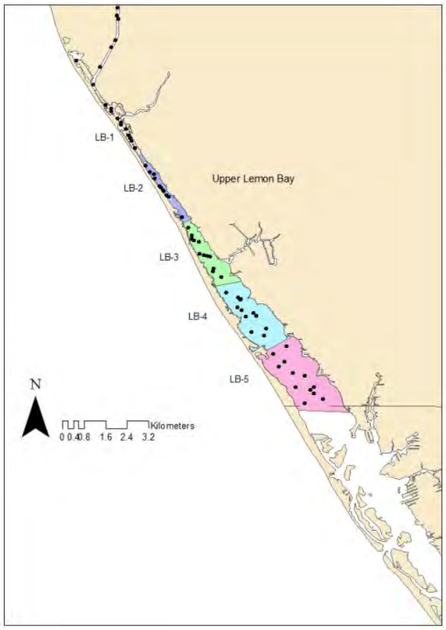

Figure 4. Map of Upper Lemon Bay with sampling strata depicted.

Hierarchical linear modeling is extension of analysis of covariance that allows for estimation of correlation among samples. One of the assumptions of traditional regression is that samples are independent. The statistical tests performed as part of this procedure relies heavily on this assumption. If however, data are correlated, these tests can lead to false declaration of statistical significance (i.e., Type 1 error). Hierarchical models can be constructed to account for this correlation by estimating the covariance among samples and adjusting the significance levels to account for this correlation. We will explore using covariance patterns models to test for correlation among samples when correlation is suspected to be affecting the statistical test.

Logistic regression models are used to predict the probability of an event occurring as a function of one or more independent variables. Because the dependent variable in logistic regression is dichotomous, this regression technique lends itself to situations where a water quality measurement results in an exceedance or impairment (e.g., dissolved oxygen < 4 mg/l). In most other respects, logistic regression is similar to ordinary least squares regression. The model can be fit to observed data using maximum likelihood estimation and statistical tests are used to determine if model coefficients differ significantly from zero (USEPA, 2009). Generally, logistic regression is most beneficial when the probability of an event ranges between near zero and near 1 over the range of some independent variable.

An example of the use of logistic regression on water quality data is presented below. The relationship between DO exceedances and flow was investigated. A general trend of lower DO concentrations at lower flows was documented. However, the ordinary least-squares regression was not sufficient to predict DO exceedances based on flows. Therefore, logistic regression was employed (Figure 5) with satisfactory results. Logistic regression can be used with categorical and continuous predictor variables and slope estimates can be translated to describe the change in odds of occurrence per unit change in the predictor variable.

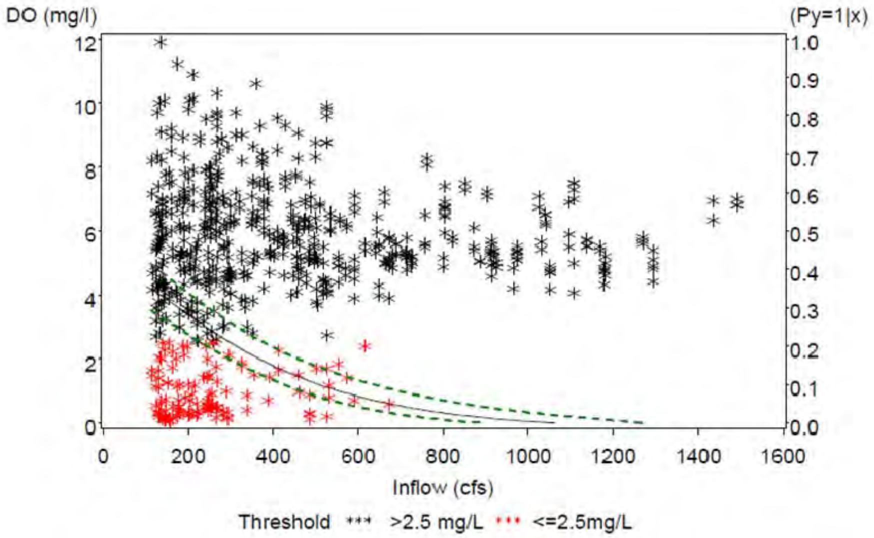

Figure 5. Relationship between the probability of DO < 4mg/l and flow as defined by a logistic regression.

