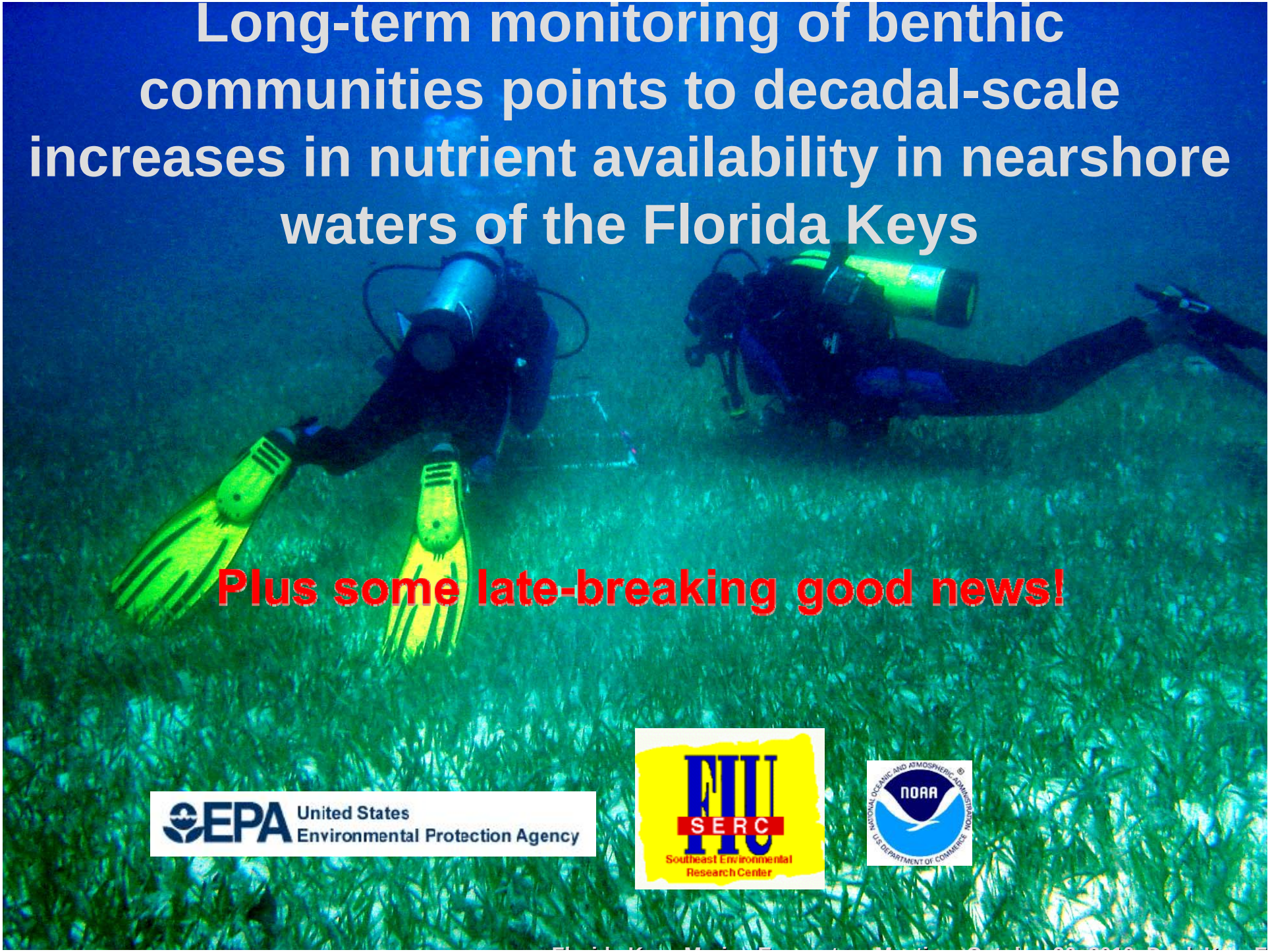
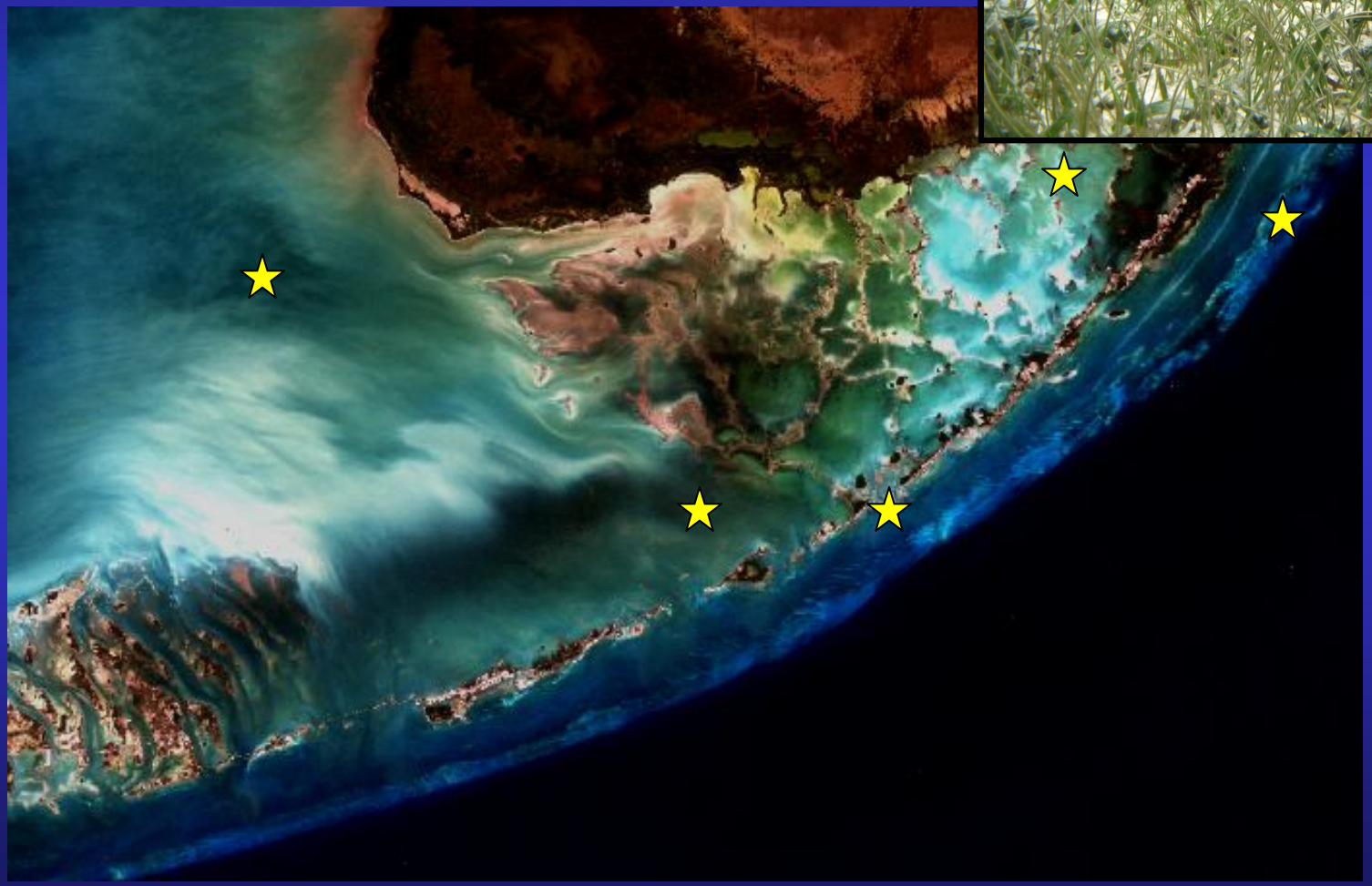
Long-term monitoring of benthic communities points to decadal-scale increases in nutrient availability in nearshore waters of the Florida Keys



