Environmental

December 6, 2010

Ms. Stephanie Sanzone
Designated Federal Officer (DFO)
EPA Science Advisory Board Staff Office (1400R)
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, D.C., 20460

Subject: Comments to the USEPA Science Advisory Board Nutrient Criteria Review Panel Pertaining to Florida's Southern Inland Flowing Waters

Dear Ms. Sanzone,

I appreciate the opportunity to provide comments to the Science Advisory Board (SAB) Review Panel on behalf of the Everglades Agricultural Area Environmental Protection District (EAA-EPD).

Water conveyance in South Florida occurs through a managed network of man-made canals, which comprises the vast majority of Florida's Southern "Inland Flowing Waters". USEPA is in the process of deriving numeric nutrient criteria to replace the current narrative criterion, which states: "in no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora and fauna". In its guidance document, USEPA is considering several methodologies, including reference condition, distributional and stressor-response approaches, to establish numeric criteria for nitrogen (N) and phosphorus (P) in south Florida canals[1]. However, due to physical, biological, and functional differences between canals and streams, and the paucity of biological data on canals, the promulgation of scientifically valid nutrient criteria for south Florida canals clearly will be a challenging task.

[1] See United States Environmental Protection Agency (USEPA) "Methods and Approaches for Deriving Numeric Criteria for Nitrogen/Phosphorus Pollution in Florida's Estuaries, Coastal Waters, and Southern Inland Flowing Waters" dated November 17, 2010.

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It is my opinion that USEPA, in its guidance document, has not identified a reliable or useful way to derive numeric nutrient criteria for south Florida Canals. Attached to this comment letter is a report[2] that my firm submitted to USEPA in April 2010, in response the earlier (January 2010) proposed south Florida canal criteria for TN (1.6 mg/L), TP (42 μg/L) and chlorophyll (4 μg/L)[3]. While USEPA currently has not yet proposed specific values for TN and TP, the proposed methodologies are similar to those in the January 2010 document, and suffer from the same constraints as pointed out in our report.

In my view, to develop scientifically defensible numeric criteria, the data and associated analyses must be available/developed to address two key questions related to south Florida canals: 1) what biological communities are being protected? and, 2) will adherence to numeric criteria produce a beneficial outcome with respect to flora and fauna, and designated uses in the canals?

I respectfully recommend that the SAB Panel Members consider the following points during their review of numeric criteria development methodologies for Florida's Southern Inland Flowing Waters:

- Because the south Florida region exhibits a wide range of geologic, soil and groundwater conditions, the natural spatial variability in water quality and biological parameters should be taken into account. USEPA's current proposed approach of dividing south Florida into sub-regions, based in part on the above features, is a useful first step.

- Because south Florida canals are primarily artificially constructed water bodies or are highly altered, the background or "natural" conditions are undefined, and prevailing conditions are often controlled largely by the location (soils, geology) or physical attributes (depth of canal, which allows for interactions with underlying rock or groundwaters), rather than anthropogenic activities. Additionally, the functions of riparian zones as found in streams, including habitat and nutrient retention, are typically lacking in the south Florida canals constructed and maintained primarily for flood

[2] See DeBusk, T. A. "An Assessment of USEPA's Proposed Nutrient Criteria and Chlorophyll Thresholds for South Florida Canals" dated April 26, 2010.

[3] See USEPA "Water Quality Standards for the State of Florida's Lakes and Flowing Waters" dated January 2010

control. As such, the biological expectations in canals differ and are lower than that of healthy stream systems.

- Flows and water levels in south Florida canals are managed by water control structures (spillways, gates, and pumps). Moreover, most south Florida canals are not constantly flowing, but rather are stagnant for extended periods. Protecting or restoring the balance of "natural populations of flora and fauna" in canals must consider the constraints on habitat imposed both by physical structure and flows in canals, as well as management activities (e.g., aquatic habitat within canals is often compromised by maintenance operations that remove canal bank vegetation and obstructions to flow).

- Significant amounts of readily available canal water quality data were not considered by USEPA in the earlier (January 2010) criteria development process, and it should be noted that there are chlorophyll, P and N data from canals throughout the EAA and other parts of inland South Florida that could be used to develop regionally appropriate criteria.

- Swimming is widely discouraged or prohibited in south Florida canals by local, state and federal authorities due to inherent dangers to public safety (e.g. steep banks, deep water, alligators). Swimming therefore cannot reasonably be considered to be among the beneficial use of canals.

- The guidance document suggests that the USEPA intends to utilize chlorophyll as the biological response variable indicative of nutrient enrichment for south Florida canals. However, because the goal is to protect overall ecological condition and designated uses, it is important to evaluate relationships among nutrients, chlorophyll a, and other food web components, such as macroinvertebrates and fisheries. Moreover, many south Florida canal waters contain moderate to high color concentrations, which as has been noted in lakes can exert a pronounced influence on water clarity and chlorophyll-nutrient relationships.

- Studies of macroinvertebrate populations in south Florida canals show that typical canals offer few substrates for colonization, and that biological expectations for canals are markedly different than for healthy streams. Additionally, available data suggest that for

both canals and healthy streams in Florida, macroinvertebrate communities are not sensitive to nutrient levels over the ranges that currently prevail throughout south Florida canals. Accordingly, USEPA's expectation that the biological communities will improve or benefit as a consequence of numeric criteria is without any basis in sound science.

- Publicly available, relevant biological data demonstrate that south Florida canals provide excellent sport fisheries at ambient nutrient levels. The consensus of scientific studies relating sport fishery production to nutrient and chlorophyll concentration in Florida waters clearly indicates that the primary beneficial use of south Florida canals is already being achieved.

- The current proposal to establish a numeric criterion for TN directly contradicts USEPA's 2007 Proposed Total Maximum Daily Load (TMDL) For Dissolved Oxygen and Nutrients In The Everglades (including canals the EAA)[4], in which they state they are unaware of any data indicating that TN causes imbalances in flora or fauna in Class III canals within the EAA.

- For south Florida canals, there will be significant challenges with the methods for derivation of in-stream protection values, including the definition, use and biological verification of the "reference condition" approach. The relationship between Landscape Development Intensity (LDI) and measures of biological health has been shown for several aquatic systems (wetlands[5], streams[6]) but not for canals. Until such relationships are established the LDI is not appropriate for use in south Florida.

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[4] See USEPA. 2007. Proposed Total Maximum Daily Load (TMDL) for dissolved oxygen and nutrients in the Everglades (WBIDs 3252A, 3252B, 3252C, 3260, 3263, 3265B) Hendry, Broward Palm Beach and Dade Counties, Florida. Prepared by USEPA Region 4, Atlanta, GA.

[5] See Reiss, K. C., and M. T. Brown 2007. Evaluation of Florida Palustrine Wetlands: Application of USEPA Levels 1, 2, and 3 Assessment Methods. EcoHealth Journal 4: 206-218.

[6] See Fore, L. S., R. Frydenborg, D. Miller, T. Frick, D. Whiting, J. Espy, L. Wolfe. 2007. Development and testing of biomonitoring tools for macroinvertebrates in Florida streams (Stream Condition Index and Biorecon). Final Report prepared for Florida Department of Environmental Protection. Tallahassee, FL.

- Many canals discharge to estuaries along Florida's south, east and west coasts, while other canals discharge into freshwater wetlands or lakes. The primary canals in the EAA deliver water to a network of Stormwater Treatment Areas (STAs) that remove nutrients from surface waters before discharge into the Everglades Protection Area. The presence of such regional water treatment facilities should be recognized in setting nutrient criteria among south Florida subregions.

Our attached report (April 2010), in which we reviewed the initial (January 2010) approach used by USEPA in developing proposed TP, TN and chlorophyll criteria for south Florida canals, provides background information on the above key points, and also addresses the following questions:

- Did USEPA consider all relevant data, and utilize appropriate data screening and analysis approaches?

- Do existing data support USEPA's contention that the proposed numeric criteria are needed to protect recreational swimming and fishing in south Florida canals?

- Do existing data support USEPA's contention that chlorophyll is an appropriate biological response variable to nutrients in south Florida canals?

- Is it likely that the quality of south Florida canal biological communities, including those not considered by USEPA such as fish and macroinvertebrates, will improve by establishment of the proposed numeric criteria?

For the above reasons and constraints, I believe a more rational approach for south Florida canals is for USEPA to retain the existing narrative criteria for nutrients as in-stream protection criteria and, when appropriate, establish numeric criteria only as downstream protection values.

Respectfully submitted,

Thomas A. DeBusk
President and Principal Scientist

Attachment

An Assessment of USEPA's Proposed Nutrient Criteria and Chlorophyll Thresholds for South Florida Canals

Comments on

United States Environmental Protection Agency's

40 CFR Part 131
[EPA-HQ-OW-2009-0596; FRL-9105-1]
[RIN 2040-AF11]

Water Quality Standards for the State of Florida's Lakes and Flowing Waters

Posted January 26, 2010

Prepared by

Thomas A. DeBusk

DB Environmental, Inc.

Rockledge, Florida

April 26, 2010

Introduction

The USEPA has proposed numeric nutrient criteria for inland freshwaters, with specific values for canals in the south Florida region (USEPA 2010). Numeric criteria for TP, TN and chlorophyll are proposed to protect the designated uses of canals in south Florida. At concentrations > 1.6 mg/L TN or > 42 µg/L TP, USEPA considers the nutrients TN and TP causative pollutants that lead to an impaired condition and a water body in such condition is expected to fail to meet its designated uses. Chlorophyll > 4 µg/L is proposed by USEPA as an alternative indicator of failure to meet designated use due to nutrient pollution.

The south Florida region is generally defined as the region south of Lake Okeechobee, the St. Lucie Canal and the Caloosahatchee River. Urban development exists along the southeast and southwest coastal ridges where sandy soils cover porous limestone. Through the center of the region is a wide flat basin with muck soils in excess of 5 feet deep. Freshwater marshes extend from the Everglades Agricultural Area south to Florida Bay. Marsh soil depths decline with distance from Lake Okeechobee, evidence of a historic nutrient north-to-south gradient in hydrology and nutrient regime (Stober et al., 2001). Canals form an extensive integrated drainage network across the entire area, though fewer canals are found within Everglades National Park and Big Cypress National Preserve than in other areas.

The promulgation of scientifically valid nutrient criteria for south Florida canals clearly is a challenging task. Because the south Florida region exhibits a wide range of geologic, soil and groundwater conditions, the natural spatial variability in water quality and biological parameters must be taken into account. Moreover, because canals are highly altered or artificially constructed water bodies, the background or "natural" conditions are undefined, and prevailing conditions are often controlled largely by the location (soils, geology) or physical attributes (depth of canal, which allows for interactions with underlying rock or groundwater), rather than anthropogenic activities. Additionally, the functions of riparian zones as found in streams, including habitat and nutrient retention, are typically lacking in canals constructed and

maintained primarily for flood control. As such, the biological expectations in canals are lower than that of healthy stream systems (DBE 2009).

In this document, we review the approach used by USEPA in developing the TP, TN and chlorophyll criteria for south Florida canals, and evaluate available data to assess the linkages between water quality and designated uses of these man-made systems. Specifically, we address the following questions to determine whether USEPA acted in an arbitrary manner in developing the criteria:

- Did USEPA consider all relevant data, and utilize appropriate data screening and analysis approaches?
- Do existing data support USEPA's contention that the proposed numeric criteria are needed to protect recreational swimming and fishing in south Florida canals?
- Do existing data support USEPA's contention that chlorophyll is an appropriate biological response variable to nutrients in south Florida canals?
- Are chlorophyll concentrations of 4 µg/L (annual mean) and 15.8 µg/L (single sample) values appropriate threshold levels?
- Is it likely that the quality of south Florida canal biological communities, including those not considered by USEPA such as fish and macroinvertebrates, will improve by establishment of the proposed numeric criteria?

USEPA's Approach to Criteria Derivation

The USEPA selected chlorophyll as a response variable to indicate impairment of the designated use. The reasons given for this approach were that canals exhibit seasonal flow regimes, and that canals are listed on Florida's list of impaired waters with chlorophyll as the parameter of concern. The threshold nutrient concentrations selected were "assumed to inherently protect aquatic life" (USEPA 2010 TSD Ch. 4 p. 4-1). The USEPA states that their "methodology will ensure that nutrient concentrations associated with biologically healthy, well-balanced communities would be considered acceptable as protective of those communities."

USEPA obtained data from several agencies for water quality in canals and conducted a multi-step data screening procedure. A final screened dataset was used to develop distributions of concentrations for several parameters. From the distributions of values, criteria for TN, TP and chlorophyll were identified as the 75th percentile values.

Site selection has a profound influence on the results of a reference distribution approach, and therefore must be representative of the region for which criteria are being developed. It is essential to carefully consider each step in the data screening process that results in the exclusion of available data. In this case, however, the sampling sites used by USEPA to provide chlorophyll data were not distributed evenly throughout the South Florida region (Figure 1). All three distribution approaches used by USEPA (75th percentile of "reference" canals; 25th percentile of "all" canal data; and 75th percentile of minimally impacted sites along highway US 41) have similar flaws based on the arbitrary screening decisions made during the USEPA analysis. For a more complete discussion of the screening methodology, see Appendix A.

USEPA also suggested alternative approaches for criteria derivation. For example, the "not to exceed" criteria approach applies statistical techniques to a screened dataset that is not representative of the range of biological conditions found throughout the South Florida region. The limited range of conditions, in terms of hydrology, soils, geology and vegetation, represented by the USEPA-selected stations does not adequately describe the variability in nutrient or chlorophyll concentrations observed in the Everglades region over time. Without an

independent verification that designated use was degraded due to nutrient impairment, it is clear that USEPA's screening procedures were subjective and that the criteria based on flawed screening methods are significantly overly protective.

Available Data Not Considered by USEPA

The USEPA conducted the South Florida Ecosystem Assessment project over the last 20 years. Chlorophyll data was collected from 50 canal sites during Phase 1 of this project, along with nutrients, and a suite of additional parameters. However, canal sampling was not conducted in Phase 2 or later assessments, and chlorophyll results were not discussed in the Phase 2 final report or the 2007 follow-up assessment that specifically addressed water quality in the South Florida region (Stober et al., 2001; Scheidt and Kalla, 2007). This stands in contrast to the emphasis USEPA places on chlorophyll as an important response variable for Class III fresh waters in the region. The limited data developed by USEPA under the Ecosystem Assessment Project was apparently not incorporated into the criteria derivation analysis.

Florida Department of Environmental Protection (FDEP) has compiled datasets relevant to the application of Florida's Impaired Waters Rule (IWR). A recent request to FDEP in April 2010 for chlorophyll data resulted in over 350 stations with available data, most of which were not acknowledged by USEPA as being evaluated during criteria development. A brief discussion of these additional chlorophyll data that was available to the USEPA is provided in the following section.

Additional response variables that could have been considered by USEPA include fisheries data and macroinvertebrate surveys in Florida canal systems. These biological endpoints are useful in determining whether the canals meet the aquatic life use. We present information on macroinvertebrates and fish in the canals that was not considered by the USEPA in the nutrient criteria derivation, in a subsequent section of this response.

Finally, studies of coastal tributaries that measured chlorophyll and nutrients were conducted by Florida International University as part of the Long Term Ecological Research (LTER) project. http://fcelter.fiu.edu/research

The findings of these research efforts provide an important basis for comparison between canals draining to coastal environments and less disturbed systems without channelization. Investigations of fisheries resources were a part of the LTER effort (e.g., Trexler et al., 2005). In areas with minimal human alteration, relative to canals, hydrologic characteristics (e.g., salinity regime, marsh connectivity, hydroperiod) structured the natural fish communities. Since canals are designed to modify regional hydrology, a degraded biological condition in canal waters cannot be assumed to relate to nutrient pollution. Those studies were overlooked by USEPA during the nutrient criteria derivation.

Chlorophyll Data From the FDEP IWR Database

The IWR database, compiled and maintained by FDEP for use in the assessment of water bodies for the state's TMDL program, contains a substantial amount of verified and usable chlorophyll data for Class 3 canals in the Everglades region. However, there was no indication in the data acquisition and screening methodology presented in the USEPA Technical Support document that USEPA considered using this data source. While there is certainly a large amount of overlap in chlorophyll data between the IWR database and those databases cited by USEPA as primary data sources, it was apparent that a substantial amount of IWR chlorophyll data was either overlooked or disregarded by USEPA in developing canal chlorophyll and nutrient criteria.

As a demonstration of the amount of additional data available in the IWR database, we extracted records from the IWR, Run 39 (available at http://publicfiles.dep.state.fl.us/DEAR/IWR/), for stations with chlorophyll-a data in south Florida canals. A data query was used to select records from four hydrologic units: Everglades, Everglades West Coast, Lake Worth Lagoon / Palm Beach Coast, and Southeast Florida Coast. Our initial screening step was extraction of only Class 3F "Stream" (Class 3 freshwater canals and streams) records, excluding data records with a result code of "J" (non-verified data). The extracted chlorophyll stations were visually screened using geographic information systems (GIS), with a base layer of south Florida canals, and also screened according to station descriptions. Stations that were not identified as being canal sites (e.g., marsh, unnamed stream, lake and private pump stations), were omitted, along with the corresponding data records from those stations. Canal stations near Lake Okeechobee were retained if they were located within the canals. Following USEPA's screening procedure, we

also eliminated several older monitoring stations due to extremely high reported values (700 – 1,100,000 mg/L).

This search and screening procedure yielded a "short list" of 385 stations containing 10,405 chlorophyll observations, spanning a time period of 1973 – 2009. After removal of stations that were already represented in the USEPA chlorophyll data set, there were 326 IWR stations remaining, with 8290 chlorophyll observations (Figure 1a). Even if our screening was not as rigorous as that performed by USPEA, it is clear that numerous additional canal stations with chlorophyll data were available for use by USEPA for criteria development. In addition, the geographical distribution of the IWR chlorophyll monitoring stations is clearly more uniform than the 72 stations used by USEPA.

A comparison of USEPA-selected chlorophyll monitoring stations to the screened data obtained from the IWR database illustrates the relatively poor representation of many parts of the Everglades region (particularly the EAA) by the USEPA stations (Figure 1a). Comparison of the number of chlorophyll observations per station further illustrates the difference in overall geographical distribution of chlorophyll data provided by the USEPA dataset compared with the additional data available in the IWR database.

A similar data acquisition and screening procedure was performed for TN and TP data contained in the FDEP IWR database. This data search yielded a total of 19,346 TN and 21,281 TP observations from sites in the Everglades region not included in the USEPA list of nutrient stations. As observed for chlorophyll data, there was clearly additional TN and TP data available from the IWR database which, when combined with existing USEPA data, would have resulted in a more spatially-distributed data set, and would provide a more equitable representation of the various basins, including the EAA, in the Everglades. Comparison of the spatial distribution of TP and TN data in the USEPA data set vs. the distribution of TP and TN data in the additional IWR stations is presented in Figures 1b and 1c.

The additional data found in the IWR database highlights the importance of using chlorophyll and nutrient data from all available verified databases. This is of particular importance where numerical criteria are developed for an under-represented (in terms of water quality data) region

such as the EAA. The enhanced data coverage provided for the EAA by addition of IWR data illustrates this point (Figure 2). Our focus on the data available from the IWR database is but one example of a major data set that may have been overlooked by USPEA, and certainly there may be other sources of usable data that were not exploited.

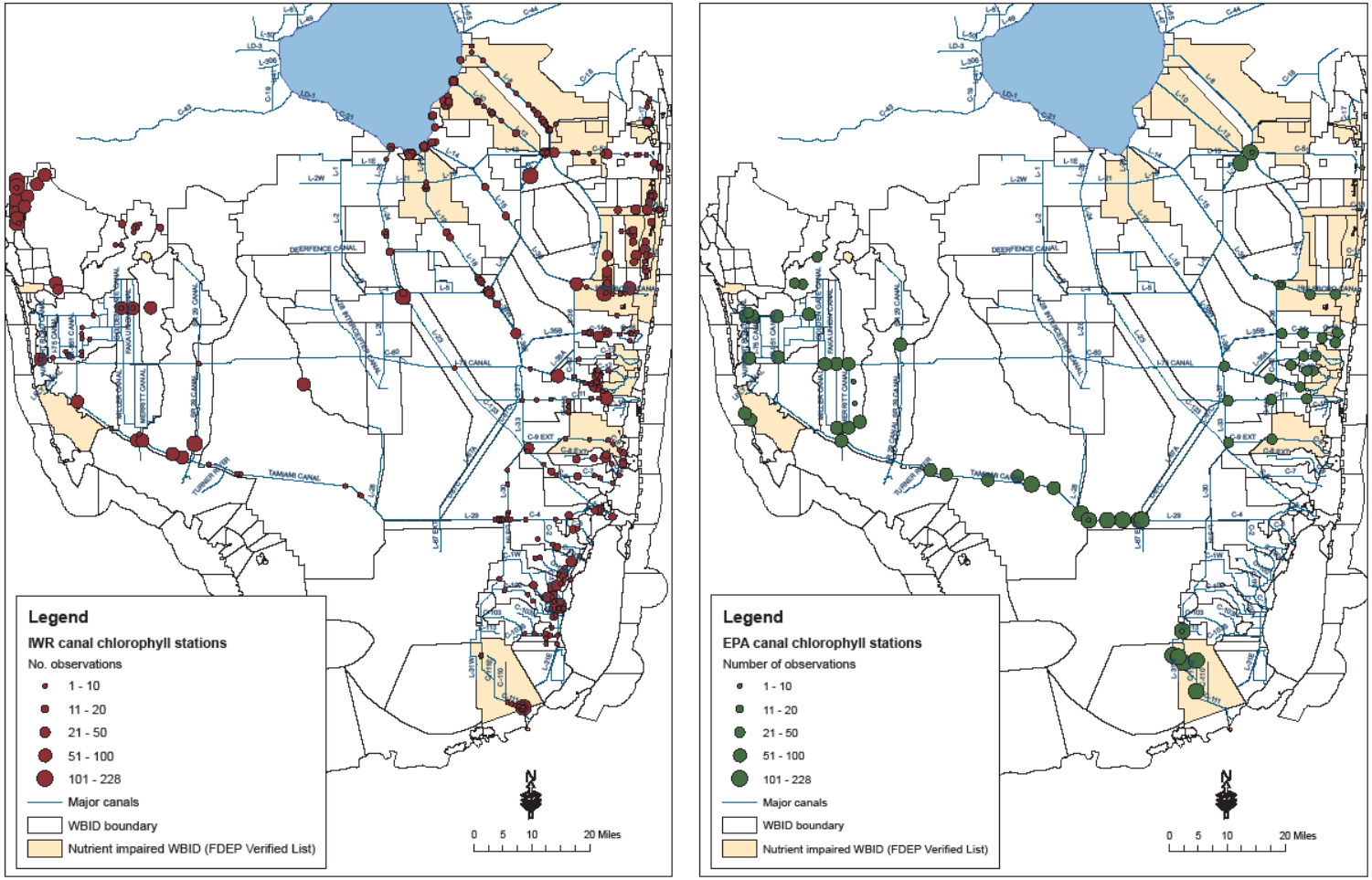

Figure 1a. Location of chlorophyll monitoring stations and distribution of associated data used by USEPA for canal nutrient criteria development (right). Note the paucity of representative data points for the EAA (just south and southeast of Lake Okeechobee). Spatial depiction of additional data that we obtained from the IWR database, apparently not reviewed or screened by USEPA, is depicted in the graphic on the left.