3.4.2 Changepoint Analysis

Changepoint methods are rapidly evolving from simple data mining tools to predictive models using advanced statistical algorithms to evaluate conditional probabilities in the stressor-response relationships over the range of the relationship. These methods are therefore useful to evaluate the stressor-response relationship whether or not a threshold value has been established. Collectively referred to as “Decision Trees”, this methodology provides an intuitive and easily conveyed approach to identify threshold responses to environmental stressors that may be used in the development of numeric nutrient criteria. We intend to use a conditional inference tree methodology (Hothorn et al., 2006) as one line of evidence for evaluating stressor-response relationships. Conditional inference trees are a form of regression tree analysis (RTA) that has been successfully used to assist in the development of numeric nutrient criteria (e.g., Soranno et al., 2008). The approach is based on recursive partitioning. The partitioning process iteratively searches for a point in the stressors variable which maximizes the difference in the response values between two groups of response data. No *a priori* threshold is specified. The regression tree approach defines the breakpoint as that which maximizes the difference between groups by minimizing the p value associated with some statistical test. The point in the stressor variable at which the p value is minimized, after adjustment for multiple comparisons, is assigned as the breakpoint defining the split of the of the response variable into 2 groups. Once the first split is made the process continues to test for subsequent splits that are conditional on the first split. Hence, the term “conditional inference” or “conditional probability analysis” that has been popularized recently by the USEPA as a potential approach for establishing numeric nutrient criteria.

Conditional inference trees embed tree-structured regression models into a well-defined theory of conditional inference procedures (Hothorn et al., 2006). This class of regression trees is applicable to all kinds of regression problems, including nominal, ordinal, numeric, censored as well as multivariate response variables and arbitrary measurement scales of the covariates. These models can be specified to provide information on the strength of the stressor-response relationship, account for covariates in the relationship and model conditional probabilities. Validation techniques are built in functions in the procedures which can be invoked to estimate the predictive power of the resultant models. Below is an illustrative example of the analytical process using conditional inference trees.

Following the example conceptual model provided, the hypothesis is established that chlorophyll a concentrations are a function of TN concentrations. The conditional inference tree is used to search for statistically significant changepoints in the relationship between TN and chlorophyll *a*. In Figure 6, the first split occurs at a monthly TN average value of 0.57 mg/l (node 1). Successive splits are performed at the conditional nodes indicating that there are several non-linear changepoints in the relationship between TN and chlorophyll *a*. The distribution of the response variable is provided in the box plots at the bottom of the figure for each of the terminal nodes. It is easy to see that there is a positive relationship between TN concentrations and chlorophyll *a* responses over the range of data and that nonlinear increases in chlorophyll *a* levels appears to occur when the TN concentrations are above 0.57 mg/l. This is information that may be used in a weight of evidence approach to develop potential criteria for TN.