A broad variety of seagrass habitats in south Florida



Goals for the project

- Define the present distribution of benthic communities within the FKNMS
- Provide high-quality, quantitative data on the status of the seagrasses within the FKNMS
- Quantify the importance of seagrass primary production in the FKNMS
- Define the baseline conditions for the seagrass communities of south Florida
- Determine relationships between water quality & benthic community status
- Detect trends in the distribution and status of the benthic communities

Attributes of a successful monitoring program

- **Predefined, management-oriented goals are essential**
- **Based on explicit models of system behavior**
- **Precise enough to allow for change detection**
- **Robust enough to survive changes in project personnel and funding levels**
- **Statistically defensible**
- **Provide information that can be used to inform resource managers of problems *before* undesirable changes occur.**

Fourqurean and Rutten, 2003. Competing goals of spatial and temporal resolution: monitoring seagrass ecosystems on a regional scale. In: Busch and Trexler, eds. Monitoring Ecosystems. Island Press.

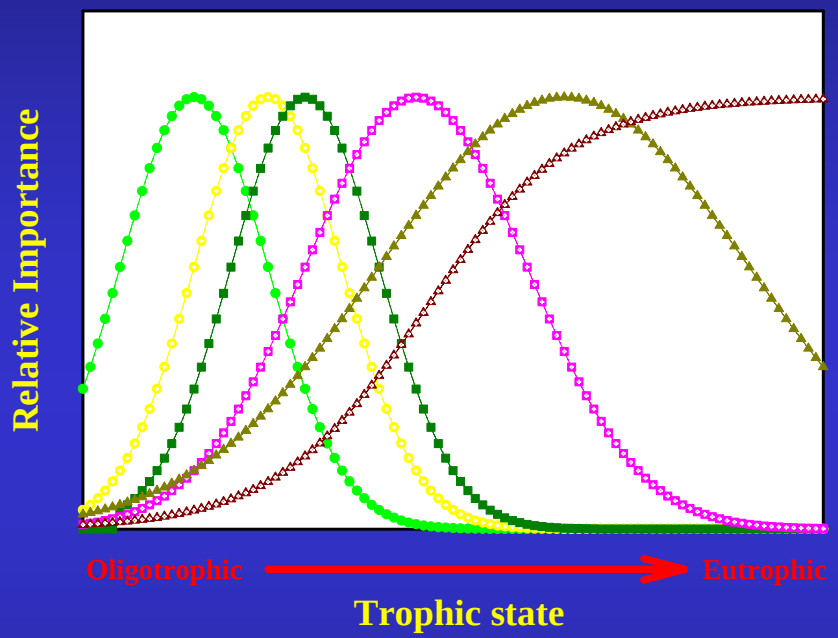
Information being collected

- Distribution & abundance of seagrasses and associated fauna and flora using rapid assessment Braun-Blanquet surveys (Mapping sites and permanent sites)

- Seagrass nutrient availability using tissue concentration assays and stable isotopic analyses (Mapping sites and permanent sites)

- Water column physicochemical data (discrete and continuous)

