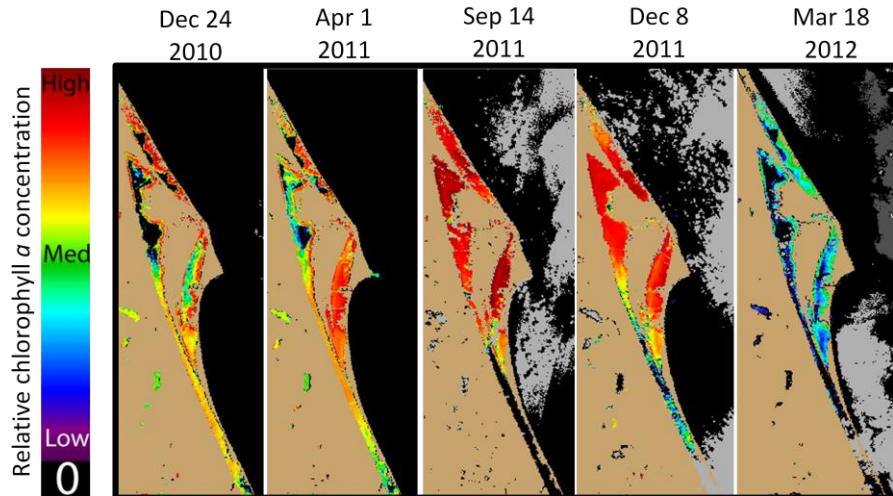


Indian River Lagoon 2011 Superbloom Plan of Investigation



MERIS Satellite images of the Indian River Lagoon system depicting the relative intensity (concentration of chlorophyll) of the 2011 phytoplankton superbloom .

June 2012

St. Johns River Water Management District
 Bethune-Cookman University
 Florida Atlantic University-Harbor Branch Oceanographic Institution
 Florida Fish and Wildlife Conservation Commission
 Florida Institute of Technology
 Nova Southeastern University
 Smithsonian Marine Station at Ft. Pierce
 University of Florida
 Seagrass Ecosystems Analysts



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Section 1. Introduction

Purpose

The purpose of this plan is to describe a deliberative, scientific approach for investigating the cause(s) and impacts of a strong and protracted phytoplankton bloom in 2011 that expanded throughout the Banana River Lagoon, northern Indian River Lagoon, and southern Mosquito Lagoon. Submersed aquatic vegetation (SAV), particularly seagrass, is the main subject of the bloom impacts.

Background

From early spring through late fall of 2011, a massive bloom of phytoplankton and loss of seagrass occurred throughout most of the Indian River Lagoon (IRL) system, extending from southern Mosquito Lagoon to just north of Ft. Pierce Inlet (Fig. 1-1; see MERIS images on title page). This bloom and seagrass decline far exceeded any past events remembered or documented in terms of geographic scale, bloom intensity and duration, and rate and magnitude of seagrass loss.

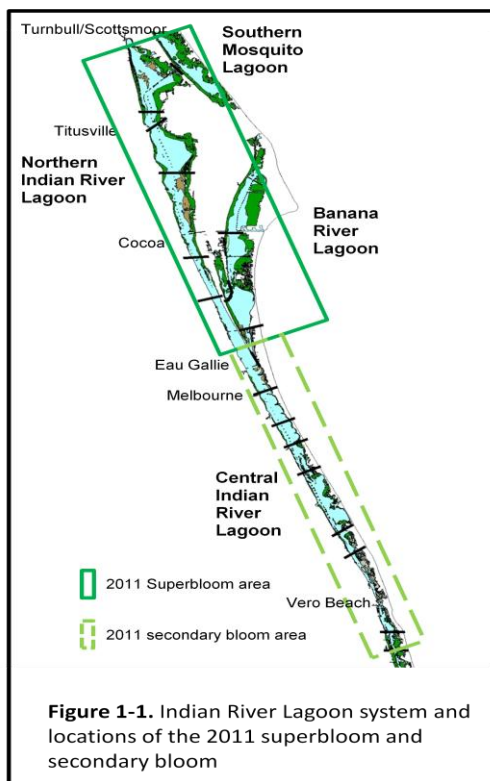
This bloom event actually consisted of two different, yet concurrent blooms (Fig. 1-1). The lesser of the two blooms was restricted to the central IRL (Eau Gallie south to Vero Beach/Ft. Pierce vicinity), covering approximately 19,000 hectares. This bloom was moderately intense, as measured by chlorophyll a (Chla)

concentration, with levels frequently within the 20 - 30 $\mu\text{g/L}$ range; and composed of a mix of dominant species: cyanobacteria followed by diatoms and dinoflagellates in the Melbourne reach, and a co-dominance of diatoms and dinoflagellates in the Sebastian and Vero reaches.

The other bloom reached immense proportions, deserving its own label or category “superbloom”. The 2011 superbloom covered approximately 53,000 hectares of open water including Banana River Lagoon (BRL), northern IRL (NIRL, north of Eau Gallie up to Turnbull/Scottsmoor area), and southern Mosquito Lagoon. This bloom surpassed all previous documented blooms in intensity, often exceeding 100 $\mu\text{g/L}$ Chla. It was dominated by pico-cyanobacteria and a species of chloro-microflagellate in the class *Pedinophyceae* that is currently unidentified. This *Pedino* species is presently considered cryptogenic: it may either be newly introduced to the IRL system or may have been present for many decades or longer, yet remaining “quiescent” until a concurrence of favorable conditions enabled it to bloom.

During the first 3 months (Apr-Jun 2011) of persistent bloom, there was a marked decline in water transparency (Secchi depth) and increase in light attenuation (IK_d). The 3-mo average Secchi depth in BRL, NIRL decreased respectively from 0.9m, 1.0m (Oct-Dec 2010) to 0.8m, <0.9m (Jan-Mar 2011) and to 0.5m, 0.7m (Apr-Jun 2011). The 3-mo average IK_d in BRL, NIRL increased

respectively from 1.1, 1.1 (Oct-Dec 2010) to 1.3, 1.2 (Jan-Mar 2011) and then to 1.7, 1.7 (from Apr-Jun 2011). By the end of June 2011, the loss of seagrass was substantial (Fig. 1-2). Relative to the summer 2010 coverage of seagrass (measured as distance from 1994 shoreline¹ to deep-edge of bed), grassbeds were reduced by ~45%



¹ 1994 was the first year of seagrass transect field measurements during which shoreline zero points were established to measure bed lengths. Bed lengths have been measured relative to the same zero-point locations ever since.

² Annual mean rainfall in BRL and NIRL was $\leq 40''$ and $< 48''$, respectively, for each of the years 2009, 2010, and 2011. For those same

overall in the BRL, NIRL, and central IRL. That reduction roughly translates to a loss of ~31,600 acres based on the previous mapped estimate (70,230 acres in 2009). Unfortunately, given the 7-month duration of the superbloom, the total loss of seagrass coverage in 2011 may have been greater.

This expansive loss of grassbeds could be a staggering blow to the local economy that is dependent upon the estuary, particularly its fisheries. The harvest of seatrout and other seagrass-dependent fish is strongly influenced by seagrass coverage (Fig. 1-3). Given the current fishery-based valuation of seagrass: ~\$5,000 to \$10,000/seagrass acre/yr (Hazen and Sawyer 2008; SJRWMD, unpublished data, 2011), the 2011 seagrass loss represents a potential reduction of 150 million to 320 million dollars in commercial and recreational fisheries value in 2011 and 2012.

Figure 1-2 . The 2011 seagrass coverage map for the IRL system is not yet completed (graph on left), so no accurate account of seagrass loss; however, grassbed lengths measured in June 2011 indicate a significant loss (graph on right). Analyses performed on SJRWMD data.

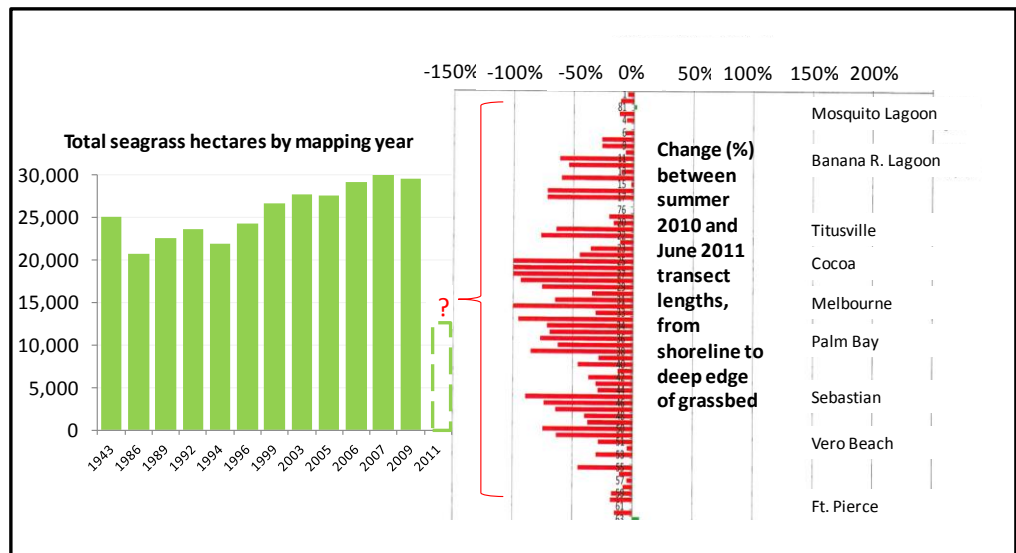
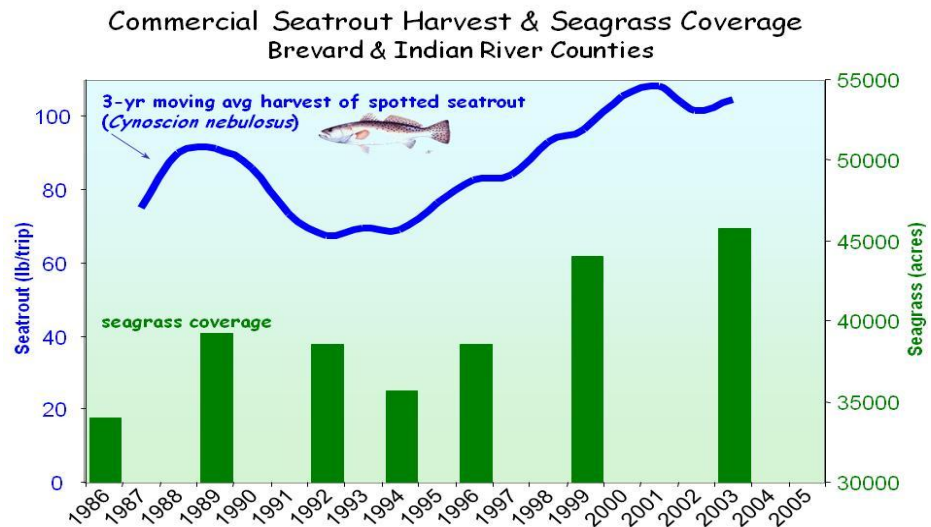


Figure 1-3. Positive relationship between harvest of spotted seatrout and seagrass coverage. Similar trend for pinfish (*Lagodon rhomboides*). This graph is current through 2003. Seatrout data from FFWCC; seagrass data from SJRWMD.