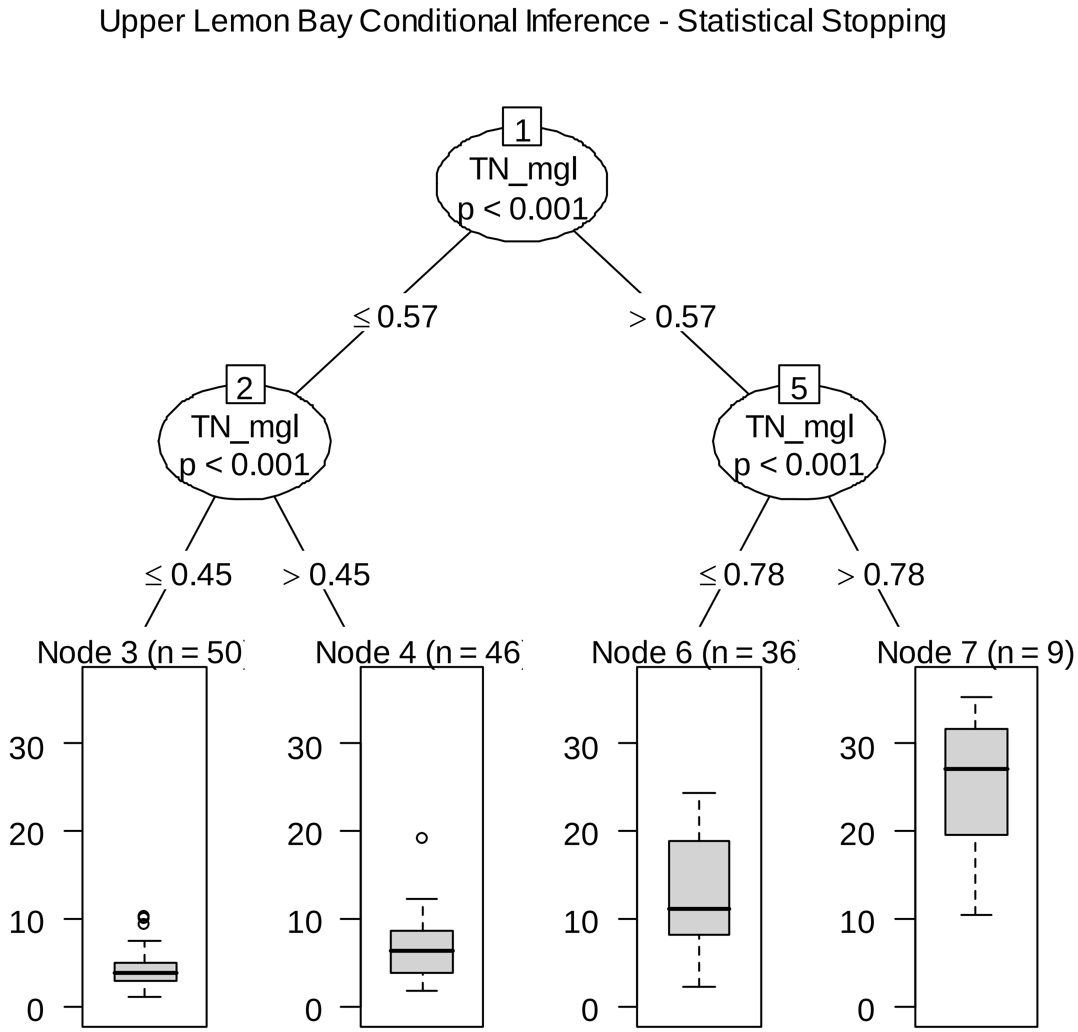

Figure 6. Changepoint analysis for relationship of TN and chlorophyll *a* in Upper Lemon Bay.

It is anticipated that decision tree methods will provide valuable information for establishing numeric nutrient criteria in some cases and not in others. Principally, the results will depend on our ability to account for the many potential confounding variables in the relationship between nutrients and phytoplankton responses. The study area for this project includes a diverse set of estuarine water bodies from lagoonal systems with high residence times and little freshwater input relative to estuarine segments with small estuarine waterbodies with large hydrologic inputs and direct influence of tidal passes. It is important to note that all of these approaches are likely to result in potential criterion values that are sometimes exceeded. In other words, a changepoint can only be identified if there are values above the changepoint value. This is an important consideration in the implementation of a proposed criterion value.

3.4.3 Exceedance Frequency Methods

Exceedance frequency analysis is a broad class of methods that includes logistic regression described above as well as several other techniques used to assess the frequency and/or duration of events. The FDEP uses an exceedance frequency approach to identify impaired waters with respect to DO values in Florida by assessing the proportion of dissolved oxygen values less than 4 mg/l in estuarine (Class 3m) waters. This evaluation procedure utilizes the binomial test to statistically evaluate whether greater than 10% of the values are below the criterion. By including confidence intervals in the evaluation procedure the method accounts for the fact that difference in the proportion of events may be due to chance alone based on the sample size. We will explore how exceedance frequency analysis can be incorporated into the development of numeric nutrient criteria in the CHNEP estuarine waters.

