Nutrients and Water Quality in the Indian River Lagoon

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FLORIDA ATLANTIC UNIVERSITY
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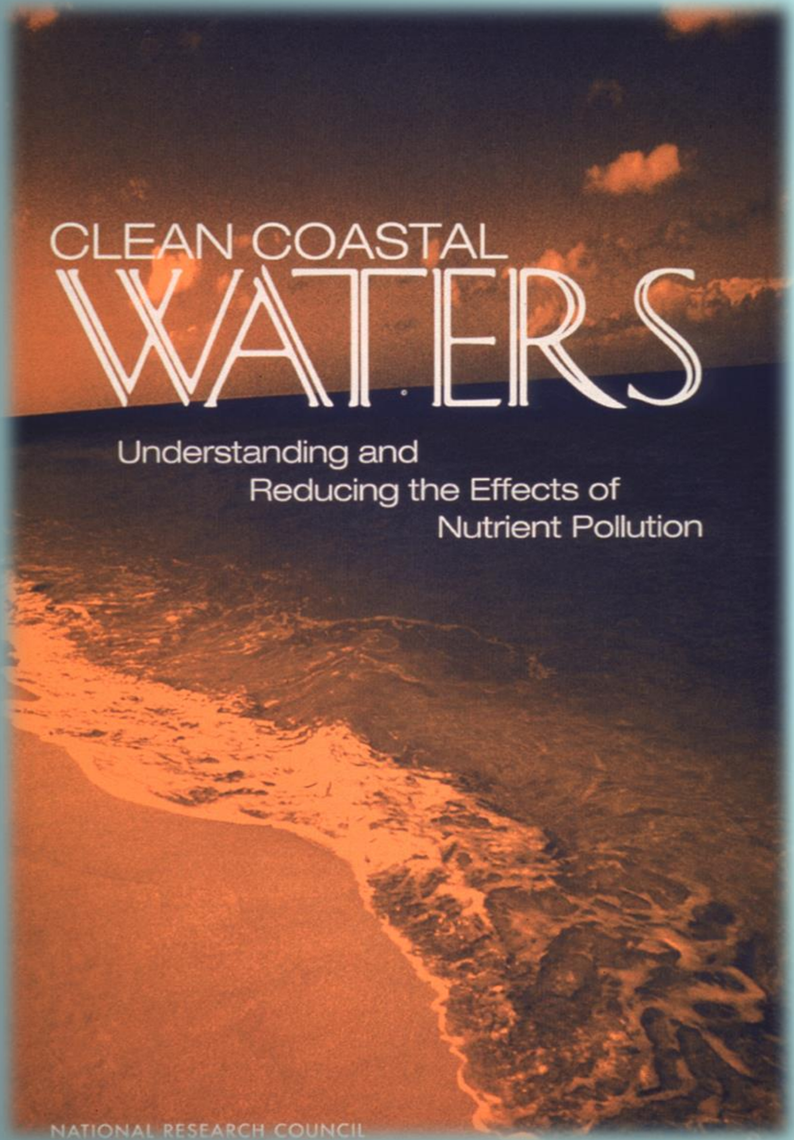
Critical Issues Facing the IRL

- Excessive freshwater releases
- Nutrient and contaminant pollution
- Harmful algal blooms
- Loss of seagrass habitat
- Decline of fisheries
- Emerging diseases and mortalities in wildlife (manatees, dolphins, sea turtles, pelicans, fish)

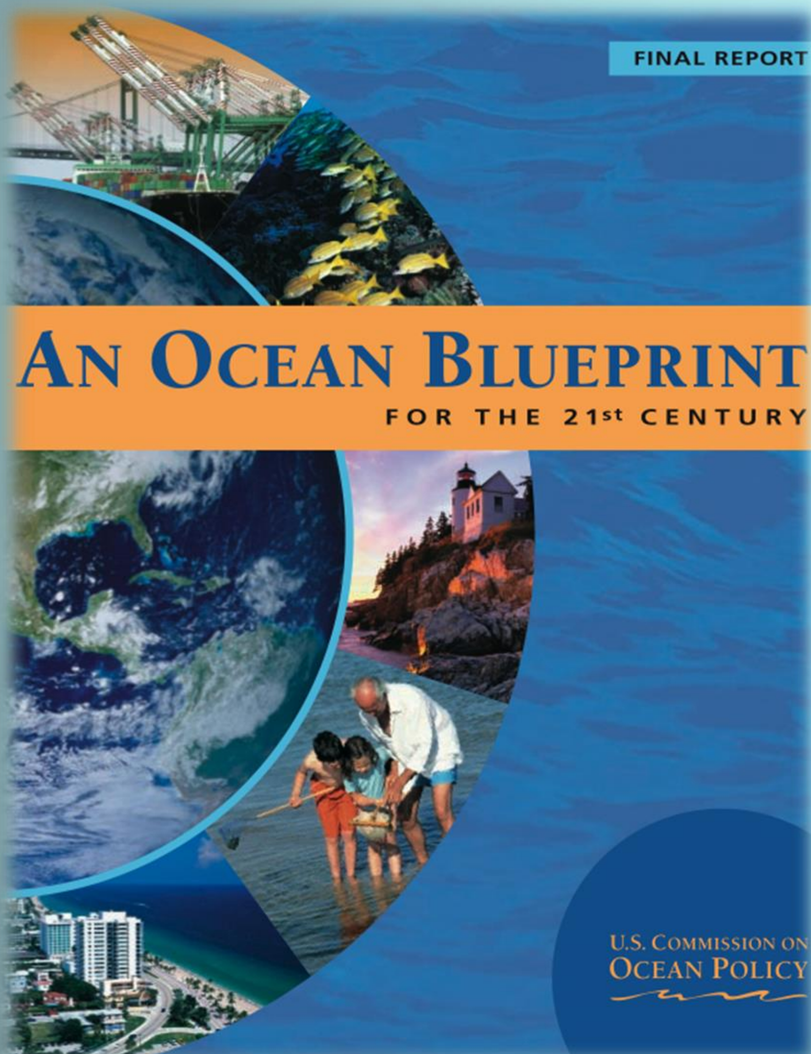
The Common Thread – Nutrient Pollution



"The fundamental driving force is the accumulation of nitrogen and phosphorus in fresh water on its way to the sea."

Clean Coastal Waters:
Understanding and Reducing the Effects of Nutrient Pollution.
(NRC, 2000)

UNITED STATES COMMISSION ON
OCEAN POLICY



Nutrient Pollution

"The most pervasive and troubling pollution problem currently facing U.S. coastal waters."

(U.S. Commission on Ocean Policy.
An Ocean Blueprint for the 21st Century.
Final Report.
Washington, D.C., 2004.
ISBN #0-9759462-0-X.)

Human Development, Land-Use and Eutrophication in the IRL

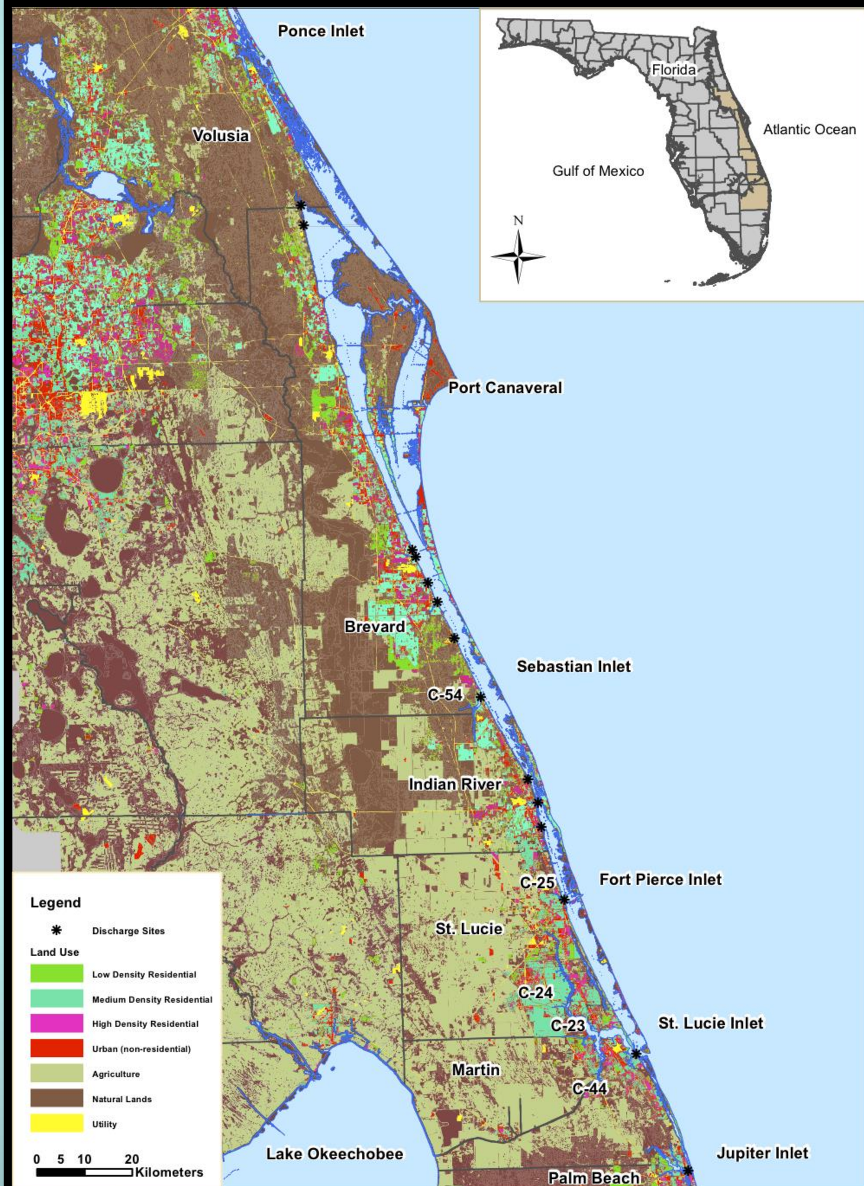
- Land-Use

  urban 39%
  agriculture 24%
  forest 4.5%
  wetland
  12.1%
  range 20.8%

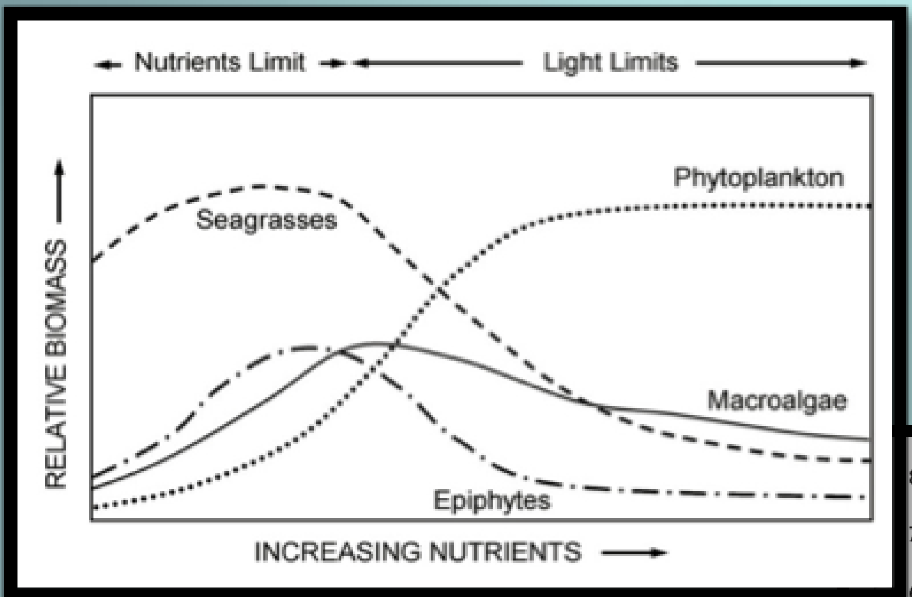
- Eutrophic Condition

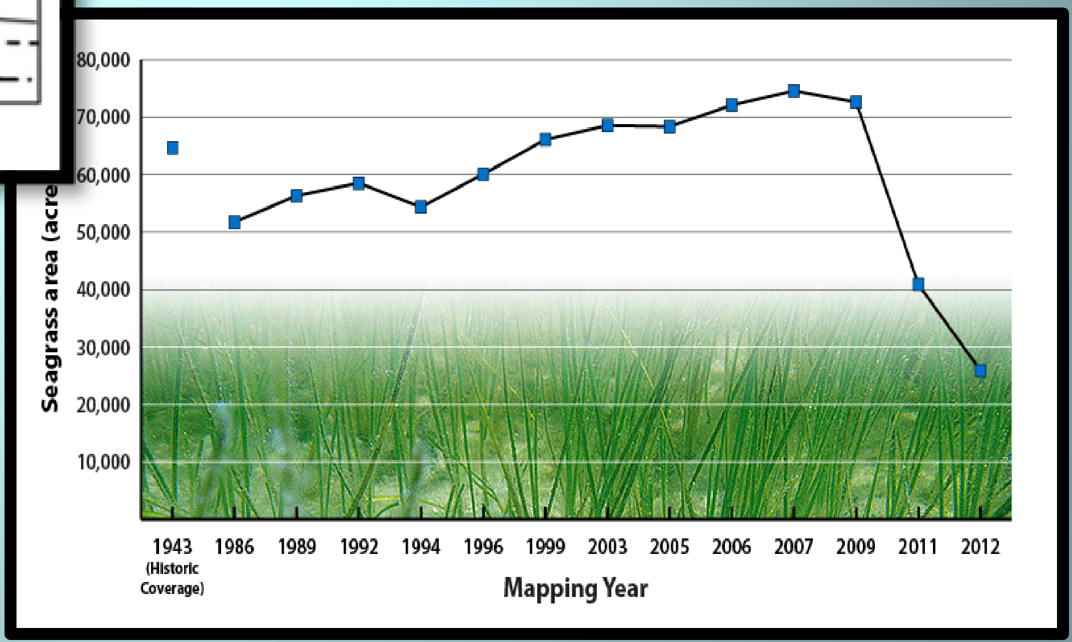
  Moderate to high nitrogen input
  High susceptibility (low flushing)
  Substantial expression of eutrophy
  Algal blooms likely to worsen