While the immensity of both the bloom and seagrass die-off was surprising, it was more surprising that the event even happened at all given the long-term drought conditions during the 2009 – 2011 period² along with the decreasing trend in treated wastewater discharges (Steward et al. 2003; FDEP Central District). Of course, a drought means comparatively little rainfall-runoff. In the IRL basin overall, a very large percentage (~75% to 80%) of its annual external nutrient loading is conveyed by watershed rainfall-runoff and stream drainage (Steward et

² Annual mean rainfall in BRL and NIRL was ≤40” and <48”, respectively, for each of the years 2009, 2010, and 2011. For those same sublagoons, the annual mean rainfall from 2000 to 2011 was below the prior 30-year (1965-1995) mean annual of 50” for 8 years out of 12.

al. 2003). The other major external sources – atmospheric and groundwater – are similarly affected by rainfall and would be diminished during the same period. Therefore; notwithstanding some unreported nutrient-laden discharge, an internal flux of nutrients may be the primary mechanism that fueled the bloom. But, what specifically was the internal source and what trigger caused the large nutrient flux from that source? For example, plausible internal sources and triggers identified to date are the unusual disappearance of drift macroalgae and

the sequence of extreme cold weather events concurrent with the drought. Such phenomena are prompting several questions.

Drift macroalgae, the most abundant aquatic macrophyte community in the IRL, apparently crashed in mid-2010 (Fig. 1-4) and has yet to recover (Apr 2012). Did drift macroalgae, by its decomposition and absence as a nutrient “sponge” become the major internal source of nutrients, or just one of the major sources?

Figure 1-4. Abundance of drift macroalgae from Jan. 2009 to and through 2011 superbloom period. Both graphs depict the mutual observation by SJRWMD and FFWCC of near-zero abundance of drift macroalgae in mid-2010.

The 2009-2010 period produced the coldest winter (2009-2010) and the coldest December (in 2010) in the region since 1937 when records were first kept (*Florida Today* newspaper, 3/20/10 and 1/12/11). Extremely low water temperatures followed suit, dropping to 4° C in January 2010, and down to 6.8° C and remaining in single digits for days in December

2010 (USGS gage in Haulover Canal). Did extremely low temperatures impact one or more biotic communities, leading to a reduction in grazing pressure on phytoplankton, or to an increase in nutrient availability for phytoplankton growth? Perhaps an additional stress imposed by the second cold snap (Dec 2010) in

combination with the drought-induced hypersalinity of early 2011 dampened the recovery of drift algae, grazers, or other biota impacted the previous year?

To help make sense of these and other questions, a conceptual ecological model of the IRL system related to the 2011 superbloom was developed (Fig. 1-5). This model provided a scientific framework toward formulating and organizing analytical questions or hypotheses for the investigation. Preliminary analyses of limited data sets helped to further refine the model and hypotheses. Because of the complex nature of this investigation, it was important to invite a select group of state agency and academic experts to review work by scientists at St. Johns River Water Management District (SJRWMD) and, if possible, collaborate on certain aspects of the investigation. This collaborative group of scientists is named the IRL 2011 Consortium.

IRL 2011 Consortium – membership, structure, and objectives

The IRL 2011 Consortium includes 25 members comprising current and former³ SJRWMD scientists (Estuaries Section, Bureau of Environmental Sciences), scientists from Florida Fish and Wildlife Conservation Commission and Smithsonian Marine Station at Ft. Pierce, and faculty and students from universities involved in IRL research: University of Florida, Bethune-Cookman University, Florida Institute of Technology, Florida Atlantic University-Harbor Branch Oceanographic Institution, and Nova Southeastern University. All scientists who were invited by the SJRWMD and agreed to participate are doing so as volunteers with no expectation of compensation.

³ Dr. Robert Virnstein is the former SJRWMD scientist, now a private consultant (*Seagrass Ecosystems Analysts*).

2011 Superbloom Plan of Investigation

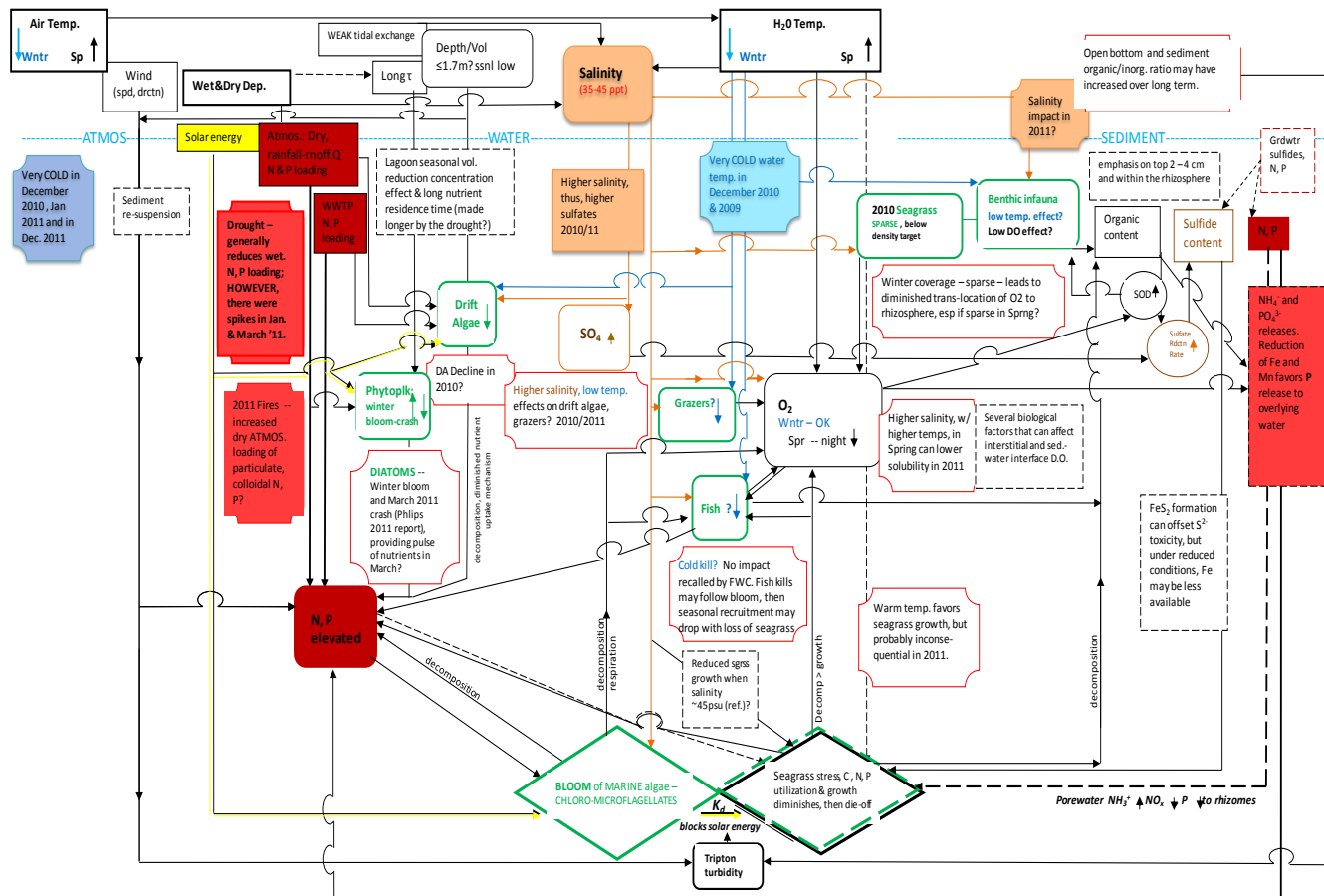
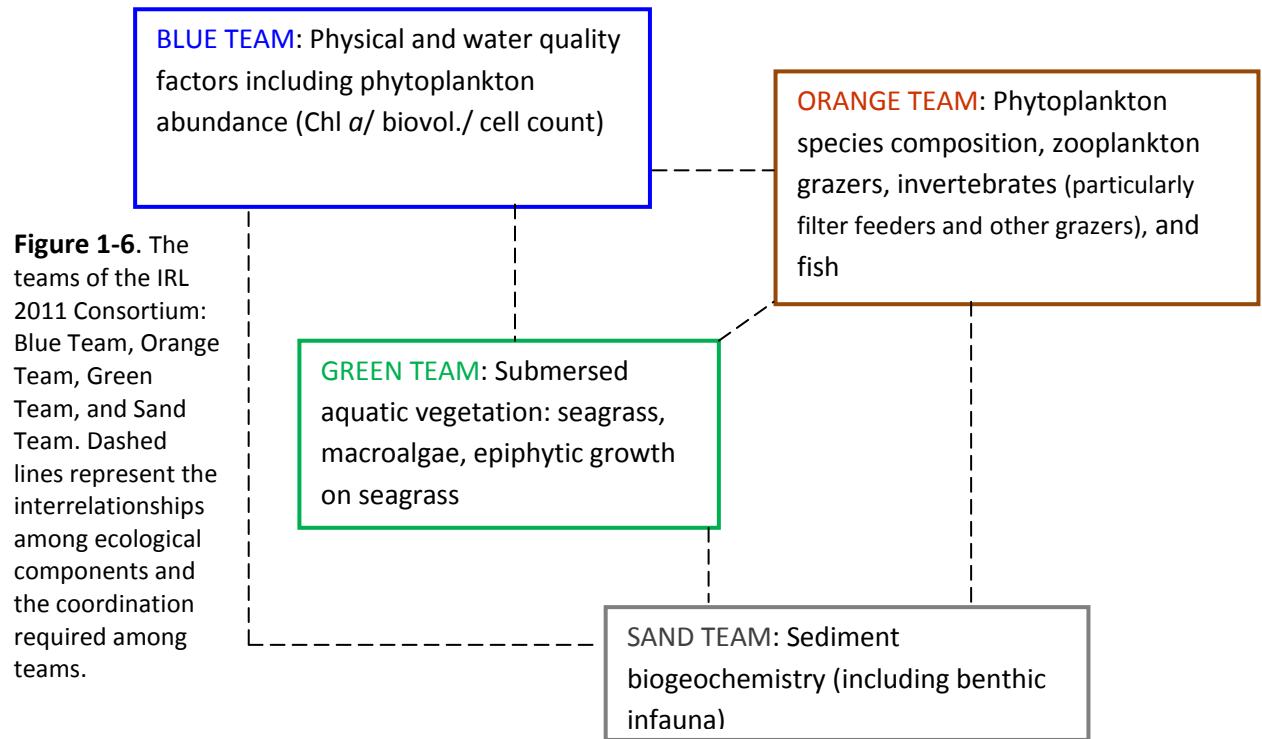


Figure 1-5. Conceptual ecological model of the IRL system that includes possible factors involved in the 2011 superbloom (superbloom and seagrass impact represented by diamond shapes at bottom).