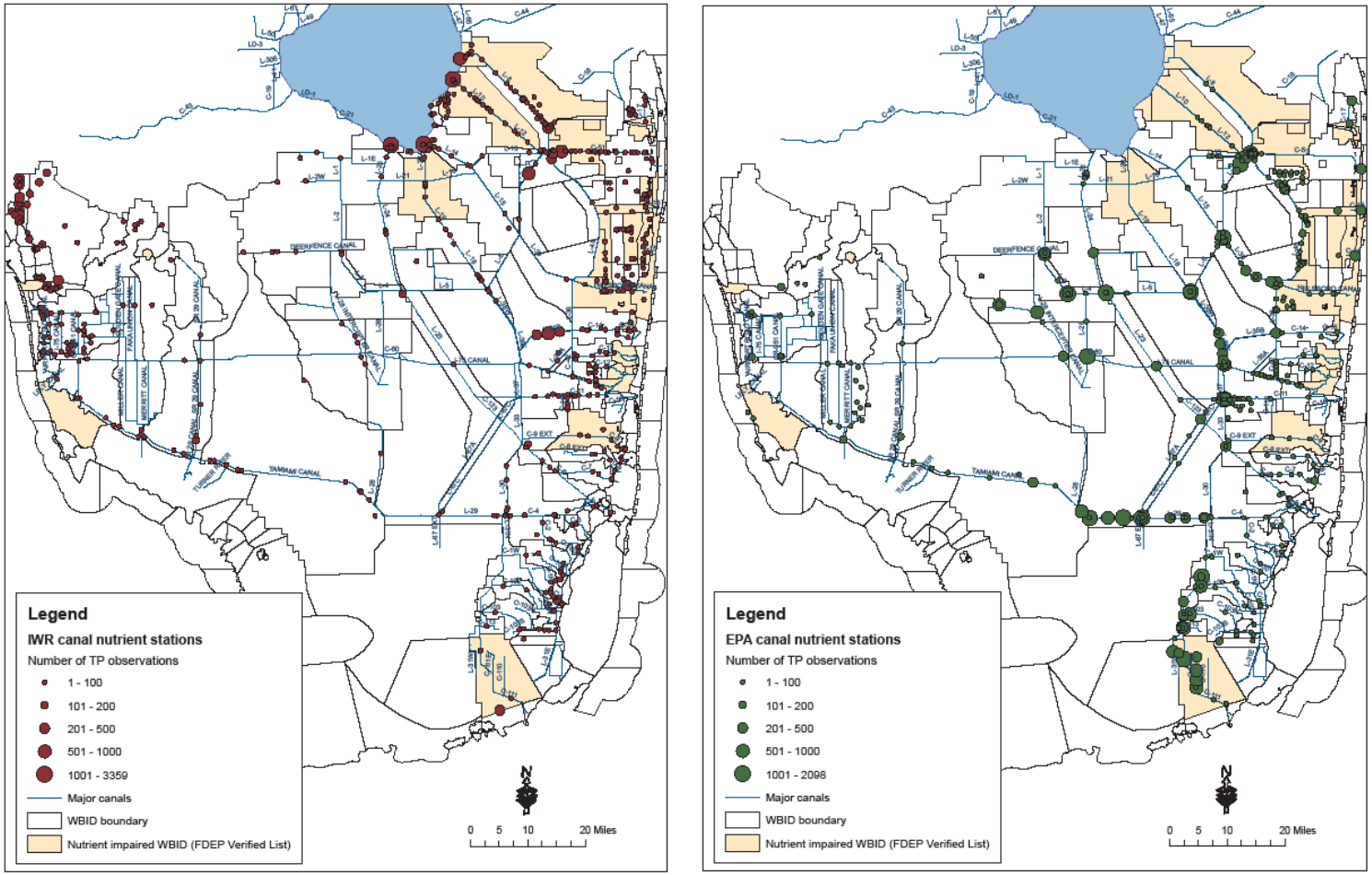

Figure 1b. Location of TP monitoring stations and distribution of associated data used by USEPA for canal nutrient criteria development (right). Note the paucity of representative data points for the EAA (just south and southeast of Lake Okeechobee). Spatial depiction of additional data that we obtained from the IWR database, apparently not reviewed or screened by USEPA, is depicted in the graphic on the left.

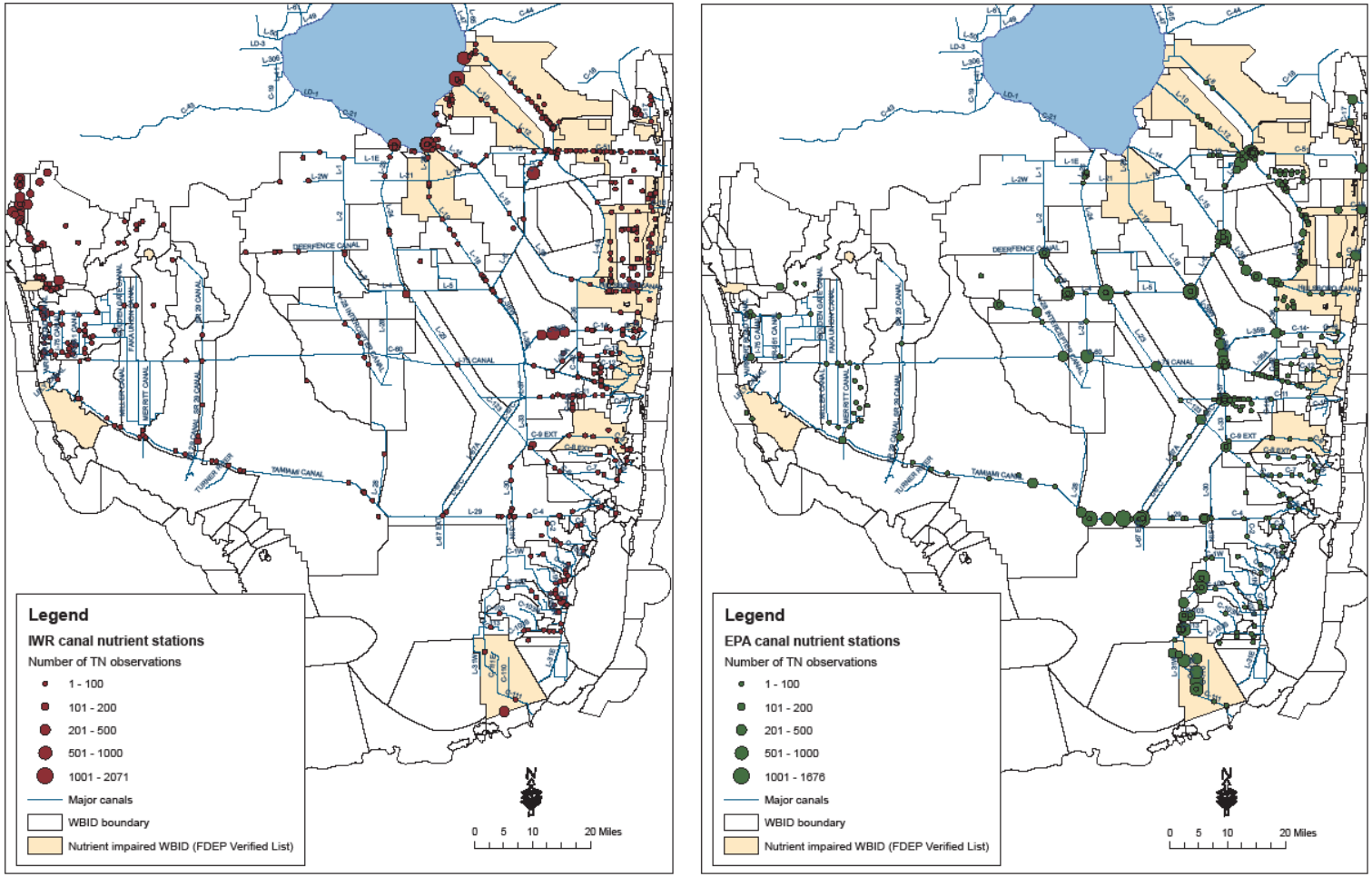

Figure 1c. Location of TN monitoring stations and distribution of associated data used by USEPA for canal nutrient criteria development (right). Note the paucity of representative data points for the EAA (just south and southeast of Lake Okeechobee). Spatial depiction of additional data that we obtained from the IWR database, apparently not reviewed or screened by USEPA, is depicted in the graphic on the left.

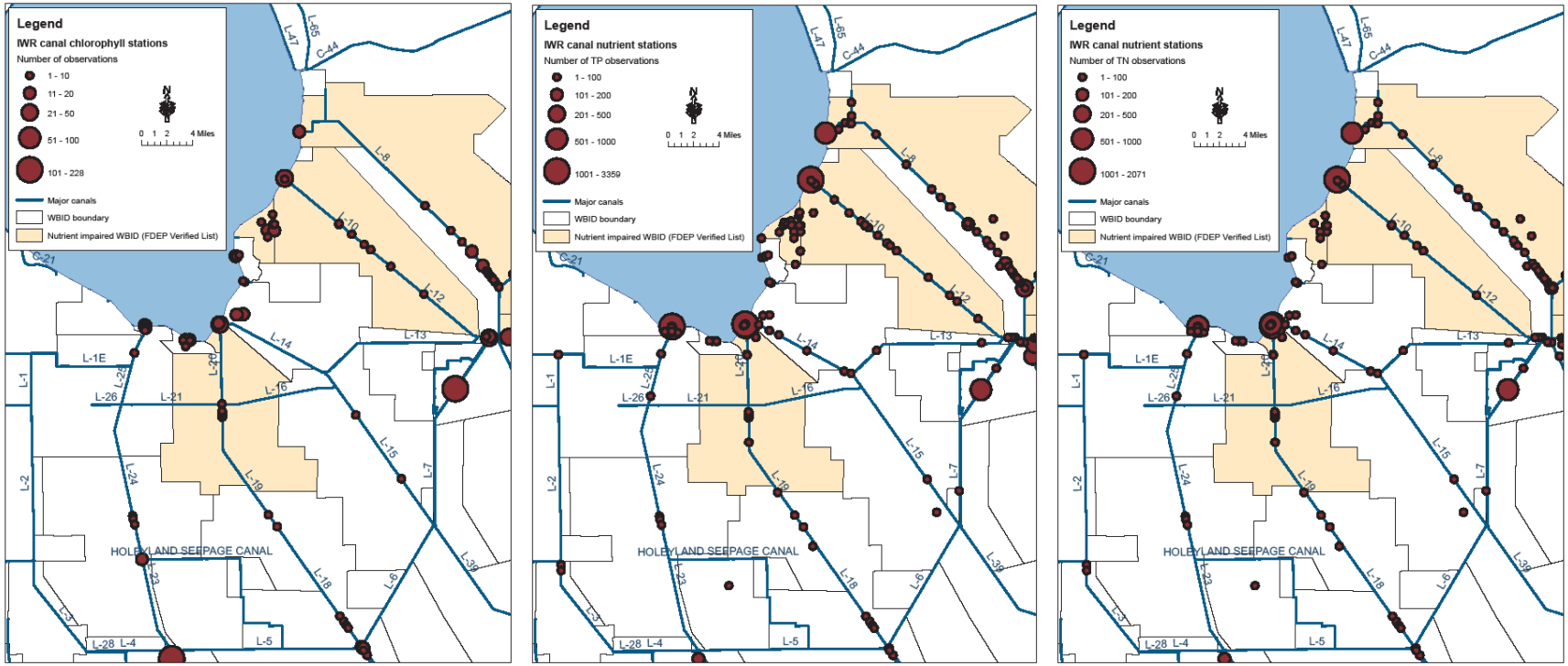

Figure 2. Spatial depiction of chlorophyll, TP and TN station (IWR database) locations in the EAA, apparently not reviewed or screened by USEPA as part of their nutrient criteria derivation. The few locations actually used in this region by USEPA for this purpose are depicted in the right hand panels on Figures 1a – 1c.

Swimming as a Designated Use of South Florida Canals

The water body classification for most canals in south Florida is Class III, which corresponds to a designated use of "Recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife." The terms "swimmable" and "fishable" are commonly used to describe this designated use. Recreational fishing is quite popular in many South Florida canals, as discussed later in this document. On the other hand, the "swimmability" of these canals is severely limited by a variety of public safety concerns. These concerns are primarily associated with human-wildlife interactions and the physical characteristics of canals, and tend to override any concerns associated with water quality.

Alligators likely represent the most commonly cited hazard associated with swimming in canals in south Florida**.** Alligators are abundant in and along the banks of canals, and pose a threat to human health and life (Figure 3). The Florida Fish and Wildlife Conservation Commission (FWC) compiles and maintains data on alligator attacks (bites) on humans in the state. The FWC data indicate that a total of 330 unprovoked alligator bites have been recorded in Florida since 1948 (FWC 2009). Descriptions of fatal attacks on humans reveal that seven of the 22 fatalities occurred in south Florida canals. Other forms of wildlife may also pose a threat to swimmers in canals, particularly poisonous snakes.

The inherent design of canals also presents an impediment to safe swimming. For example, the steep slope of the banks and lack of a shallow water zone make both entry to and exit from the water a difficult and potentially dangerous process. South Florida canal banks were typically constructed with slopes of 2.5:1 (H:V) or greater (USCOE 1953), whereas most bathing beaches have slopes in excess of 8:1 or 10:1 (Appendix B). The presence of water control structures, pumps and locks represents additional hazards for swimming (Figure 4).

Due to the safety concerns discussed above, swimming in canals is strongly discouraged by the Department of Health (Bob Cummings, Palm Beach County DOH, personal communication, 3/26/2010). Accordingly, canals are not considered legitimate swimming areas, and are not included in the list of beaches monitored regularly by DOH for bacterial contamination.

Figure 3. Alligator in roadway adjacent to a canal (top), and alligators in canal adjacent to a wetland (bottom). Both photos taken in Palm Beach County, FL.

Figure 4. Swimming typically is prohibited in south Florida canals by local, state and/or federal ordinances. Examples of common physical hazards that preclude safe swimming in south Florida canals include trash, steep banks, deep water, concrete- or rock-armored banks and water control structures.

In summary, a combination of public health hazards, unrelated to water quality, effectively precludes safe swimming in south Florida canals**.** Chief among these hazards are steep banks, deep water, concrete- or rock-armored banks, water control structures, local, state and federal ordinances (see Appendix B), and dangerous wildlife (e.g. alligators and snakes). These hazards create an overriding concern in the eyes of the general public, which serves to limit the

recreational use of canals to activities such as boating and fishing, neither of which represents "direct contact" with the water.

Previous Studies of Public Perception of Water Quality, and Relationship to Chlorophyll a

Heiskary and Walker (1988) proposed a method for incorporation of the "fishable-swimmable" goals of the Clean Water Act into the development of water quality criteria for Minnesota lakes. They related measurements of phosphorus, chlorophyll and transparency (Secchi depth) to perceived impairment of physical appearance and recreational (primarily swimming) suitability, based on visual assessments during routine water monitoring events. Both of the subjective assessment parameters were determined via a rating system on a scale from 1 (highest quality) to 5 (lowest quality), with the presence of algal blooms used as a primary visual indicator. Their study results showed that measured TP, chlorophyll and transparency values varied significantly with response rating in each category, with transparency (Secchi depth) being most strongly associated with both physical appearance and recreation ratings. Transparency, also described as water clarity or visibility, is a function of both color and turbidity, which in turn may be derived from either organic or mineral sources. Measured parameter values also ranged widely within visual impairment categories, particularly those representing the transition between desirable and undesirable conditions. For example, a visual assessment of "slightly impaired for swimming" corresponded to an inter-quartile range of approximately 15 to 60 µg/L for chlorophyll-*a* and 0.5 to 1.5 m for Secchi depth.

A follow-up study, based on a larger data set from user surveys of lakes in Minnesota and Vermont, produced similar results (Smeltzer and Heiskary, 1990). Results from this study also indicated that user perception of water quality was significantly influenced by the region in which the lakes (and users) were located, i.e., the correlation between measured chlorophyll or Secchi depth values and user perception of water quality varied according to the characteristic trophic status of lakes in different eco-regions. This demonstrates that the observed or perceived water quality is partially dependent on user familiarity with the general appearance of surface waters within their region.

A third study, incorporating the same user-perceived rating system as the first two studies discussed above, was conducted for a set of 116 Florida lakes in 28 counties (Hoyer et al., 2004).

Their results were similar to those of Heiskary and Walker (1988) and Smeltzer and Heiskary (1990). Hoyer et al. (2004) found that lake waters perceived as suitable for swimming by the majority of survey respondents ranged from oligotrophic to eutrophic, based on measured levels of chlorophyll, TN, TP and transparency.

All three studies demonstrated that "water quality" is a subjectively determined characteristic that is dependent on both water chemistry and the desired use of the water body. Thus attainment of designated recreational uses, in particular swimming and fishing, is most accurately determined where user perceptions of suitability for these uses are taken into account. This is especially important for man-made water bodies such as canals, since there is no "natural" or "pre-disturbance" condition from which to draw comparisons with existing condition.

Comparison of Visual Assessment of Water Quality With Measured Water Quality Parameters

Because of their photosynthetic pigments (e.g., chlorophyll), phytoplankton blooms often are responsible for imparting a green color to surface waters, which in turn may create conditions undesirable for swimming. The intensity of the green color is related to the number of phytoplankton cells per unit volume, which is measured as the chlorophyll concentration. If it were possible to render selected south Florida canal areas non-hazardous (e.g., through alligator removal, construction of segments with appropriate side slopes, routine microbiological testing by county health agencies), then it would be of interest to determine whether the proposed chlorophyll criterion level of 4 μg/L is needed to maintain desirable aesthetic conditions for swimming.

We performed two assessments (detailed methodology in Appendix C) to evaluate the relationships among chlorophyll concentration, the visual appearance of canal waters, and the levels of other water quality constituents (such as color) that influence optical properties. For the first effort, we collected water from the Miami Canal, just north of S8, and inspected the native phytoplankton populations microscopically. This water contained an algal assemblage dominated by diatoms and green algae (Figure 5). We then amended aliquots of canal water with various concentrations of a dense green algal culture (Figure 6) to obtain a range of chlorophyll

concentrations. As a comparison, aliquots of deionized (DI) water also were amended with chlorophyll *a*.

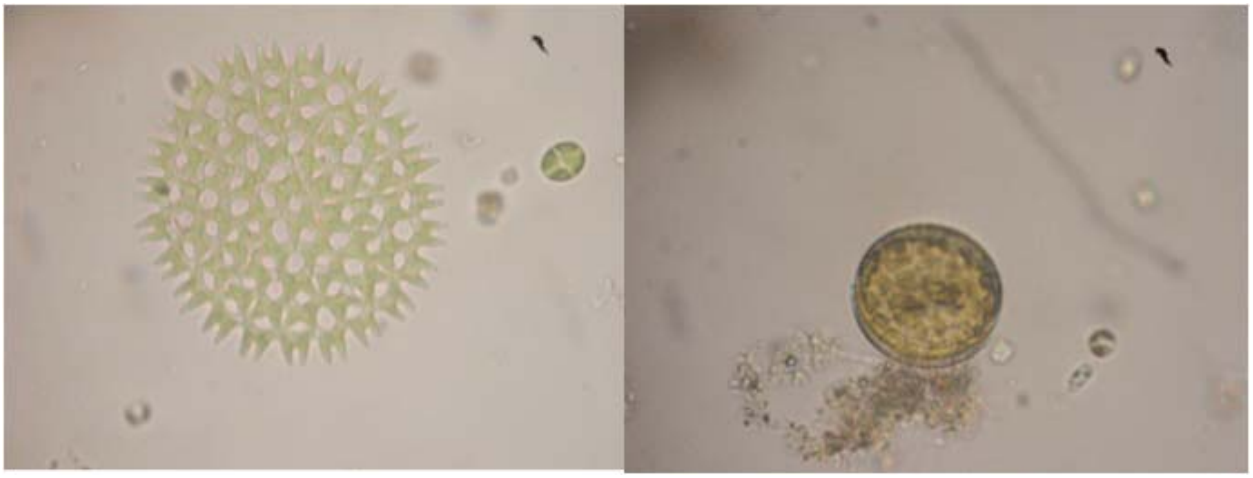

Figure 5. A green alga (*Pediastrum*, left) and diatom (a centric diatom, right) in the Miami canal water collected on March 26, 2010.

Figure 6. Concentrated stock solution of green algae (*Nannochloropsis*) used to amend the Miami canal waters to varying concentrations of chlorophyll.

For the DI water, the green color imparted by the chlorophyll is dramatic at a high concentration (130 µg/L, a level representative of dense algal blooms), but essentially undetectable at levels far exceeding the proposed criterion of 4 µg/L (Figure 7). For the waters collected from the Miami

Canal, that have a relatively high true color content (158 PCU), any green color imparted by the algae at concentrations in the range of 3 to 22 µg/L is totally masked (Figure 8).