From: Bricker et al. 2007 National Estuarine Eutrophication Assessment, NOAA, Silver Springs, MD

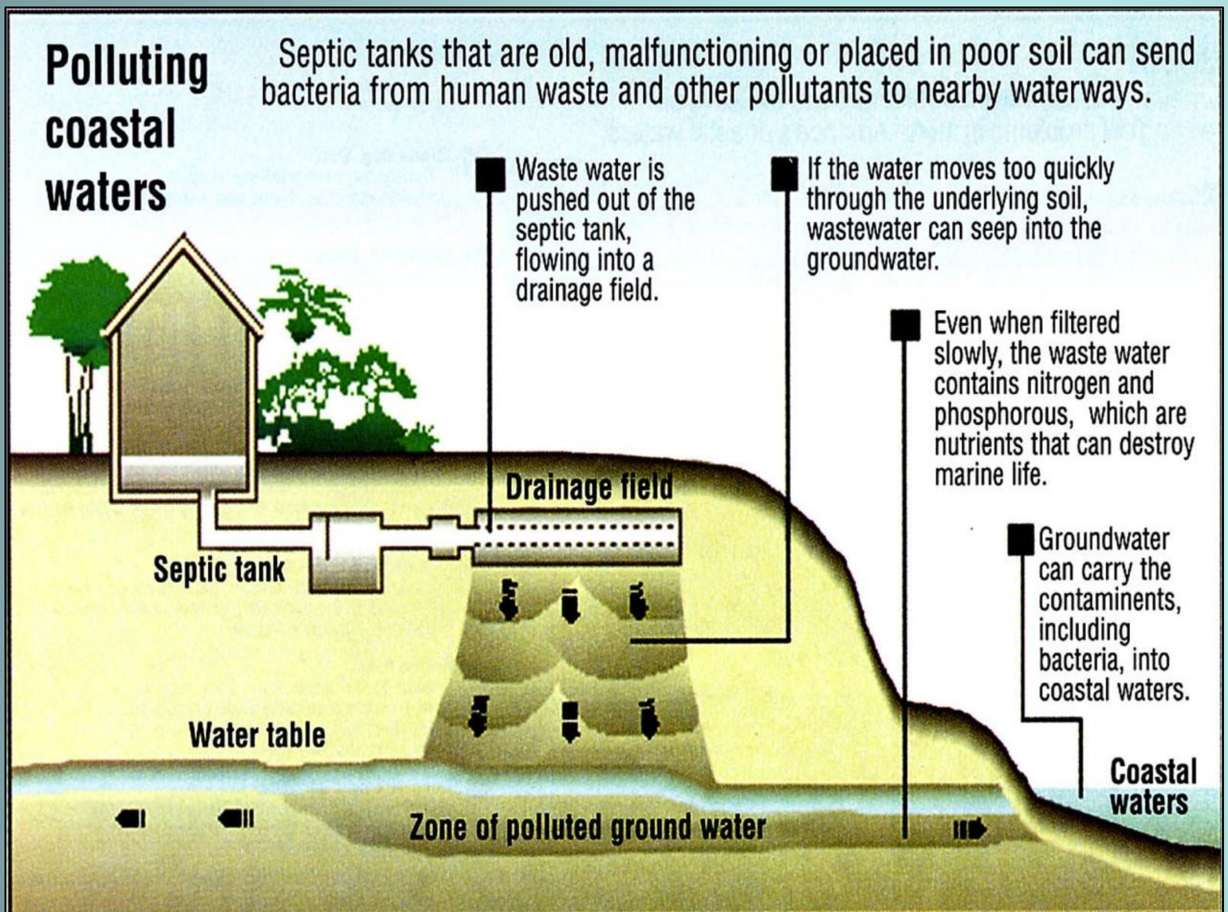


Nutrients and Ecological Changes in IRL



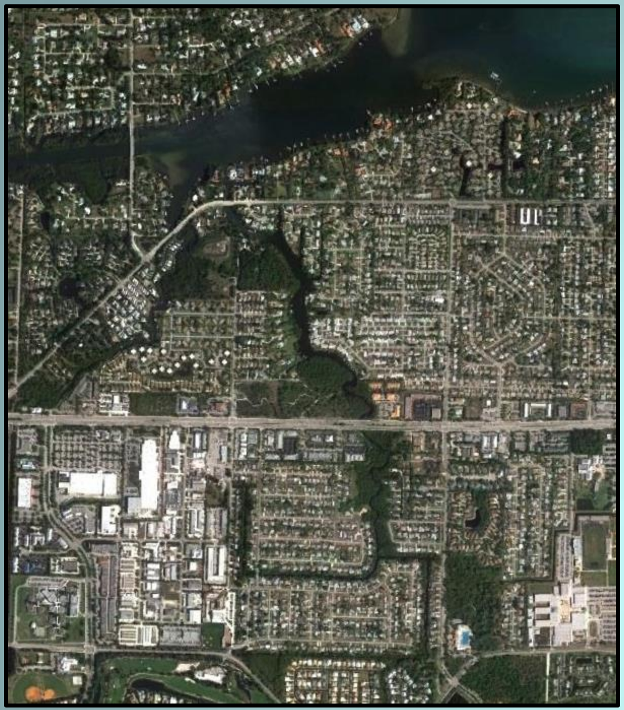


Septic Tanks and Coastal Pollution



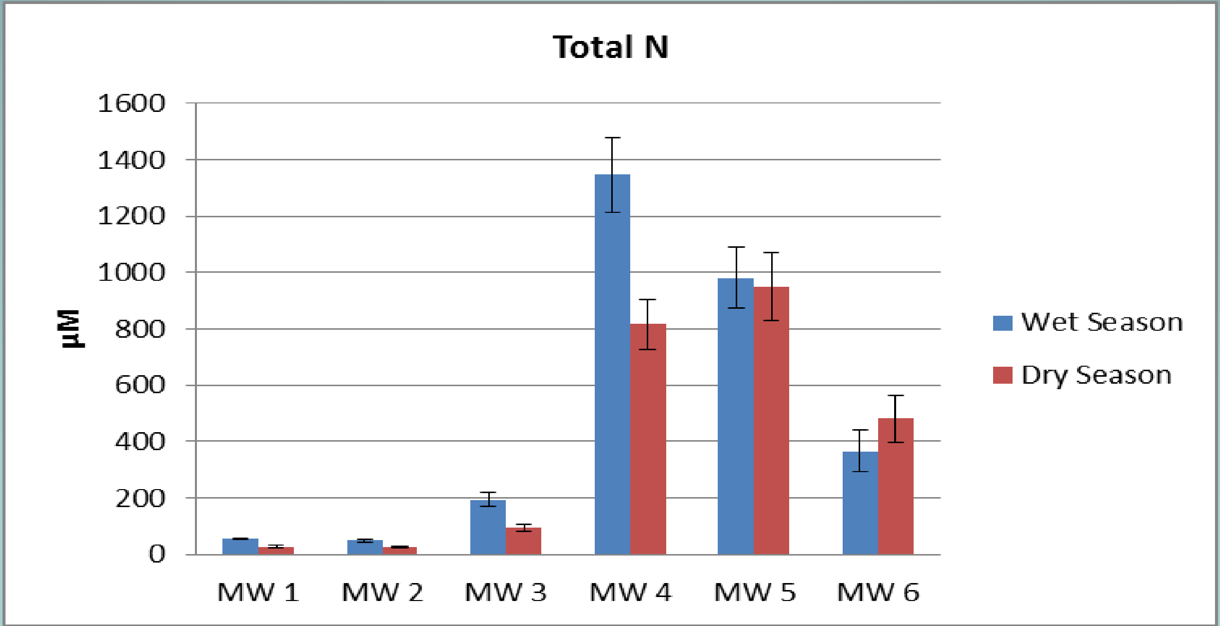
- 320,000 OSTDS
- ~ 50% of total sewage treatment on IRL
- 9 lbs/N/person/year
- Assuming 2.5 people/ OSTDS and 60% removal of N, ~ 1 million kg/N/yr in NIRL, BR, ML
- Total non-point source; 832,645 kg/N/yr Sigua and Tweedale 2003

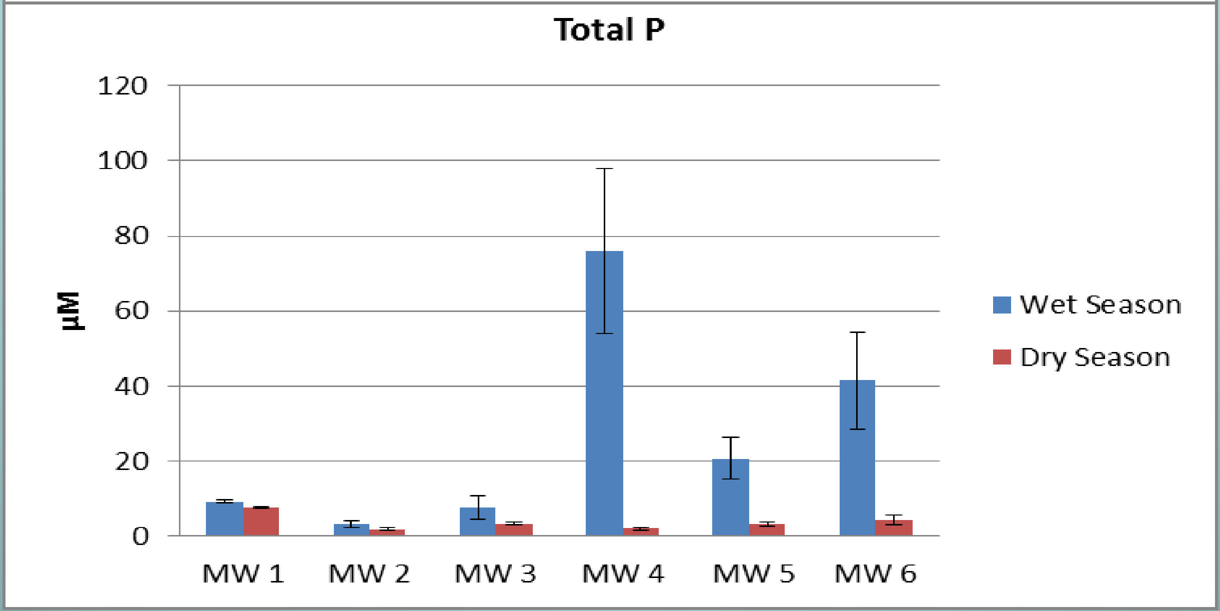
Jupiter Creek Septic Tank Study: 1994-1995



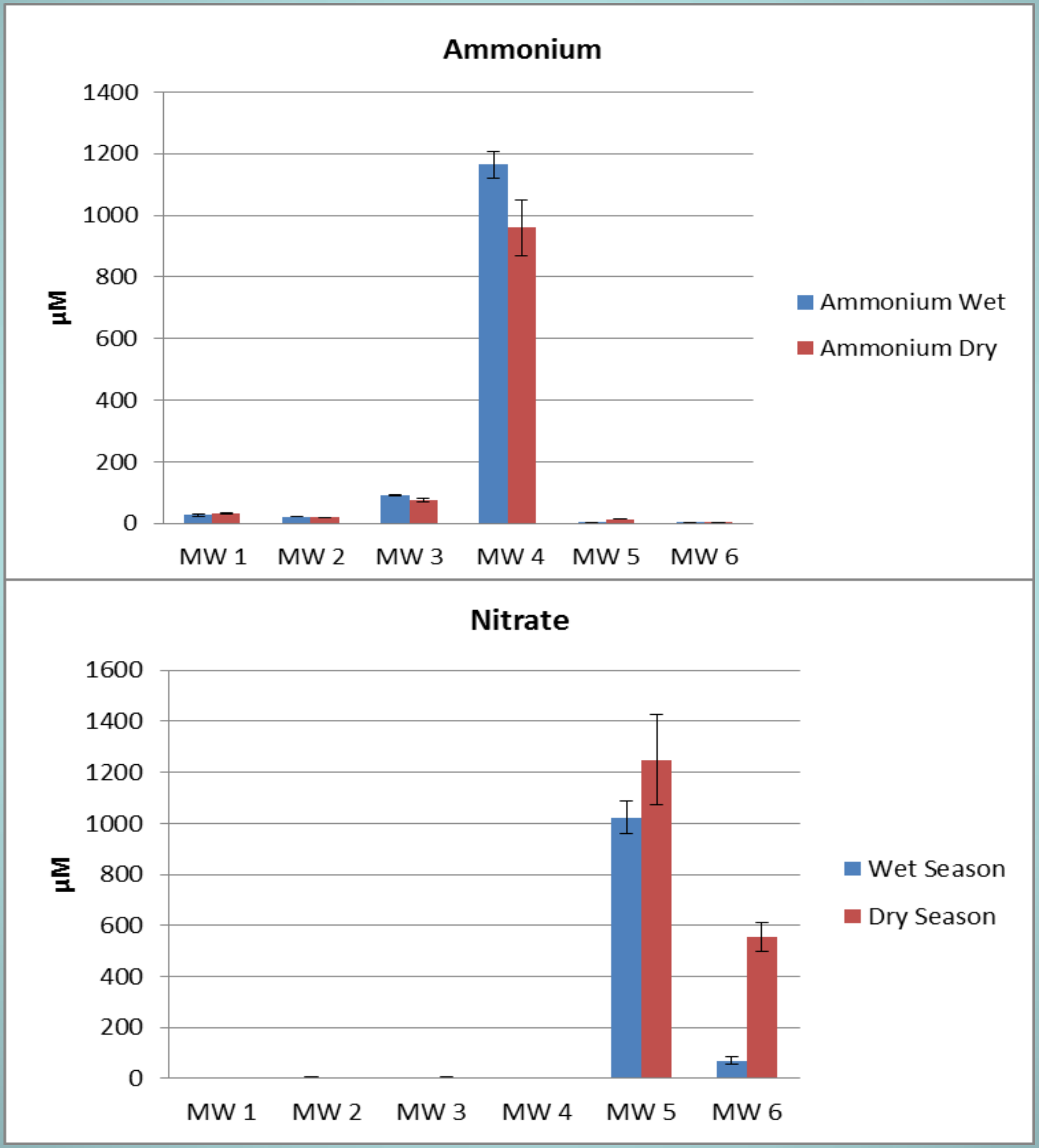
- Loxahatchee River District
- Monitored wells and surface waters
- Continuous discharges of STE into Jupiter Creek
- Wells violated State Standards for groundwaters (fecal coliform)
- Nutrient and fecal coliform contamination > 100' from septic tank
- High $\delta^{15}N$ in groundwaters and surface waters and coprostanol in sediments confirmed human sewage