One method previously used to evaluate the status of CHNEP estuarine waters was the use of the Horovitz-Thompson (HV) estimator (Janicki Environmental, 2008). Briefly, the HV estimators characterize the entire distribution for each water quality indicator of interest and estimate the probability of obtaining a value at random less than or equal to a given value for each strata and season with known confidence. Using the CCHMN data collected since inception of the program, the samples were assigned seasons based on accepted results of previously defined studies:

- Wet Season: July through November
- Dry Season: December through June

Based on these baseline data, the HV estimator was used to establish an expectation for a given strata and season with respect to the likelihood of obtaining a sample of a given value for each water quality indicator parameter of interest. Figure 7 displays the CDF for chlorophyll *a* in stratum East Wall for dry (top) and wet (bottom) seasons. Inset in this figure is a pie graph displaying the percent of the distribution less than or equal to 11 µg/l, a target indicator for FDEP in their assessment of impaired waters in Florida estuaries. Also included are the 95% confidence intervals for the estimates which are based on the uncertainty associated with the sample data.

It seems reasonable that if a waterbody is meeting its designated uses and does not have a degrading trend in water quality, existing exceedance frequencies over the baseline period could be used to establish numeric nutrient criteria.

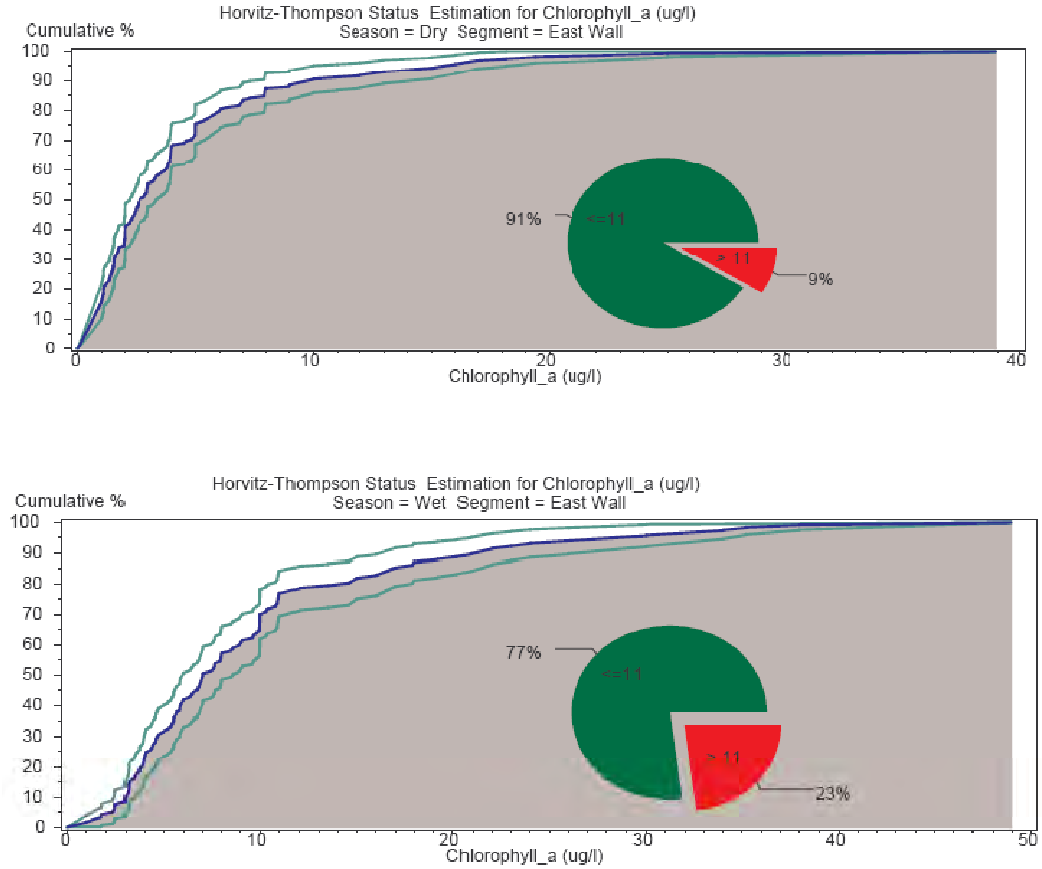

Figure 7. Results of HV estimation for chlorophyll *a* in East Wall in the dry season (top) and wet season (bottom) with the percentage of samples greater than 11 ug/l inset as a pie graph.