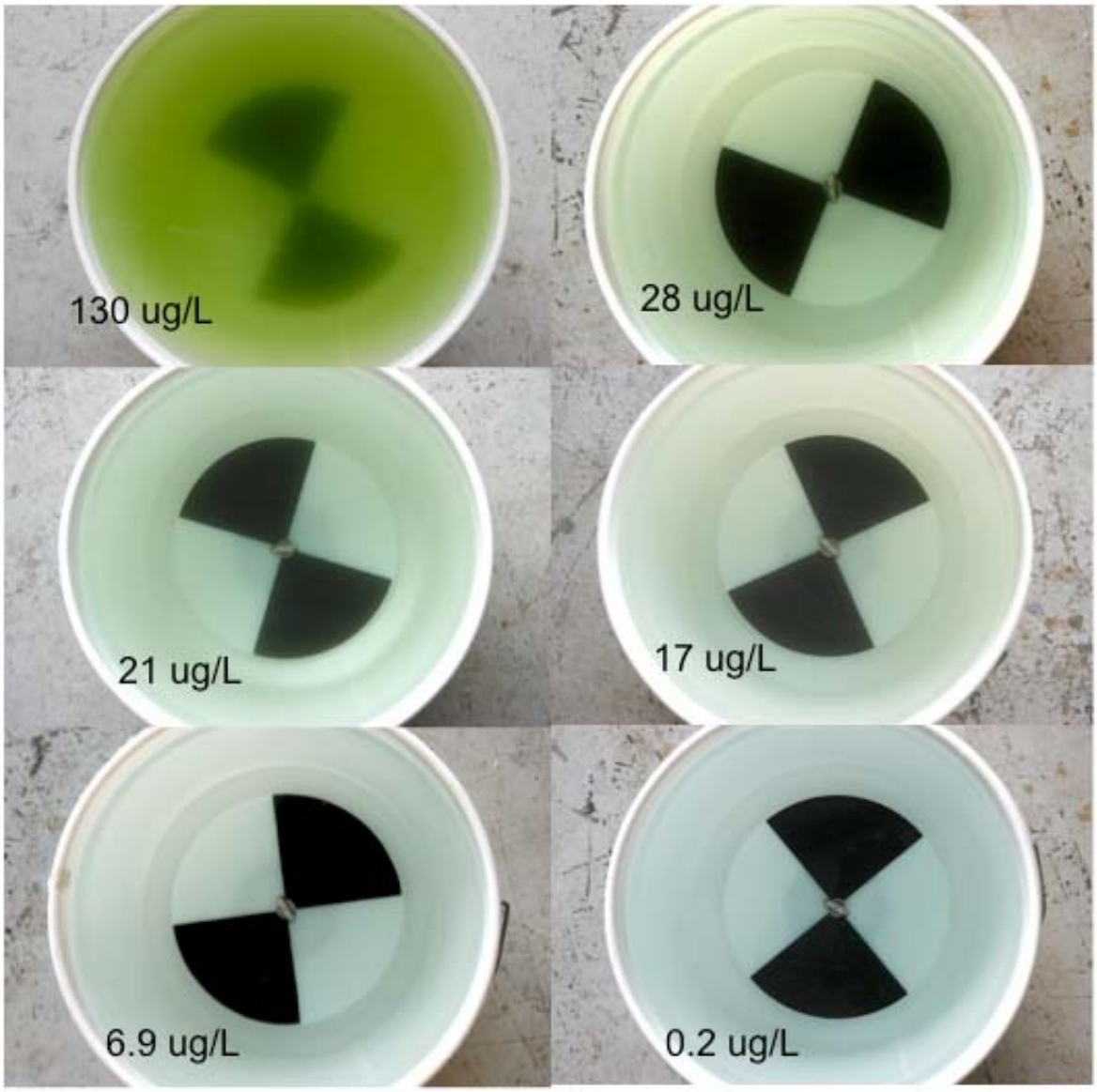

Figure 7. Effect of chlorophyll concentration on appearance of deionized water (native color of < 1 PCU). Various corrected chlorophyll levels were obtained by amending deionized water with aliquots of the green alga, *Nannochloropsis*. The USEPA-proposed chlorophyll threshold is 4 µg/L (annual mean) or 15.8µg/L (single sample). Water depth in the secchi bucket is 0.3m. Photos were taken outdoors in natural light.

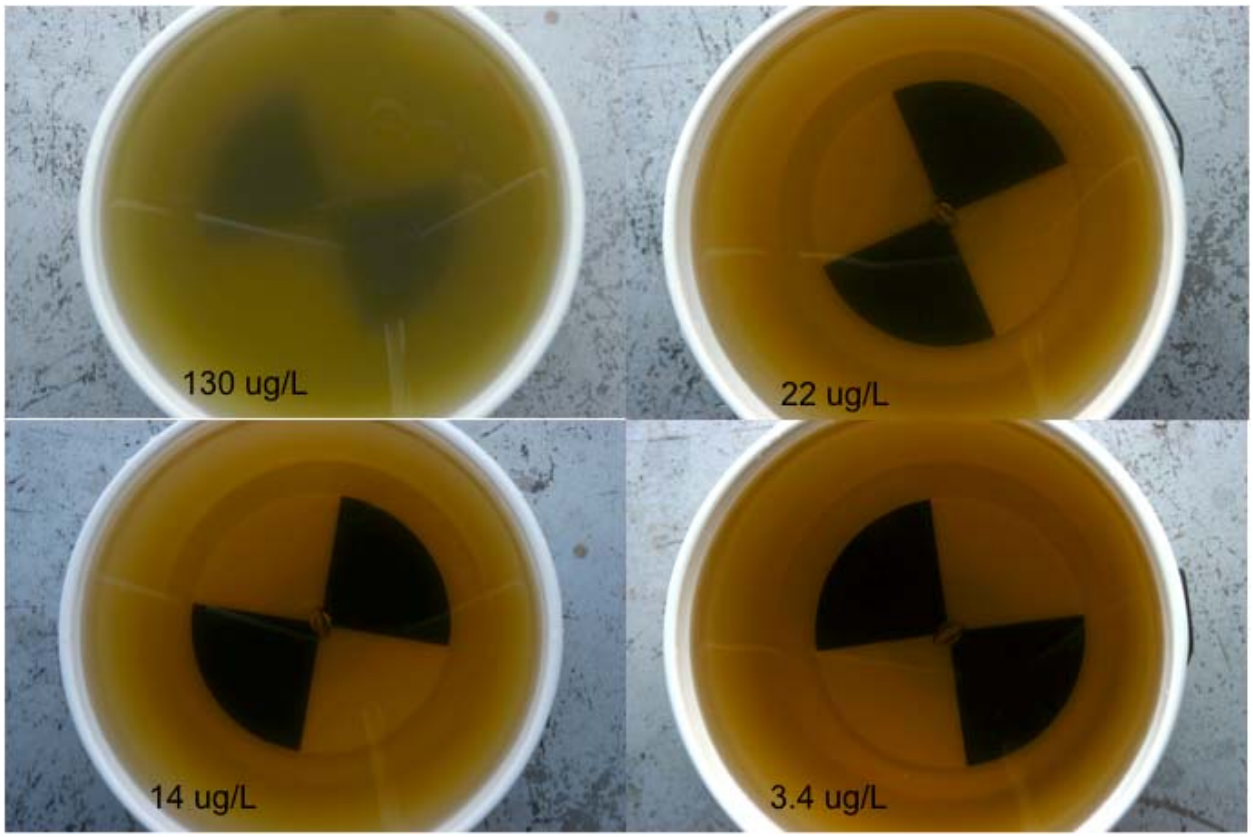

Figure 8. Effect of chlorophyll concentration on transparency and aesthetic characteristics of Miami canal waters (true color of 158 PCU), collected from an unimpaired WBID north of S8. Various corrected chlorophyll levels were obtained by amending the settled Miami canal water (native corrected chlorophyll concentration of 3.4 µg/L) with aliquots of the green alga, *Nannochloropsis*. The USEPA-proposed chlorophyll threshold is 4 µg/L (annual mean) or 15.8µg/L (single sample). Water depth in the secchi bucket is 0.3m. Photos were taken outdoors in natural light.

For a follow-up effort, we collected water samples from 14 canal locations throughout south Florida (Figure 9), and evaluated optical characteristics of the waters along with color, chlorophyll a, and nutrient concentrations.

In this survey, we found a wide range of color and chlorophyll concentrations in canals throughout the region. Figure 10 depicts all stations ranked in order of color concentration. Note that clarity of the water is strongly linked with color levels, and chlorophyll concentrations exert essentially no influence on water appearance. Additional water quality data (e.g., nutrients, turbidity) for each site are provided in Appendix C.

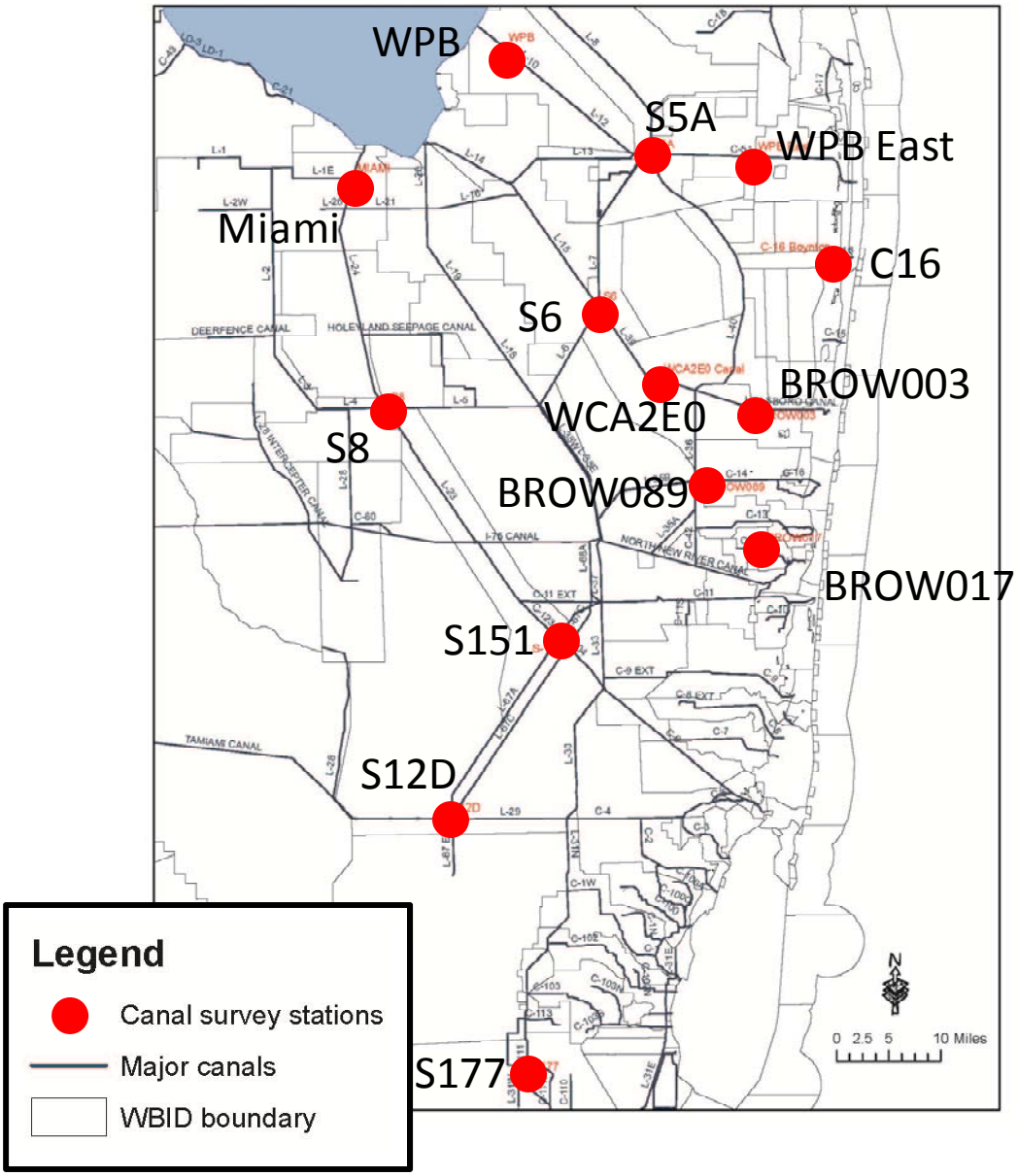

Figure 9. Sampling locations (N=14) for a survey of south Florida canals conducted April 6-8 2010 by DBE to show the range of color, chlorophyll and nutrient concentrations in the central and eastern portion of the south Florida eco-region.

Side-by-side comparisons of specific canal sampling locations (Figures 11 and 12) also demonstrate the lack of influence of chlorophyll levels and the dramatic effect of color on water clarity and appearance. Because color is recognized as a master factor in chlorophyll – nutrient relationships in lakes, it is unclear why USEPA ignores its role in canals, particularly since canals often exhibit many morphological and ecological characteristics more similar to lakes than streams.

Station ID	Secchi Bucket	Chl. a (µg/L)	Color (PCU)
Brow017		2.4	43
S-177		2.7	59
C-16 Boynton		2.7	92
Brow003		5.4	109
S12D		1.4	119
Brow089		1.8	132
S-151		1.1	139

Station ID	Secchi Bucket	Chl. a (µg/L)	Color (PCU)
WCA2E0 Canal		2.6	156
S8		14	179
Miami		9.6	226
S6		1.7	235
WPB East		4.7	323
S5A		4.2	333
WPB		29	577

Figure 10. Photos of water transparency, chlorophyll and color values for 14 canal stations sampled April 6-8, 2010. The USEPA-proposed chlorophyll threshold is 4 µg/L (annual mean) or 15.8µg/L (single sample).

Our review of factors that influence the "perception" of the suitability of south Florida canal waters for swimming demonstrates that color is a master factor in controlling transparency, and much more important than chlorophyll. Many of the major S. Florida drainage canals have relatively high levels of color (e.g., 50 – 300 PCUs) (Figures 10 and 13), and for such waters, chlorophyll levels of 20 µg/L and below would not be detectable. We conclude, therefore, that chlorophyll criteria proposed by USEPA are irrelevant and arbitrary with respect to designated use.

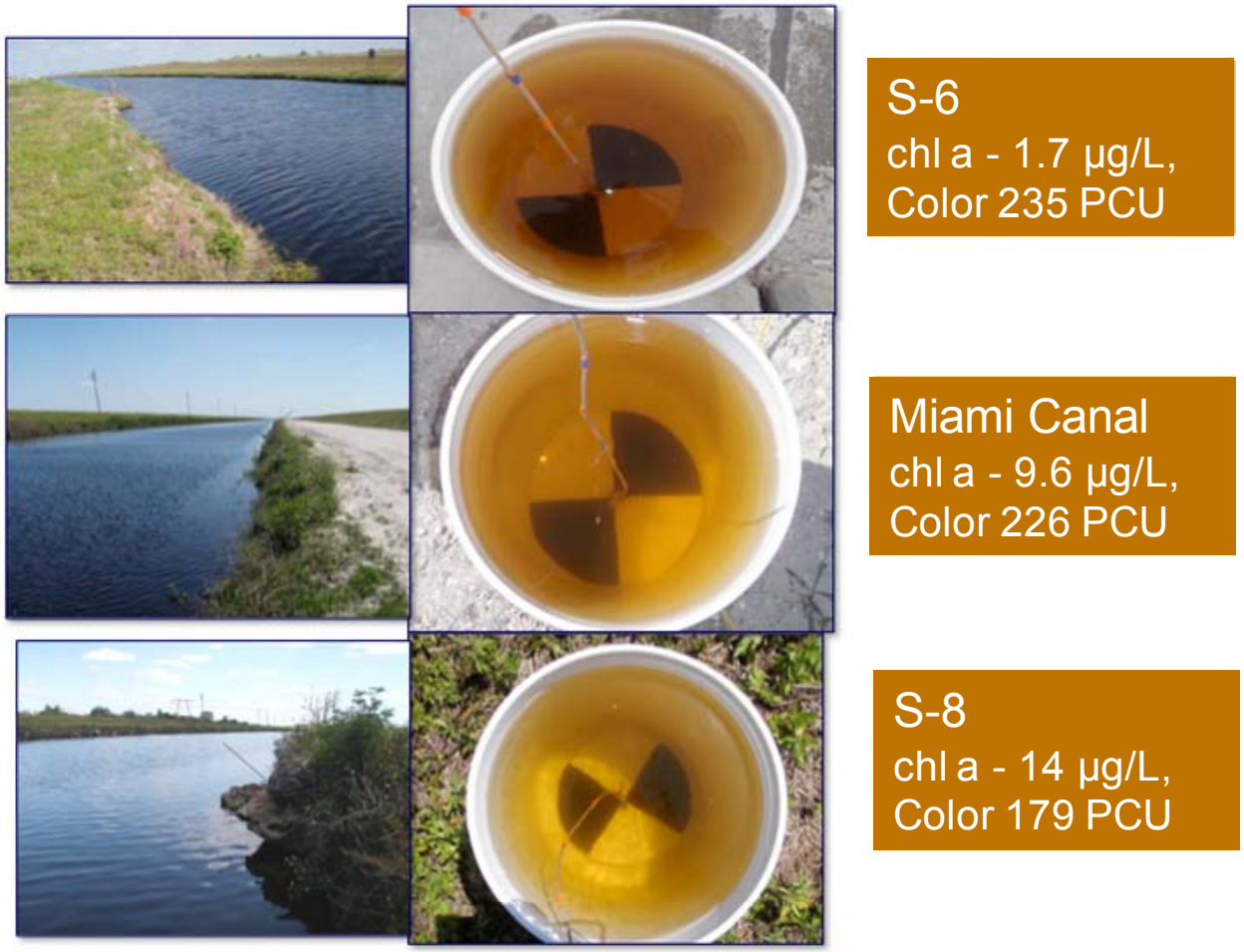

Figure 11. Visual appearance of canal waters collected from three locations in south Florida. The sites are ranked in order of ascending (top to bottom) chlorophyll levels, but decreasing color levels. The USEPA proposed chlorophyll threshold is 4 µg/L (annual mean) or 15.8µg/L (single sample). Turbidity was relatively low (1.9, 3 and 2.7 NTU) at the time of sample collection. Water depth in the secchi bucket is 0.3m. The S6 waters (top photo) represent the only waters with chlorophyll values below the proposed 4 µg/L threshold.

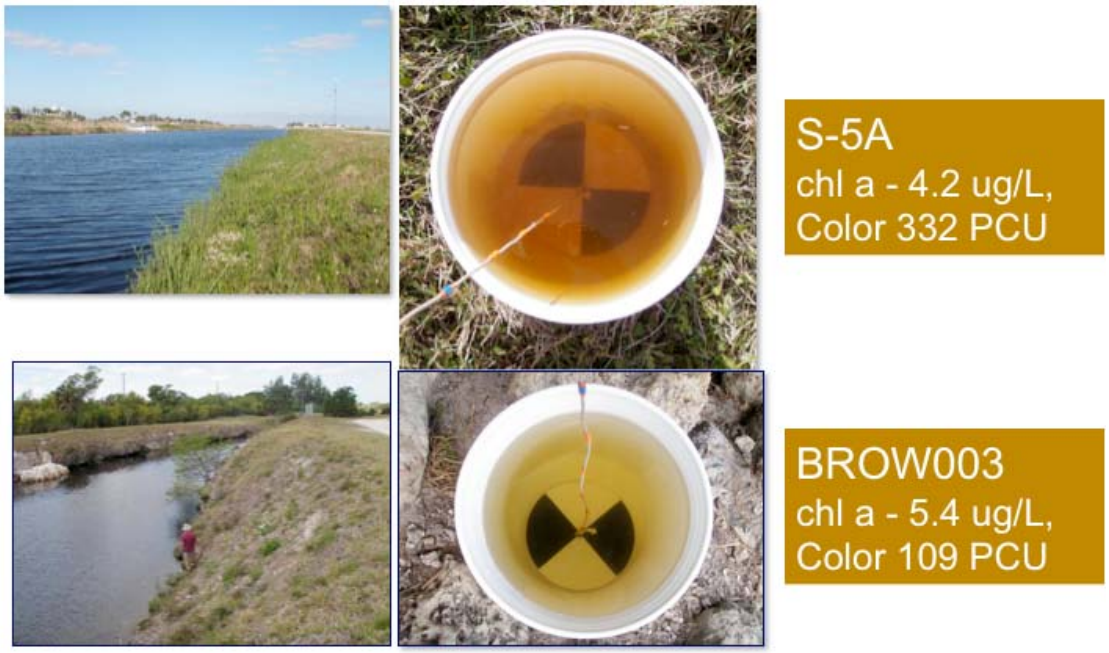

Figure 12. A comparison of two south Florida canal waters with similar chlorophyll levels, but different color concentrations. This demonstrates the dramatic effect of color on water appearance. Turbidity was 7.4 NTU at S5A, and 0.6 NTU at BROW003 at the time of sample collection. The USEPA-proposed chlorophyll threshold is 4 µg/L (annual mean) or 15.8 µg/L (single sample). Water depth in the secchi bucket is 0.3m.