Monitor Wells: Total N and Total P

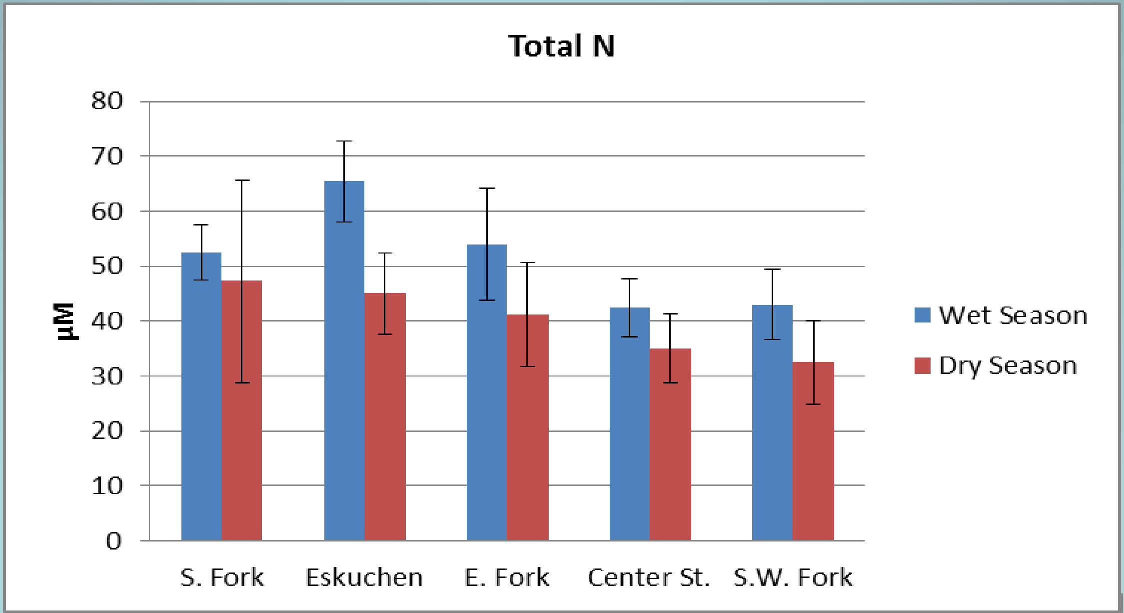


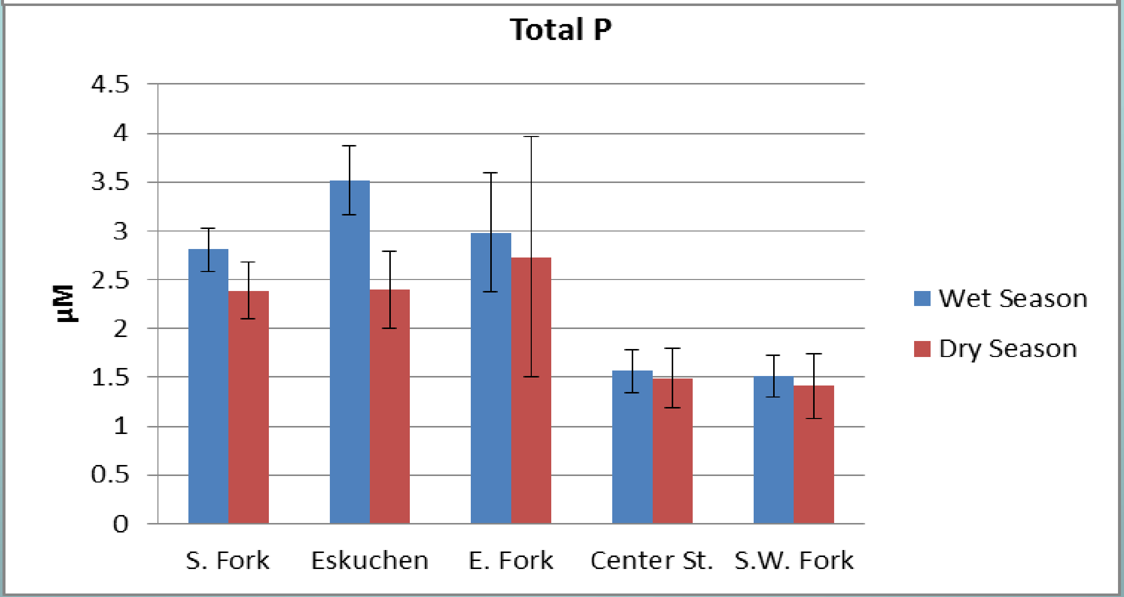


Monitor Wells: Ammonium vs. Nitrate

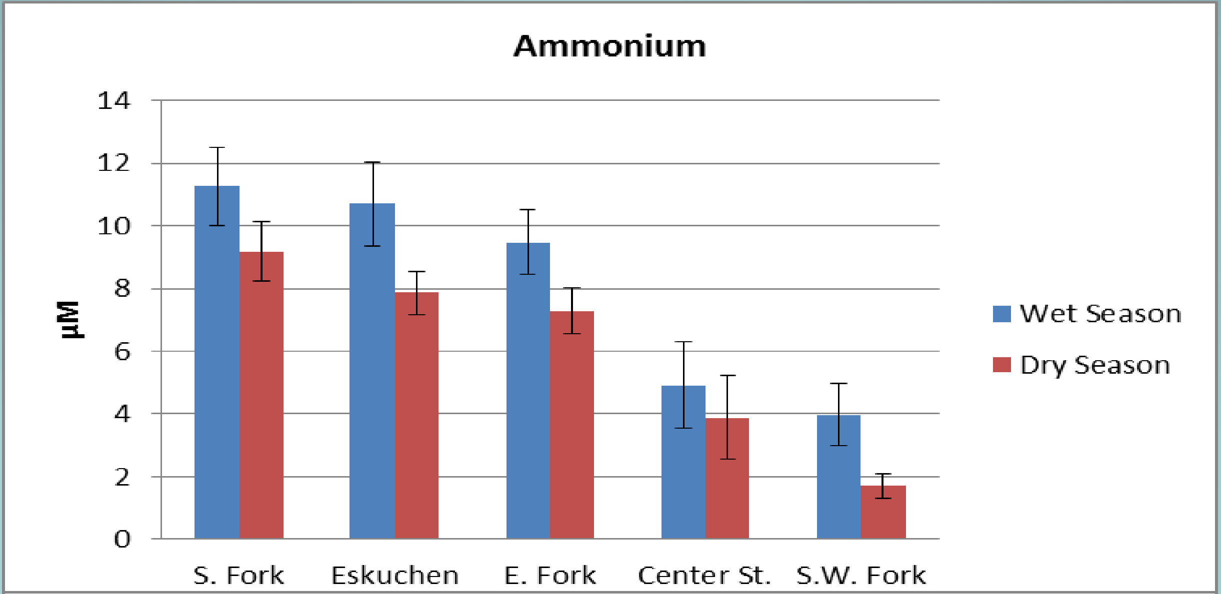


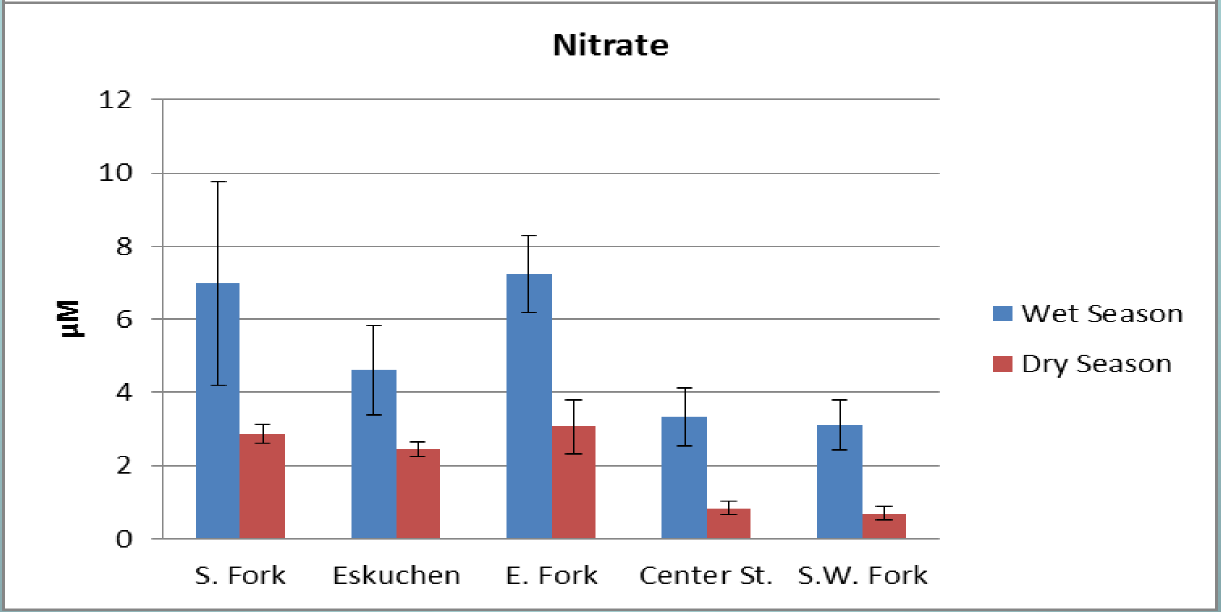
Jupiter Creek: Total N and Total P



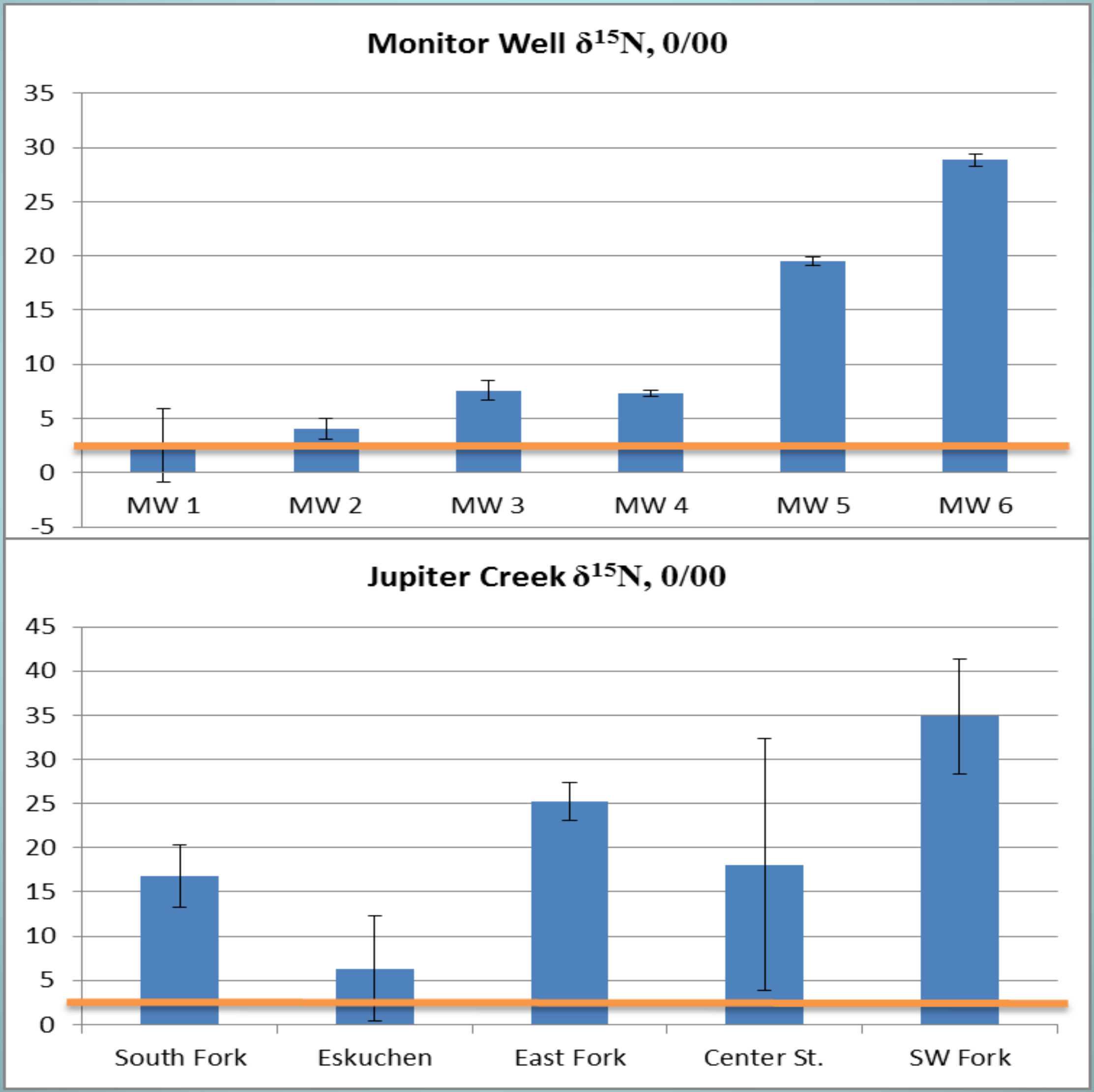


Jupiter Creek: Ammonium and Nitrate

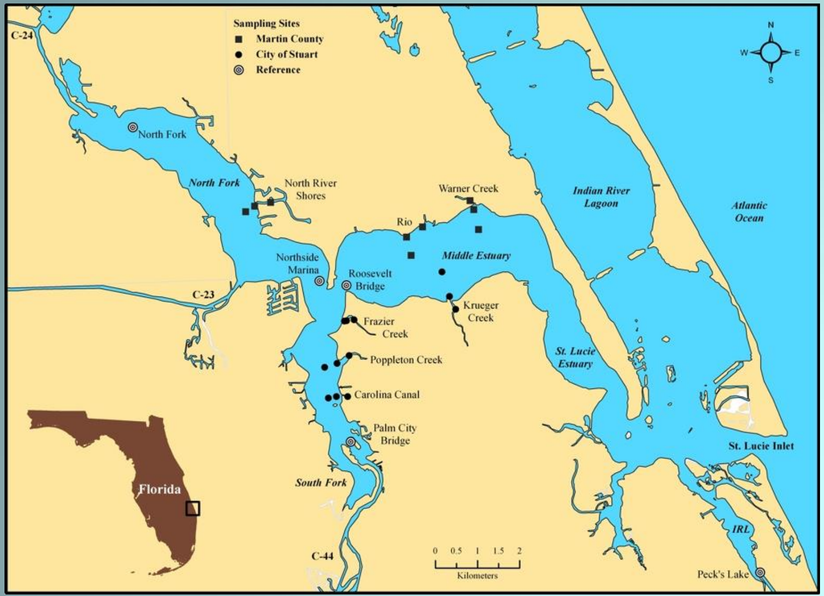




Aqueous Stable Nitrogen Isotopes



St. Lucie Estuary Study: 2005-2006



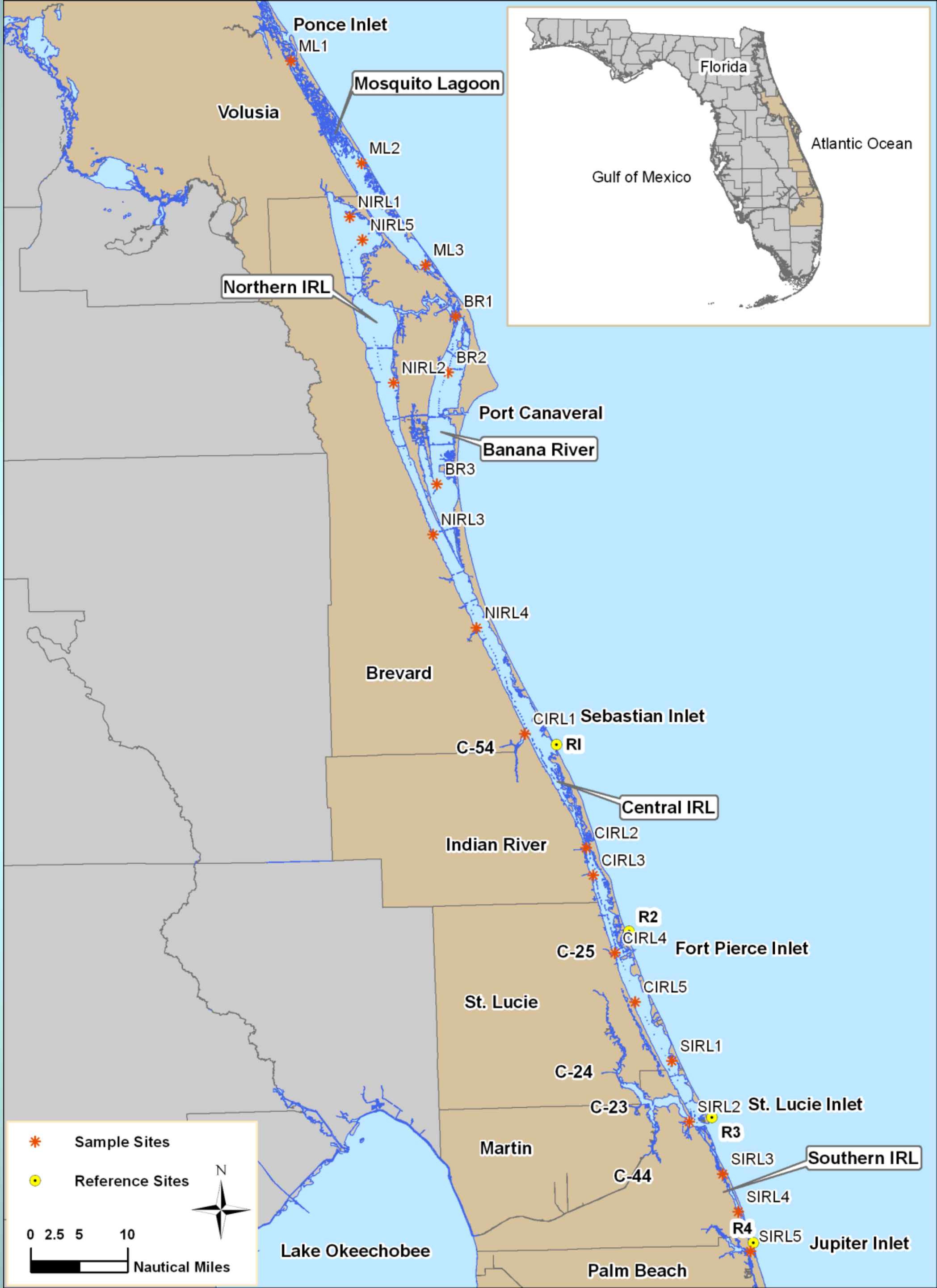
- Sampled in June & November 2005, March 2006
- Freshwater discharges caused low salinity and DO, high nutrients, turbidity, coliforms
- Highest turbidity, nitrate, and TN in South Fork from C-44; highest ammonium and phosphate in North Fork (C-23, C-24)
- High nutrients and coliforms near dense residential areas (septic tanks)
- Toxic blue-green algae blooms