3.4.4 Spatial models

There appear to be portions of the CHNEP study area, such as the Tidal Peace River, that may not be nutrient limited (Pribble et al., 1997). McPherson et. al. (1990) among others has suggested that most of the variability in light-normalized productivity and chlorophyll *a* could be attributed to two factors derived from Principal Component Analysis of ambient water-quality characteristics. One factor related to seasonal variability and the other to spatial variability. The seasonal factor incorporated the interaction of temperature and nutrients. The spatial factor incorporated the interaction of salinity, nutrients, and water color that resulted from the mixing of freshwater inflow and seawater. Although freshwater inflow increased the availability of nutrients in low salinity (less than 10‰) waters, the highly colored freshwater restricted light penetration and phytoplankton productivity. Maximum productivity and biomass occurred where color associated with the freshwater inflow had been diluted by seawater so that light and nutrients were both available. Indeed scatterplots of nutrients and chlorophyll *a* indicate that other factors likely mediate the relationship between total nitrogen and chlorophyll *a* in the Tidal Peace River (Figure 8).

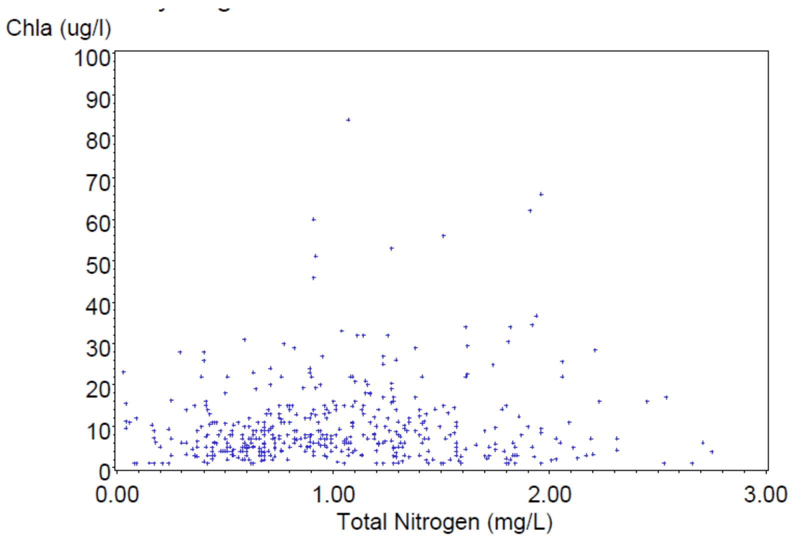

Figure 8. Scatterplot of Total Nitrogen and chlorophyll *a* in the Tidal Peace River from a probabilistic sampling design conducted by the Coastal Charlotte Harbor Monitoring Network.

In the Bokeelia segment of Charlotte Harbor which is located closer to and under much more direct influence from the Gulf of Mexico, it is clear that there is a great deal of variability if the relationship between TN concentrations and chlorophyll *a* concentrations but that higher concentrations of chlorophyll *a* appear to be associated with lower salinities (Figure 9). We intend to test hypotheses that nutrient and hydrologic loads from the Tidal Peace and Myakka rivers influence the relationship between TN concentrations and chlorophyll *a* concentrations in the East Wall, West Wall, and Bokeelia strata. In order to that we are proposing to build a statistical model that incorporates the distance from the mouth of the Tidal Peace River to estimate the spatial and temporal variation in chlorophyll as a function of hydrologic load, nutrient load and distance from the mouth. We may use existing fixed station locations within the Tidal Peace such as stations 9 and 10 sampled by the Peace River Manasota Regional Water Supply Authority as reference points from which to calculate distances. These points were also used in Turner et al. (2006) in their study of paleo-indicators and water quality change in Charlotte Harbor.