Eutrophication model

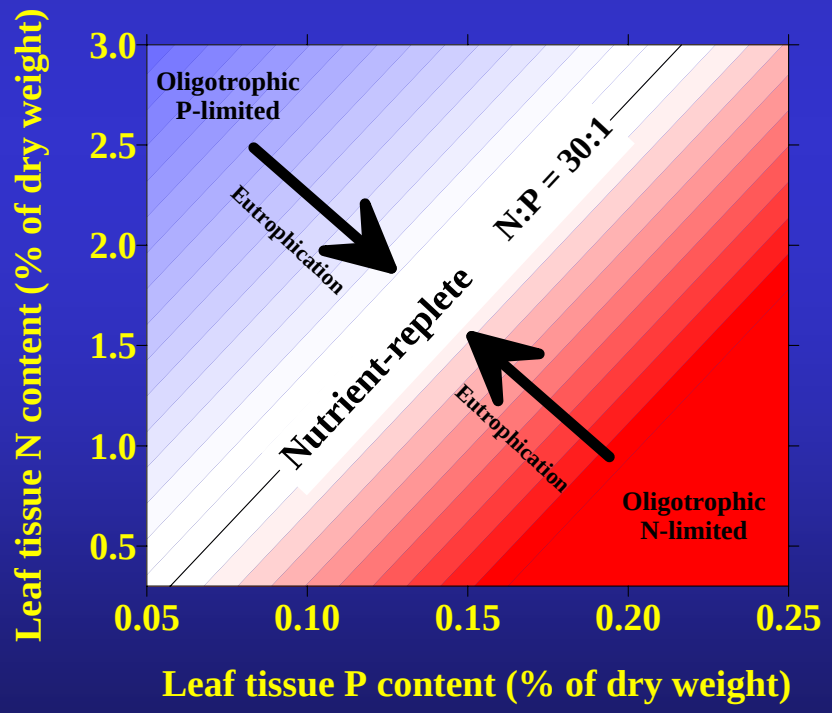


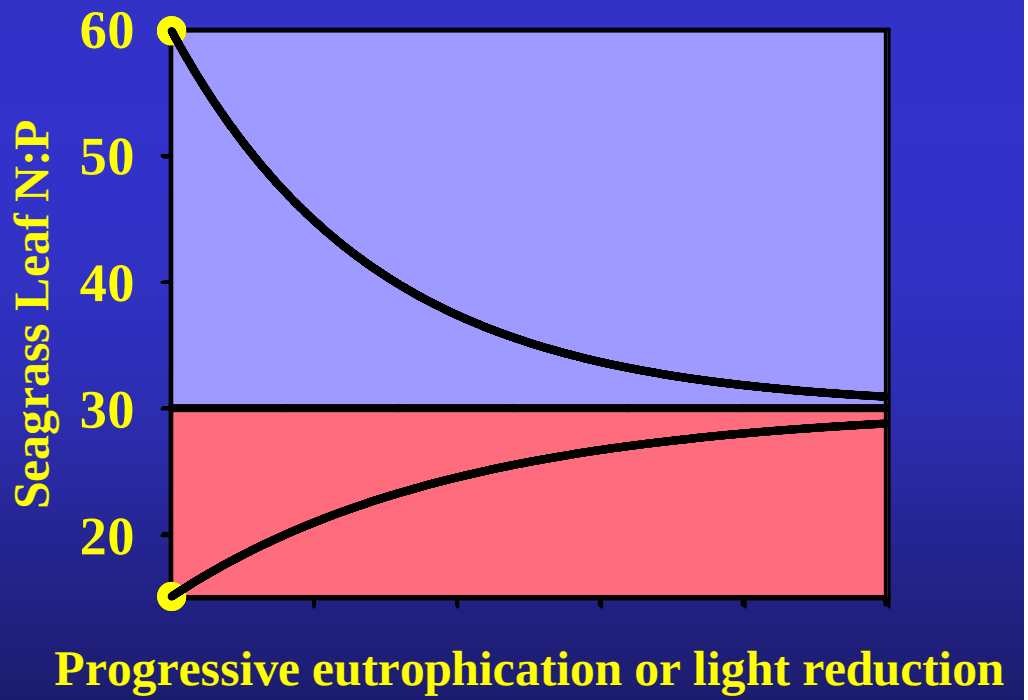
Explicit model of ecosystem behavior #1

Nutrient pollution will lead to changes in relative abundances of primary producers in a predictable way.