IRL-Wide Study 2011-2012

20 IRL Sites + 4 Reference Sites

1. Use multiple lines of evidence (dissolved nutrients, C:N:P and $\delta^{15}N$ in macroalgae) to assess spatial/temporal patterns in nutrients, N- vs. P-limitation of algal growth, and N sources fueling eutrophication in the IRL.

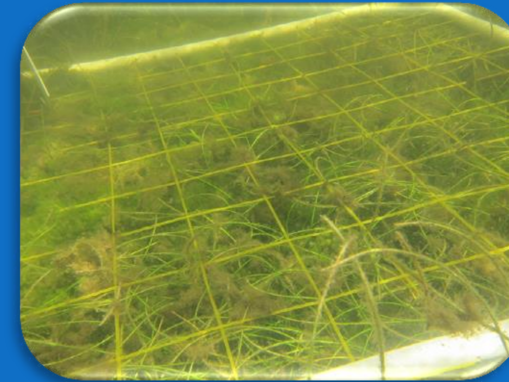
2. Improve water quality in the IRL by providing high-quality, user-friendly data to resource managers and policy-makers.



Indian River County Sites

CIRL 1 = St. Sebastian River Mouth
CIRL 2 = Main Relief Canal
CIRL 3 = South Canal
Reference Site 1 = Ambersand Wormrock Reef

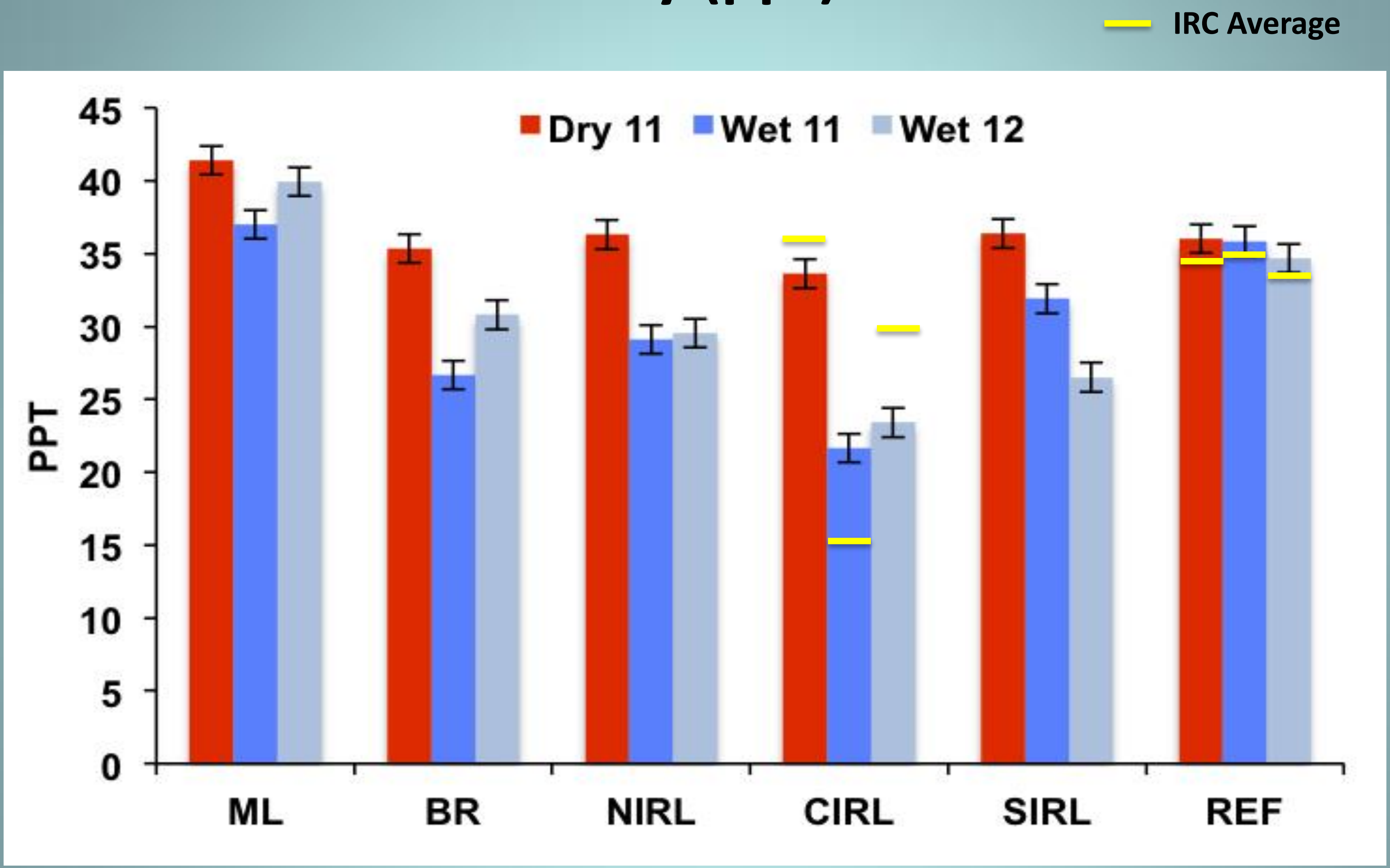
1. Collect water and macroalgae and document field conditions



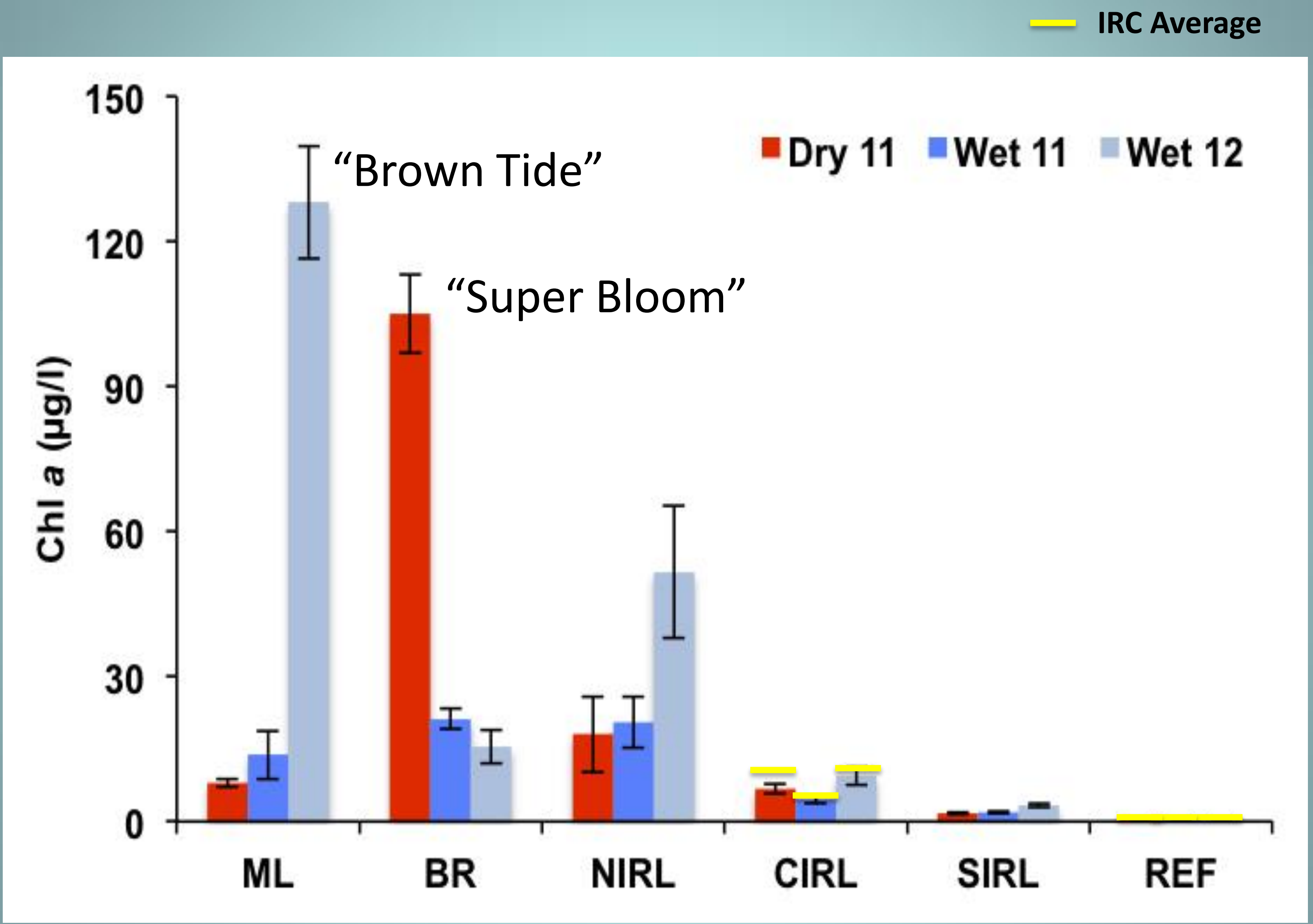
2. Remove epibionts from algae, rinse, dry, grind, and analyze for natural abundances of stable N & C isotopes and C:N:P contents