Because of the number of members as well as the large scale and complexity of the problem, the Consortium was divided into 4 teams, each team addressing a different subject area or “compartment” of the conceptual model (Fig. 1-5) as illustrated below (Fig. 1-6).

Although each team’s focus is on its own set of ecological components, cross-compartment relationships do exist and are important to consider as the Consortium develops its investigation. That consideration is manifest in the participation of many members on two or more teams. The names of members and their professional affiliations are listed by team in the individual team plans (sections 2 – 5) that follow.

The main objective of the Consortium is to prepare a report to the SJRMWD Governing Board and IRL National Estuary Program Advisory Committee that includes a consensus-driven thesis on the 2011 superbloom, its impacts on SAV, any observations regarding post-2011 recovery of SAV and water quality, and management recommendations. There are also two secondary objectives. One is to identify, prioritize, and fill critical gaps in our understanding of the Lagoon, particularly its nutrient-trophic relationships with an emphasis on a balanced macrophyte community. The other secondary objective is to continue inter-institutional collaboration among the Consortium institutions beyond this investigation to sustain and improve long-term research and management of the IRL system.



Team plans – investigative parameters shared in common by the teams

The teams’ individual plans of investigation are found in the following sections of this document. There are investigative parameters that all teams share in common: study area, study period, coordination and communication, questions and hypotheses, synthesis of findings and recommendations, and schedule. These shared investigative parameters are described below.

Study area: The study area includes the sublagoon reaches affected by the 2011 superbloom (Fig. 1-1): northern IRL (NIRL, from Turnbull through Rockledge), Banana River Lagoon (BRL, excluding its southern tip from Pineda Causeway to Dragon Point), and the southern Mosquito Lagoon (SML). The secondary bloom area within central IRL is not a focus of this investigation; however, each team is free to relate or compare findings between bloom areas to further develop its thesis or address a particular hypothesis concerning the superbloom area.

Study periods: Time series plots of physical, water quality, SAV and other biological data are examined to develop an holistic chronology of conditions and events in the IRL. Based on a preliminary time-series analysis of phytoplankton species composition and key water quality variables (chlorophyll *a* and dissolved nutrients) by the Blue Team, three periods of study are defined:

Event Period (EP): March 2011 – February 2012

Proximal Antecedent Period (PAP): January 2010 – February 2011

Distal Antecedent Period (DAP): 1996-2009

The Event Period (EP) is the period of the Pedinophyceae/pico-cyanobacteria as indicated by monthly phytoplankton composition (Dr. Philips, UF) and Chl_a concentration trends (SJRWMD data). The bloom began in March 2011 in BRL when Pedinophyceae was first detected, spread into the NIRL and then into southern Mosquito Lagoon. At the bloom’s peak in early to mid-October (7 months later), Chl_a concentrations ranged between 86 ug/L in SML to more than 130 ug/L in NIRL and BRL. By late October, the bloom synchronously and precipitously declined or crashed throughout, but did not completely return to pre-bloom levels. In BRL and NIRL, Chl_a concentrations rebounded slightly over the next three months, dropping below 20 ug/L after January 2012 in NIRL and after February 2012 in SML. Based on these results, a tentative ending date of February 2012 was assigned to the EP, but could be revised later as newer data since March 2012 become available.

2011 Superbloom Plan of Investigation

For most of BRL and a sizeable area in the NIRL (Titusville to Cocoa), annual median concentrations of total dissolved phosphorus (TP-D) and Chl_a were higher in 2010 and substantially higher in 2011 than previous years while annual median nitrogen levels (TKN-D) were relatively unremarkable⁴ (Fig. 1-7). Thus, 2010 is regarded as an atypical year and its own period, the Proximal Antecedent Period (PAP), which actually covers a 14-month period from January 2010 through February 2011.

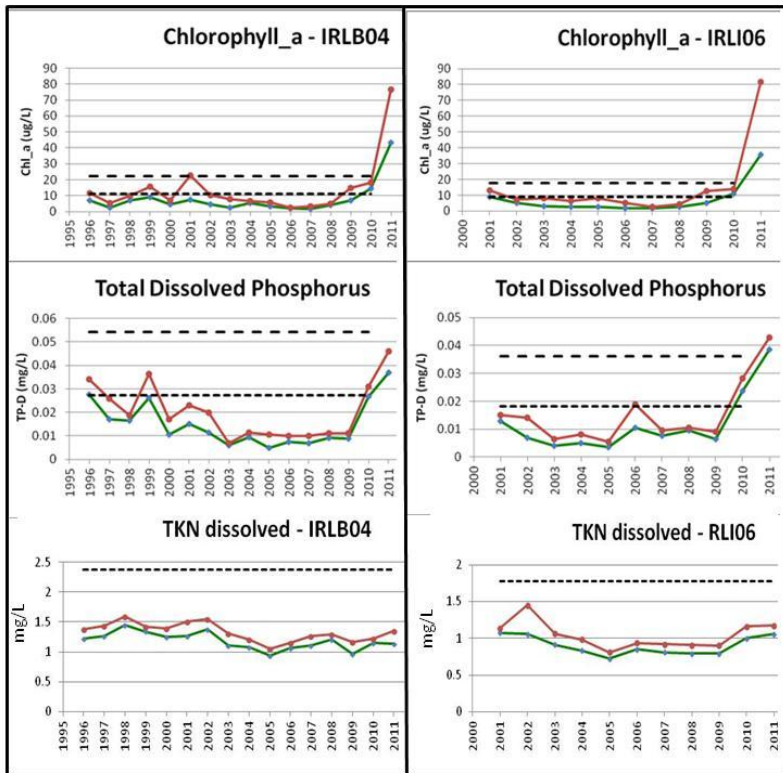


Figure 1-7. Time series of annual median Chl_a, TP-D, and TKN-D concentrations in BRL near Cocoa Beach (B04) and in NIRL near Titusville (I06). NO₃ + NO₂ trend not shown, but like TKN-D, its annual medians were relatively flat.

— Annual median
 - - - 75th %
 ····· 2 * avg of medians through 2009
 - · - · 4 * avg of medians through 2009 (not shown for TKN-dissolved)

The Distal Antecedent Period (DAP) begins in 1996, the year that the IRL Water Quality Monitoring Network was significantly revised, and ends in 2009. The DAP's beginning year may be set earlier depending upon the analyte or parameter in question or the need to examine earlier trends.

Coordination and communication: The SJRWMD is handling overall coordination, planning, and facilitation of meetings for the Consortium and the teams. The Consortium was assembled in September 2011 and its first meeting (via teleconference) was held in November 2011. During that initial 3-month period, the Consortium reviewed and discussed objectives of the investigation, basic organizational details including the break-out team structure, the conceptual model (Fig. 1-5), any preliminary data analysis and findings, the development of hypotheses, and the inventories of relevant IRL data from all possible sources. Since November 2011, most of the review of work products and discussions were conducted at the team level and for the most part will continue at that level to the investigation's conclusion. Team meetings are monthly to bi-monthly.

Meetings of the whole Consortium will take place as needed. Communications, data and document exchange, and reviews of drafts within teams or among Consortium members are facilitated by the use of Microsoft SharePoint.

Questions and related hypotheses: Many of the questions posed in the following team plans were developed as a result of developing the conceptual ecological diagram and visually examining preliminary time-series plots of all long-term data collected on a regular schedule (hourly, daily to weekly, monthly, seasonal). Time-series plots can reveal possible relationships between or among factors or other potential patterns that can be further examined. Many of the questions are worded as testable null hypotheses. A null hypothesis (H₀) will be tested based on valid statistics using site-specific data. If such data are lacking, then the hypothesis cannot be adequately tested, leading to a conclusion that a H₀ cannot be rejected. However, non-rejected H₀ could still be deemed improbable in the IRL system based on literature information, professional judgment, and knowledge of the system. Certain cases of data insufficiency may yield recommendations for future research/data collection needs that would enable adequate hypothesis testing in the future.

⁴ This analysis of annual median nutrient concentrations was done strictly for the purpose of discerning major shifts in concentrations over time. Other time-series analyses with higher temporal resolution (e.g., monthly) will be performed as part of this investigation to discern shorter term patterns in concentrations (peaks and troughs) and whether those patterns align with causal or response variable patterns: drift algae crash, Chl_a levels, diatom bloom/crash, Pedino bloom/crash, etc.

Synthesis of findings and recommendations: Each team will develop its own report that will be treated as a section or chapter in a larger final report. SJRWMD scientists, primarily the team facilitators, will collaborate on drafting a synthesis chapter summarizing the significant findings, which presumably will require elucidation of possible interrelationships, including cause-effect relationships and feedbacks among ecological factors (e.g., physical → SAV → water quality, sediments → SAV). Drafts of all chapters, including the synthesis chapter, will be reviewed by Consortium members for the purposes of scientific integrity and consensus. Toward that end, uncertainty or confidence in findings will be addressed in the synthesis chapter by having the Consortium perform some of the guidance steps on assessing uncertainty as developed by the Intergovernmental Panel on Climate Change (IPCC 2010). This uncertainty assessment is particularly important as it pertains to possible cause-effect relationships based largely on field observations (without complementary control experiments).