Explicit model of ecosystem behavior #2

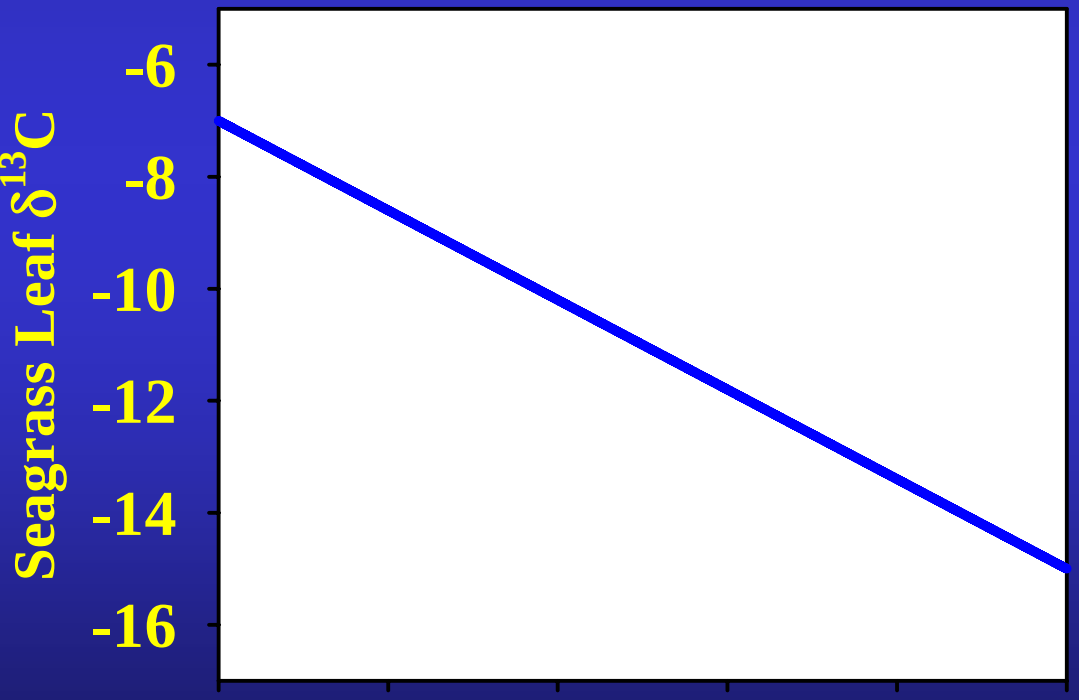
Nutrient pollution will shift N:P ratios of primary producers towards a taxon-specific "Redfield ratio"