3. Filter water and analyze for dissolved nutrients

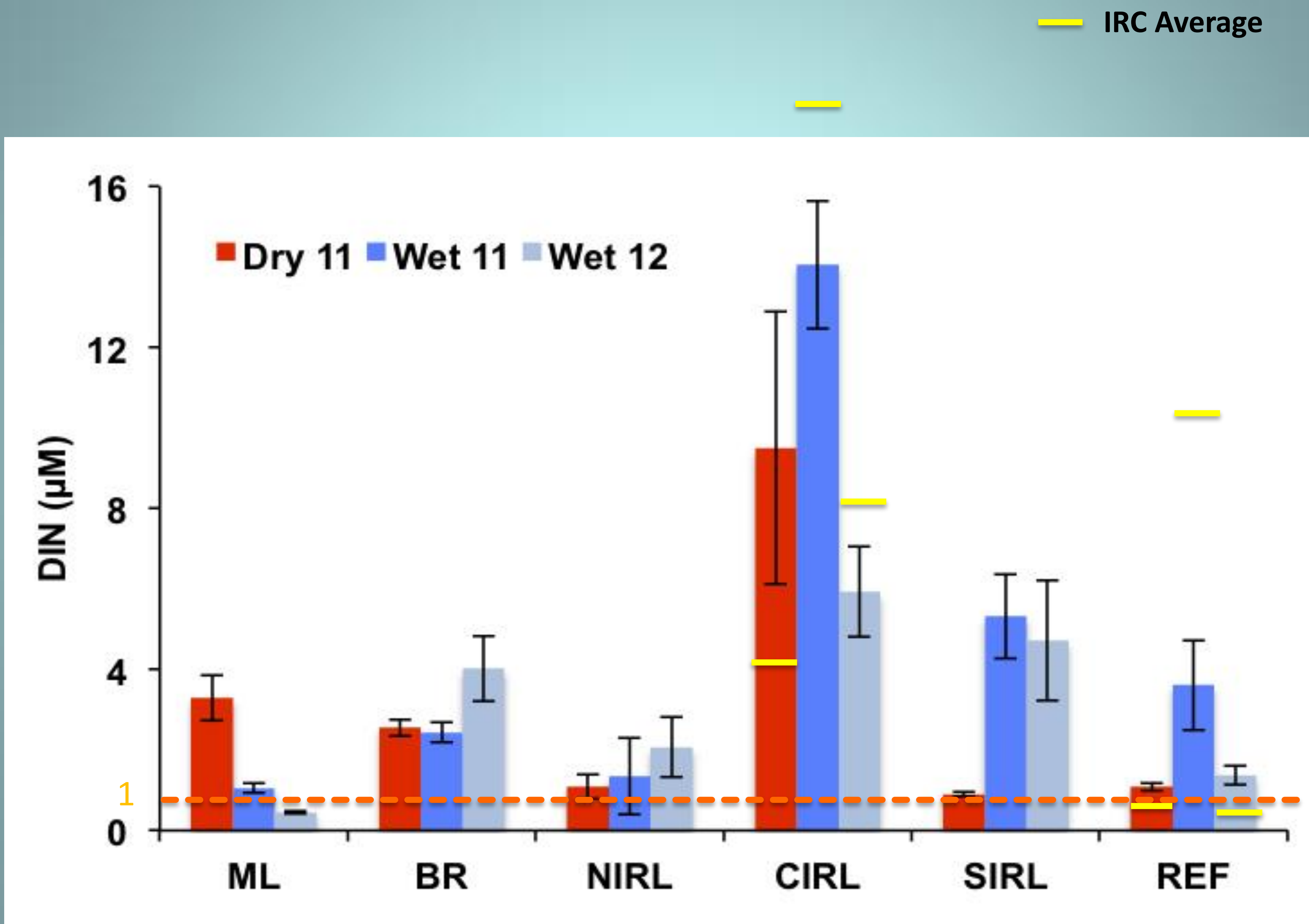
Salinity (ppt)



Chlorophyll *a* (µg/l)

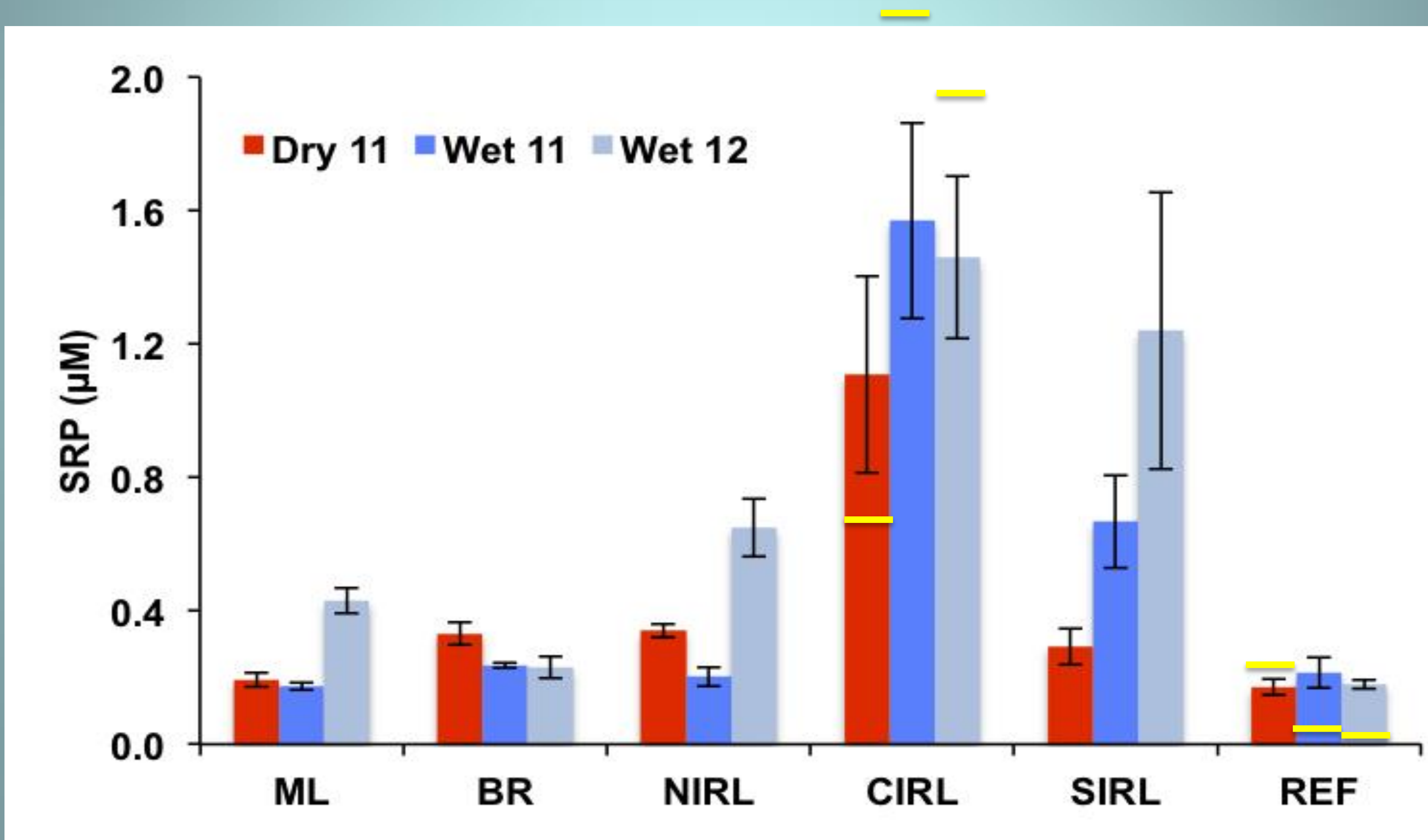


DIN (Ammonium + Nitrate + Nitrite)

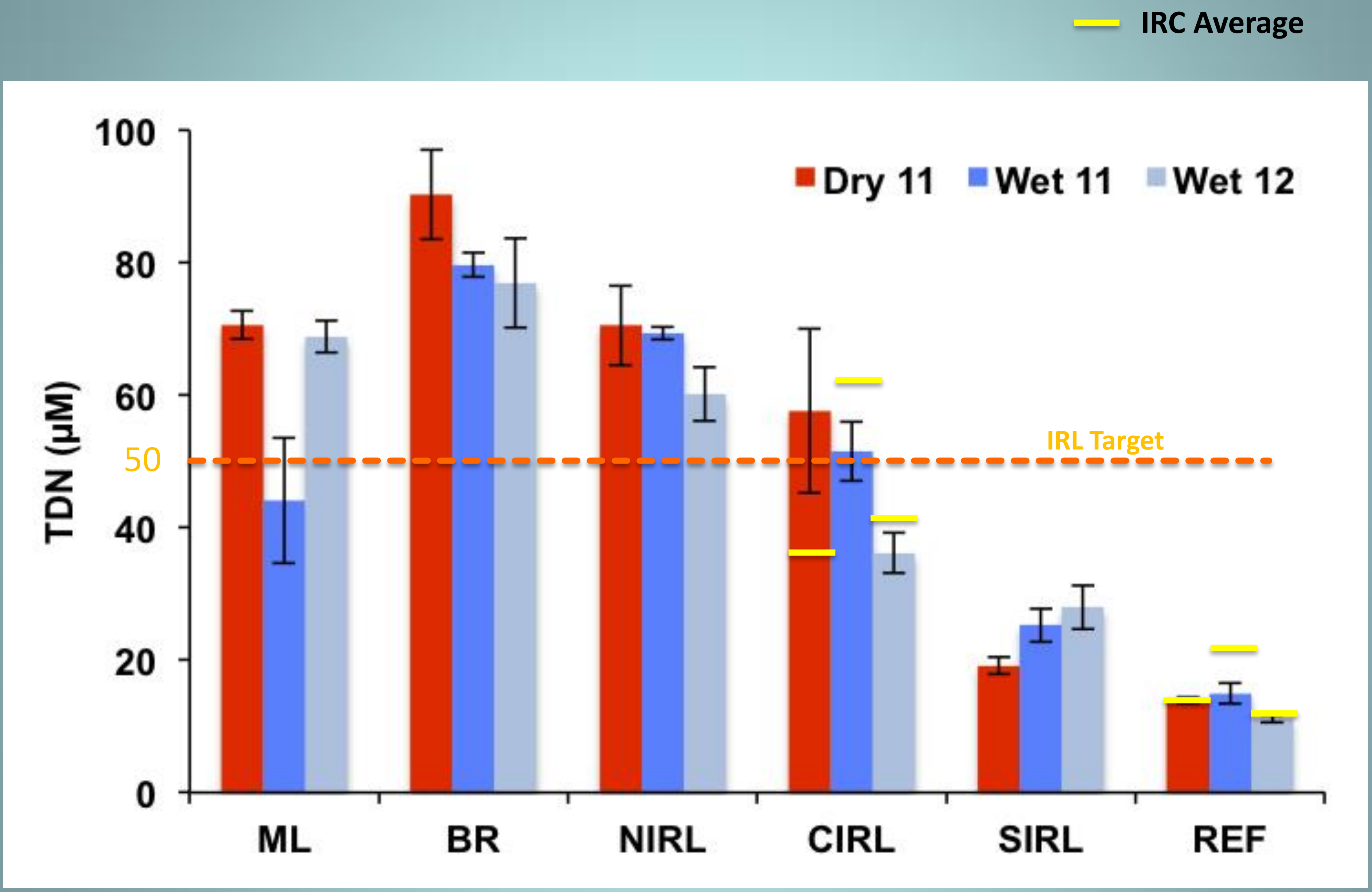


SRP (Soluble Reactive Phosphorus)