Schedule: The schedule of major tasks is shown below (Table 1-1). The schedule starts after the first meeting of the Consortium, November 2011, and concludes with completion of the final report in December 2012

Table 1-1. Task Schedule for IRL 2011 Consortium

| TASKS | Start | End | wks |
|--|-----------|------------|-----|
| Data inventory; exchange and compile data among teams | 14-Nov-11 | 1-July-12 | 28 |
| Develop team investigative plans (hypotheses, methods) | 1-Feb-12 | 30-Apr-12 | 12 |
| Analyze data and review literature to address hypotheses | 1-Apr-12 | 31-July-12 | 18 |
| Draft individual team reports | 1-Aug-12 | 30-Sep-12 | 9 |
| Review & revise reports as chapters of larger report | 8-Oct-12 | 15-Dec-12 | 9 |
| Final revision of report | 16-Dec-12 | 15-Jan-13 | 4 |

} 15 mo

References

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Section 2. BLUE Team Investigation Plan (physical and water quality factors)

Introduction

The Blue Team, in collaboration with the other three investigative teams (Orange, Green and Sand), will produce a consensus paper describing the phytoplankton superbloom of 2011 and its likely causes and effects, including the decline of seagrasses, in the Banana River Lagoon (BRL), northern Indian River Lagoon (NIRL), and southern Mosquito Lagoon (SML).

The Blue Team is comprised of the following scientists and their affiliations:

| | |
|--------------------|--|
| R. Chamberlain | SJRWMD |
| J. Cho | Bethune-Cookman University |
| Nikki Dix | Florida Atlantic University, Harbor Branch Oceanographic Institution |
| Whit Green | SJRWMD (physical factors leader) |
| Dennis Hanisak | Florida Atlantic University, Harbor Branch Oceanographic Institution |
| Paul Hargraves | Florida Atlantic University, Harbor Branch Oceanographic Institution |
| Steve Jachec | Florida Institute of Technology |
| Charles Jacoby | SJRWMD |
| Andrew Kameronosky | Bethune-Cookman University |
| Margie Lasi | SJRWMD (water quality team leader, team facilitator) |
| Ed Philips | University of Florida |
| Joel Steward | SJRWMD |
| John Windsor | Florida Institute of Technology |
| Gary Zarillo | Florida Institute of Technology |

The charge of the Blue Team is to identify what roles that physical factors (climate or weather, hydrology, hydrodynamics), external and internal nutrient sources, and water quality played in prompting and/or sustaining the 2011 superbloom dominated by chloro-microflagellates (Pedinophyceae) and pico-cyanobacteria. By documenting the above, as well as the physical and water quality conditions prevalent during the superbloom (Fig. 2-1), the Blue Team will also provide the other three teams the information they need to answer their respective team questions.

Questions and Methods

In an attempt to identify possible causal factors for the 2011 Superbloom, the Blue Team used the physical/water quality compartment of the conceptual diagram (Fig. 2-1), in combination with team meeting discussions, to propose specific questions and related null hypotheses where applicable.

The investigation will place primary emphasis on available data and information collected in the NIRL and BRL. If after pooling available data sets, team members find that site-specific data are still lacking or are insufficient to answer questions, they will then address these questions as best as possible using available literature (e.g. peer-reviewed publications, literature reviews, technical reports, etc.) and expert opinion as deemed appropriate.

The Blue Team will apply graphical analyses such as time series and frequency distributions to help detect change across space and time. Certain questions may be addressed by using a variety of univariate and/or multivariate statistical procedures (parametric and non-parametric) aimed at comparing means or medians (e.g., ANOVA, Mann Whitney U test, etc.), and describing functional relationships between parameters (e.g., regression analysis, PCA, possibly non-metric MDS, etc.). The nature of the question being addressed, sometimes posed as a testable null hypothesis (H_0), will dictate the approach or analysis used.

2011 Superbloom Plan of Investigation

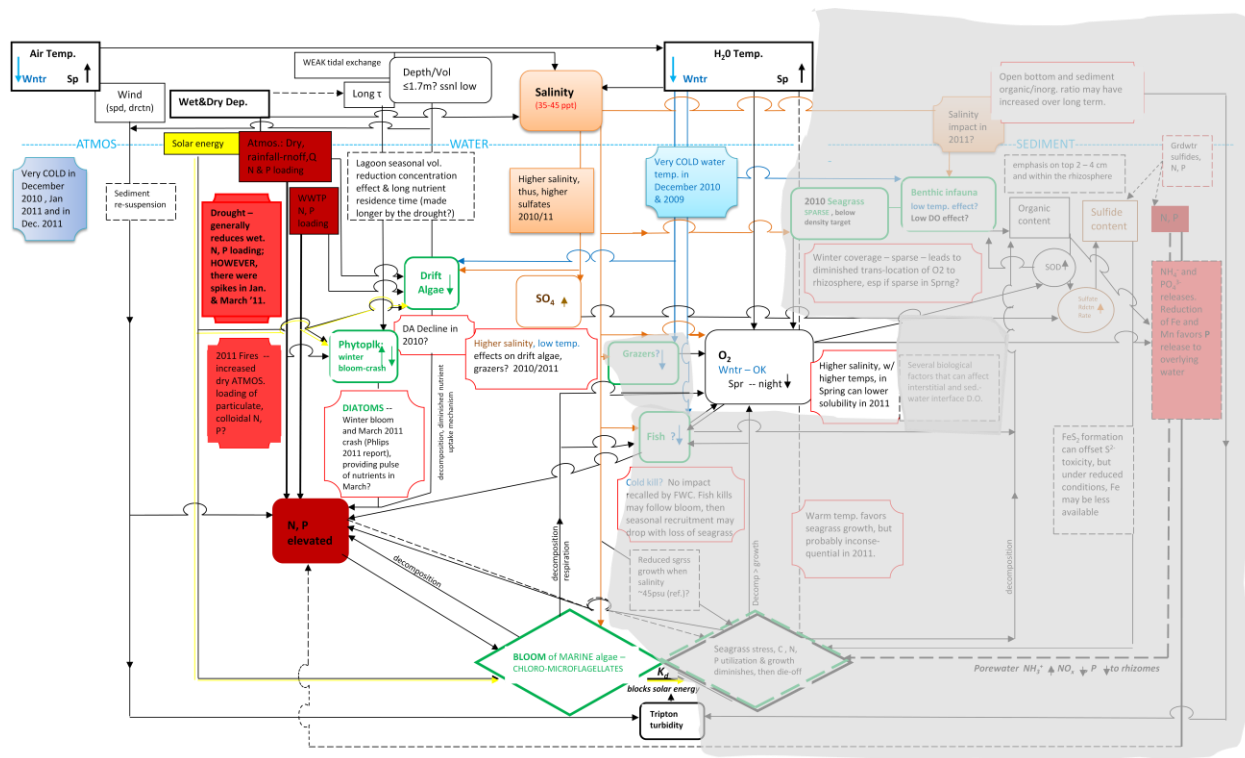


Figure 2-1. The unshaded compartment of the conceptual ecological model is the focus of investigation for the Blue Team (boxes: factors or components; arrows: effect pathways).

1. Q: How does the IRL 2011 superbloom compare to past blooms in the IRL system?

This question provides an opportunity to categorize IRL blooms over the period of record according to magnitude first and duration second. The categorization approach is based on seagrass protection Chla targets; i.e., some Chla concentration limit that will enable sufficient light penetration for the growth of seagrass to targeted depth limits. For the sake of seagrass and its light requirement, incipient Chla targets have been established as annual medians (50th %), 75th %, 90th % for each of the sublagoons. Using the established annual medians as starting points, successive multiples of those median values are proposed to develop magnitude categories:

- Minimum impairment level (MIL):** simply exceeds the Chla annual median per sublagoon, but does not reach magnitudes defined as moderate or greater (e.g., BRL’s incipient, annual median Chla target is 3.1 µg/L, so any value exceeding that up to 12.4 µg/L as an annual median would violate the MIL).
- Moderate Bloom:** $4 \times 50^{\text{th}}\% < x \leq 8 \times 50^{\text{th}}\%$ (e.g., BRL’s moderate bloom would be 12.5 to 24.8 µg/L, even for a one-time sampling).
- Strong Bloom:** $8 \times 50^{\text{th}}\% < y \leq 16 \times 50^{\text{th}}\%$ (e.g., BRL’s strong bloom would be 24.9 to 49.6 µg/L, even for a one-time sampling).
- Severe Bloom:** exceeds the maximum level of the “strong” category.

Chla data over the period of record will be “binned” according to these categories to determine the number, frequency, and duration of the different bloom categories over time, to compare past blooms to the 2011 superbloom (which is distinguished from other blooms as a strong to severe bloom of long duration), and to categorize future blooms. This categorization could provide another means of performing correspondence analyses with nutrients and other water quality/physical variables and with SAV as a response variable.

2. **Q:** How does nutrient (N and P) loading compare across periods and to Chla?

a. *External loadings (atmospheric, groundwater, wastewater & surface water drainage)*

H_o1a₁: External nutrient loadings, combined or individually by source, were not statistically different among the three periods (EP, PAP, or DAP) or between any two of the periods. Perform separate tests of seasonal means or medians as it relates to loading source as well as for combined load.

H_o1a₂: External nutrient loadings are not statistically related to the increasing levels of Chla observed during PAP and/or event period. Perform separate regression tests on seasonal data as it relates to loading source as well as for combined load for each period (PAP and EP).

b. *Internal Loading: biotic (release from decomposing seagrass, epiphyton, macroalgae, nekton and plankton) and abiotic (sediment flux)*

H_o1b₁: Internal biotic and abiotic nutrient loadings were not statistically different among the three periods (EP, PAP, and DAP) or between any two of the periods. Perform separate tests of seasonal means or medians as it relates to each loading source as well as for combined load.

H_o1b₂: Internal biotic and abiotic nutrient loadings are not statistically related to the increasing levels of Chla observed during the PAP and/or event period. Perform separate regression tests on seasonal data as it relates to each loading source as well as for combined loadings.

c. *External + Internal Loadings*

H_o1c₁: No combination of internal or external nutrient loading is statistically related to the increasing levels of chlorophyll *a* observed during the PAP or event periods. Perform multivariate regression tests from best subsets analysis and/or PCA analysis (possibly including non-metric MDS).

H_o1c₂: The sum total internal and external nutrient load is not statistically related to the increasing levels of chlorophyll *a* observed during the PAP or event periods. Perform regression tests.

3. **Q:** How does water quality compare across periods and to Chla?