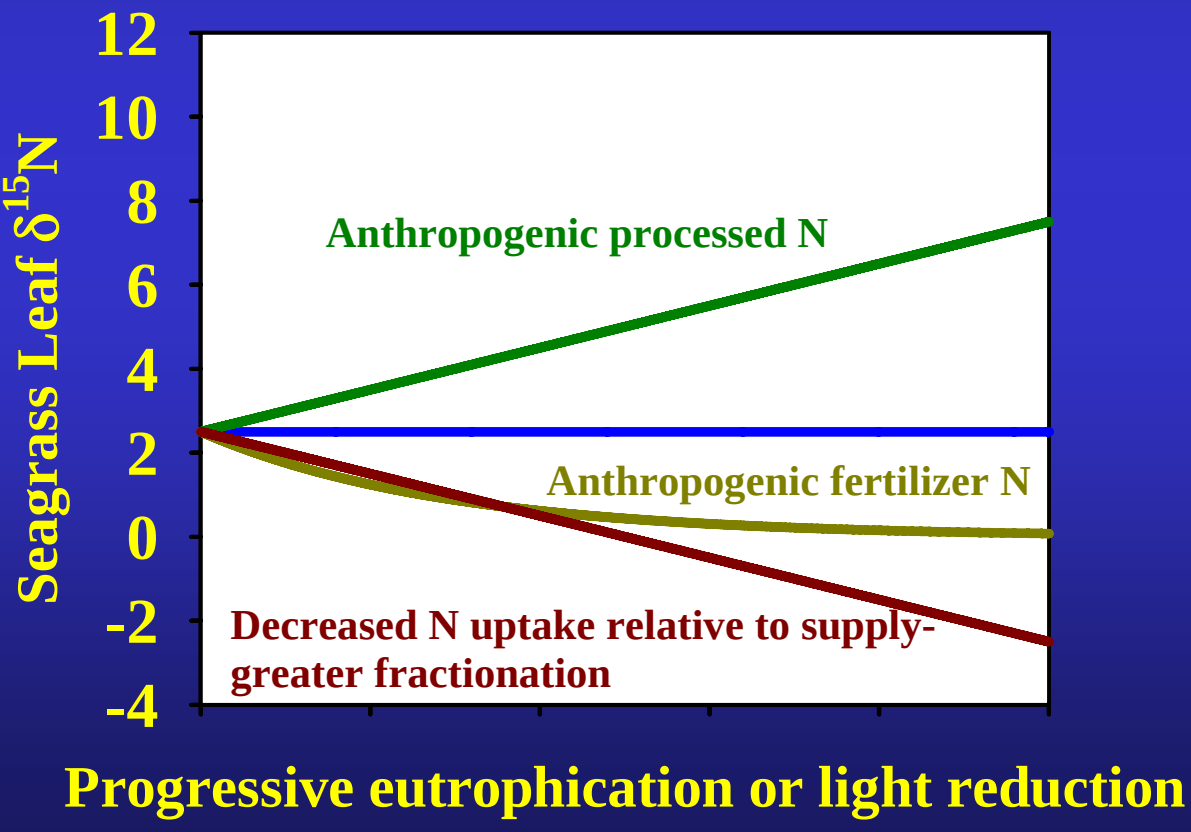
Explicit model of ecosystem behavior #3

Nutrient pollution will shift seagrass $\delta^{13}C$ towards more negative values because of increased discrimination against ^{13}C in low light conditions



Not-so-Explicit model of ecosystem behavior #4

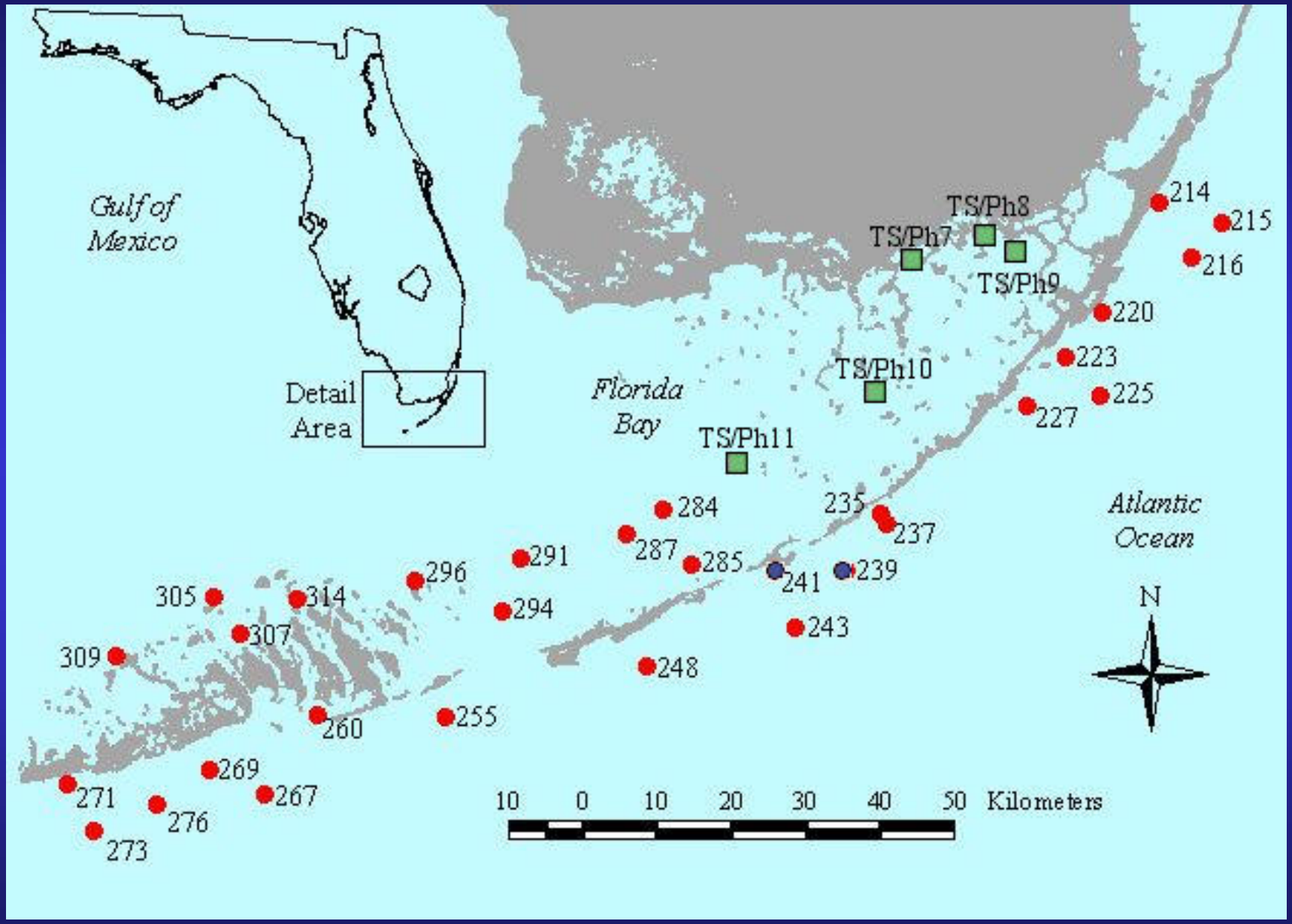
Nutrient pollution will cause some kind of change in $\delta^{15}N$ of primary producers