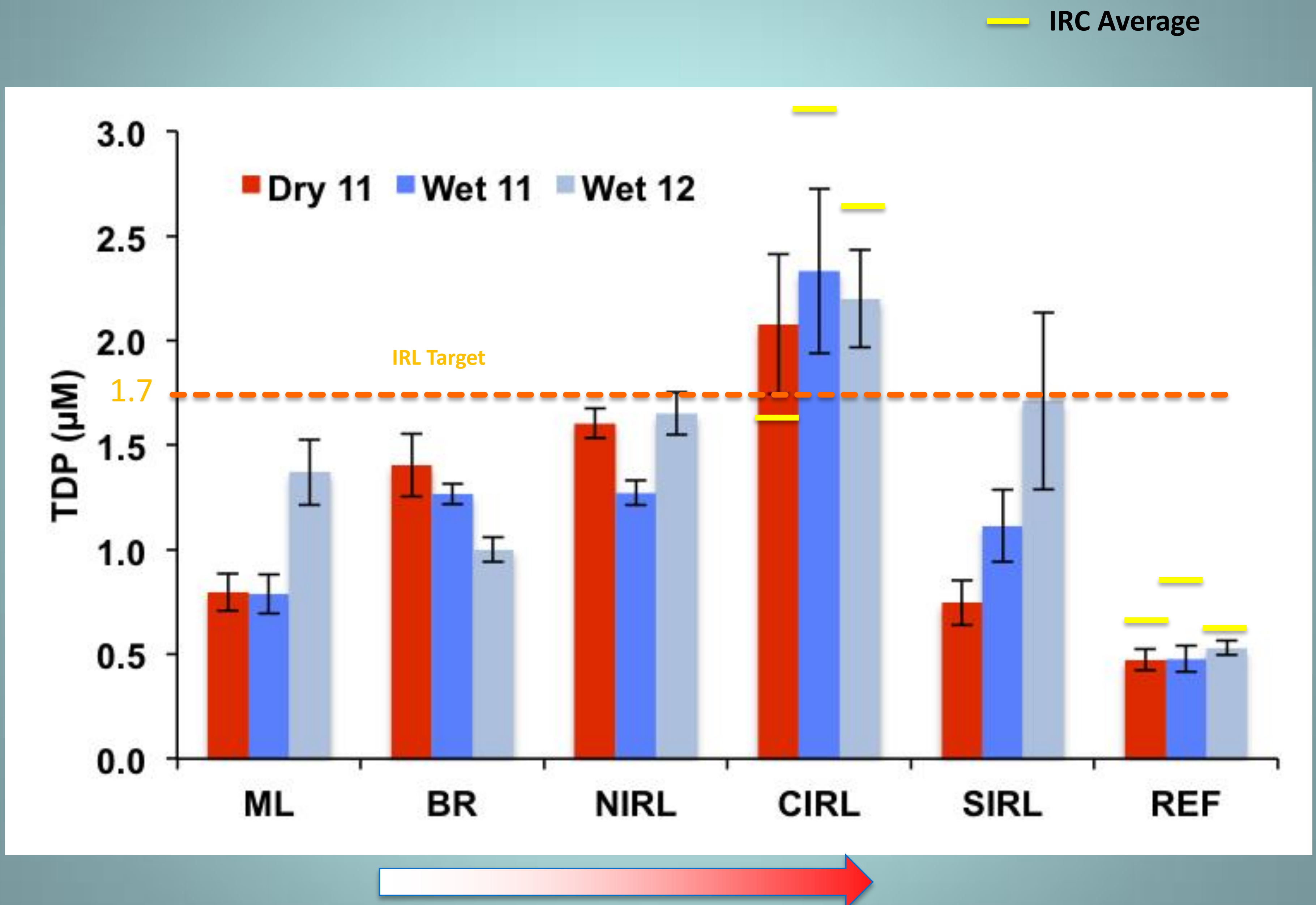
IRC Average
3.46 SSRM
1.65 MRC
1.60 SC



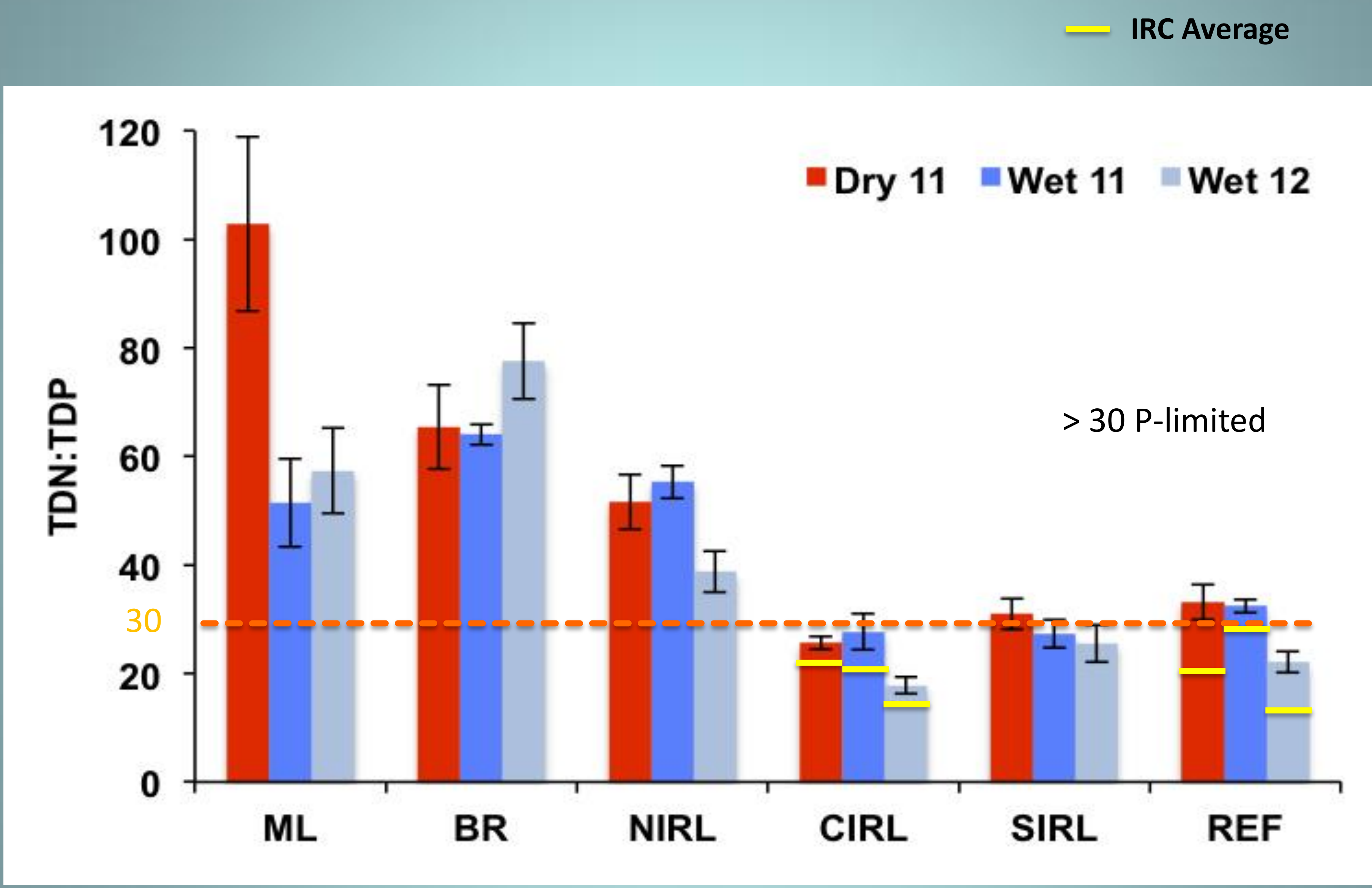
TDN (Total Dissolved Nitrogen)



TDP (Total Dissolved Phosphorus)



TDN:TDP

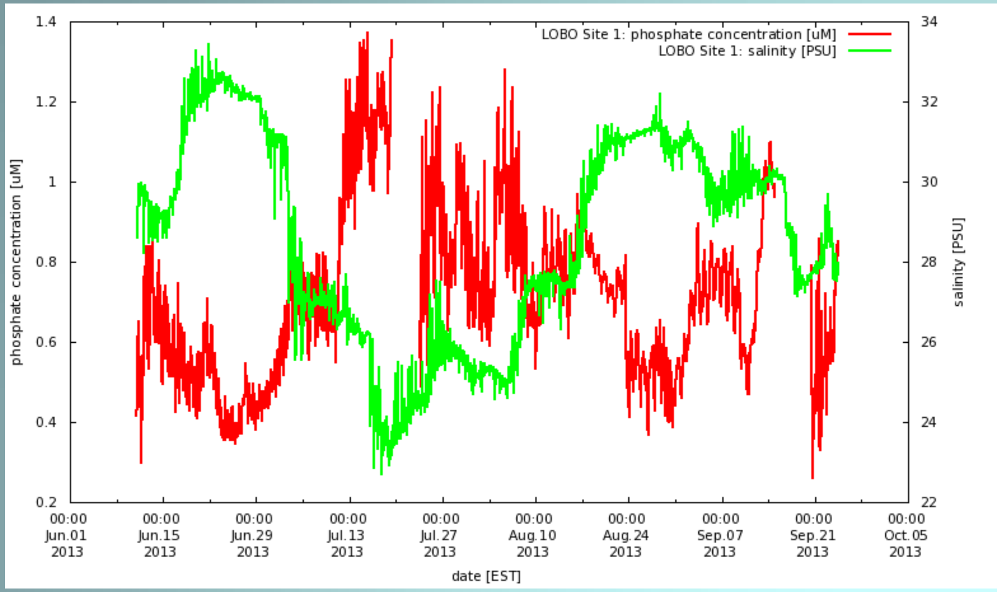


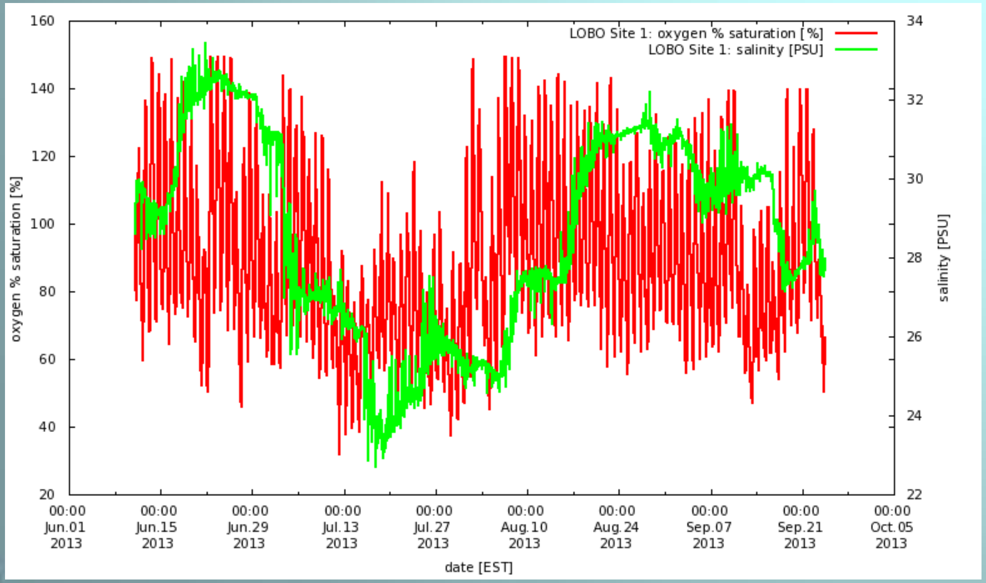
P-limited

N-limited

Land/Ocean Biogeochemical Observatories (LOBOs)

http://fau-hboi.loboviz.com



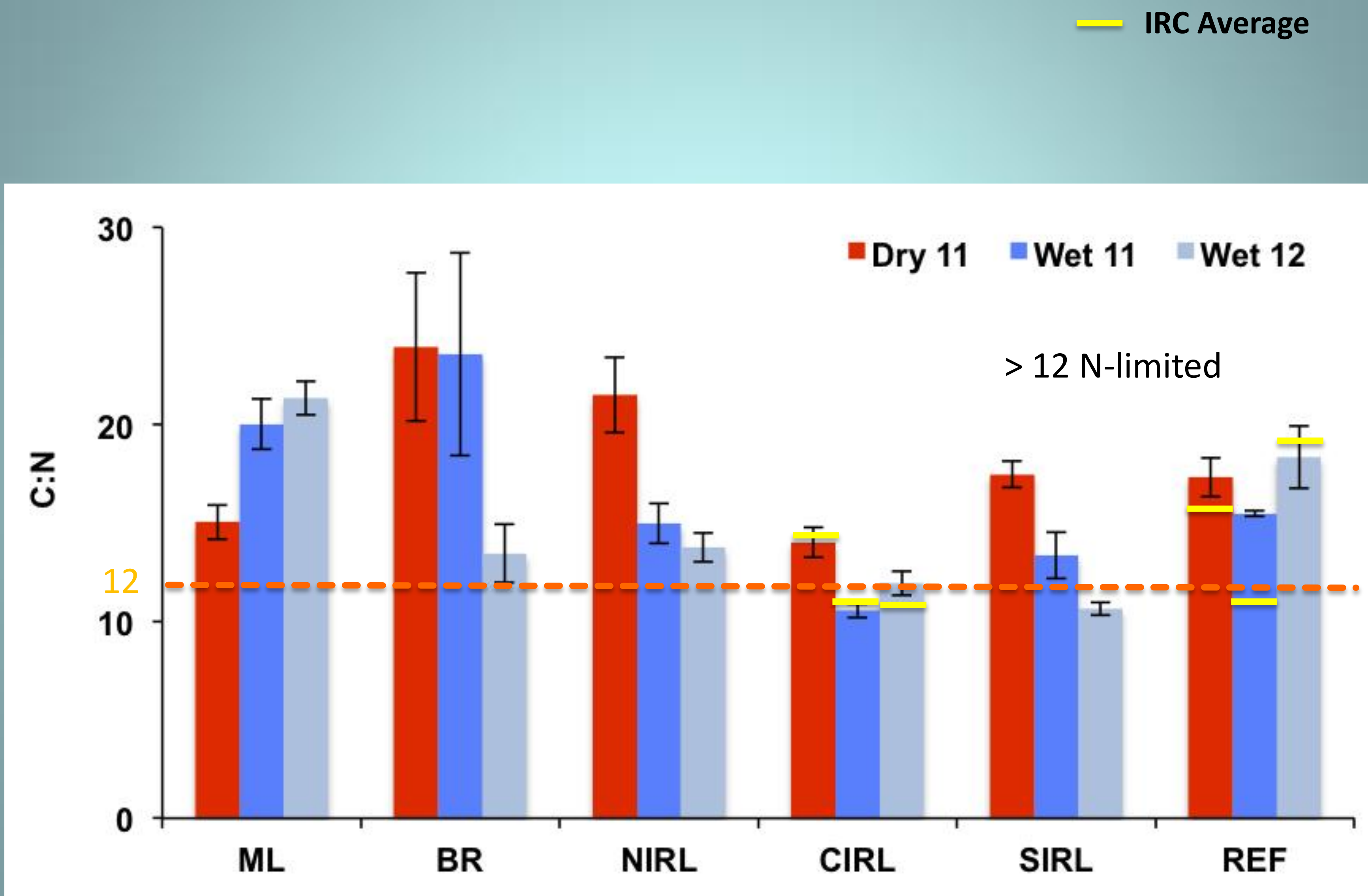


- Available to all through a dedicated interactive website
- Continuous real-time, high-accuracy and high-resolution data
- Data needed to quantify and model relationships between environmental factors and biological processes in the IRL