A similar (analogous) set of hypotheses like the ones listed under Question 2 apply to this question. *Variables of interest:* Chla, TN, TP, TP-D, TKN-D, PO₄-D, NH₄-D, NO_x-D, TOC, DOC, SiO₂, water temperature, salinity, DO, turbidity, K_d, TSS/VSS, Secchi. A considerable amount of these data are collected by the IRL Water Quality Monitoring Network under the management of SJRWMD (see Fig. 2-2 for location of IRL WQMN stations). The team will conduct a series of univariate tests of seasonal/annual means or medians among the three periods. Suggested statistical tests for the relationships with Chla include simple correlation and regression analysis, multiple regression analysis and PCA. Convey the results of these analyses to the Green and Orange teams for their assessments of the effects of superbloom on the Lagoon biota.

4. **Q:** Where relationships between water column concentrations and Chla are discerned, are these cause-effect type relationships, and if so, which water column variable(s) are predictors of Chla, and which are affected by Chla?

This is an important question in determining the probable causes and effects of the superbloom. Among the predictor variables, the dissolved nutrient fractions need to be examined more critically because they are the more readily bio-available forms. This question will be addressed primarily from theoretical and practical knowledge of the Consortium membership supported by literature reviews.

5. **Q:** Did unusual patterns in water temperature and/or solar irradiance affect the formation of the superbloom?


H₅: Seasonal, monthly, or daily water temperatures and solar irradiance (particularly in the winter and spring months) were not significantly different among the three periods or between any two of the periods as follows: EP vs. PAP, EP vs. DAP, PAP vs. DAP, EP + PAP vs. DAP.

Compare results to optimal temperature and solar irradiance levels (range?) for phytoplankton growth.

Compare seasonal, monthly, or daily water temperatures and solar irradiance during the winter 2010/2011 and spring of 2011 with same seasons in PAP and DAP using outlier analysis.



Figure 2-2. Location of IRL WQMN water quality (WQ) stations in the superbloom area of investigation

WQ stations 

Segments **IR6-7**

Note: Segments were established by the SJRWMD in the late 1990s in recognition of the system's heterogeneity in water quality and seagrass distribution. The segmentation method is briefly described in Steward et al. 2003, p. 2-6, Fig. 2-3a (full ref. citation is found in Section 1 of this document)

6. Q: Did hydraulic residence time (HRT) play a role in the development of the superbloom and were wind-driven currents the principle means of its dissemination to other regions of the IRL System? Having a period-specific hydrodynamic model to

answer this question is unlikely at best; therefore, it will not be possible to calculate the HRT for the three periods. Nonetheless, it is generally accepted that rainfall has an inverse effect on HRT, and the drought-like conditions during the PAP and EP likely caused some further, albeit slight, increase in the HRT, which has been estimated under a range of "average" conditions (1996- 2001) for the affected areas. The above notwithstanding, rainfall's influence on forcing water movement (current direction and velocity) in the IRL is minor to that of the wind. Wind field data can be used as a surrogate for hydrodynamic-salinity model data to determine whether the spatial and temporal trend in chlorophyll a concentrations during the superbloom can be explained by wind field patterns.

Expected Output

The Blue Team will generate a report, with supporting tables and graphs, summarizing the outcomes of the various data analyses and statistical tests performed to address the questions and hypotheses identified above. Overall, the Blue Team will present plausible explanations for which of the physical and chemical factors (climate, external/internal loading, water quality) may have acted as triggers of the 2011 superbloom, along with some measure of uncertainty to accompany the reported results. Additionally, the Blue Team will provide the data needed by other teams to answer their questions.

Data required from other teams (listed by providing team)

Orange Team: Blue team requires estimates of 1) presence/absence of Pedino pre-March 2011, 2) changes in phytoplankton and zooplankton community composition during and prior to the superbloom, 3) feeding or trophic strategies of Pedinos and picocyanos (e.g., autotrophic vs. mixotrophic), and 4) growth requirements and tolerances for Pedinos and picocyanos, with emphasis on salinity, temperature, light/photoperiod, and nutrients (in their various forms; e.g., organic vs. inorganic, etc.).

Sand Team: Estimates of nutrient (C, N & P) input to water column from sediments (advective and diffusive flux) during EP, PAP, and DAP.

Green Team: Estimates of C, N, P input to water column from SAV (seagrasses/epiphyton and macroalgae) during EP, PAP, and DAP, based on tissue content and changes in standing crop. From those estimates, one can infer estimates of reduced nutrient uptake from loss of seagrass/epiphyte/macroalgal biomass.

Data provided by Blue Team to other teams (listed by receiving team)

Orange Team: water quality data, with vertical profiles where appropriate, documenting key forcing factors affecting the phytoplankton and faunal assemblages, i.e., salinities, water temperatures, dissolved oxygen concentrations, sulfate concentrations, sulfide concentrations, and any unusual conditions.

Sand Team: salinity (including depth profiles or near bottom if available), water temperatures, dissolved oxygen, sulfate, meteoric groundwater estimates of sulfides and nutrients.

Green Team: water column temperature and salinity, including profiles or near bottom data if available; water column chlorophyll a concentrations (including from satellite imagery if available); surface radiation (daily estimates from regional continuous recorders if available); monthly light attenuation data (PAR, Kd and Secchi).

Section 3. GREEN Team Investigation Plan (submersed aquatic vegetation)

Introduction

The Green Team, in coordination with the other three teams, will produce a consensus explanation of the factor(s) responsible for the seagrass decline during the 2011 superbloom event. The Green Team's objectives are: (1) Assess the strength of spatial and temporal relationships between phytoplankton (Chla) and SAV (seagrass, epiphytes on seagrasses, and drift macroalgae) during the 3 periods (DAP, PAP, and EP); (2) investigate all possible factors (physical, chemical, and biological) that may have contributed to changes in SAV, especially the loss of seagrass in 2011 (refer to Green Team's compartment of conceptual ecological model in **Figure 3-1**); and (3) provide data or information to the other teams that are investigating potential effects of SAV loss on other Lagoon conditions (e.g., bloom dynamics, sediment biogeochemistry, herbivory, etc.).

The Green team includes the following scientists and their agencies or institutions:

| | |
|---------------------|--|
| Carlson, Paul | Florida Fish and Wildlife Conservation Commission |
| Chamberlain, Robert | SJRWMD |
| Cho, Hyun Jung | Bethune-Cookman University |
| Dix, Nikki | Florida Atlantic University, Harbor Branch Oceanographic Institution |
| Green, Whitney | SJRWMD |
| Hall, Lauren | SJRWMD |
| Hanisak, Dennis | Florida Atlantic University, Harbor Branch Oceanographic Institution |
| Jacoby, Charles | SJRWMD |
| Kamerosky, Andrew | Bethune-Cookman University |
| Lasi, Margaret | SJRWMD |
| Morris, Lori | SJRWMD |
| Riegl, Bernhard | Nova Southeastern University |
| Steward, Joel | SJRWMD |
| Virnstein, Robert | Seagrass Ecosystems Analysts |

Questions and Methods

The first two objectives above were used to develop questions and methods. The third objective concerns data or information generated by the Green Team that would be useful to the other teams. Questions are posed as null hypotheses (H_0), which generally describe potential correlations in terms of magnitude and temporal concurrence and will be addressed spatially in each of the sublagoons and each of the segments within the sublagoons within the superbloom area. Please see Figure 3-2 for location of segments and SAV monitoring stations.

Different analytical approaches will be used to temporally describe the data and draw statistical correlations or other comparisons between various parameters. Initial data treatment will consist of time series and frequency distributions coupled with parametric analyses (e.g., ANOVA and regression). Nonparametric tests (e.g., Mann Whitney tests, PCA and MDS) may be applied if normal distributions of data do not exist, or if additional statistical treatment is warranted.

The team will also review IRL literature documenting historical water quality and SAV conditions along with a review of the general scientific literature documenting events similar to the 2011 IRL superbloom and seagrass die-off. Literature reviews can support or complement data analyses and fill the knowledge-gap where site-specific data are lacking.

2011 Superbloom Plan of Investigation

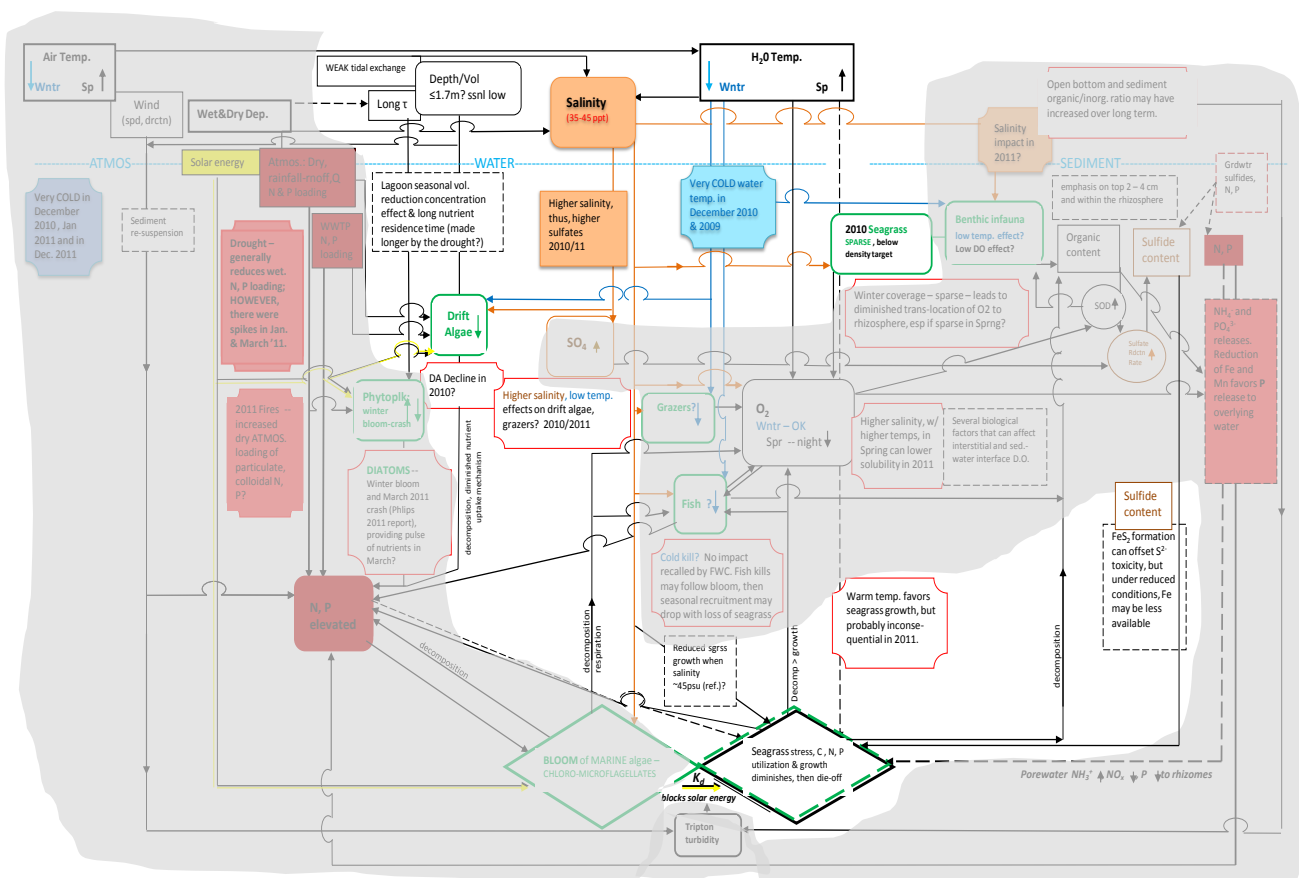


Figure 3-1. The unshaded components (boxes) and pathways (arrows) in the conceptual model comprise the Green Team’s SAV area of focus.