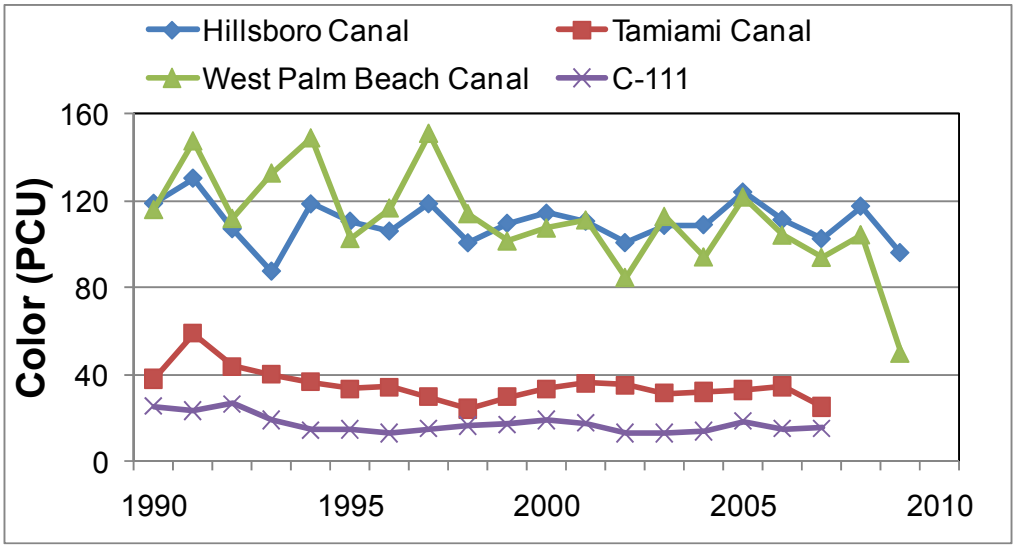

Figure 13. Mean annual color in surface waters of major canals in South Florida. Hillsboro canal (S6) and West Palm Beach canal (S-5A) have color concentrations typical of water draining the histosols of the EAA, which are markedly higher than locations used for chlorophyll criteria development, such as Tamiami Canal (average of S-12A-E) or the C-111 canal (average of S-177 and S18C).

Biological Response of Canal Waters to Nutrients

Chlorophyll is Not a Suitable Response Variable for South Florida Canals

USEPA's documentation for lakes states that a chlorophyll concentration of < 20 µg/L, representing the borderline condition between mesotrophic and eutrophic conditions for the "Trophic State Index" (TSI) metric, is desirable for supporting balanced biological communities. This is a marked contrast to the proposed 4 µg/L criterion for south Florida canals.

USEPA technical documents, prepared in support of this criterion, recognize the importance of color to nutrient, chlorophyll and trophic state relationships in Florida lakes. (USEPA 2010 TSD Ch. 1, USEPA 2010 proposal). Higher TSI conditions (60 vs. 40), and chlorophyll levels (limit of 20 µg/L), are considered acceptable in lakes with color levels in excess of 40 PCU (Impaired Waters Rule, 62-303. FS). This is in part due to the masking effect of color on visual appearance of chlorophyll, and the potential for color to inhibit water column light penetration, which in turn alters the algal (and chlorophyll) response to N and P concentration.

The USEPA utilizes chlorophyll as the only biological response variable indicative of nutrient enrichment for south Florida canals. However, because the goal is to protect overall ecological condition and designated uses, it is important to evaluate relationships among nutrients, chlorophyll a, and other food web components, such as macroinvertebrates and fisheries.

The relationships observed in lake datasets across a wide range of nutrient concentrations do not inevitably apply to south Florida canals. For example, strong correlations were found in 2007 between TP or TN and chlorophyll concentrations in 47 lakes throughout the state (Figure 14, FWC 2008). We plotted the relationships between chlorophyll and nutrients for our 14-station south Florida canal sampling effort, and it is clear that the response of chlorophyll to nutrients is muted, probably due to the influence of color limiting light penetration in the canals.

We also compared the relationship of chlorophyll to nutrients over time at specific locations. The response of chlorophyll levels at the West Palm Beach canal S5A station (high color) differs markedly from the same response at Tamiami Trail station S-12D (low color) (Figure 15).

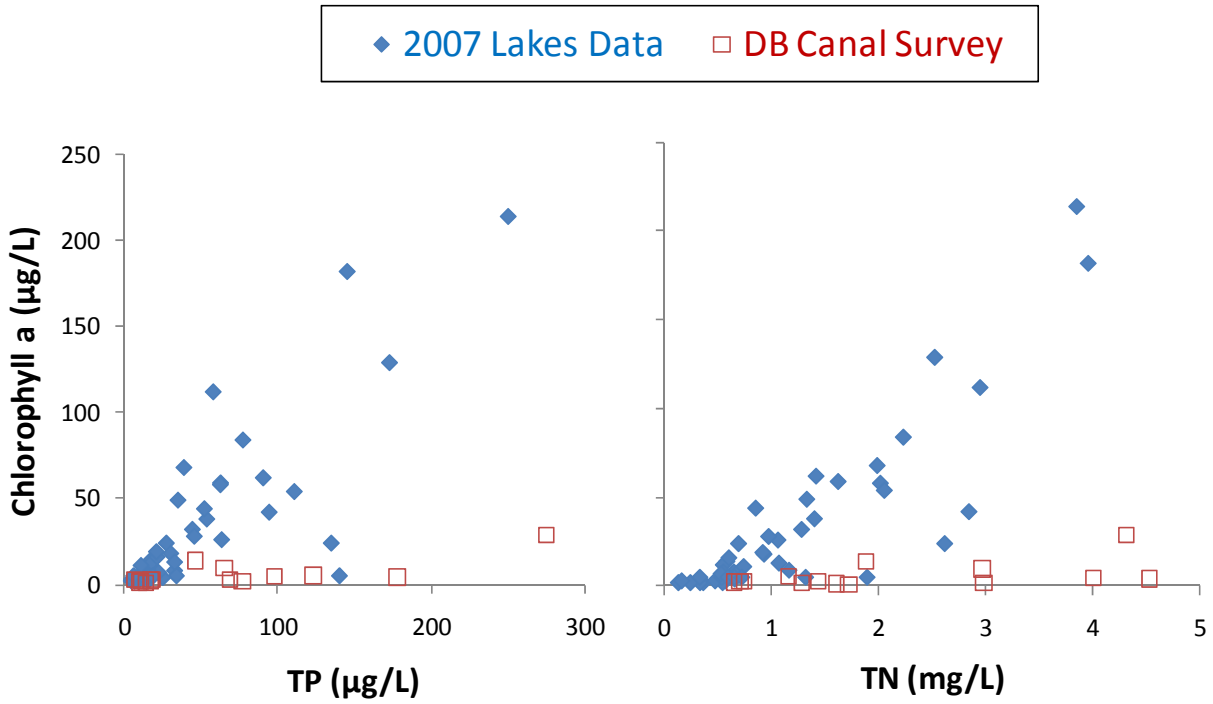

Figure 14. Relationships between nutrients and chlorophyll concentrations in canals (N=14) are compared to water quality in 48 Florida lakes during 2007 (FWC 2008, using Lakewatch water quality data).

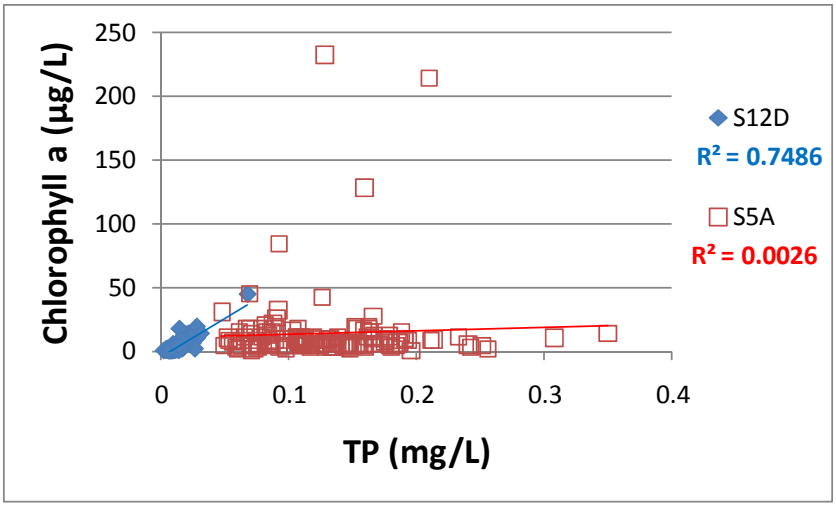

Figure 15. Average monthly concentrations of TP and chlorophyll at two south Florida canal stations. At S-12 D, there is a linear relationship between chlorophyll and TP, while at S5A no relationship was observed.

Biological Response of Macroinvertebrate Populations

Healthy balanced populations of flora and fauna occur in both oligotrophic and eutrophic systems, despite differences in the ambient nutrient concentrations. Models relating biological condition to human disturbance gradients across different water bodies suggest that the aggregate impact of multiple stressors can result in a measureable difference in biological assessment scores, when compared to water bodies with minimal disturbance (e.g., USEPA 2010 TSD Ch. 2 Figure 2-10; Fore et al., 2007). However, it is unclear how individual communities will respond to reductions in nutrient levels over time, when a variety of factors influence biological health.

Canals and streams differ in physical, biological, and functional traits that are relevant to nutrient criteria development. Macroinvertebrates are ubiquitous in both streams and canals, and sampling the population can provide a way of evaluating biological response to nutrient levels. Several studies provide strong evidence that macroinvertebrate community structure and function is not sensitive to small changes in nutrient concentration where habitat is available (DBE and Azurea 2009, USEPA 2010 TSD Ch. 2). Additional studies of macroinvertebrate populations in South Florida canals show that typical canal conditions offer few substrates for colonization, and that biological expectations for canals are markedly different than for healthy streams (Fore et al., 2007; Snyder et al., 1998; DBE 2009).

Macroinvertebrates show no correlation to ambient nutrient concentrations in canals

DBE surveyed five sites across four seasons in large canals near Lake Okeechobee (DBE 2009). All five canals exhibited consistently poor habit for macroinvertebrates (i.e., "marginal" or "poor"). As expected, macroinvertebrate communities were "impaired" across a wide range of ambient TP concentrations from 59 to 259 µg/L, in comparison to the biological expectation for healthy streams of peninsular Florida (DBE 2009) (Figure 16). These canals contained a low percentage of filterers, a feeding guild that is common to healthy stream systems.

Snyder et al. (1998) found that macroinvertebrate communities in canals were distinct from healthy streams in Florida, even in locations where the surrounding land use was in a natural state (southern Everglades marsh). The canals in that survey, including the Tamiami, L-67 and C-111 canals, are all located in the southeastern portion of the south Florida eco-region. While

these canals are extremely low-nutrient systems (at the time, 4-10 µg/L TP, 0.7 – 1.6 mg/L TN, data from SFWMD DBHydro), They exhibited a low proportion of macroinvertebrate species that feed by filtering food particles from the water column (Figure 17).

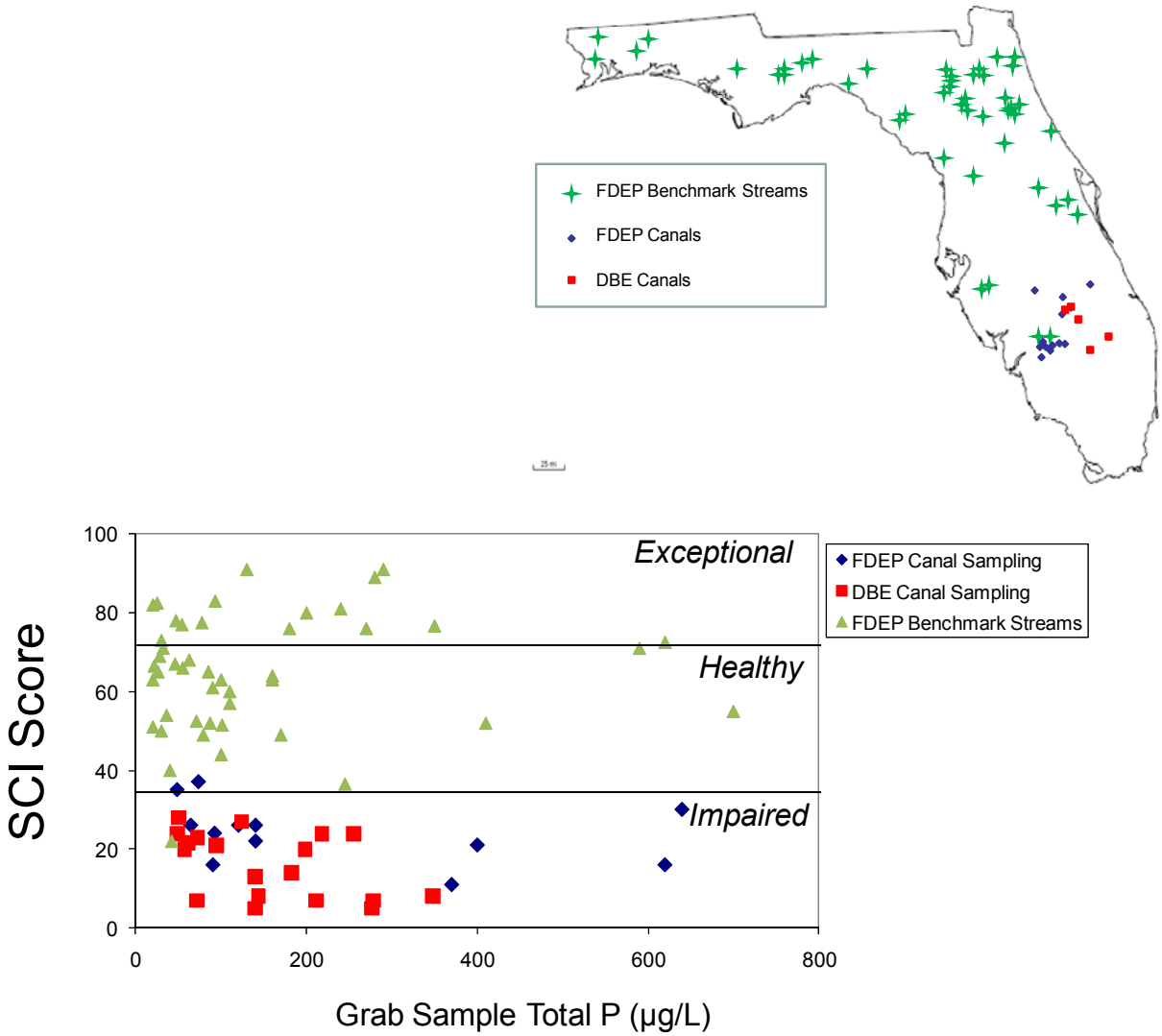

Figure 16. Stream Condition Index (SCI) results from DBE canal sampling (N=19), are compared to results from Florida Department of Environmental Protection (FDEP) sampling in canals near Lake Okeechobee (N=12), and in benchmark streams, sites throughout the state with minimal human disturbance (N = 53). FDEP data reflect the average of 1-3 events using the same protocols used in this study. Only grab sample data for TP were available for FDEP sites. Therefore, the comparison between datasets is made across a range of grab sample TP concentrations of 20-700 µg/L. The distribution of site locations throughout Florida is shown in the upper panel.

Both the DBE (2009) and Snyder et al. (1998) studies used the same dip net collection methods, and demonstrate that the canal environment does not support macroinvertebrate communities typical of healthy Florida streams, regardless of nutrient condition or FDEP impairment status. The total number of taxa in samples from canals with low nutrients (Tamiami, L-67, C-111) and high nutrients (WPB, Miami) was 21-27, at or below the 25th percentile value for healthy Florida streams (Figure 17). Fewer than four Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa per sample were found in canals, lower than the 25% percentile for healthy Florida streams. The dominant taxon in canal samples ranged from 17-43 % of the total assemblage. Universally poor habitat conditions therefore prohibited the development of a diverse assemblage of these indicator organisms.

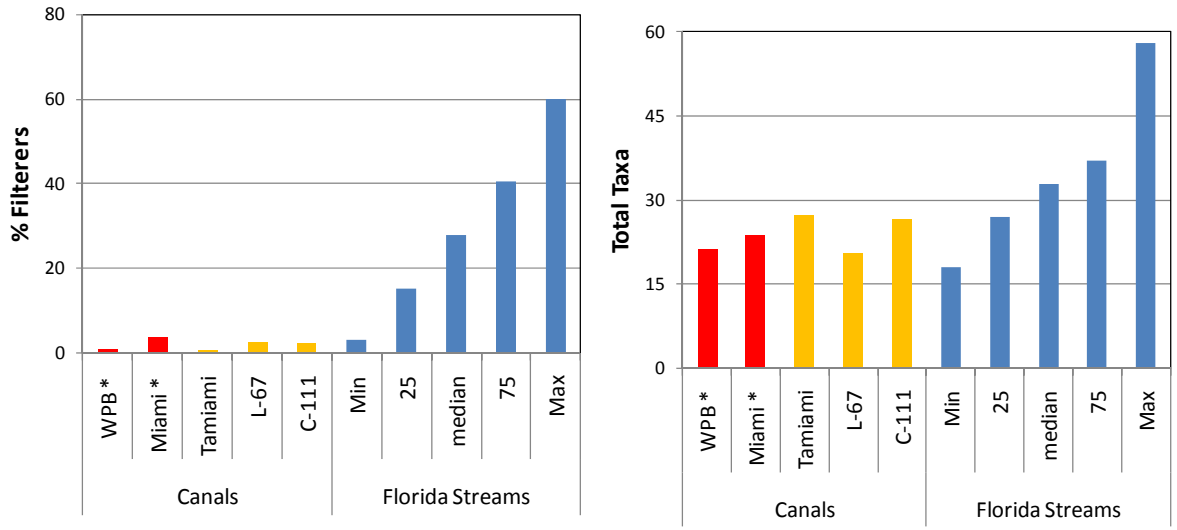

Figure 17. Measures of macroinvertebrate community structure and function in canals of south Florida, compared to the distribution of values for healthy streams state-wide. * denotes data from DBE 2009, otherwise data taken from Snyder et al. 1998. Canal sites depicted by red bars are relatively high color (and moderate nutrient concentration) canals, and sites depicted by yellow bars are low color (and low nutrient) canals.

Macroinvertebrates show a lack of response to nutrient reductions in Reedy Creek

In the 1980s, Reedy Creek supported a healthy, balanced macroinvertebrate community at TP levels ~250 – 400 µg/L, in excess of the proposed TP criterion (107 µg/L) for streams in the Peninsula Bioregion (Figure 18, Figure 19). TN in Reedy Creek was 1.7-2.0 (in excess of the proposed 1.6 mg/L criteria for streams). In 1990, advanced-treated wastewater effluent was diverted from the creek for beneficial reuse.

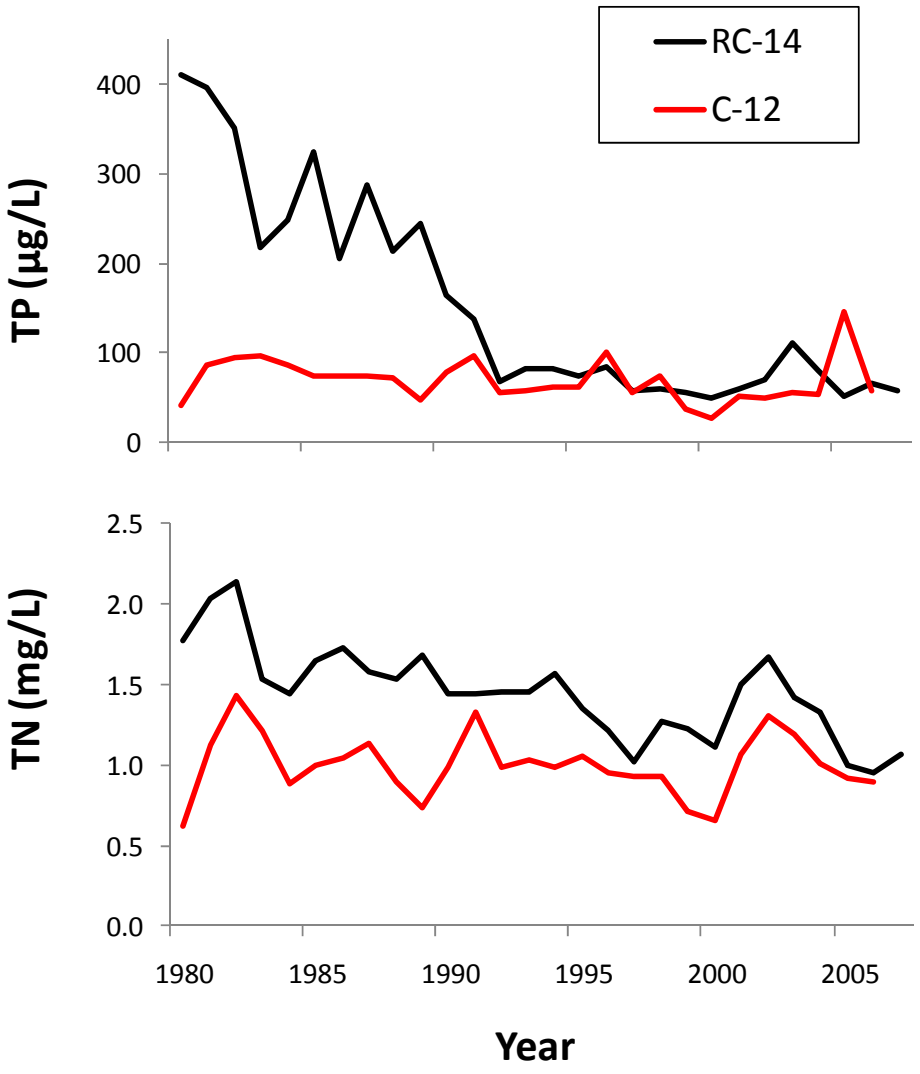

Figure 18. Annual mean T and TN) concentration in surface waters of Reedy Creek in central Florida (RC-14) and a tributary canal (C-12) between 1980 and 2007.

The Florida Biotic Index and number of sensitive taxa were high in Reedy Creek under both lower and higher TP concentrations, while the proportion of very tolerant organisms was low. In contrast, in a channelized tributary to Reedy Creek (station C-12) these metrics indicate an impaired biological condition, despite lower nutrients in the tributary. No improvement in macroinvertebrate community metrics has been observed in the 16 years since the diversion of advanced-treated wastewater effluent from Reedy Creek, despite a marked reduction in ambient TP concentrations (decline from ~250–400 µg/L to < 100 µg/L TP). Moreover, there was no imbalance in the macroinvertebrate fauna living within the high quality habitat of this blackwater stream during the period of record (1980-2007) across a wide range of nutrient concentrations (DBE and Azurea 2009).

Macroinvertebrates show a strong response to habitat conditions

Clear differences in macroinvertebrate community metrics were observed between sites of contrasting habitat quality in the Reedy Creek watershed. Sites with high quality habitat exhibited the most "desirable" macroinvertebrate assemblages, whereas poorer habitats supported less desirable assemblages (DB and Azurea 2009). Taxa that are able to persist in canals are frequently very tolerant of high nutrient levels, while sensitive taxa are absent or rare (DBE 2009).