Monitoring strategy

Given that it is not possible to measure everything, everywhere, all the time:

- **Limited resources had to be allocated to addressing the competing goals of spatial comprehensiveness and temporal sensitivity.**
- **Spatial comprehensiveness assured by adopting a distributed, stratified-random site selection procedure for "synoptic mapping" sites (EMAP)**
- **Temporal sensitivity assured by concentrating some of the sampling effort on randomly-selected, permanent sites**


Gulf of Mexico
Detail Area
Florida Bay
Atlantic Ocean
TS/Ph7
TS/Ph8
TS/Ph9
TS/Ph10
TS/Ph11
214
215
216
220
223
225
227
235
237
239
241
243
248
284
285
287
291
294
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267
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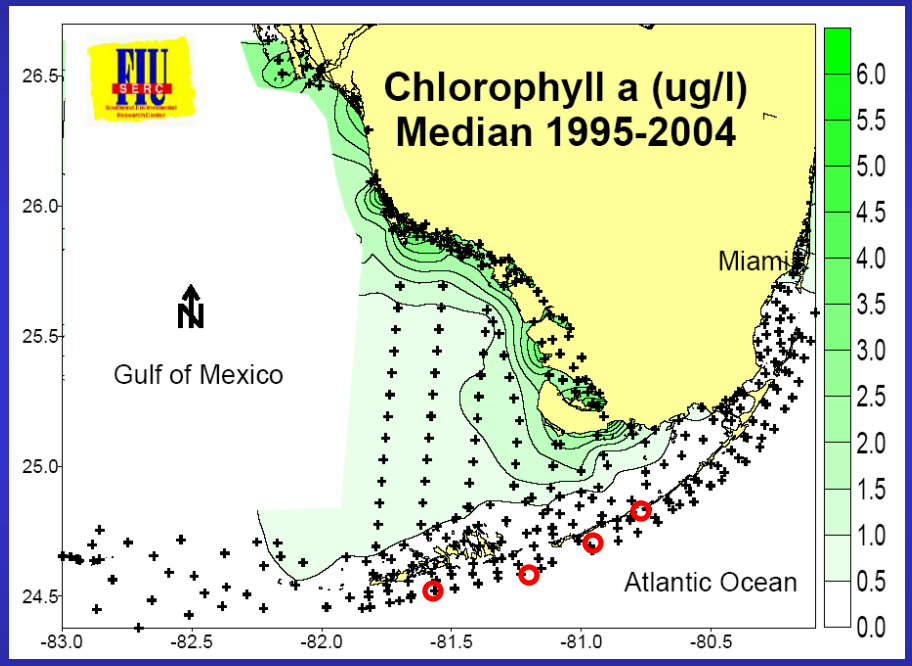
271
273
276
N
10 0 10 20 30 40 50 Kilometers