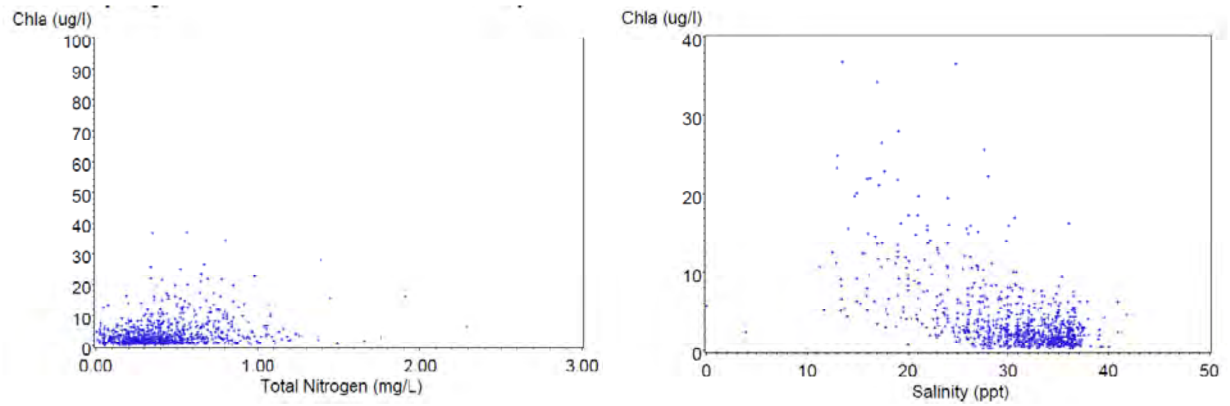

Figure 9. Scatterplot of TN and chlorophyll (left) and salinity and chlorophyll *a* (right) in the Bokeelia stratum.

The statistical model used for this assessment will incorporate a spatial component and quite possibly be of the form of a non-parametric or semi-parametric form.

Generalized additive models allow for a combination of distribution specific and distribution free methods to be employed. Generally, smoothing parameters are specified for the covariates that contribute to noise in the relationship but are not specifically of interest in the modeling exercise while parametric distributions (i.e. normal) are specified for the causal variables of interest. This approach allows for the model to account for noise in the covariates that may not take a particular distributional form but model the relationship between the stressor and response using parametric methods. Interpolation using GIS will likely be used to characterize the spatial distribution for parameters of interest when building the conceptual model for this exercise. If these methods fail to achieve their intended objectives, we will investigate the use of artificial neural networks as a potential approach to describe the spatio-temporal variability in the relationship between nutrients and chlorophyll. These more complex methods also result in more complex interpretation in order to establish numeric nutrient criteria. Sensitivity analysis and simulation may be required in order to assess the effects of varying nutrient loads and concentrations on chlorophyll a responses.

4.0 Practical Considerations

The CHNEP area has historically been subject to occasionally extreme natural events including hurricanes, blooms of the red tide causing organism *Karenia brevis* and episodic hypoxic events. The impact of these episodic natural events will likely impact water quality and should be somehow accounted for in the evaluation process for determining impairment of southwest Florida estuaries. While it is not possible to accurately predict the timing or influence of these events, an evaluation of the frequency of previous events when water quality data were available will lend insights into how these events might impact water quality in terms of frequency and duration. Anthropogenic activities may also cause acute and severe impacts to water quality. The phosphate mining industry has previously had episodic spills of acidic wastewater from the phosphate mining process. These spills have resulted in acute impacts to water quality and biota. While the mining industry has made great efforts in reducing the probability of these episodic events, the potential still exists for these types of events to occur in future years.

Irrespective of the cause of these impacts, the evaluation process should consider how to handle these events in evaluation of a waterbody. Short-term water quality exceedances are likely event driven, while long-term exceedances are likely more indicative of chronic conditions. These practical considerations will be evaluated within the context of establishing the numeric nutrient criteria. The proposed numeric nutrient criteria will also be considered within the context of expected future data collection efforts.

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