These findings are supported by FDEP data across a wide range of nutrient concentrations - as high as 700 µg TP/L. Macroinvertebrate communities in sites with high habitat quality (FDEP reference streams throughout Florida) showed diverse balanced communities across a wide range of nutrient concentrations (DBE 2009). USEPA's analysis of the same FDEP data (USEPA 2010 TSD Chapter 2 Figure 2-34 and Figure 2-35) indicated no relationship between SCI and TN or TP across reference streams (streams that had adequate stream habitat to support a diverse macroinvertebrate assemblage, and had low development intensity in the watershed).

<u>The above factors demonstrate: 1) habitat is a master factor in controlling macroinvertebrate communities, while TP and TN (in the range investigated at Reedy Creek and at FDEP reference locations) exhibited no effect on population structure or function; 2) importantly, the long-term</u>

Reedy Creek data also demonstrate that marked reductions in TP to levels below the proposed stream criterion will yield no beneficial effect to macroinvertebrates.

Collectively, these findings demonstrate that no improvement in canal macroinvertebrate assemblages would occur as a result of implementing the proposed TN and TP criteria, due both to 1) poor habitat conditions in canals, and 2) insensitivity of the macroinvertebrates to a broad range of TN and TP concentrations. These data support the conclusion that healthy, diverse macroinvertebrate populations require suitable habitat, and do not require low levels of ambient nutrients. Therefore, USEPA was arbitrary in their development of canal nutrient criteria according to the distribution of a subset of canals in oligotrophic south Florida.

Physical differences between canals and streams

Streams have floodplains that provide intermittent hydrologic connectivity between the stream and adjacent riparian zone. This facilitates movement of dissolved and particulate organic matter, nutrients and minerals from the stream to the floodplain. Floodplain vegetation provides riparian habitat and releases organic matter (e.g. leaves) to the stream as a food/carbon source for micro- and macro-fauna. Trees serve as a riparian buffer - they provide shading of the stream for temperature regulation, and provide branches ("snags") onto which leaves accumulate to create hotspots of secondary productivity (Benke et al., 1985). Stems and root mass of the riparian (stream bank) vegetation provide aquatic habitat and physical substrate for biofilms.

An undisturbed natural stream channel moves water and sediment through the reach without causing aggradation or degradation (Doll et al., 2003). Undisturbed streams also enable the sorting of bed material, which results in habitat diversity. Sorting benefits aquatic organisms by providing stable habitats.

The natural sinuosity of streams creates a mix of sandbars, shallow zones and deeper pools (riffles and pools). These stream features increase dissolved oxygen levels and a high level of habitat diversity important to maintaining fish populations.

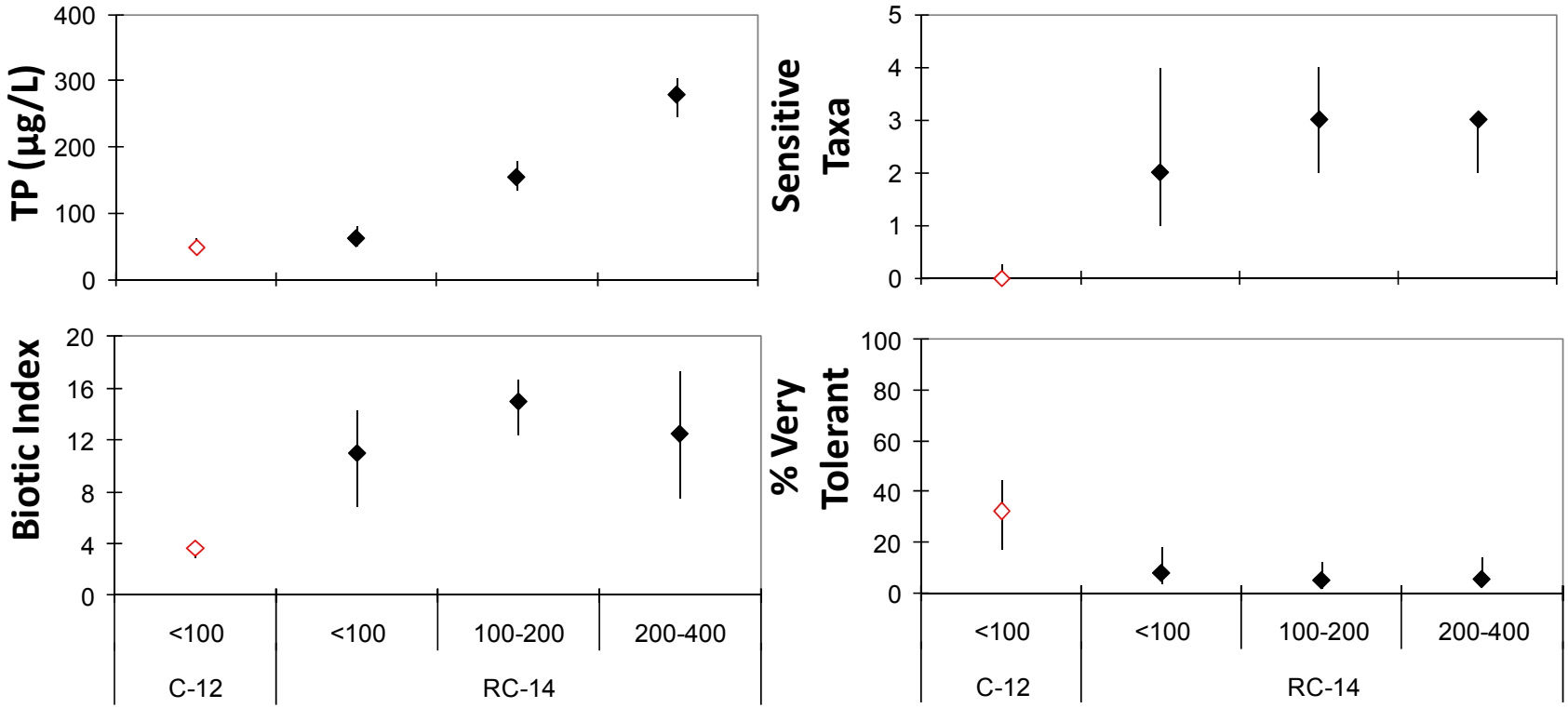

Figure 19. Sampling events over several decades at Reedy Creek station RC-14 were categorized according to ambient TP concentration as < 100 µg/L (N=25), 100-200 µg/L (N=25), or 200-400 µg/L (N=18). The inter-quartile range and median values of TP and macroinvertebrate metrics show that RC-14, a station with diverse substrates and intact riparian buffer, supported a healthy biological community across a range of TP concentrations. For comparison, the macroinvertebrate community in a channelized tributary (sampled at station C-12, N=12) was impaired by poor habitat conditions, despite low TP concentrations (< 100 µg/L).

Canals are highly altered or artificially constructed water bodies. They serve as reservoirs to retain stormwater, and as streams to convey excess water downstream. Like streams, canals discharge into receiving water bodies, typically lakes or estuaries. In South Florida, canals also discharge into freshwater marshes. Lakes, estuaries and marshes each have different water retention times, and the impacts of nutrients on aquatic systems is strongly linked to retention time. Canals may exhibit little or no flow over long periods, coupled with seasonal pulses of high flow. In this way canals are similar to seasonally connected oxbows of a large river system – part lake, and part stream.

Biological Response of Fisheries

Compliance with the overprotective criteria proposed by USEPA will reduce nutrient concentrations in streams and canals below levels necessary for the protection of the designated use of those waters. This could lead to a decline in fisheries productivity, since fish standing stocks in oligotrophic lakes are lower than in meso-eutrophic lakes (Bachmann et al., 1996). While lakes and canals do not appear to show any direct relationship between catch rates of largemouth bass and ambient nutrient concentrations (DB analysis of FWC Reports), other fish species, such as redear sunfish, exhibit higher standing stocks in mesotrophic lakes than in oligotrophic lakes (Bachmann et al., 1996).

FWC has conducted surveys of fish populations in canals throughout southeast Florida, and while the number of canals sampled has changed over time, a quantitative method (electro-shocking) has been used consistently (FWC 2008, Gestring et al. 2003, 2004, 2006; Shafland et al. 2001a,b). The available data indicate that south Florida canals support excellent fisheries over a wide range of nutrient (TP) concentrations. Three canals (West Palm Beach, Hillsboro, and C-111) that are periodically sampled by FWC and support high-quality sportfisheries were also visited during our April 2010 canal survey (discussed above). Water clarity and nutrient concentrations during that survey are shown in Figure 20.

In 2000, 2002, 2003 and 2005, the West Palm Beach Canal had largemouth bass catch rates of 0.8-1.01 fish per minute (fpm), where > 0.6 fpm is considered "excellent" fishing conditions (Gestring et al. 2003, 2004, 2006; Shafland et al. 2001a,b). Annual mean TP concentrations for 2000-2005 was 80-171 µg/L TP (at S5A and S155). During April 2010, TP, TN and chlorophyll

levels were 98 µg/L, 4.02 mg/L and 4.7 µg/L, respectively, in this canal at station WPB East (Figure 20).

During 1997, 1998 and 1999 the catch rates of largemouth bass in the urban portion of the Hillsboro Canal were 0.91-1.56 fpm, among the highest reported (Figure 21). Hillsboro Canal has also had the highest TN and TP levels among Broward County freshwater canals, and nutrients increase from western portion of the canal near S-39, to the eastern limit of the freshwater at G56 (Broward County Water Quality Department of Environmental Protection 2001). During the years 1997, 1998 and 1998, annual mean TP concentrations at S-39 were 33, 41, and 52 µg/L, respectively.

Figure 20. Three canal sites have different water clarity and markedly different TN and TP levels, but all support excellent fisheries. Differences in clarity are related to color, not chlorophyll or nutrient levels. See Figure 9 for station locations.

The C-111 canal produced 1.85 and 0.62 fpm in 1997 and 1999 at TP concentrations of 6 and 8 µg/L, respectively (Figure 21). Tamiami Canal was sampled 8 years between 1995 and 2003, and had a average catch rate (0.38 fpm) slightly lower than the state-wide average (0.41 fpm) for largemouth bass. TP in the Tamiami canal was also low 11 ± 1 µg/L. The 1998-2002 composite catch rate for all the southeast canals surveyed was 0.56 fpm, across a wide range of TP concentrations.

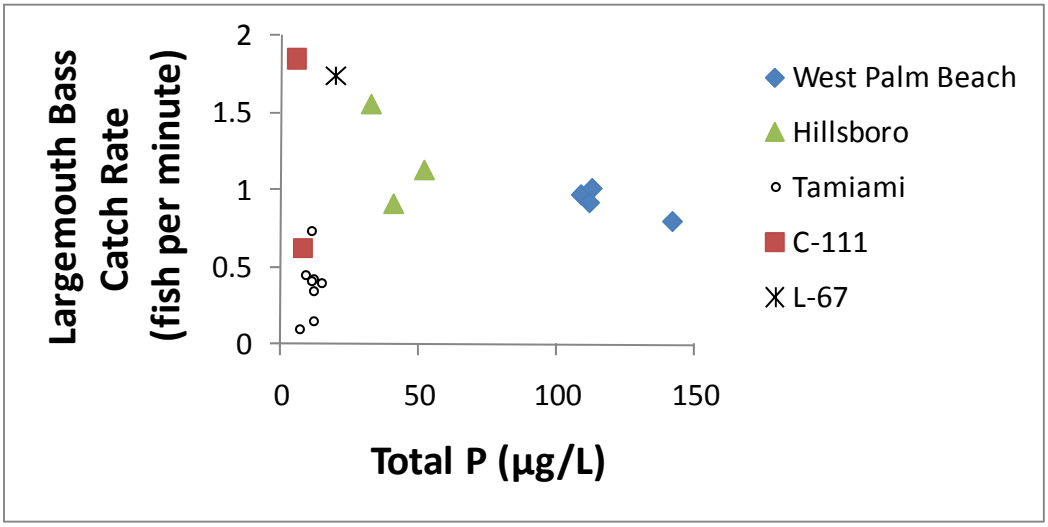

Figure 21. Largemouth bass catch rates as a function of annual TP concentration in several southeast Florida canals. Catch rate data from FWC annual reports (FWC 2008, Gestring et al. 2003, 2004, 2006; Shafland et al. 2001a,b) and water quality from SFWMD DBHydro.

The use of chlorophyll as a response variable for assessing nutrient impairment is based on empirical relationships between nutrients, chlorophyll, and lake trophic state in lakes (Carlson 1977). It is well known that fish biomass is correlated with trophic state, algal productivity and nutrient concentrations in lakes and reservoirs. For example, Bachmann et al. (1996) analyzed data from 65 Florida lakes and found positive correlations between nutrients (TN and TP) and fish biomass across a range of chlorophyll concentrations from 1 to 241 µg/L. While largemouth and bluegill frequently occurred in lakes from oligotrophic to hypereutrophic conditions, other important sportfish such as the redear sunfish and the black crappie showed a strong increase in both frequency of occurrence and standing crop biomass with increasingly eutrophic conditions (Bachmann et al., 1996) (Figure 22).

Sport fisheries likely do not reach peak biomass at TP levels below ~ 100 µg/L (Ney 1996). Reservoirs that have undergone nutrient reductions (oligotrophication) have seen declines in sport fish biomass (Maceina and Bayne 2001, Ney 1996, Stockner et al 2000), and oligotrophic lakes supported lower bass stocks than Florida lakes in higher trophic states (Hoyer and Canfield 1996). While the relationship may be less clear in streams (Hoyer and Canfield 1991) than in lakes and reservoirs, it could be argued that the canal environment is much more like a linear lake or reservoir than a free-flowing stream (FDEP 2008). However, the influence of connectivity between southeast canals and the vast Everglades marshes is more important than specific nutrient concentrations in these canal waters.

Connectivity between Everglades marshes and canals during high water periods allow large fishes to exploit macroinvertebrate and small fish prey items found in the marshes. Large fish, small fish and macroinvertebrate densities were all higher within 5 m of canals than further into the marsh, in both wet and dry seasons in the Everglades (Rehage and Trexler 2006). For obvious reasons, extreme draw down events in the Everglades marshes can cause high mortality among large fishes (Kushlan 1974, Nelson and Loftus 1996). The deep-water canal environment functions as important dry-season refugia from the adjacent marsh for both large and small fishes.

High connectivity between canal and marsh may explain why catch rates of largemouth bass in the L-67 canal are among the highest recorded in Florida. In 2007, the L-67 canal had an average 1.75 fish per minute (fpm), TP and TN were 20 µg/L and 1.2 mg/L, respectively (FWC 2008). Marsh connectivity from the L -31W and Tamiami canals was cited as a primary reason that these canals support large populations of Florida gar, a long-lived, apex predator that can structure lower trophic levels (Murie et al. 2009).

Recent fisheries data from Florida lakes sampled in 2007 (FWC 2008) confirm that chlorophyll is not an appropriate response variable for evaluating impairment of aquatic life uses by nutrients in south Florida canal environments (Figures 24 and 25). Moreover, there is no evidence that nutrient concentrations are causing stress to biota within canals themselves.

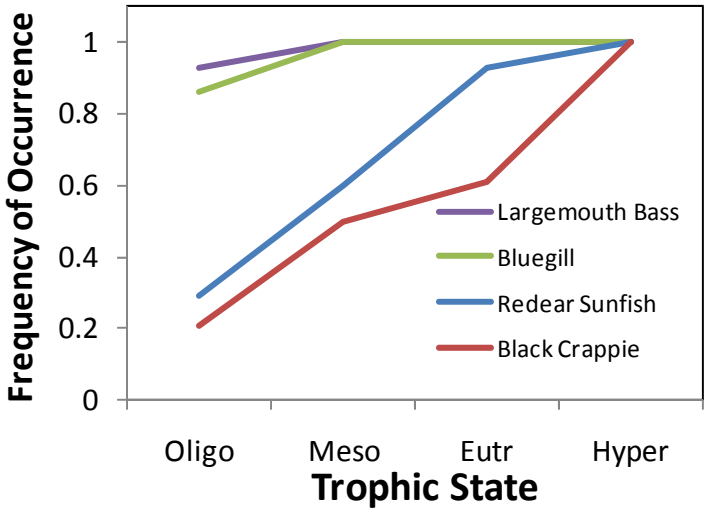

Figure 22. Occurrence of fish species during electrofish sampling of 65 Florida lakes between 1986 and 1992. Redrawn from Bachmann et al., 1996.

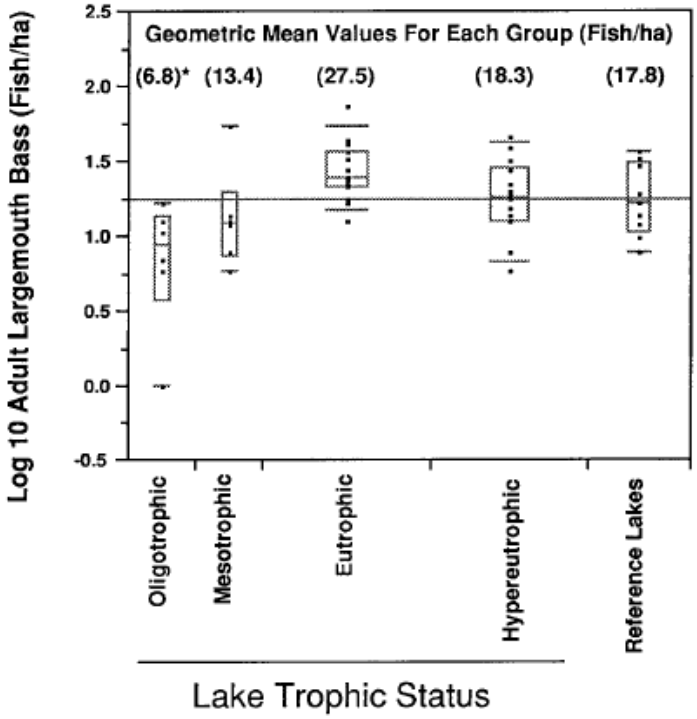

Figure 23. Geometric mean values of adult largemouth bass stocks of four lake trophic states and grass carp lakes (reference lakes). The horizontal line is the mean of all values. From Hoyer and Canfield (1996).

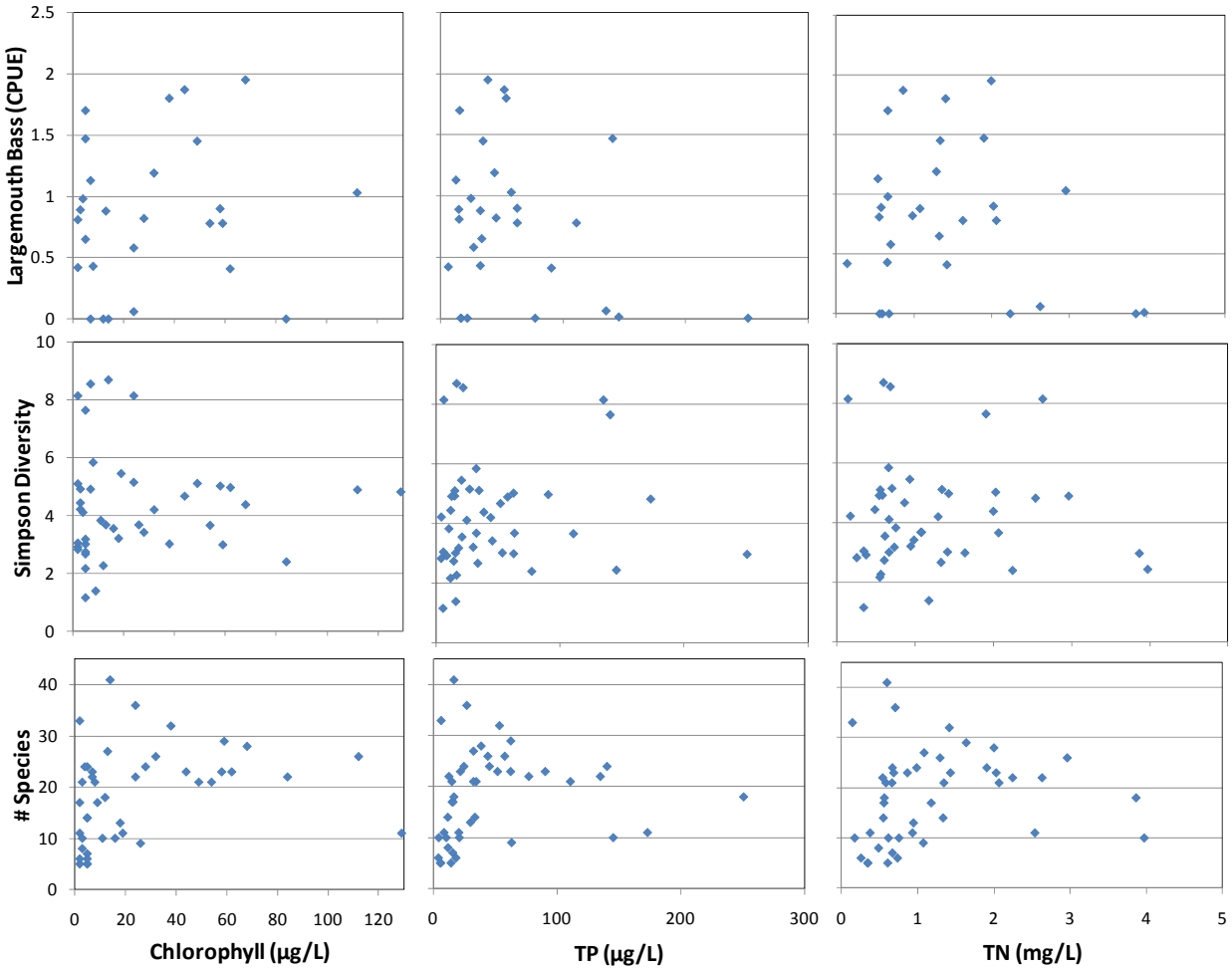

Figure 24. Relationships between mean nutrient (TN, TP) or chlorophyll concentrations and measures of fish abundance (catch per unit effort, CPUE, for largemouth bass), diversity (Simpson's Diversity Index) or taxa richness (# fish species). No significant relationship was observed between water quality and fish population metrics for the lakes dataset (N = 45). Data from FWC (2008), analyzed by DBE.