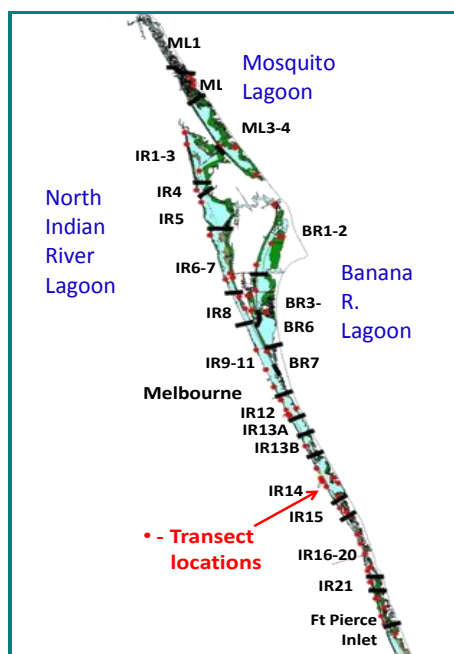


Figure 3-2. Indian River Lagoon system, depicting lagoon segments or segment-groups (e.g., ML3-4) and seagrass transect stations. The superbloom area was generally restricted to BR1-7, IR1-8, and ML3-4. The seagrass-water quality segments were established by SJRWMD in the late 1990s in recognition of the heterogeneity of the IRL system. The segmentation method is briefly described in Steward et al. 2003, p. 2-6, Fig. 2-3a (ref. citation found in Section 1 of this document).

1. **Q:** Was there any significant change in a SAV component (seagrasses, epiphytes, drift algae or DA), over the period of record; and if a significant change did occur, can it be attributed to phytoplankton (Chl a) levels or to a corresponding change in another SAV component?

H₀1a: There was no significant change (emphasis on loss) to any SAV component among the 3 periods, which consists of the distal antecedent period (DAP): 1994 – 2009, the proximal antecedent period (PAP): 2010 – Feb 2011, and the superbloom event period (EP): March 2011 – January 2012.

H₀1b: There were no significant temporal changes in seagrass or DA over the 3 periods that can be attributed to phytoplankton levels or to the IRL bloom [Chla] categories.

Method:

H₀1a: If the 2011 aerial seagrass map is available before August 2012, then it will be used to assess changes in seagrass coverage (hectares). The initial statistical design analyses will be: a 1-way ANOVA that compares years (Figure 3-3, 3a); and a 2-way ANOVA (Figure 3-3, 3b), with mapping years (n = 9, that includes 1994-2011) X sublagoons (n = 3) or segment-groups (n = 8 or less) to determine whether significant spatio-temporal differences occurred between segments during the mapping years. The observations used to populate the analysis will be the SAV coverage for each segment, with ≥ 2 segments assigned to each Segment-Group for the two-way ANOVA (Figure 3-3, 3b). A multiple range test will determine the homogeneous groupings and ranking of significance for both years and segment-groups. This analysis will help determine which segment- groups or sublagoons, and in which years, were significantly different.

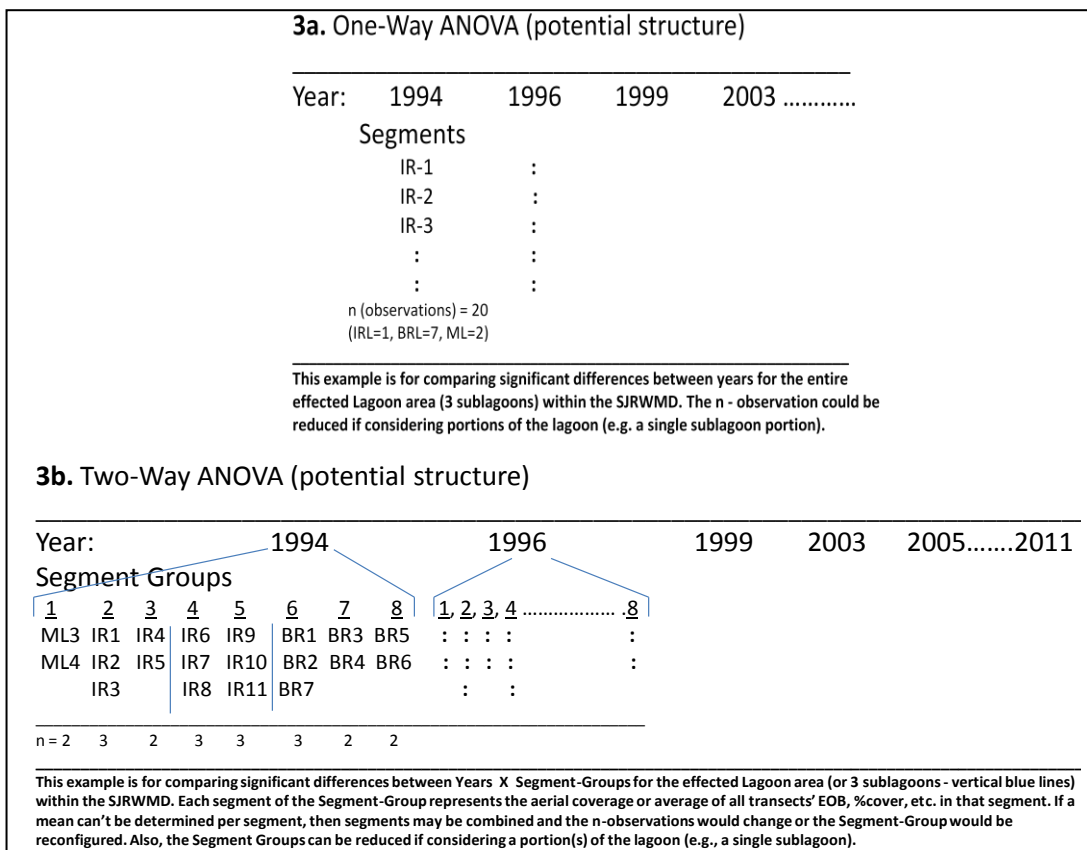


Figure 3-3. Example ANOVA designs and structuring of data/segments for analyzing of all or portions of the lagoon (potential sublagoon groups depicted by vertical blue lines).

The same approach will be explored for seagrass from seasonal (summer/winter) and monthly transect monitoring. The transect metrics to consider include seagrass edge-of-bed depth, distance from shore, and possibly general and species-specific percent cover (density).

Epiphyte and DA data in transects will be statistically treated the same way as described above for the seagrass data sets. The SJRWMD seagrass transect database is the only source of epiphyte data (a visual estimate of epiphyte cover on seagrass blades known as the Epiphyte Photo-Index – EPI as described in Miller-Myers and Virnstein 2000; Morris et al. 2001).

DA metrics that are collected as part of the SJRWMD seagrass transect database and the DA survey database⁵ will provide most of the DA data. [Note –the Nova SE Univ. 2012 survey data is needed to determine if there is significant DA change/loss in 2012, which infers a loss after the spring 2010 survey. Additional DA data were obtained from the Fisheries Independent Monitoring (FIM) program of the FFWCC. Those data will be treated separately or together with the SJRWMD data set contingent upon both data sets being normalized as a common biomass and/or percent cover metric. It is important that the preliminary observation of significant DA decreases in 2010 into 2011 (Fig. 1-4) be confirmed by more rigorous analysis of the FIM DA data (monthly) and the SJRWMD DA data (monthly and seasonal) as well as by the results of the 2012 DA survey.

H₀1b: The results (ranking of significance) from the H₀1a analyses above will be assessed against the Chla concentrations and to Chla-based bloom categories. Using both regression and correlation analyses, we can compare Chla concentrations and Chla bloom categories to the SAV results derived from the ANOVA analyses above. We will explore lag times between response variables and prior bloom levels. Estimates of Chla concentrations from satellite imagery (if available) may further elucidate relationships between Chla and SAV.

2. **Q:** What are the SAV tolerances limits for low PAR (or high IK_d), water temperature (low and high), high water salinity, and high sulfides in sediment? Were there exceedances of any of these limits during the proximal antecedent period or 2011 superbloom event period? Was there a singular or combined effect of these factors, beyond or just below their respective exceedance limits, on any SAV component that may have ultimately contributed to the 2011 seagrass decline? Were there any significant changes in solar radiation, water depth, or general weather pattern (cycles) during 2011 compared to antecedent conditions?

H₀2: There are no effects on seagrass and DA from low subsurface PAR, water temperature minima or maxima, salinity minima, high sediment sulfide levels, and/or meteorological conditions during 2010-2011.

Method: A literature review will be the basis for selecting seagrass and DA tolerance limits for each of the possible impact factors listed in the questions above. We also will search the literature for numerical limits on combined or synergistic effects of two or more of the impact factors. The target SAV species for this line of investigation are: the two dominant seagrass canopy species within the superbloom area, *Halodule wrightii* and *Syringodium filiforme*; and the IRL's dominant *Gracilaria* DA complex – a reference to the common co-occurrence of multiple DA species, predominantly *Gracilaria tikvahiae*, *G. spp.*, and *Bryothamnion* sp., that are widely distributed benthically and found as *drifting* clumps or wracks.