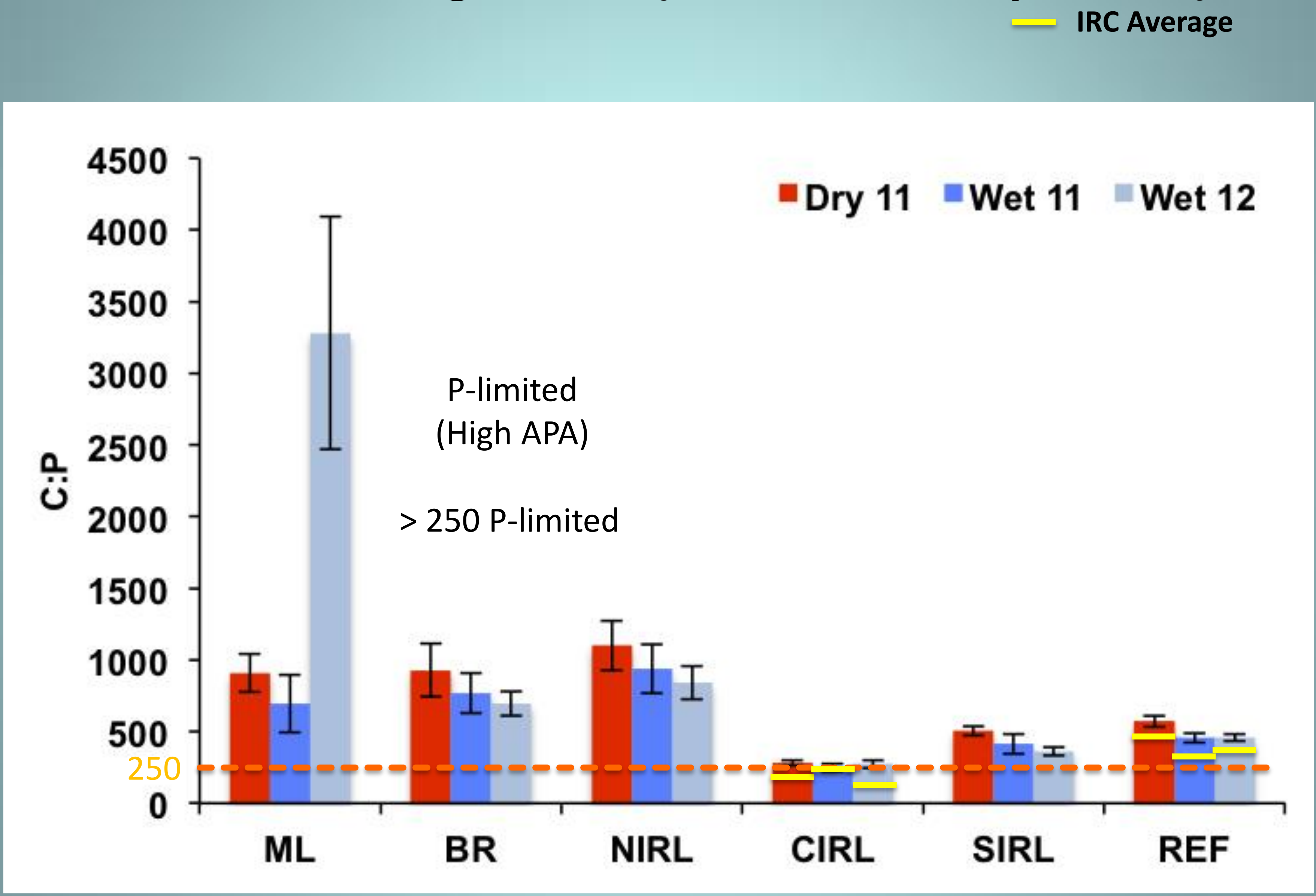
Macroalgae as Bio-Observatories in the IRL

Gracilaria tikvahiae		*Caulerpa prolifera*	
Hypnea musciformis		*Hypnea spinella*	
Caulerpa mexicana		*Laurencia filiformis*	
Acetabularia schenckii		*Acanthophora spicifera*	

Macroalgae C:N (Carbon:Nitrogen)

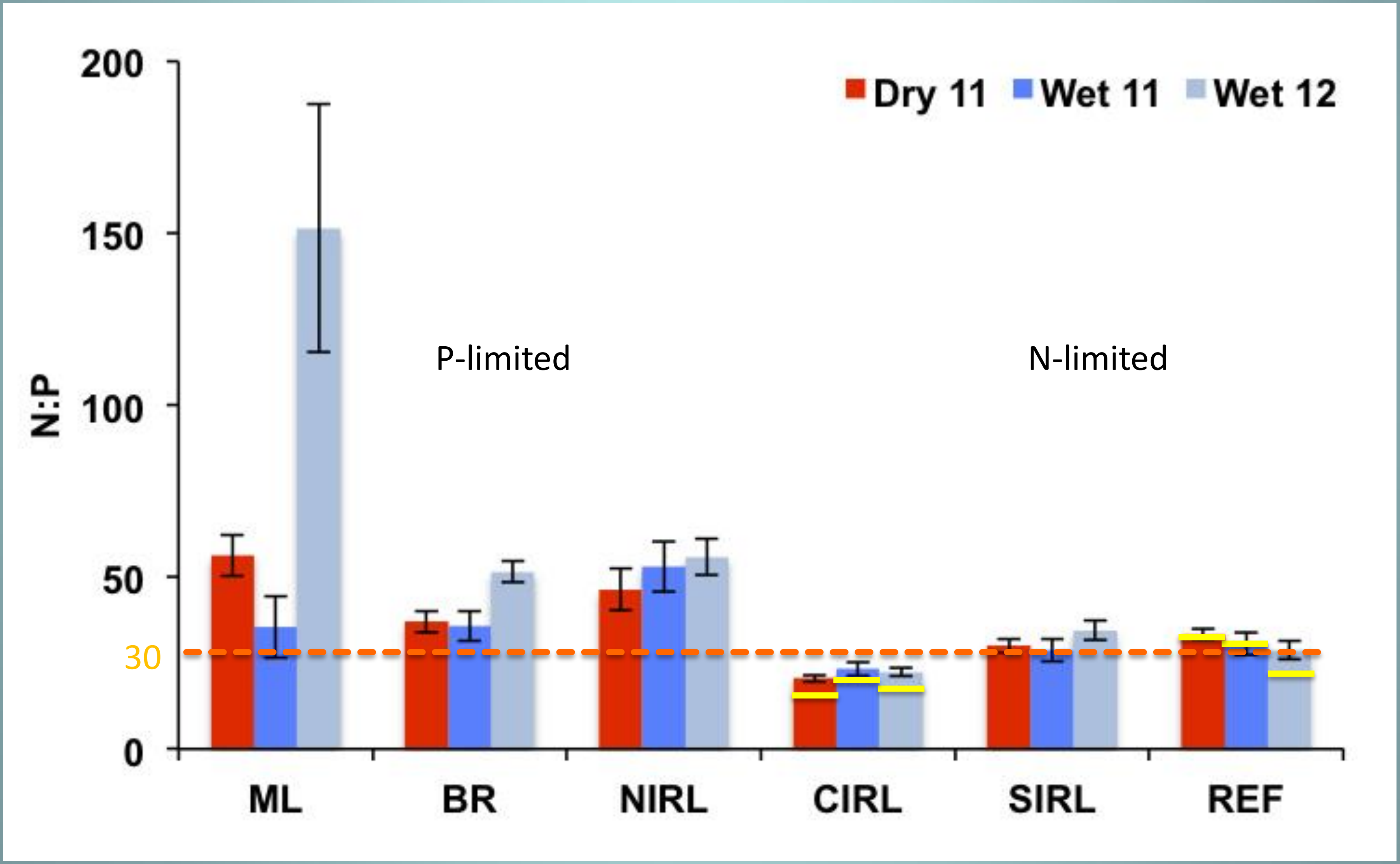


Macroalgae C:P (Carbon:Phosphorus)



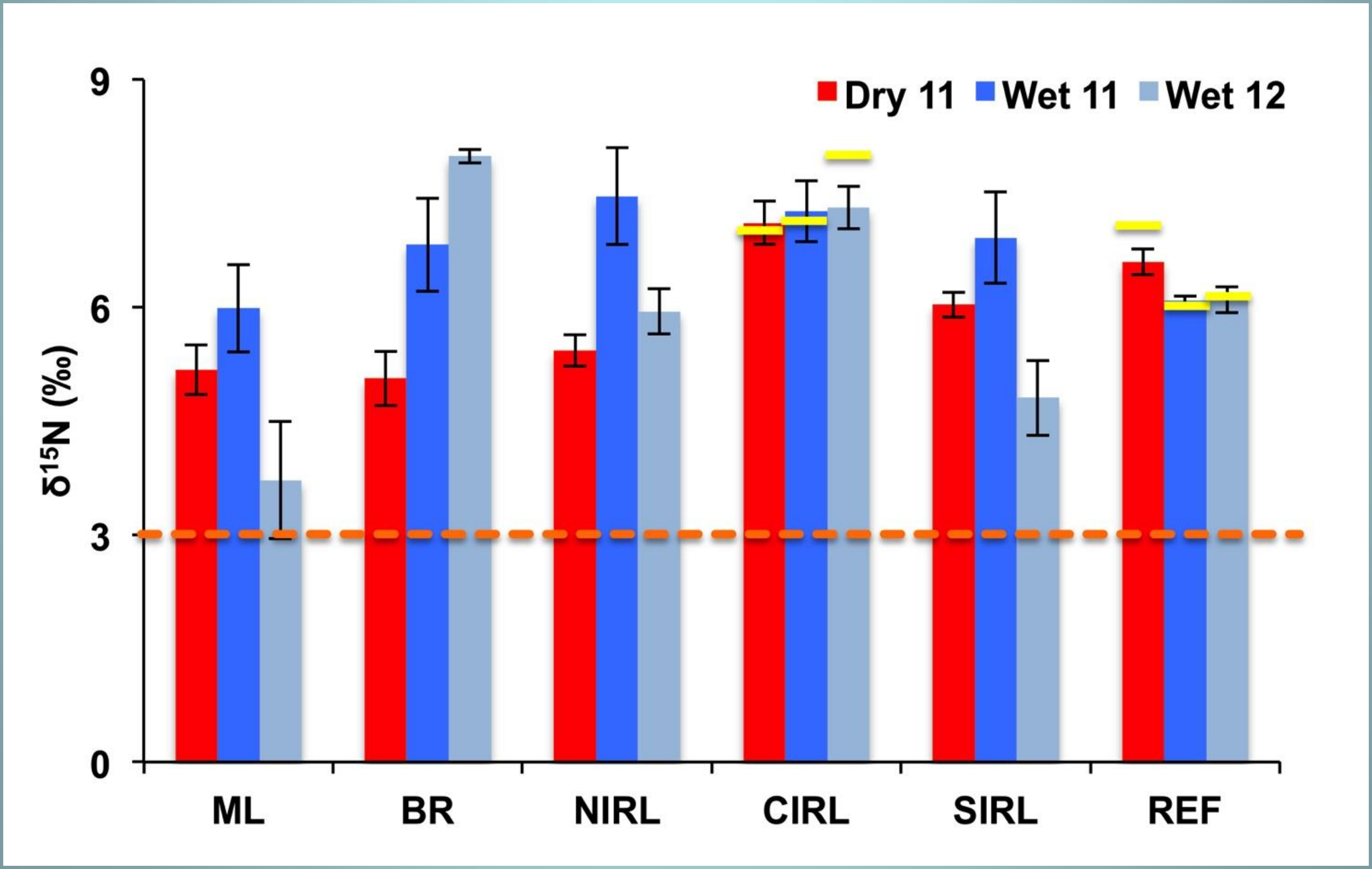
Macroalgae N:P (Nitrogen:Phosphorus)