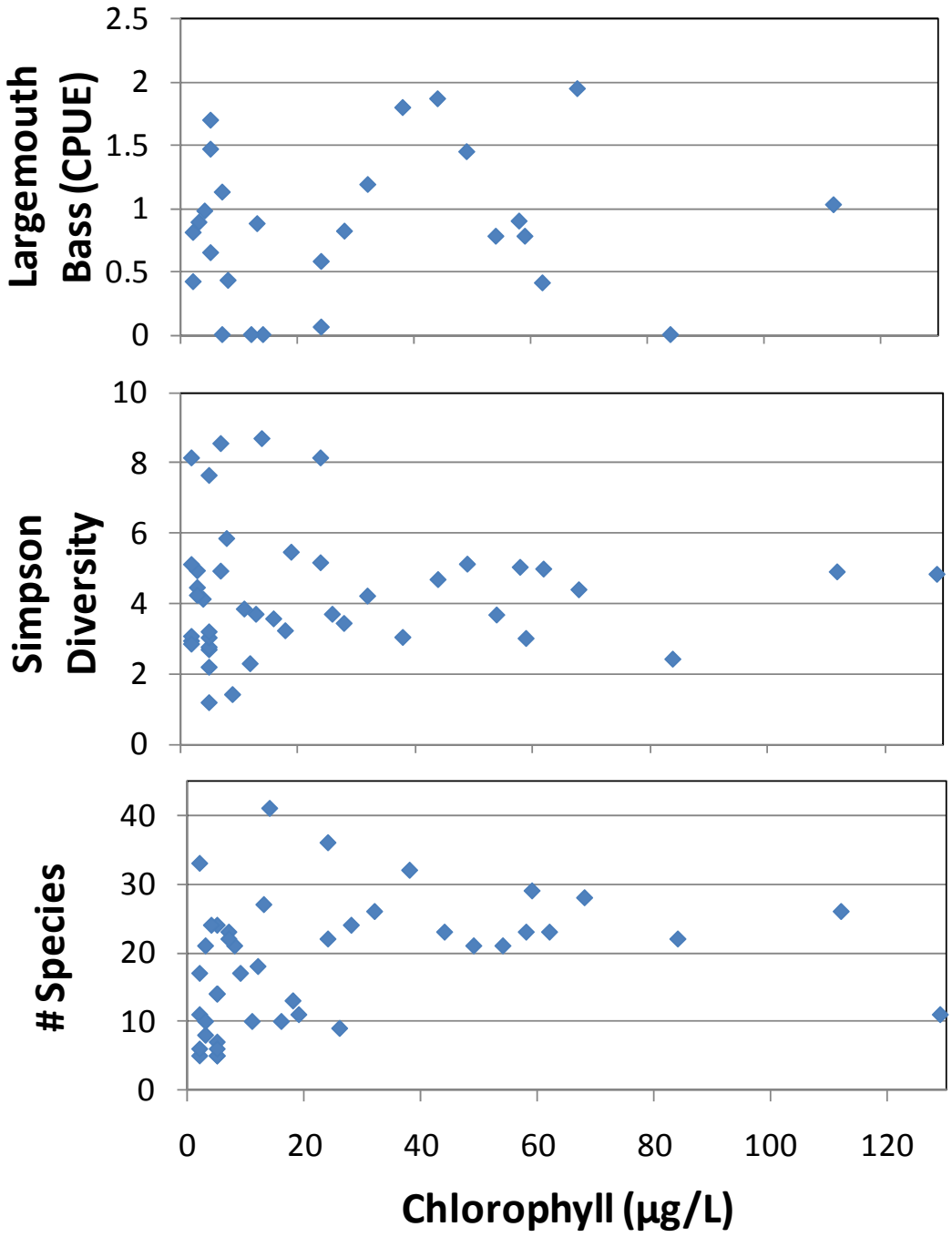

Figure 25. Expanded scale version of the relationships between chlorophyll concentrations and measures of fish abundance (catch per unit effort, CPUE, for largemouth bass), diversity (Simpson's Diversity Index) or taxa richness (# fish species). No significant relationship was observed between water quality and fish population metrics for the lakes dataset (N = 45).

Relationship between Chlorophyll Levels and "Harmful Algae Blooms"

Water column chlorophyll concentrations in canals are linked to the standing crop of microalgae, which in turn utilize nutrients and light to sustain their populations. A subset of microalgae can produce chemical compounds (algal toxins) that can be toxic to fish and humans. Blooms of such toxin-producing microalgae are termed "Harmful Algal Blooms" (HAB), and their presence has been linked to nutrient enrichment, in particular extremely high N and P concentrations.

Microcystin in South Florida Canals

Algal blooms can be of particular concern because some strains of cyanobacteria produce toxins, the most common of which is microcystin. Although microcystin is most commonly associated with the species *Microcystis aeruginosa*, other cyanobacteria, including *Anabaena circinalis*, also produce microcystin (Bigham et al., 2009). *Anabaena circinalis* and *Microcystis aeruginosa* are two of the most widely distributed species of phytoplankton in Florida, often forming extensive surface blooms and scums in eutrophic waters during warm weather and calm winds (Abbott et al., 2009). Toxic *Anabaena* and *Microcystis* have been found in lakes Okeechobee and Istokpoga, and *Microcystis aeruginosa* strains reportedly produce 37 of the 52 microcystins that occur in these two lakes (Abbott et al., 2009).

Humans can be exposed to cyanobacteria and their toxins (e.g. microcystin) through direct skin contact or ingestion of contaminated waters; however, there are relatively few case reports or epidemiologic studies of the effects of cyanobacteria toxins on human health (Abbott et al., 2009). The World Health Organization (WHO) suggests a guidance value for microcystin of 1 µg/L for drinking water, and recreational guidance values of 20 µg/L for activities in direct contact with water and 100 µg/L for indirect contact with water (Bigham et al., 2009).

A survey of lakes throughout Florida was conducted during 2006 to determine the frequency of microcystin contamination, and to establish a correlation between microcystin concentration and the values of two commonly measured parameters, chlorophyll and Secchi depth. Based on survey data from 187 lakes and 862 individual water samples, the probability of exceeding the WHO recreational guidance value for microcystin (20 µg/L) was calculated over the entire range

of chlorophyll concentration in the sample set (0 – 280 µg/L). For lake water samples having a chlorophyll concentration less than or equal to 128 µg/L, the probability of finding microcystin concentration in exceedance of the WHO recreational guidance value was negligible (Table 1). Photographs of chlorophyll concentrations at this level in deionized water and in canal waters are provided in Figures 7 and 8. Among the 29 samples in the highest chlorophyll concentration range (130 – 280 µg/L), only 7 percent contained microcystin at concentrations greater than 20 µg/L. Results of this study suggest that unhealthy levels of microcystin contamination in surface waters in Florida are not common, and are associated with extremely high densities of cyanobacteria, equivalent to chlorophyll concentrations greater than 130 µg/L

Table 1. Probability (%) that microcystin concentrations (µg/L) will exceed the listed WHO microcystin guidance values as suggested by the chlorophyll concentration categories, which were constructed to include at least 50 of the individual water samples (N=856) collected form 187 Florida lakes. (from Bigham et al., 2009)

		Microcystin conc. (µg/L) of 856 individual water samples		
Chlorophyll (µg/L)	N	<1	1 ≤ x ≤ 20	≥20
0-1.9	59	100%	0%	0%
2-2.9	75	100%	0%	0%
3-3.9	70	100%	0%	0%
4-4.9	61	100%	0%	0%
5-5.9	53	100%	0%	0%
6-7.9	86	99%	1%	0%
8-10.9	77	100%	0%	0%
11-13.9	54	94%	6%	0%
14-21.9	64	95%	5%	0%
22-31.9	56	91%	9%	0%
32-42.9	56	89%	11%	0%
43-69.9	63	83%	17%	0%
70-128	53	70%	30%	0%
130-280	29	45%	48%	7%

Source: Bigham et al. (2009)

A search of DBHYDO (SFWMD), Florida STORET (FDEP) and IWR (FDEP) databases retrieved a modest amount of data for microcystin concentrations in south Florida canal waters. Additional data, both microcystin and chlorophyll, for some of the same stations was found in "data summaries" obtained from the SFWMD web site. A total of 218 data points from 21

stations were found for microcystin concentrations in south Florida canals. All of the available data was collected during the period August 2005 and January 2007, presumably in response to an algal bloom event in Lake Okeechobee during the summer of 2005. A SWFWMD data summary for microcystin monitoring in the lake indicated that microcystin levels exceeded the WHO recreational guidance value (20 µg/L) at monitoring stations near the lake's northwest and east shores during August – October 2005.

It is important to note that during the 2005-2006 monitoring period for microcystin in Everglades canals, only one exceedance of the WHO recreational guidance value was reported (at L8.M_CNL) among the 21 stations and 281 observations (Figure 26).

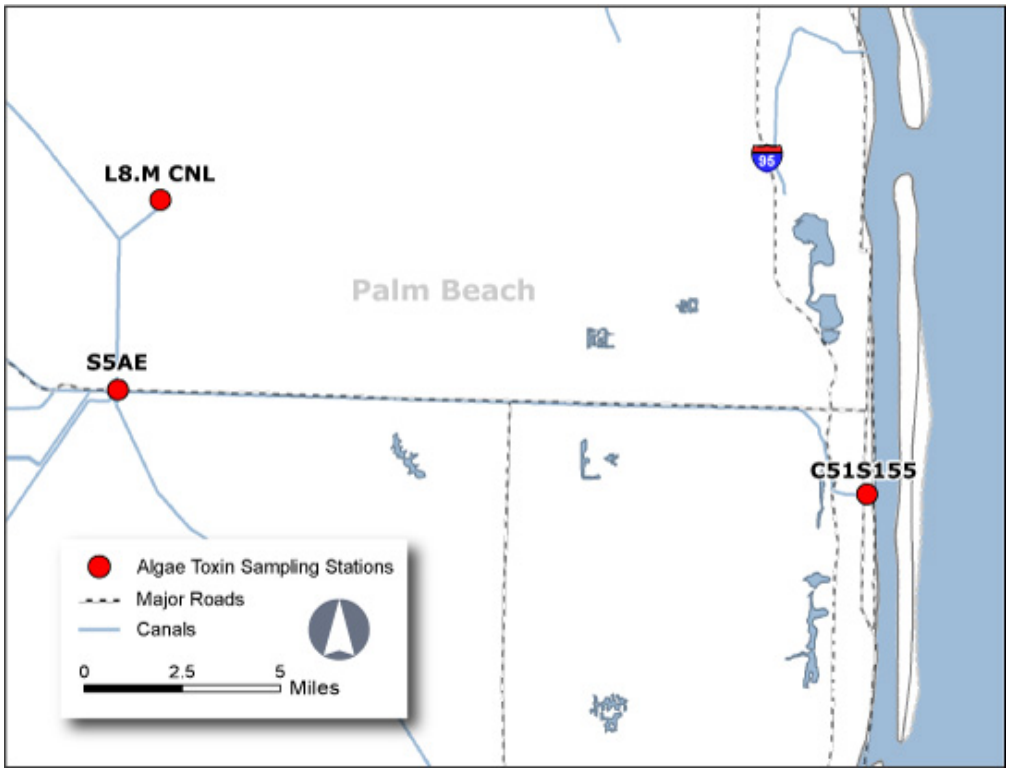

Figure 26. South Florida canal sites for which microcystin and chlorophyll were monitored concurrently during 2006. Source: SFWMD.

Chlorophyll was monitored concurrently with microcystin at three of the canal sites during 2006; however, chlorophyll was not monitored during the summer-fall 2005 monitoring period for microcystin (Figure 26). Although this precluded comparison of chlorophyll and microcystin levels during the episode of elevated microcystin in the lake, it did afford a simultaneous

comparison of these parameters during a one-year period (seasonal comparison), over a wide range (1 – 45 µg/L) of chlorophyll values. This comparison clearly shows that there was no correlation between microcystin and chlorophyll levels at these three stations, all of which are located within nutrient-impaired WBIDs (Figure 27).

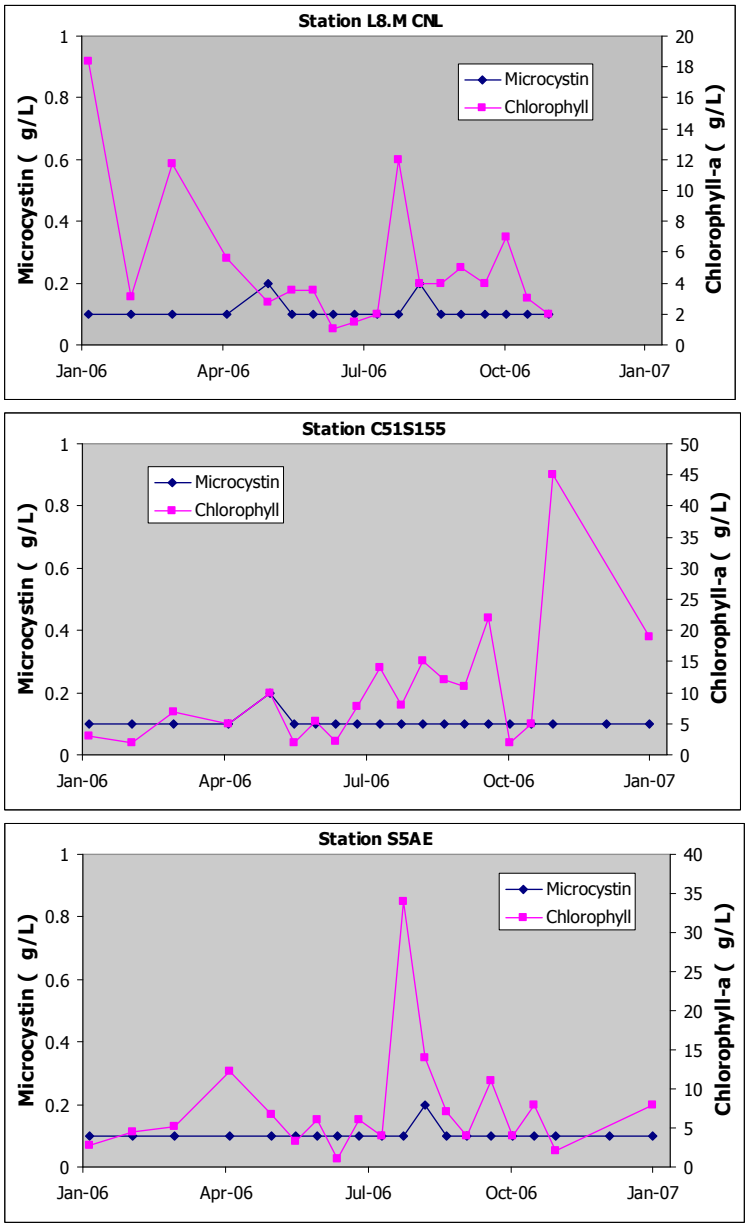

Figure 27. Concentrations of microcystin and chlorophyll (corrected) at three eastern south Florida canal stations during the 2006-2007 SFWMD microcystin monitoring period.

Lake Okeechobee microcystin and chlorophyll data from the 2005 – 2006 monitoring period reflect the results obtained from the broader Florida lake dataset: namely, that production of algal toxins such as microcystis is related to intense bloom (chlorophyll levels about 100 – 120 µg/L) conditions (Figure 28).

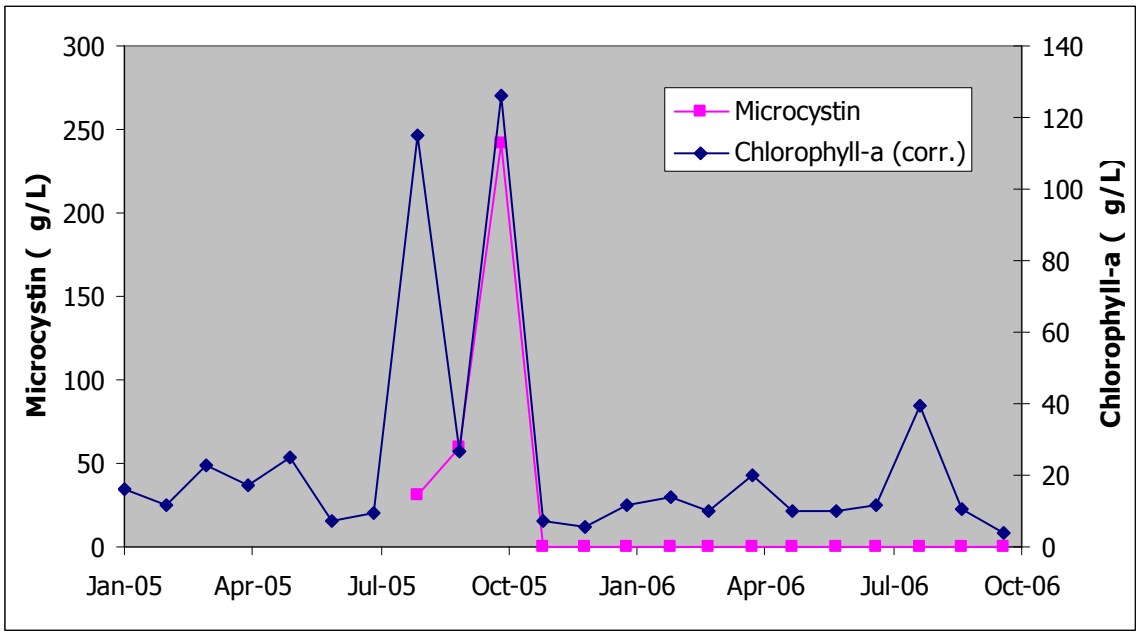

Figure 28. Relationship between microcystin and chlorophyll in Lake Okeechobee. Values represent means of four sites in the Lake. Note that chlorophyll and microcystin sampling stations differed slightly in spatial distribution (water samples for the two constituents were not collected simultaneously, nor were station locations exactly the same).

Alternative Approaches Proposed by USEPA

Phosphorus Concentration in Canals Upstream of Stormwater Treatment Areas

Many canals discharge to estuaries along Florida's south, east and west coasts, while other canals discharge into freshwater wetlands or lakes. The primary canals in the EAA deliver water to a network of stormwater treatment areas (STAs) that remove nutrients from surface waters before discharge into the Everglades Protection Area. Applying criteria with low nutrient concentrations (e.g., 42 µg/L TP) upstream of the STAs will make these facilities inefficient and obsolete. We concur with the notion that the public investment in regional treatment facilities (the STAs), as well as the geologic differences between the EAA and coastal areas, require that nutrient criteria be established for EAA canals separately from criteria for canals in other parts of south Florida that do not have downstream nutrient removal facilities.

A previous USEPA proposal suggested that 100 µg/L is an appropriate TP criterion for inflow waters to STAs, a value that was derived by the USEPA to support a proposed TMDL for dissolved oxygen and nutrients in portions of the EAA (USEPA 2007). We provided a critical review of that TMDL proposal to USEPA (Federico et al 2008, DBE 2008) and found several areas where USEPA's data analysis should revised before setting nutrient limits on canals in the EAA (Appendix D). First, STA outflow TP concentrations in the range of 10-20 µg/L have been shown to be insensitive to reduced TP mass loading rate (Juston and DeBusk 2006). Second, the data analysis used in the TMDL proposal included only a small portion of the data available at that time (i.e., data through 2007) (see Appendix D).

Additional data for 2007-2009 are now available for analysis of STA performance. A recent report by SFWMD, the agency that operates these nutrient removal facilities, stated that "inflow TP generally accounted for only a small amount of the variation in treatment performance. Much of the unexplained variance in outflow TP is attributed to other factors such as differences in soil characteristics, the occurrence and duration of dryout, or changes in plant community species composition" (Pietro et al., 2010). There is no direct relationship between inflow concentration and outflow concentration from STAs in the range of outflow concentrations required by the Everglades Protection Area.

In their 2007 TMDL proposal, the USEPA acknowledged several aspects of nutrient dynamics in the EAA that run counter to the current numeric nutrient criteria proposed for that area. First, the USEPA states "because the Everglades marsh is phosphorus-limited, nitrogen has not been a concern. There is no numeric water quality criterion for total nitrogen in the Everglades. USEPA is unaware of any data indicating that nitrogen causes imbalances in flora or fauna in Class III canals within the EAA." This contradicts the assertion in the current numeric nutrient criteria proposal that a TN criterion be applied throughout the south Florida region, including the EAA.

Second, the USEPA states "For the EAA WBIDs, the 100 ppb target was derived as what is necessary at STA inflows in order to protect downstream waters" (USEPA 2007). This concentration is over 2-fold higher that the TP criterion in the current USEPA proposal. This contradiction shows clearly that the criteria concentrations proposed by USEPA are arbitrary values that are not supported by sound science or independent verification.

Calculation of a TP Criterion for the Everglades Agricultural Area (EAA) Using a Downstream Protection Approach

The USEPA criteria proposal suggests that a separate TP criterion for canals in the EAA may be considered, and the EAA region was recognized as geologically distinct from other parts of south Florida where fresh water canals have been constructed (USEPA 2010). One method proposed for deriving EAA-specific criteria is the Downstream Protective Values (DPV) approach, which we consider inappropriate for canals in its present form.

In its proposed rule for water quality standards for the State of Florida (dated January 26, 2010), USEPA does not allow for in-stream losses of TP for calculation of DPV for streams. USEPA states that there are no long-term TP net removal processes at work in streams, due to desorption of sorbed P in sediments and resulting nutrient spiraling, and that over the long term, upstream phosphorus inputs reach equilibrium with downstream phosphorus outputs. If USEPA applies this same logic to the process of DPV development for canals, the resulting values will be overprotective. Such an approach would represent a disregard for the extensive P assimilative

capacity in Everglades canals, documented by scientific research demonstrating significant P burial, and resulting long-term P storage, in canal sediments.