A time series output for each of the impact factors by sublagoon, segment, and water quality station (made available from the Blue and Sand teams) will be reviewed for measurements that are proximal to or exceeded tolerance limits per SAV species, and whether those particular measurements were concurrent or contemporaneous. An attempt will be made to understand and evaluate the combined stress effects of low light, extreme water temperatures, and variable, but generally increasing salinity may have had on seagrass and DA, per segment, during the antecedent period compared to 2011. University members of the Green Team are

⁵ DA survey refers to the Lagoon-wide drift algae survey conducted by Nova Southeastern University under contract with SJRWMD. Nova's DA surveys were conducted in 2005, 2008, 2010, and another is planned in 2012.

encouraged to conduct short-term experiments that may help establish singular or synergistic effect limits for *Gracilaria* complex species.

One method of evaluating a stressor-response phenomenon is application of a multi-variable Reference Condition Index (RCI). For each factor (light, water temperature, salinity, and possibly sulfides), a SAV Habitat Suitability Index (SHSI) curve is developed, which provides a numerical representation (0.0 – 1.0) of a SAV condition relative to changes in factor values. The SHSI curve will be based on a literature search that describes tolerance limits and preferred factor value ranges for the two SAV groups (*H. wrightii* and/or *S. filiforme* as one group and the *Gracilaria* complex as the other group). The SHSI values for all factors will be combined to develop a running RCI (time series) of additive effects. The RCI values can be averaged and lagged to provide the best RCI point values and trend patterns for comparison to measured SAV abundance. A simple regression analysis of RCI values vs. SAV abundance will help assess correlation and, perhaps, the degree of cause-effect for each of the stressor parameters. Exposure, lag effect, and recovery times will be considered in this analysis.

Expected Output

H₀1a: SAV time series graphs and a matrix or table that clearly presents the ANOVA results (levels of significance change over time). The main point to be made with this output is the amount and significance of the SAV decline in 2010 and 2011 (beginning in 2010 with DA decrease) relative to abundances in previous years.

H₀1b:

- Correlation/regression results (graphical or tabular) that depict the strength of the relationships between SAV (especially seagrass) and water column Chl_a during all 3 periods.
- 3-d graph (X,Y,Z plot) of SAV metrics vs. bloom categories and duration of exposure.
- Tabular or graphical output showing bloom category as a treatment factor and duration of exposure as a second factor from a two-way ANOVA analysis that depicts which bloom categories by duration significantly affected SAV.

H₀2: Time series graphs for each of the stressor parameters and RCI results, as well as graphical depiction and statistical results comparing measured SAV to the RCI values that would illustrate the separate and combined effect of limited PAR, water temperature, salinity, and possibly sediment sulfide on each of the two SAV groups (seagrass and DA).

Data required from other teams (by providing team)

Certain data or information generated by the other teams would be very helpful to the Green Team's investigation.

Blue Team (for the entire POR considered for analysis):

- a. Chl_a concentrations from the WQMN
- b. The Maximum Chlorophyll Index (MCI) and Normalized Difference Chlorophyll Index (NDCI) values from the MERIS satellite imagery
- c. Monthly time series of bloom categories per WQMN station (include formula for calculation if used)
- d. (1) WQMN salinity and water temperature (include depth when available)
(2) Secchi disk measurements during WQMN sampling
- e. (1) Daily solar radiation (PAR) from regional continuous sensors located within the IRL basins
(2) From USGS, and other sources of continuous sensor data: daily water depth (corrected), salinity, and temperature at regionally available sensors
- f. E/LNSO and other occurrences of meteorological events

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Orange Team: The abundance of DA in collections, along with other associated data/information that defines the site location, depth, date, algae species (if available), and catch effort

Sand Team: Spatio-temporal sediment sulfide concentrations for evaluating potential toxicity to seagrasses.

Data provided by Green Team to other teams (by receiving team)

Sand Team and Orange Team: Total macroalgae and seagrass areal biomass (within segments if possible) and estimated amount loss (percent and/or biomass) in 2010/2011 (e.g. prelim. data indicate >90% loss in drift macroalgae).

Blue Team: Estimates of seasonal or monthly (if possible) net mass loading (kg release or uptake) of dissolved carbon, nitrogen, and phosphorus (C, N, P) from seagrass, epiphytes, and DA).

References

- Miller-Myers, R. and R. Virnstein. 2000. Development and use of an Epiphyte Photo-Index (EPI) for assessing epiphyte loadings on the seagrass *Halodule wrightii*. In: Seagrasses: Monitoring, Ecology, Physiology, and Management (S. A. Bortone, ed.). CRC Press, Boca Raton, FL.
- Morris, L., L. Hall, and R. Virnstein. 2001. Field Guide for Fixed Seagrass Transect Monitoring in the Indian River Lagoon. SJRWMD, Bureau of Environmental Sciences, Palatka, FL.

Section 4. ORANGE Team investigation plan (phytoplankton composition and fauna)

Introduction

The Orange Team will collaborate with the other three investigative teams (Blue, Green and Sand) to produce a consensus description and thesis on likely causes and effects of the phytoplankton superbloom that occurred in 2011. The current membership of the Orange Team comprises:

- | | |
|----------------|--|
| Ron Brockmeyer | St. Johns Water Management District |
| Nikki Dix | Florida Atlantic University, Harbor Branch Oceanographic Institution |
| Dennis Hanisak | Florida Atlantic University, Harbor Branch Oceanographic Institution |
| Kevin Johnson | Florida Institute of Technology |
| Margie Lasi | St. Johns Water Management District |
| Rich Paperno | Florida Fish and Wildlife Conservation Commission |
| Ed Philips | University of Florida |
| Bjorn Tunberg | Smithsonian Marine Station at Fort Pierce |
| Chuck Jacoby | St. Johns Water Management District (facilitator) |

For its contribution to the broader consortium, the Orange Team will focus on the taxonomic composition of the phytoplankton assemblage and questions related to higher trophic levels (Fig. 4-1). Particular attention will be paid to the assemblage composition and abundance of planktonic, benthic and pelagic invertebrate and vertebrate taxa, as well as their trophic interactions with phytoplankton, submerged aquatic vegetation and each other.

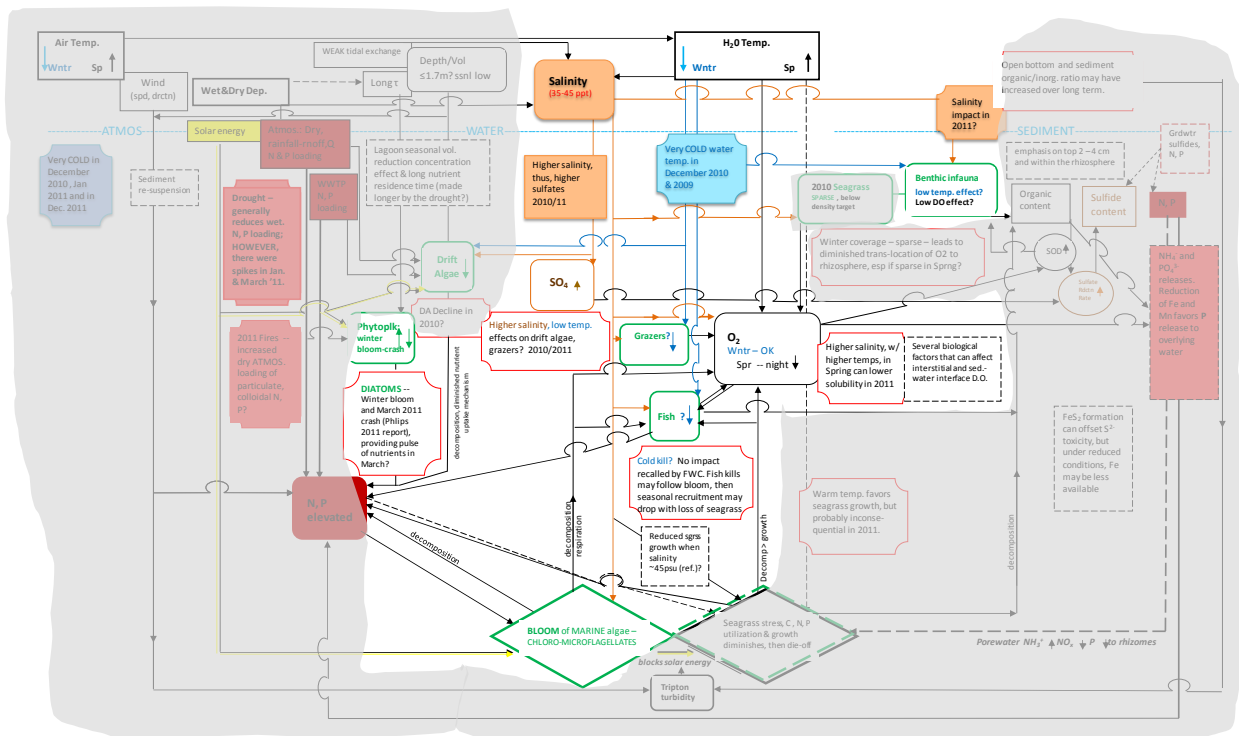


Figure 4-1. Foci for the Orange Team shown as unshaded boxes (factors) and arrows (effects pathways).

Questions and Methods

Questions: Broad, core questions related to the bloom include:

1. **Did the compositions of the phytoplankton assemblage and various faunal group assemblages differ from those observed in the past** (i.e., were the species “filling” the boxes in the conceptual model different from historical records)?
2. **Did abundances of fauna differ from past observations** (i.e., did the “size” of the faunal boxes in the conceptual model differ from historical records; Note: the Blue team will address issues related to non-specific phytoplankton biomass largely through analysis of Chla concentrations)?
3. **Did physical, chemical or biological conditions observed prior to or during the superbloom lead to any of the observed changes in phytoplankton composition or fauna** (i.e., is there evidence that changes documented by other teams affected the boxes or arrows within the Orange Team compartment)?
4. **Did differences in the composition of the phytoplankton assemblage or the composition and abundance of faunal assemblages lead to unusual trophic interactions or interactions with unusual magnitudes** (i.e., did the “direction or size” of the arrows in the conceptual model differ)?
5. **Did changes in abundance or trophic interactions observed during the superbloom lead to unusual deposition of organic matter or levels of grazing or predation pressure** (i.e., is there evidence that changes documented by the Orange Team affected or could have affected the boxes or arrows addressed by other teams)?