IRC Average

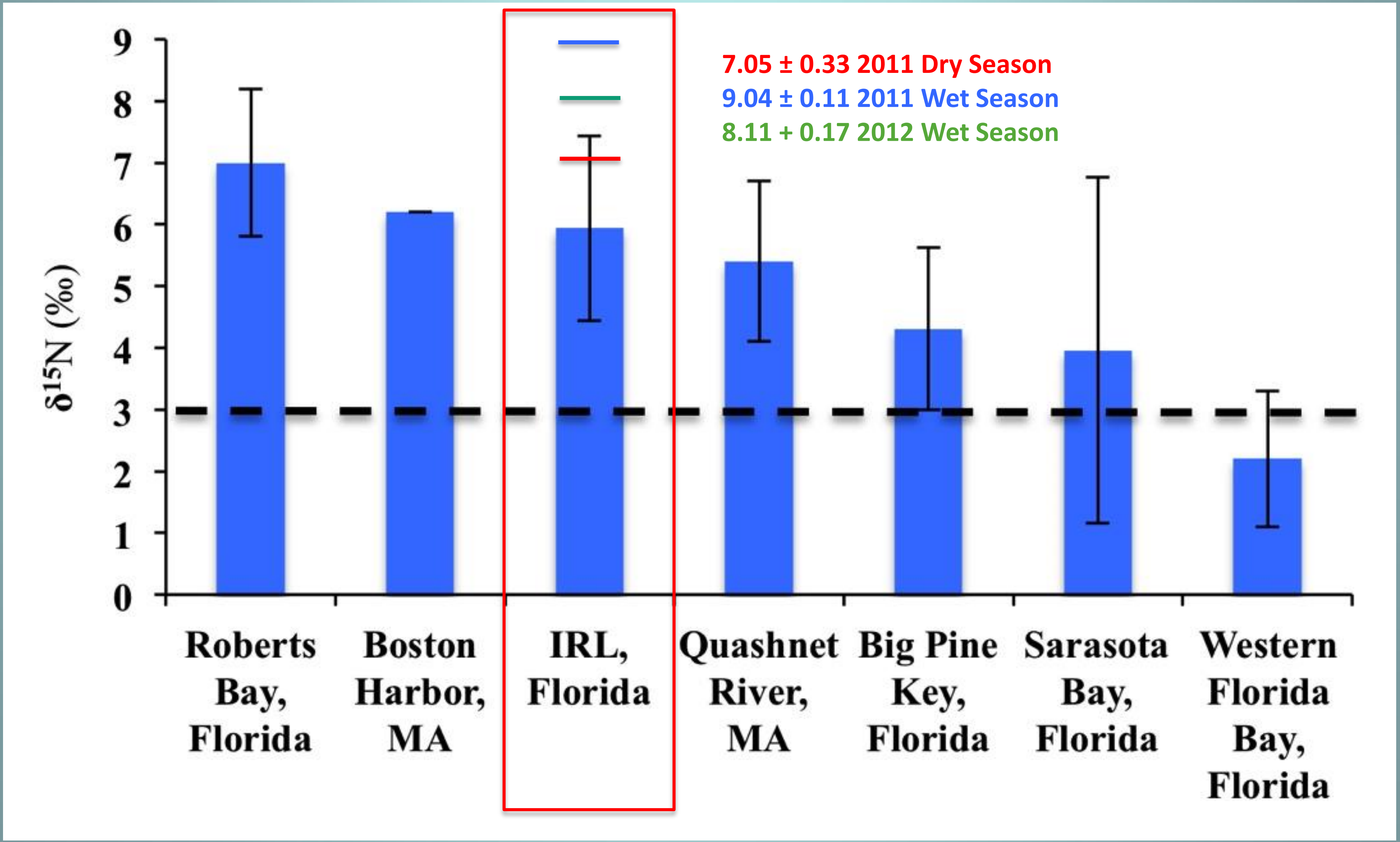


δ^{15}N (o/oo) in Macroalgae

IRC Average



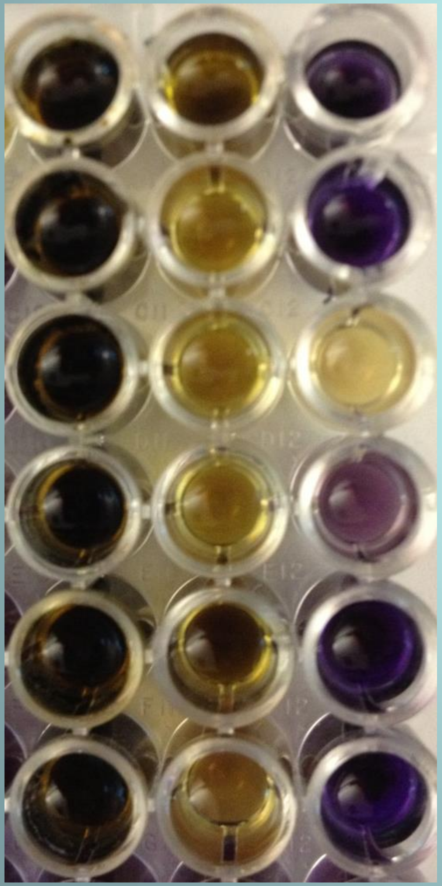
Comparison of $\delta^{15}N$ in Macroalgae From Sewage-Impacted Coastal Waters in Florida and Massachusetts



IRL Manatee Mortalities: Toxins Induced by High N?

- *Gracilaria* extracts from May and July assayed for bioactivity (N2A, mouse neuronal cells; MCF-7, mammary gland epithelia tissue; Collaboration with NOAA)
- Methanol extracts and HPLC showed three bands of activity; two bands glycosidic
- NMR confirmed toxic glycosides
- Also looking at *Gracilaria* epiphytes and phytoplankton as potential toxin sources

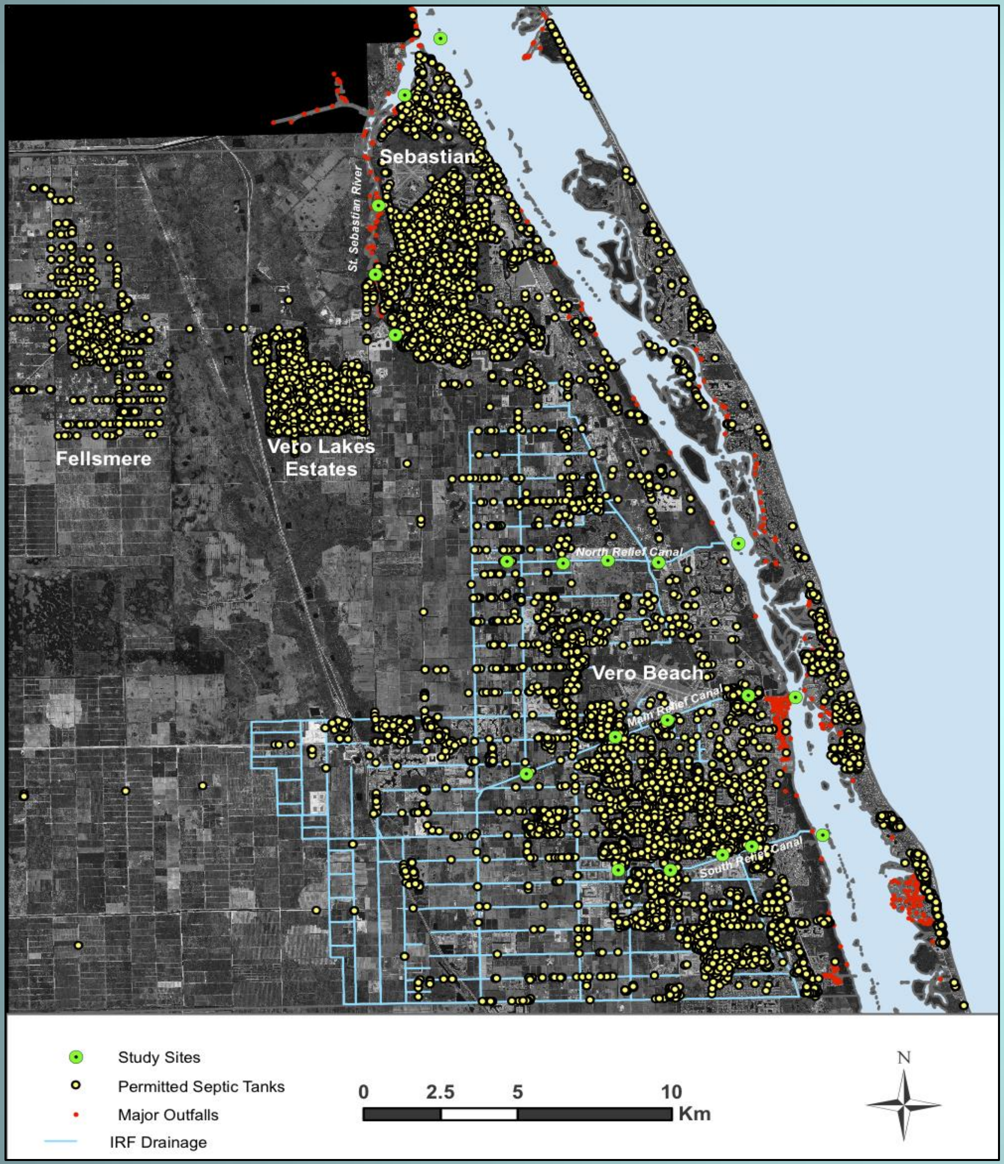
Toxicity in IRL Macroalgae Samples: Shorty's Pocket



Sample ID	Content	Latitude	Longitude
Shorty' s Pocket 1	Gracilaria tikvahiae	28.300028°	-80.613132°
Shorty' s Pocket 2	Gracilaria tikvahiae	28.300028°	-80.613132°
Shorty' s Pocket 3	Gracilaria tikvahiae	28.300028°	-80.613132°
Shorty' s Pocket 4	Mixture, including Gracilaria tikvahiae, Hypnea spp. Acanthophora spicifera	28.300028°	-80.613132°
Shorty' s Pocket 5	Mixture, including Gracilaria tikvahiae, Hypnea spp. Acanthophora spicifera	28.300028°	-80.613132°
Shorty' s Pocket 6	Mixture, including Gracilaria tikvahiae, Hypnea spp. Acanthophora spicifera	28.300028°	-80.613132°

yellow = cell death, active
purple = no death, inactive

Couplings Between Septic Tanks/IRL: Indian River County



- St. Sebastian River, 3 canals in IRF
- Wet season vs. dry season sampling
- Dissolved N and P in surface water and groundwater
- Sediment coprostanol (fecal sterol)
- Stable C and N isotopes in macroalgae
- Aqueous 15N in surface waters and groundwaters
- Optical brighteners

Can We Save the IRL ? A Case Study in Tampa Bay

- Watershed became urbanized between 1950s and 1980s
- Eutrophication caused algal blooms and seagrass loss
- Odor problems from decomposing macroalgae resulted in decision to remove N from sewage in 1979

Algal Blooms Decline, Seagrasses Expand

- Grizzle-Fig Act required AWT from sewage, decreased nutrients by 90%
- Improved urban, industrial and agricultural stormwater management
- 8,000 acres of seagrass recovery already achieved, 10,000 more acres will reach 1950s areal extent

TBEP & Partners Integrate Science & Management

Step 1. Set specific, quantitative seagrass acreage goal of 38,000 acres (95% of what existed in the 1950s)

Step 2. Determine the light requirements of the target seagrass species *(Thalassia testudinum)* in Tampa Bay

Step 3. Determine the water clarity levels necessary to provide adequate light to meet the seagrass acreage goals

Step 4. Determine maximum chlorophyll *a* concentrations that allow water clarity to be maintained at appropriate levels

Step 5. Determine maximum nutrient loadings that allow chlorophyll *a* targets to be achieved

Step 6. Implement the nitrogen (N) management strategy and assess its effectiveness

Nutrient Bioextraction With *Gracilaria* Aquaculture

- *Gracilaria* aquaculture in the Bronx River estuary in summer removes 2 kg N/ha/day (C. Yarish, pers. comm.)

- In the IRL, *Gracilaria* could potentially remove 4 kg N/ha/day (based on yield of 20 g dry wt/m^2/day and 2 %N of dry weight; Lapointe & Ryther 1978)

- To remove 1 million kg N year with *Gracilaria* aquaculture, need 694 hectare farm (1,700 acres)

- IMTA utilizing oyster/*Gracilaria* farms for nutrient bioextraction ?

IRL Summary

- DIN and SRP were at or above the threshold concentrations for the formation and maintenance of macroalgal blooms in the IRL

- N:P in seawater and algal tissue indicated strong P-limitation in the NIRL, BR and ML; N-limitation in CIRL and SIRL

- High (> 50 µM) TDN concentrations and N:P ratios in NIRL, BR and ML support brown tides, cyanobacteria blooms, toxins

- Enriched $\delta^{15}N$ values (> + 6 o/oo) in IRL macroalgae reflect high wastewater N loading to IRL (septic tanks, leaking sewage systems, re-use)

- IRL-wide program needed to address N reduction strategies, specifically focusing on wastewater sources (e.g. RNME)

Responsible Nutrient Management Entity (RNME)

- RNME is a collaborative/utility around which nutrient management and services can be holistically addressed

- Mechanism by which stakeholders in a watershed with a completed Total Maximum Daily Load (TMDL) and Basin Management Action Plan (BMAP) can address complex pollution reduction actions necessary to improve water quality

- Make specific watershed science-based decisions on use of non-central wastewater treatment such as septic tanks, cluster systems, advanced wastewater treatment plants to limit and reduce nutrient/pollutant impacts

- One-stop management entity for watershed-based responsible nutrient management which overtime uses a host of means to manage the inventoried populations of septic systems and nutrient contributors in a basin toward nutrient reduction(s).

60 Municipalities in Florida have passed strong fertilizer ordinances

INCLUDING	PROPOSED
Indian River County	Orchid Island
City of Vero Beach	Indian River Shores
St Lucie County	Brevard County
Martin County	Titusville
Sewall's Point	Cocoa Beach
City of Rockledge	Cape Canaveral
Satellite Beach	Grant/Valkaria
Melbourne Village	

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