There is evidence (i.e., low sediment accumulation) that sediment transport may occur in some south Florida canal reaches due to a combination of unusually high flow volumes and small canal cross-sectional area (Diaz et al., 2006). However, Diaz et al. (2006) found substantial bottom sediment accumulation in their characterization of approximately 196 km (122 miles) of major canals draining the EAA. Average sediment depths in 10 canal reaches ranged from 54 to 245 cm (1.8 to 8.0 feet). The estimated volume of sediment contained within the 122 miles of canals surveyed by Diaz et al. (2006), representing only a fraction of total Everglade's canal-miles, was 6,769,922 m^3 (8,854,724 cubic yards) providing for storage of approximately 1800 Mg (1984 tons) of TP.

USEPA also assumes that sediment TP is largely biologically available and that this pool of TP will be transported in its entirety, via nutrient spiraling, to downstream receiving waters. However, analysis of sediment TP in the canals draining the EAA and STAs strongly suggests that this is not the case. Results of a chemical fractionation procedure used extensively for characterizing inorganic and organic forms of P in Everglades soils and sediments (Reddy et al., 1998) indicated that the dominant forms (>80%) of sediment P in Everglade's canals were calcium or magnesium bound (inorganic) P and residual (recalcitrant) organic P (Diaz et al., 2006). Both of these sediment P fractions are chemically stable and resistant to biological uptake or degradation, and therefore represent an important long-term sink for P in these canals (Diaz et al., 2006).

Much of the particulate P load entering the major canals from the network of smaller farm canals is derived from detrital residue of aquatic plants growing in the farm canals (Stuck et al., 2001). It is therefore highly likely that much of the particulate P found in downstream canal reaches is autochthonous, rather than allochthonous, i.e., originating from plant detritus introduced in situ. Thus, the contribution of such activities as aquatic plant management (primarily herbicide application) in canals by the District and other government entities should be considered as likely sources of particulate P in downstream waters.

Based on the information presented above, it is clear that USEPA's approach to calculation of DPV for TP in streams is not appropriate for development of DPV for TP in canals, and would result in an overprotective DPV. Such an approach ignores direct scientific evidence of the P assimilative capacity of canals, and therefore is arbitrary and capricious.

Stressor-Response Approach to Criteria Derivation

An alternative approach suggested by USEPA is to use stressor-response relationships to identify nutrient concentrations that are associated with a certain biological response. The stressor-response model is useful for establishing criteria for toxic pollutants. However, ecological response to increased nutrient supply can exhibit a subsidy-stress relationship (Odum 1979) or no response if nutrient concentrations are within the range of tolerance. Macroinvertebrate communities show no relationship between nutrient concentration and biological health in Florida streams and canals (Fore et al. 2007, DBE and Azurea 2009, DBE 2009, USEPA 2010). Without a confirmed stressor-response relationship, this approach alternative is not appropriately applied to nutrients. We have stated our concerns about the use of chlorophyll as the response variable in earlier sections of this report. Those concerns notwithstanding, the fact that there was no significant relationship between either TP or TN and chlorophyll concentrations in the USEPA dataset for EAA canals, makes any criteria for the EAA region based on the stressor-response approach arbitrary and capricious.

Conclusions

The USEPA has proposed numeric nutrient criteria for inland freshwaters, with specific values to be used for canals in the south Florida region. When TN concentration exceeds 1.6 mg/L or TP exceeds 42 µg/L for sufficient frequency or duration, USEPA purportedly considers nutrients to be the causative pollutant that leads to an impaired condition, and a water body in such condition is expected to fail to meet its designated uses. A chlorophyll level > 4 µg/L is proposed by USEPA as an alternative indicator of failure to meet designated use due to nutrient pollution. We performed an extensive review of the proposed criteria and associated technical documents, as well as available water quality and biological data for south Florida canals, and we conclude that USEPA's proposed criteria are arbitrary and capricious.

Significant amounts of readily available canal water quality data were not considered by USEPA in their criteria development process, and the resulting analysis is therefore biased towards the regions represented in the "reference" dataset. Additionally, USEPA's current Nutrient Rule for TN and TP directly contradicts a 2007 USEPA TMDL proposal for south Florida canals, including those in the Everglades Agricultural Area (EAA), in which they note they are unaware of any data indicating that TN causes imbalances in flora or fauna in Class III canals within the EAA.

Publicly available, relevant biological data not considered by USEPA demonstrates that south Florida canals provide excellent sport fisheries at ambient nutrient levels considerably higher than the proposed criteria. Moreover, literature data have demonstrated that TN and TP levels as low as the proposed criteria values actually reduce fish productivity and the occurrence of certain desirable fish species. The consensus of scientific studies relating sport fishery production to nutrient and chlorophyll concentration in Florida waters clearly indicates that the primary recreational use of south Florida canals is already being achieved.

Similarly, we cite studies demonstrating that macroinvertebrate populations in canals are generally poor due to habitat limitations, and that for both canals and healthy streams, macroinvertebrate communities are not sensitive to nutrient levels over the ranges that currently prevail throughout south Florida canals. USEPA did not consider these measures of biological health, but instead relied on chlorophyll as a measure of biological health. Accordingly,

USEPA's expectation that the biological communities will improve or benefit if the nutrient values in the Rule are achieved is misplaced, arbitrary and capricious, and without any basis in sound science.

Swimming is widely discouraged or prohibited in south Florida canals by local, state and federal authorities due to inherent dangers to public safety (e.g. steep banks, deep water, alligators), thus swimming cannot reasonably be considered to be among the recreational uses of canals. Regardless, the suggestion that nutrient concentrations above the proposed criteria impair aesthetic or swimming use of canals is contrary to the findings of our survey of canal water clarity. Many south Florida canal waters contain moderate to high color concentrations, which we demonstrate in photographs, to totally mask any potential green color added by phytoplankton.

Our review of pertinent data sets and research studies on the algal toxin microcystin in Florida canals and lakes indicates zero risk of exceedance of World Health Organization (WHO) microcystin exposure guidelines at chlorophyll levels less than ~ 120 µg/L. Any causal link between nutrients and toxic algae is incomplete, at best, with no sound scientific finding for support.

Alternative approaches proposed by USEPA for nutrient criteria development are inherently flawed. The stressor-response approach is based on the erroneous assumption, discussed above, that using chlorophyll as the response variable to nutrient enrichment will predict the effects of nutrient concentration on "valued ecological attributes" or environmental harm in canals. The downstream protection approach disregards the scientifically documented nutrient assimilative capacity of canals, and therefore results in the calculation of an overly protective DPV for South Florida canals.

In summary, EPA's proposal has major flaws that have resulted in arbitrary and capricious criteria values that will not protect the designated uses of South Florida Class III waters.

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USEPA. 2009. Amended decision document regarding Florida Department of Environmental Protection's Section 303(d) list amendments for basin groups 1, 2, and 5. September 2, 2009. Environmental Protection Agency, Region 4 Water Management Division

USEPA 2010. Technical Support Document for EPA's proposed rule for numeric nutrient criteria for Florida's Inland Surface Fresh Waters. Washington, DC.

WCCD 2010. Steps in building a pond. http://www.washtenawcd.org/you/pondprep.php Washtenaw County Conservation District. Ann Arbor, MI.

Appendix A

USEPA's Approach to Criteria Derivation

The USEPA selected chlorophyll as a response variable to indicate nutrient pollution. The reasons given for this selection were that canals exhibit seasonal flow regimes, and that canals are listed on Florida's list of impaired waters with chlorophyll as the parameter of concern. The threshold nutrient concentrations selected were "assumed to inherently protect aquatic life" (USEPA 2010 TSD Ch. 4 p. 4-1). The USEPA states that their "methodology will ensure that nutrient concentrations associated with biologically healthy, well-balanced communities would be considered acceptable as protective of those communities."

USEPA obtained data from several agencies for water quality in canals and conducted a multi-step data screening procedure. A final screened dataset was used to develop distributions of concentrations for several parameters. From the distributions of values, criteria for TN, TP and chlorophyll were identified as the 75th percentile values.

In the criteria proposal, USEPA provided the following reasoning for using a distribution-based approach to using chlorophyll as an indicator of nutrient impairment:

"Based on the available information for canals, EPA determined that the most scientifically sound way to derive protective numeric nutrient criteria for south Florida's canals is to use a similar approach to what EPA used to derive numeric nutrient criteria for streams. That is, EPA chose a nutrient concentration distribution-based approach using data from only those canals that have been determined to support the applicable designated use. EPA used existing water quality assessments and identified canals that have been determined to be impaired for nutrients. Data for those canals were excluded from the larger data set in order to create a set of data representing canals attaining the designated use of aquatic life, according to FDEP's assessment decisions." (from USEPA 2010 - criteria proposal, p.139-140)

Site selection has a profound influence on the results of a reference distribution approach, and therefore must be representative of the region for which criteria are being developed. It is essential to carefully consider each step in the data screening process that results in the exclusion

of available data. In this case, however, the sampling sites used by USEPA to provide chlorophyll data were not distributed evenly throughout the South Florida region [refer to map?].

Additional "lines of evidence" were offered by the USEPA to support the conclusion that chlorophyll was an appropriate response variable and that the criteria values were reasonable. These included:

1. Stressor response relationship between chlorophyll levels in canals and TN and TP levels
2. Distribution of chlorophyll measurements, TN measurements and TP measurements from all canals (impaired and not impaired)
3. Distribution of chlorophyll a, TN, and TP values from only canals "minimally impacted by nutrient related pollution.
4. Downstream protective values appropriate for STA inflows
5. An analysis of establishing a "not to exceed" values by looking at variance in the screened data for sites that comply with the proposed criteria.

USEPA's "not to exceed" criteria approach applies statistical techniques to a screened dataset that is not representative of the range of biological conditions found throughout the South Florida region. The limited range of conditions, in terms of hydrology, soils, geology and vegetation, represented by the USEPA-selected stations does not adequately describe the variability in nutrient or chlorophyll concentrations observed in Everglades canals over time. Without an independent verification that designated use was degraded due to nutrient impairment, it is clear that USEPA's screening procedures were subjective and that the criteria based on flawed screening methods do not ensure protection of waters.

Downstream protective values are not appropriate for canals in their present form. Many canals discharge to estuaries along Florida's south, east and west coasts, while other canals discharge into freshwater wetlands or lakes. STA inflow P concentrations have been shown to be insensitive to reduced P loads and inflow P concentration below approximately 1.3 g $P/m^2/yr$.

All three distribution approaches used by USEPA (75th percentile of "reference" canals; 25th percentile of "all" canal data; and 75th percentile of minimally impacted sites along highway US

41) have similar flaws based on the arbitrary screening decisions made during the numeric nutrient criteria development. As shown in this document, the relationships among nutrients and chlorophyll and designated uses in south Florida canals was not successfully demonstrated by USEPA.

USEPA's Data Screening

The USEPA canal data screening process included removal of :

a. Canal sites in nutrient impaired WBIDs
b. Canal sites within 1000 m of a nutrient-impaired WBID
c. Sites with lake-like conditions near Lake Okeechobee
d. Sites not within Everglades eco-region
e. Sites with missing location information
f. Sites with marine matrix samples
g. Sites with high conductance (5% of samples > 3000µs/cm)
h. Stations associated with stormwater treatment areas, marshes, wetlands, class IV canals, private pump stations

USEPA used chlorophyll data only from sites located in WBIDs that are not listed as nutrient-impaired on FDEP's 303(d) list. Everglades canal WBIDs are listed by FDEP as impaired, not based on attainment of biologically healthy, well-balanced communities, nor of "designated use" (recreational fishing and transport of water for canals), but by comparison of the long-term median concentration of TN or TP to an arbitrary threshold value (the 70th percentile of stream nutrient concentrations from sites state-wide, Friedemann and Hand 1989). The threshold values used by FDEP to screen WBIDs and prioritize the use of watershed assessment resources have been remained constant since at least the mid-1990s.

Appendix B-9 of the USEPA Technical Support Document describes the use of 303(d) lists for screening proposed benchmark streams. The lists were taken from the USEPA decision document dated September 9, 2009 (USEPA 2009). According to App B-9, 63.6%, of potential benchmark streams, or 320 of 503 sites, were located within impaired WBIDs. No similar approach was documented for the screening process applied to South Florida Canals.

Since 2001, DEP has used methods outlined in the Impaired Waters Rule to determine nutrient impairment. The IWR finds a water body to be impaired by nutrients if any of the following are true

i. Mean annual chlorophyll > 20 µg/L
ii. 2-year average of mean annual chlorophyll > 150% x lowest 5-year average chlorophyll concentration
iii. Algal mats are present in sufficient quantities to pose a nuisance or hinder reproduction of a threatened or endangered species

The IWR also provides an explanation of the threshold of 20µg/L for chlorophyll:

> "Nutrients in Lakes: For the purposes of evaluating nutrient enrichment in lakes, TSIs shall be calculated based on the procedures outlined on pages 86 and 87 of the State's 1996 305(b) report, which are incorporated by reference." IWR 62-303.352

In the State of Florida's 1996 305(b) report:

> "We developed Florida lake criteria from a regression analysis of data on 313 Florida lakes. The desirable upper limit for the index is 20 micrograms per liter of chlorophyll, which corresponds to an [trophic state] index of 60. Doubling the chlorophyll concentration to 40 micrograms per liter increases the index to 70, which is the cutoff for undesirable (or poor) lake quality."

The 20 µg/L value for chlorophyll as originally developed from lakes data apparently has been applied to streams and canals by FDEP as well, though there is no documentation available on the exact origin of this screening criteria. USEPA's exclusion of chlorophyll monitoring stations in higher-nutrient canals eliminates a major subset of biologically productive canals and skews the resulting chlorophyll (and nutrient) criteria toward lower nutrient canals that are no more productive or biologically diverse than many of the excluded canals. The low-nutrient canals in the reduced subset are not representative of overall population of South Florida canals. Thus, the

unjustified screening of stations based on the FDEP 303(d) listing of associated WBIDs is arbitrary and capricious.

"Allowing for potential inaccuracies in location data, sites that were within 1,000 meters of a WBID that was listed by FDEP as nutrient-impaired were excluded." This screening method is arbitrary and inappropriate. Most monitoring stations are provided with descriptive names in addition to the station ID, which often can be used to determine an exact location, e.g. adjacent to a known control structure, regardless of the accuracy of the coordinates listed for the station. USEPA made no mention of using this technique to minimize the number of stations excluded during screening. Furthermore, the 1000-meter radius used to determine station membership in an impaired WBID is excessive, give that the precision of GPS receivers is typically 10-fold greater than this (i.e. less than 100 meter error) and often 100-fold greater.

USEPA excluded 163 sites "because they were from Lake Okeechobee or nearby canals that might be expected to behave more like a lake than a freshwater canal." It was not stated how many of the 163 sites were actually in the lake vs. in canals, nor was it stated what cutoff distance from the lake was used for screening the canal stations. FDEP's most recent state-wide water quality assessment found that "most fresh waterbodies in South Florida are canals, which usually support plants and animals more typical of lakes than rivers" (FDEP 2008). USEPA guidance documents acknowledge the importance of selecting appropriate reference conditions and verifying that selections "represent the range of natural factors likely to control the biotic composition in the region of interest" (USEPA 2006). Exclusion of canal stations is unjustified unless those stations are located in the immediate vicinity of the lake.

Appendix B

Government Regulations and Safety Constraints to Swimming in Canals

The inherent design of canals presents an impediment to safe swimming. For example, the steep slope of the banks and lack of a shallow water zone make both entry to and exit from the water a difficult and potentially dangerous process. The presence of water control structures, pumps and locks represent additional hazards for swimming.

Bank slope in south Florida canals generally ranges from 1:1 to 1:2.5 (V:H), depending on soil properties and other factors (USCOE 1953). As a comparison, design parameters for construction of ponds for swimming use in Michigan, published by the Washtenaw Conservation District, specify a maximum side slope of 1:8 to allow for gradual entry into the pond (WCCD 2010).

Similarly, the State of New York incorporates design standards for bathing beaches into the New York Sanitary Code, Subpart 6-2, which are enforced by the state Department of Health (New York DOH 2004).

> *6-2.19 Bathing beach design standards (Effective Date: 06/23/2004).*
>
> *0.0 Introduction. These standards are to be used by public health officials, design engineers and architects, and the owners and operators of bathing beaches for the design of new or modified bathing beaches regulated by this Subpart. These standards are enacted to ensure adequate design and establishment of bathing beaches, reflecting current safety and sanitary requirements. These standards are applicable to all bathing beaches located on ponds, lakes, streams or other bodies of water in the State.*
>
> *1.0 Definitions.*
>
> *1.1 Bathing beach shall mean a bathing place, together with any*

buildings and appurtenances, and the water and land areas used in connection therewith, at a pond, lake, stream or other body of fresh or salt water which is used for bathing or swimming with the express or implied permission or consent of the owner or lessee of the premises or which is operated for a fee or any other consideration or which is openly advertised as a place for bathing or swimming.

…

4.0 Design. The following criteria shall be used for establishing a bathing beach:

...

4.5 Bottom slopes. For depths up to four feet, the slope shall be uniform and not exceed 1:10. For greater depths, the slope should not exceed 1:3.

Agency Policies and Restrictions Related to Swimming in South Florida Canals

Safety issues such as those described above are of significant concern to local, state and federal governments and agencies. This concern is reflected in various ordinances and policies discouraging or prohibiting swimming in south Florida canals.

The South Florida Water Management District provides a public warning on their internet site regarding swimming in District canals (Figure B-1). (SFWMD 2010), which presents the hazards discussed above as the overriding reasons for discouraging canal swimming**:**

Swimming is not recommended. The canals are used for water movement and storage. In addition to the aquatic animals that live in the canals, including snakes and alligators, there are water control structures and locks that could be deadly. Many structures are automated and could change in operation while you are

swimming, creating a dangerous, or even deadly, situation. Also, since water is stored in the canals, there may be human health issues associated with swimming.

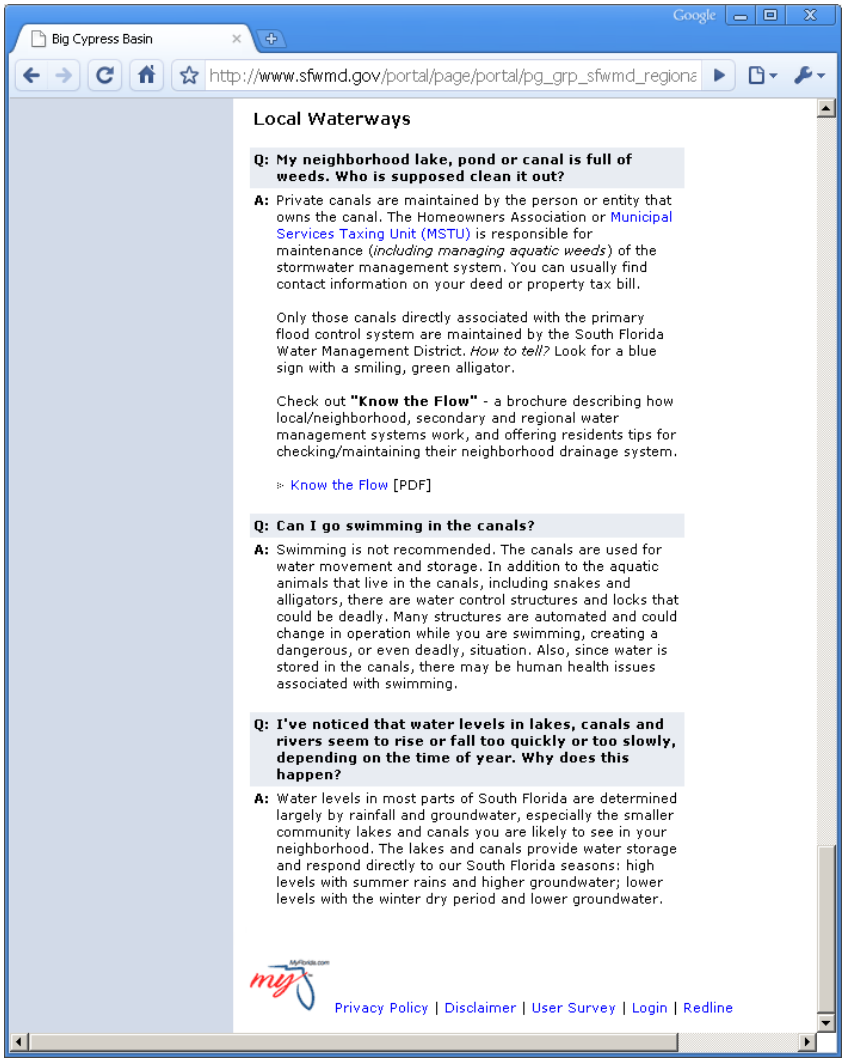

Figure B-1. Screen capture from SFWMD website discussing swimming in canals.

http://www.sfwmd.gov/portal/page/portal/pg_grp_sfwmd_regionalserv/pg_sfwmd_regionalserv_bigcypressbasin?_piref2414_10508739_2414_10508738_10508738.tabstring=tab2094075

The National Park Service "Trip Planner" publication for Everglades, Biscayne and Dry Tortugas National Parks and Big Cypress Preserve (NPS 2009) provides the following warning:

> *Wading or swimming is prohibited in most freshwater bodies of water in the parks. Take special care with your small children and dogs; they are closer in size to an alligator's natural foods.*

The matrix table of park activities provided in the Trip Planner includes swimming; however, this activity is not listed for either Big Cypress or Everglades National Park.

Similarly, the SFWMD Recreational Guide (SFWMD 2009) lists activities such as hunting and fishing for visitors to the Everglades (including WCAs and STAs); however, there is no mention in the guide of swimming as an option for recreation.

Swimming in canals is addressed indirectly by the Palm Beach County Parks and Recreation Ordinance, Section 9A (Ord. No. 04-022, § 9, 8-17-04), which states *"No person shall swim or wade in any beach, water area, waterpark or pool within any park property, except where specifically designated and in compliance with such regulations as to hours of the day and safety limitations for such use as set by the Department."*

A survey of the listed facilities/amenities in the 81 Palm Beach County parks (PBC 2010) revealed that only 13 county parks have designated swimming beaches, and that all of these are ocean or other salt water beaches. County parks with canal access have signs prohibiting swimming in the canals (Bob Cummings, Palm Beach County DOH, personal communication, 3/26/2010).