Questions 1 and 2 will differentiate the superbloom from non-bloom periods and previous blooms by examining data spanning the superbloom area of the IRL system and the antecedent and event periods of record (i.e., 1996–2011).

In contrast, questions 3–5 are likely to focus on the superbloom area during late 2010 and 2011 (proximal antecedent and event periods only). More detailed aspects of questions 3- 5 include:

Question 3a: Were differences in the phytoplankton assemblage caused by:

- a. unusual speciation or concentrations of nutrients;
- b. low temperatures;
- c. high salinities;
- d. decreased light penetration;
- e. unusual microbial assemblages that altered nutrient cycles;
- f. or other physical, chemical or biological factors?

Question 3b: Were the faunal assemblage and its impacts on phytoplankton, SAV, or prey changed by alterations in abundances of key grazers. Were the composition or abundance of grazers caused by:

- a. low temperatures;
- b. high salinities;
- c. low dissolved oxygen concentrations;
- d. high hydrogen sulfide concentrations;
- e. or by predation?

Question 4: Was grazing pressure altered due to a phytoplankton assemblage exhibiting unusual:

- a. “catchability”;
- b. palatability;
- c. or toxicity?

Question 5a: Were the faunal assemblage and its impacts on phytoplankton, SAV, or prey species changed by alterations in the availability of habitat provided by:

- a. seagrasses;
- b. or drift macroalgae?

Question 5b: Was sediment biogeochemistry affected by an unusual deposition of organic matter caused by mortality of:

- a. zooplankton;
- b. infauna;
- c. fish;
- d. or other invertebrates or vertebrates?

Methods: Analyses of site-specific data will be the primary approach to answering questions. Frequency distributions, multivariate statistics and univariate statistics can be applied as appropriate to differentiate the superbloom as a unique event. Similarly, multivariate statistics can assess spatial and temporal coherence between unusual physical, chemical and biological conditions; the composition of the phytoplankton assemblage; and the assemblage composition and abundance of fauna, with reports in the literature pointing to key interactions.

It is unlikely that key processes (e.g., physiological tolerances related to temperature, salinity and dissolved oxygen concentrations; mortality rates; catchability, palatability and toxicity for phytoplankton; grazing rates; and predation rates) were being measured in the appropriate places at the appropriate times. Literature values may be available to guide explanations of differences or changes.

Expected output

Tables and graphs illustrating how conditions during the superbloom differed from historical conditions, along with similar documentation of spatial and temporal coherence between potential forcing factors and observed differences or changes. In addition, a narrative will explain the team's views on how events leading to the superbloom unfolded, including any consensus and alternatives.

Data required from other teams (by providing team)

Data or results generated by other teams will help the Orange Team conduct its analyses and interpretations. In particular, the Orange Team seeks:

Blue Team: water quality data, with vertical profiles where appropriate, documenting key forcing factors affecting the phytoplankton and faunal assemblages, i.e., salinities, water temperatures, dissolved oxygen concentrations, and any unusual conditions.

Green Team: extent and distribution of submerged aquatic vegetation, including macroalgae and seagrasses, as a way to evaluate changes in habitats.

Sand Team: surficial sediment data, including sulfide concentrations and dissolved oxygen concentrations, as a way to assess stress on infauna.

Data provided by Orange Team to other teams (by receiving team)

Certain data generated by the Orange Team may be useful to the other teams. We foresee providing:

Blue Team: estimates of grazing pressure on phytoplankton, phytoplankton assemblage composition.

Green Team: estimates of grazing pressure on submerged aquatic vegetation.

Sand Team: estimates of carbon and nutrient inputs to sediments from faunal decomposition.

Questions and Methods

The Team used the sediment compartment of the conceptual diagram (Fig. 5-1) and meeting discussions to develop questions and methods specific to the possible role of biogeochemistry. The Team acknowledges that site-specific data related to sediments and infauna of the IRL system are considerably lacking, especially for the many months prior to and during the superbloom. Thus, despite best efforts to mine data from all possible sources, literature reviews and theoretical knowledge may be the primary or sole basis for addressing some of the questions.

1. Q: Did any change in sediment physical or chemical conditions, benthic infauna characteristics, or external drivers (e.g., surface water salinity) occur within the antecedent period, 1999 – Feb 2011⁶, or in the immediate months leading up to beginning of the 2011 superbloom or subsequent seagrass loss? Alternatively, was the biogeochemical condition relative to **(a)** physical characteristics (grain size, organic content, pH, Eh of sediments); **(b)** sediment sulfide levels; **(c)** meteoric groundwater nutrient, sulfide inputs; and/or **(d)** declines in benthic infauna abundance poised to contribute to a massive bloom or seagrass die-off?

H₀₁: The question above can be posed as a null hypothesis as follows: **There were no long-term trends during the antecedent period (DAP + PAP) specific to 1a – d that were potentially bloom forming or deleterious to seagrasses.**

Method: In order to reject or not reject the null hypothesis for any of the parameters above (**1a – d**), their antecedent levels within N. IRL and Banana R. Lagoon sediments need to be evaluated by conducting data analysis and literature reviews. Emphasis will be placed on evaluating any change in parameters values over the course of the antecedent period that may have facilitated either the superbloom (approximate start date of March 2011) or the subsequent seagrass loss (by May 2011) or both.

SJRWMD will collect data from literature sources and from data sets contributed by Consortium members to develop temporal and spatial patterns, comparisons to literature threshold values. These data analyses, coupled with a theoretical knowledge of sedimentary processes, will provide clues to further trend or relationship analyses that can be explored. For example, published literature values can be compared against IRL sediment parameter values to determine the potential that some sediment condition was poised to contribute to the 2011 superbloom/seagrass loss contingent upon some trigger effect or input (e.g., large input of organics that could trigger toxic levels of sulfide).

2. Q: Was there any abrupt change in the sediment immediately preceding the superbloom (spring 2011) or subsequent seagrass decline (summer 2011) that could be considered a trigger, further facilitating either the bloom or the seagrass decline (e.g., a pulse-release of sediment nutrients that helped sustain the bloom, or an increase in sulfide to a toxic threshold impacting seagrass?)?

H₀₂: *There were no abrupt changes relative to any of the parameters 1a - e during the event period that could be considered a trigger facilitating the 2011 superbloom or seagrass loss.*

Method: It is unlikely that there are sufficient site-specific data to statistically address this question or its associated null hypothesis. Therefore, the team will need to review published literature information and numeric values for other estuaries that experienced similar episodes of algal bloom-to-macrophyte decline. Literature values can be compared to any of the trend results developed to address question 1 (or its H₀) in order to assess the potential for some sediment-induced trigger in the IRL.

Literature reviews will emphasize those studies of estuaries similar in character or type to that of the Indian River and Banana River lagoons and located along sub-tropical to tropical latitudes. However, any report or

⁶ The end date of Feb 2011 for the Sand Team's antecedent period differs from that adopted by the other teams (which is June 2010). The additional 8 months (June 2010 to Feb. 2011) accounts for any lag-time response in the sediments to changes in external drivers since mid-2010 up to March 2011.

paper found that pertains to the role of sediment biogeochemistry in algal blooms or in catastrophic declines of submersed aquatic vegetation, regardless of type or location of estuary, may be of great value.

No sediment threshold values of any kind have been set or proposed for the IRL system for the purpose of protecting natural resources; nonetheless, literature values may provide clues as to generally what the thresholds may be for critical parameters (e.g., sulfides, nutrient content or flux, organic content, SOD, Eh, or some combined-factors effect). Then, a determination of likelihood for threshold exceedance could be made.

Expected Output

H₀1: Tables or graphs of IRL sediment physical, chemical, biological data can be compared against literature toxicity or sediment suitability thresholds specific to seagrasses. If the data are lacking, or are sufficient but do not contradict the H₀, then the only conclusion one can reach is that there is no strong evidence rejecting the H₀.

General estimates of sediment nutrient efflux will be provided. These estimates can assist the Blue Team's quantification of nutrient loadings from likely sources and the development of nutrient mass-balance as affecting nutrient concentrations and the superbloom.

H₀2: The output may be similar to that for question 1 or H₀1 above; perhaps presented as sediment quality threshold values relevant to seagrass protection vs. probability of threshold exceedance in the Indian R. or Banana R. lagoons. This matrix analysis would utilize the measurements or calculations of sediment sulfide levels fluxes under *a priori* conditions (question 1) along with estimates of bloom-accelerated organic or nutrient input from decomposing drift algae, seagrass, phytoplankton, and fauna (as provided by the Green, Blue, and Orange teams) to assess the probability that a threshold exceedance was reached.

Given that requisite data sets are probably lacking, the statistical conclusion is that there is no strong evidence rejecting the H₀. However, the probability matrix as described above can assess the *likelihood* of sediment threshold exceedances based on literature reviews and practical application of theoretical knowledge to the IRL system.

Data required from other teams (by providing team)

Certain data generated by the other investigative teams will be very helpful to the Sand Team investigation. These data are listed below by the providing team.

Blue Team: wind speed and direction, salinity (including depth profiles or near bottom if available), water temperatures, dissolved oxygen, sulfate, meteoric groundwater estimates of sulfides and nutrients.

Green Team: For estimation of organic, C, N, P input to sediments:

Total macroalgae areal biomass and estimated amount (%) loss in 2010/2011.

Estimates of C, N, P content in macroalgae

Total seagrass areal biomass (2009 maps and 2010/2011 transect data on areal extent and density) and estimated amount (%) loss in 2010/2011

Estimates of C, N, P content in seagrass

Orange Team: For estimation of organic input to sediments:

Quantity estimates or some qualified assessment of the degree of organic build-up in sediments resulting from unusual faunal mortality during 2010 or 2011 winters.

Data provided by Sand Team to other teams (by receiving team)

Certain data generated by the Sand Team may be useful to the other investigative teams.

Blue Team: Estimates of sediment nutrient flux (diffusive and advective or as net flux) could be provided to the Blue Team (water quality) to assist with nutrient source inventory and development of nutrient biomass-balance calculations relevant to phytoplankton abundances (e.g., Chl *a*, cells/ml, biovolume)
Advection of mineralized nutrients from sediments due to recirculated groundwater (another source of nutrients to inventory).

Levels of re-suspended solids as seagrass coverage declines (note: this is a modeling exercise that may not be conducted because of budget constraints).

Green Team: Sediment sulfide concentrations for evaluating potential toxicity to seagrasses.

Orange Team: Changes in benthic infauna over time that could affect nutrient efflux and/or sulfide levels in the surficial (top 5 cm) sediments.