Broward County places similar restrictions on swimming in county parks:

> *Sec. 25½-4. - Recreational activities and facilities.*
>
> *(a) Bathing and swimming.*
>
> *(1) No person, regardless of age or manner of dress, shall swim, bathe or wade in any waters or waterways within park boundaries, except in such waters and at such places and times as are provided therefore and in compliance with this chapter.*

Due to the inherent safety concerns discussed above, swimming in canals is strongly discouraged by the Department of Health (Bob Cummings, Palm Beach County DOH, personal communication, 3/26/2010). Accordingly, canals are not included in the list of beaches monitored regularly by DOH for bacterial contamination.

In summary, a combination of public health hazards, unrelated to water quality, effectively precludes safe swimming in south Florida canals**.** Chief among these hazards are steep banks, deep water, concrete- or rock-armored banks, water control structures, local, state and federal ordinances, and dangerous wildlife (e.g. alligators and snakes). These hazards create an overriding concern in the eyes of the general public, which serves to limit the recreational use of canals to activities such as boating and fishing, neither of which represents "direct contact" with the water.

Appendix C

Survey of Transparency, Nutrients and Chlorophyll in South Florida Canals

We performed two assessments to evaluate the relationships between the visual appearance of canal waters and chlorophyll concentration, as well as the levels of other water quality constituents (such as color) that influence optical properties. For the first effort, we collected water from the Miami canal, just north of S8, and inspected the native phytoplankton populations microscopically. This water contained an algal assemblage dominated by diatoms and green algae (Figure 5). We then amended aliquots of canal water with various concentrations of a dense green algal culture (Figure 6) to obtain a range of chlorophyll concentrations. As a comparison, aliquots of deionized (DI) water also were amended with chlorophyll a.

For a follow-up effort, we collected water samples from 14 canal locations throughout south Florida (Figure 9), and evaluated optical characteristics of the waters along with color, chlorophyll a, and nutrient concentrations.

Methodology for Chlorophyll Amendments to Miami Canal and Deionized Waters

Miami canal surface water (~190 L) was collected on March 26, 2010. A survey of the plankton conducted three days after water collection showed centric and pennate diatoms to be the most abundant algal class (Bacillariophyceae). Green algae (class Chlorophyceae) were a sub-dominant, and included the genera *Closterium*, *Staurastrum*, *Scenedesmus*, *Chlamydomonas*, *Actinastrum*, *Gloeocystis*, and *Pediastrum.* Euglenophytes, such as *Phacus* and *Euglena*, were present in low numbers, as were cyanobacteria.

Water quality characteristics for Miami canal surface water collected on this date are presented in Table C-1. Since the initial chlorophyll (Chl. *a*) concentration of 21 µg/L was too high for comparing Chl. *a* concentrations in the 15-20 µg/L range, phytoplankton within the water column was allowed to settle under refrigerated, dark and quiescent conditions. After five days of settling, water was carefully withdrawn by siphoning 1.0 L from each of the following depth

layers of a 30-cm deep water column: 25, 50, and 75%. The Chl. *a* concentration associated with each of the depth layers indicated that phytoplankton settling had occurred with equal efficiency throughout the upper 75% of the water column. We subsequently siphoned 95 L of Miami canal from these buckets, taking care not to collect water within 25% of the bottom of the settling chambers. Using a unialgal culture of *Nannochloropsis* (class Chlorophyceae) cells (Carolina Biological Supply, Burlington, NC 27215) as a Chl. *a* stock, we amended the siphoned Miami canal water on April 8, 2010 to yield a range of nominal concentrations, from approximately 3 to 28 µg/L, in separate five-gallon white buckets. In addition to amending *Nannochloropsis* cells to the Miami Canal water, we also added the cell suspension to 0.01 M KCl in deionized water to produce comparable Chl. *a* concentrations as those achieved in the amended Miami Canal water (Table C-2).

Table C-1. Apparent color, turbidity, total phosphorus, and phytoplankton pigment concentrations, and pH, of the surface water from the Miami Canal collected on March 26, 2010. The method number followed for each analysis is also provided.

Parameter	**Concentration**	**Method No.**
Apparent Color	185 PCU	EPA 110.2
pH	7.95	EPA 150.1
Turbidity	3.84 NTU	EPA 180.1
Total Phosphorus	37 µg/L	SM 4500-P F
Chlorophyll *a*	21.0 µg/L	SM 10200H
Pheophytin *a*	13.5 µg/L	SM 10200H
Uncorrected Chlorophyll *a*	34.5 µg/L	SM 10200H

Note: EPA methods from USEPA 1979; Standard Methods (SM) from APHA 1992.

Each background and amended water treatment in the five-gallon white buckets was immediately photographed outside during the day under a cloud cover. After photography was completed, water was collected immediately from each bucket for Chl. *a* analysis. The measured corrected Chl. *a* concentration in the unamended Miami canal water was 3.4 µg/L, and the concentrations of the various amended treatments are depicted in Table C-2.

Table C-2. Amended and unamended chlorophyll (Chl. *a*) concentrations (µg/L) in Miami Canal and 0.01 M KCl deionized water. These waters were deployed outdoors in five-gallon white buckets on April 8, 2010, and samples for Chl. a analyses were collected immediately after photographs were taken.

Amendment No.	**Miami Canal Chl. *a***	**Deionized Chl. *a***
None	3.4 (background)	0.16
1	Not required	6.9
2	12	17
3	14	21
4	22	28
5	130	130

Canal Survey Methodology

A survey of 14 canal stations was conducted between April 6-8, 2010, to provide insight into the relationships between nutrients, chlorophyll and transparency in canal surface waters. Sites were selected from primary canals in South Florida. Each station had additional available data associated with water quality monitoring programs. At each station, water was collected for analysis of the parameters listed in Table C-3. Turbidity, Secchi depth, conductivity and DO were measured in situ at each site, while other samples were preserved and analyzed according to standard methods.

In addition to the above parameters, the water transparency at each site was assessed with a novel approach called the "Secchi Bucket". Site water was collected in a five gallon white bucket and a standard Secchi Disk was placed in the bottom of the bucket. The water depth in the bucket was adjusted so that 0.3 m water was above the secchi disk. A picture was taken from above the bucket to provide a visual estimate of transparency that could be compared between stations.

Table C-3. Water quality constituents measured during a recent survey of water quality in south Florida canals

Canal Name Station ID	Sample Date Time	TP (µg/L)	NOx (mg/L)	TKN (mg/L)	TN (mg/L)	Color (PCU)	Chl a (mg/m3)	Pheo a (mg/m3)	Uncorrected Chl a (mg/m3)	Secchi (m)	Turbidity (NTU)	Conductivity (µs/cm)	DO (mg/L)
West Palm Beach Canal													
WPB	4/6/2010	275	0.334	3.985	4.319	578.5	29	19.5	48.5	0.3	31.15	2506	8.49
S5A	4/6/2010	178	1.26	3.27	4.53	333	4.2	4.6	8.7	0.8	7.4	1607	8.21
WPB East	4/7/2010	98	0.185	3.83	4.015	323	4.7	4	8.7	0.4	27.6	715	8.88
Hillsboro Canal													
S6	4/8/2010	77	0.479	2.51	2.989	234.5	1.65	1.015	2.65	1.45	1.95	1475	7.335
WCA2E0 Canal	4/8/2010	18	0.026	1.42	1.446	156	2.6	1.3	3.8	1.5	1.1	737	8.77
Brow003	4/7/2010	123	0.103	1.06	1.163	109	5.4	4.7	10	2	0.57	777	9.71
Miami Canal													
Miami	4/6/2010	65	0.735	2.24	2.975	226	9.6	12	22	1	3	1708	12.9
S8	4/6/2010	46	0.012	1.88	1.892	179	14	12	25	1.3	2.7	606	9.89
S151	4/7/2010	14	0.036	1.69	1.726	139	1.1	1.1	2.2	2.4	3.4	839	6.74
S12D	4/7/2010	10	0.052	1.56	1.612	119	1.4	0.46	1.9	2.8	0.9	724	6.45
Other Canals													
C-16 Boynton	4/7/2010	69	0.026	0.73	0.756	93	2.7	2.1	4.8	2.5	0.9	517	10.3
Brow089	4/7/2010	11	0.022	1.27	1.292	133	1.8	0.59	2.4	2.3	0.4	603	9.4
Brow017	4/7/2010	17	0.031	0.63	0.661	43	2.4	<0.3	2.6	1.7	0.5	335	11.37
S177	4/7/2010	7	0.004	0.71	0.714	59	2.7	0.75	3.5	2	1.4	679	7.79

Appendix D

An Analysis of Factors that Influence STA Outflow Phosphorus Concentrations

Background

In September 2007, the United States Environmental Protection Agency (USEPA 2007) proposed nutrient (specifically phosphorus [P] and dissolved oxygen) total maximum daily loads (TMDLs) for several water body segments (WBIDs) in the Everglades Agricultural Area (EAA). For these EAA WBIDs, the USEPA states: .. *"a TP concentration target is derived that is necessary to protect the downstream areas of the Everglades. This 100 ppb target is determined to be the concentration required at Stormwater Treatment Area (STA) inflows in order to result in the STA outflow of 16 ppb."*

The USEPA's analysis of the relationships between STA outflow P concentrations and inflow P concentrations is fundamentally flawed in several respects. It is our assessment that:

1) There was readily available data that the USEPA did not consider in their analysis, and the available information strongly suggests a different result; and,
2) USEPA did not adequately explain how it came to its decision to select 100ppb as an STA inflow TP concentration requirement.

The Everglades Stormwater Treatment Areas (STAs) are large constructed wetlands, ranging in size from 870 to 16,543 acres. Most STAs are comprised of two or more flow paths that can be operated independently with respect to water depths, flow rates and P loading rates (Figure D-1). Individual flow paths within a single STA often have entirely different vegetation types. Moreover, within some STAs, separate flow paths have been exposed to markedly different historical management practices (i.e., different antecedent conditions). As an example, STA-2 is

comprised of three flow paths: two flow paths (Cells 1 and 2) are dominated by emergent aquatic vegetation (EAV) (i.e, cattail and sawgrass), situated on lands that were not previously farmed (historically wetland (HW)). The third flow path (Cell 3), is dominated by a different vegetation type (submerged aquatic vegetation [SAV]), and was constructed on lands that had been farmed for several decades. Hence, while flow paths within an STA typically share common inflow and outflow pump stations (or gravity flow structures), they usually differ in several respects, many of which can influence treatment performance.

The STA flowpaths vary in size, and many are extremely large. For example, the easternmost flowpath of STA 3-4, comprised of Cells 1A and 1B, comprises 5,581 acres. Most, but not all, STA flow paths consist of two to three cells in series. The upstream cells often contain emergent macrophytes, while the downstream cell(s) is designated for a SAV community, useful for polishing TP to low levels. During the past decade, it has become clear that a number of parameters, such as vegetation type, vegetation health, chemical characteristics of the water, and wetland hydraulic characteristics can influence STA P removal performance. STA treatment performance also can be influenced by antecedent soil conditions during startup, as well as the gradual accrual over time of P-enriched sediments within the wetland itself. Due to the numerous variables that impact STA performance, prior rigorous investigations of the factors that influence STA outflow P concentrations have utilized either individual flow paths (Juston and DeBusk 2006), or individual cells (W.W. Walker, Jr., http://wwwalker.net/dmsta/index.htm) within each STA flow path, rather than each STA in its entirety. These approaches increase the number of replicates, and therefore maximize the strength of the statistical analyses.

USEPA Analysis: Data Limitations

There are numerous deficiencies in USEPA's analysis of factors (i.e, P loading rate, P inflow concentration) that purportedly influence STA performance. These include:

- Their analysis incorporated only three of 13 years of STA performance data. Further, the three years selected (1997, 1998, 1999) for analysis were a period during which only two STAs were operational (STA-6 fully, and STA-1W partially) (Table D-1).
- From a surface area ("footprint") standpoint, their analysis of two STAs encompassed a maximum wetland footprint of only 4,685 acres. By contrast, in recent years, annual

performance data from up to 32,980 acres of STA treatment area have been available for analysis (Table D-1; Figure D-1).

- The bulk of the acreage (3,815 of 4,685 acres) in USEPA's analysis consists of the Everglades Nutrient Removal Project (ENRP), the pilot-scale predecessor system to the larger STA-1W. The flow regime to the ENRP differed markedly from that of how STAs now typically function, since it was operated under low, and relatively stable hydraulic loading conditions (Figure D-2). Upon incorporation of an additional flow path (Cell 5) and different inflow structures, the ENRP was converted to STA-1W, and the wetlands began receiving storm-event based runoff in 2000. This pulsed flow hydraulic loading regime (Figure D-2) reflects how all STAs now operate.
- In addition to addressing only three years of performance data (1997 – 1999), USEPA compromised the strength of their analysis of STA performance by ignoring individual flow path data. While USEPA states that a flow-weighted mean total phosphorus (FWM TP) concentration of 16 ppb is the purported target outflow concentration for the STAs, neither of the entire STAs (STA-1W or STA-6) selected for analysis attained TP outflow levels below 19 ppb. By contrast, in our analysis of 75 STA flow path-years of data, we found that 14 achieved a FWM TP of 16 ppb or less. Utilization of this STA flow path data set therefore makes it possible to better define the factors that influence STA performance, while disregarding this information is unreasonable.

To summarize, USEPA utilized only a small subset of available STA data to evaluate P loading rate and inflow P concentration effects, and the majority (81%) of the wetland acreage used for the analysis was operated under hydraulic loading conditions not representative of how the six STAs currently function.

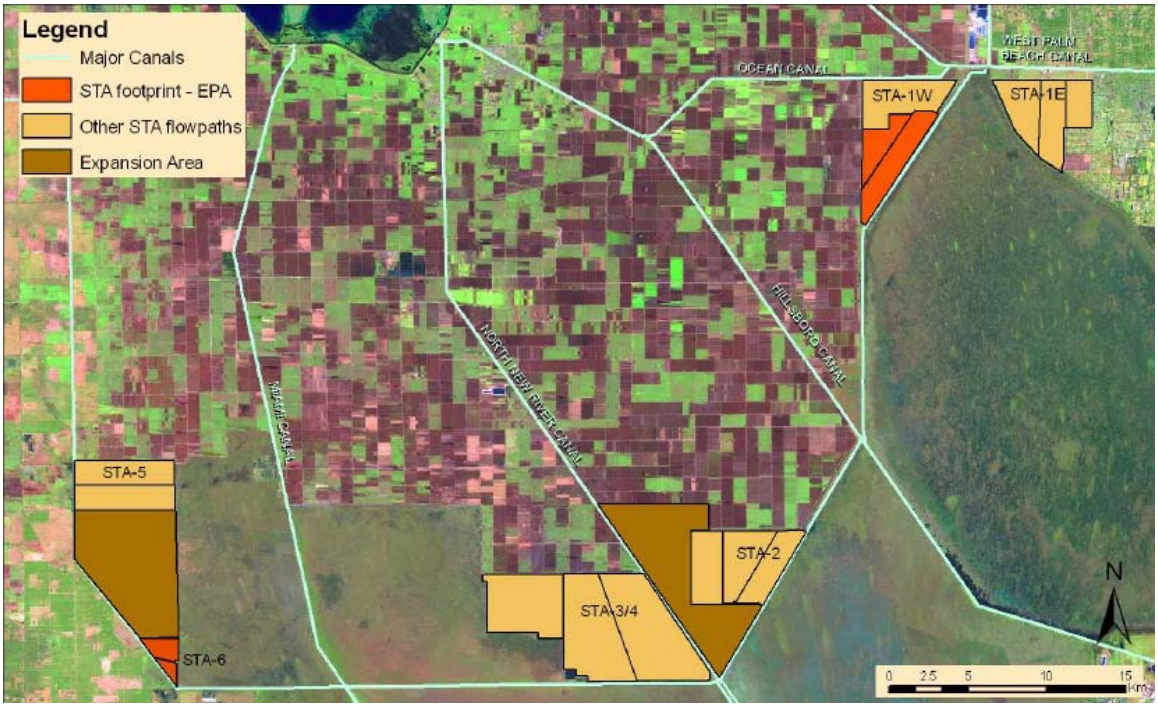

Figure D-1. USEPA utilized only 4,685 of a possible 32,890 acres of treatment wetland to arrive at their conclusions regarding inflow P concentration and loading effects of STA performance. This map depicts the location of the STA footprints utilized for the USEPA analysis (*STA footprint – EPA*), the remaining STA areas operational as of 2006 (*Other STA flow paths*) and STA expansion areas (*Expansion Area*) that either recently have been completed, or are under design/construction as part of the Long Term Plan (Burns and McDonnell 2003).

Table D-1. USEPA utilized only four STA flow paths to arrive at their conclusions regarding inflow P concentration and loading effects of STA performance. This table depicts operational Stormwater Treatment Areas (STAs), the number of internal flow paths, and the effective treatment acreage by water year since the beginning of the STA program. The Everglades Nutrient Removal Project (ENRP), a "pilot" system, was the predecessor to STA-1W.

WaterYear	STAs Operational	Effective Treatment Area (acres)	Number of operational flow paths	Included in USEPA TMDL development analysis?
1995	ENRP	3815	2	No
1996	ENRP	3815	2	No
1997	ENRP	3815	2	Yes
1998	ENRP, STA 6	4685	4	Yes
1999	ENRP, STA 6	4685	4	Yes
2000	STAs 1W, 5, 6	8795	6	No
2001	STAs 1W, 2, 5, 6	17604	10	No
2002	STAs 1W, 2, 5, 6	18080	10	No
2003	STAs 1W, 2, 5, 6	18080	10	No
2004	STAs 1W, 1E, 2, 3-4, 5, 6	31080	14	No
2005	STAs 1W, 1E, 2, 3-4, 5, 6	28601	14	No
2006	STAs 1W, 1E, 2, 3-4, 5, 6	32980	15	No
2007	STAs 1W, 1E, 2, 3-4, 5, 6	34276	15	No

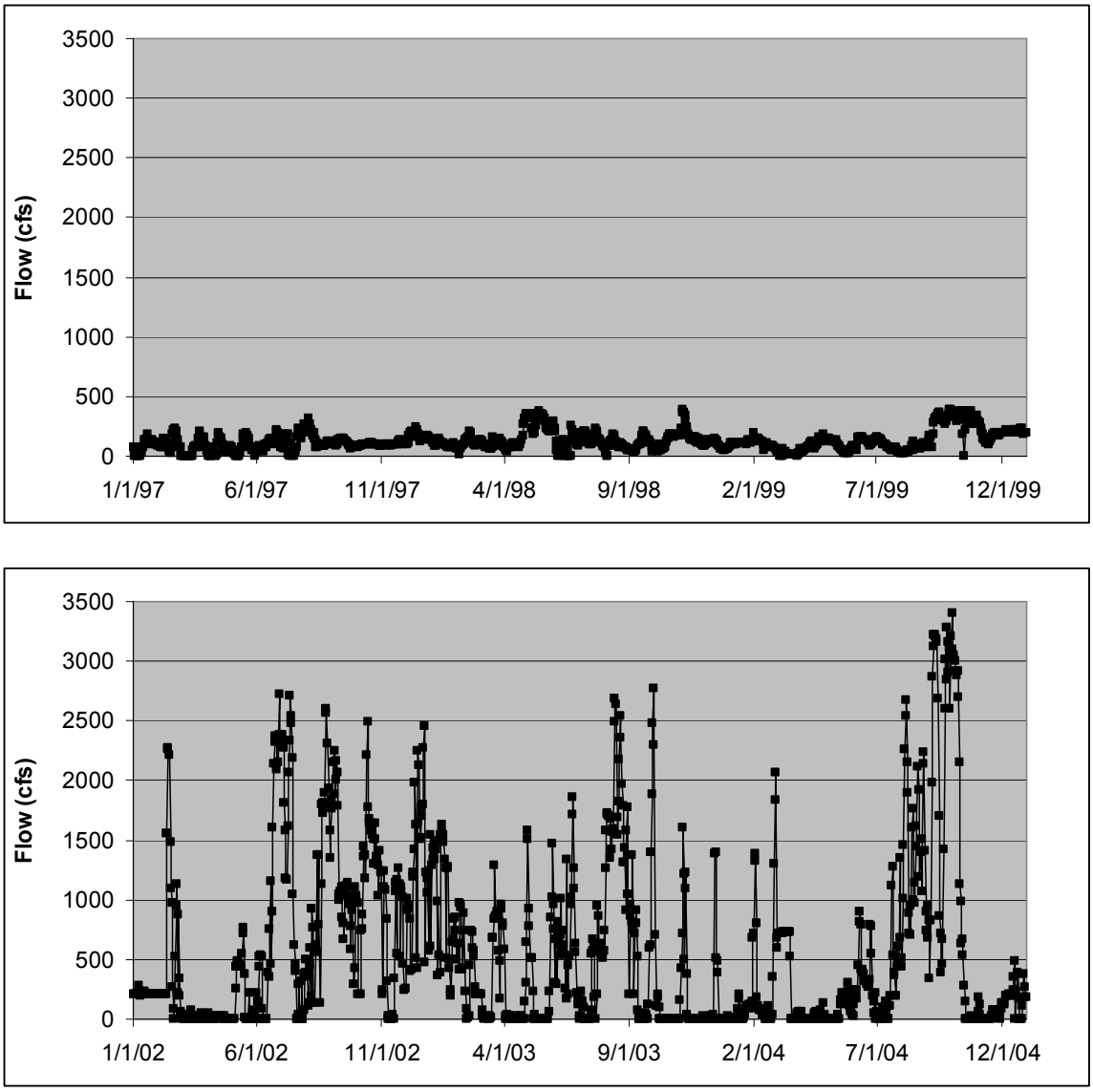

Figure D-2. Daily flows, in cubic feet per second (cfs), for three years of Everglades Nutrient Removal Project (ENRP) operations (top) and three subsequent years of STA-1W operations (bottom). The ENRP flows in the top graph, which are not representative of current STA operational conditions, represent the period USEPA used for identifying the target TP concentration of 100 ppb for STA inflow waters.