Changes in relative abundance of primary producers #1



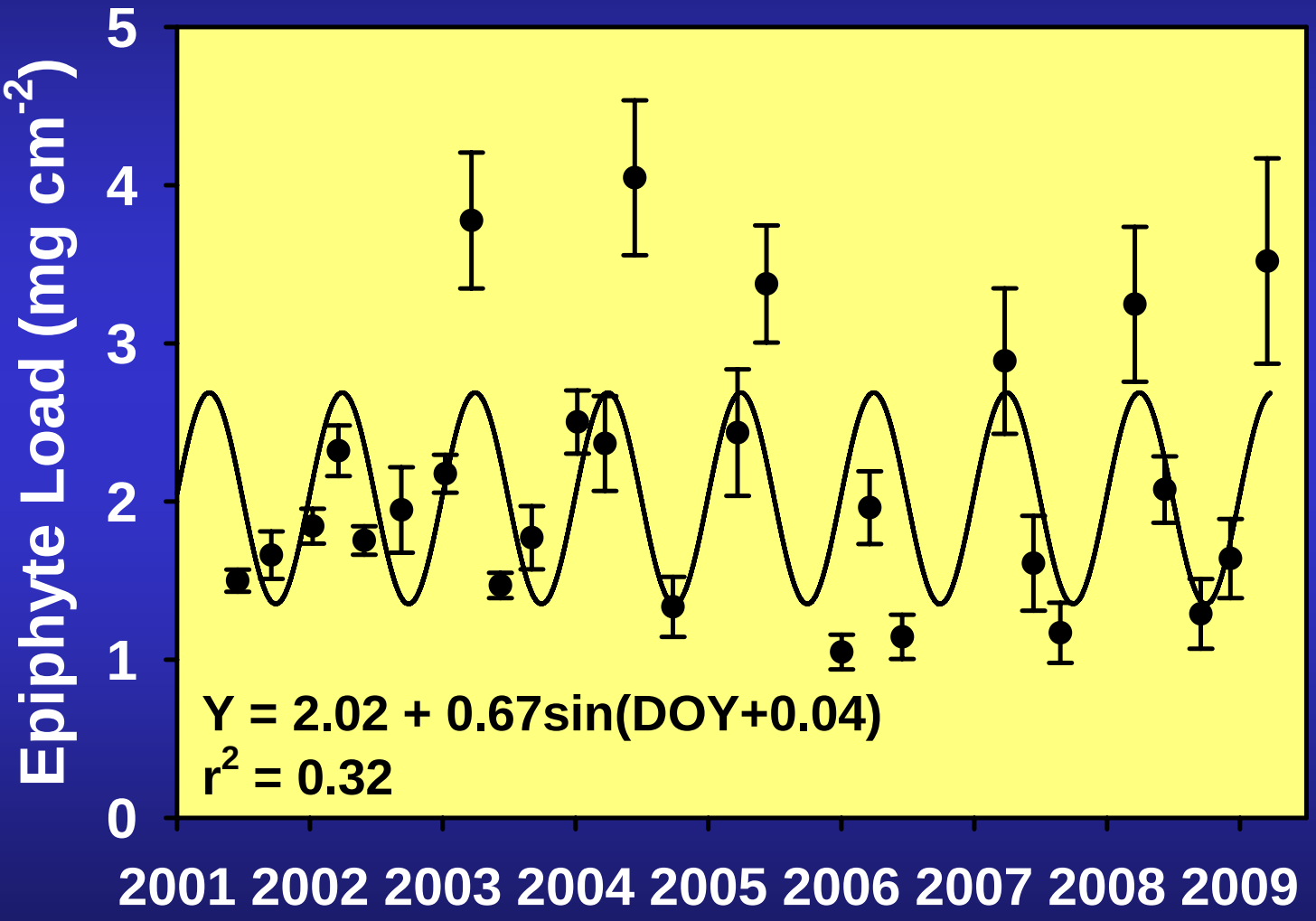
Phytoplankton concentrations are low across the system, and there are no sites with a significant increase in Chl-*a* over the time period.

In fact, at four of our monitoring sites, there has been a statistically significant decrease in Chl-a over the period (slopes of -0.03 μg $l^{-1}y^{-1}$)

Data from FKNMS water quality monitoring program

Changes in relative abundance of primary producers #2

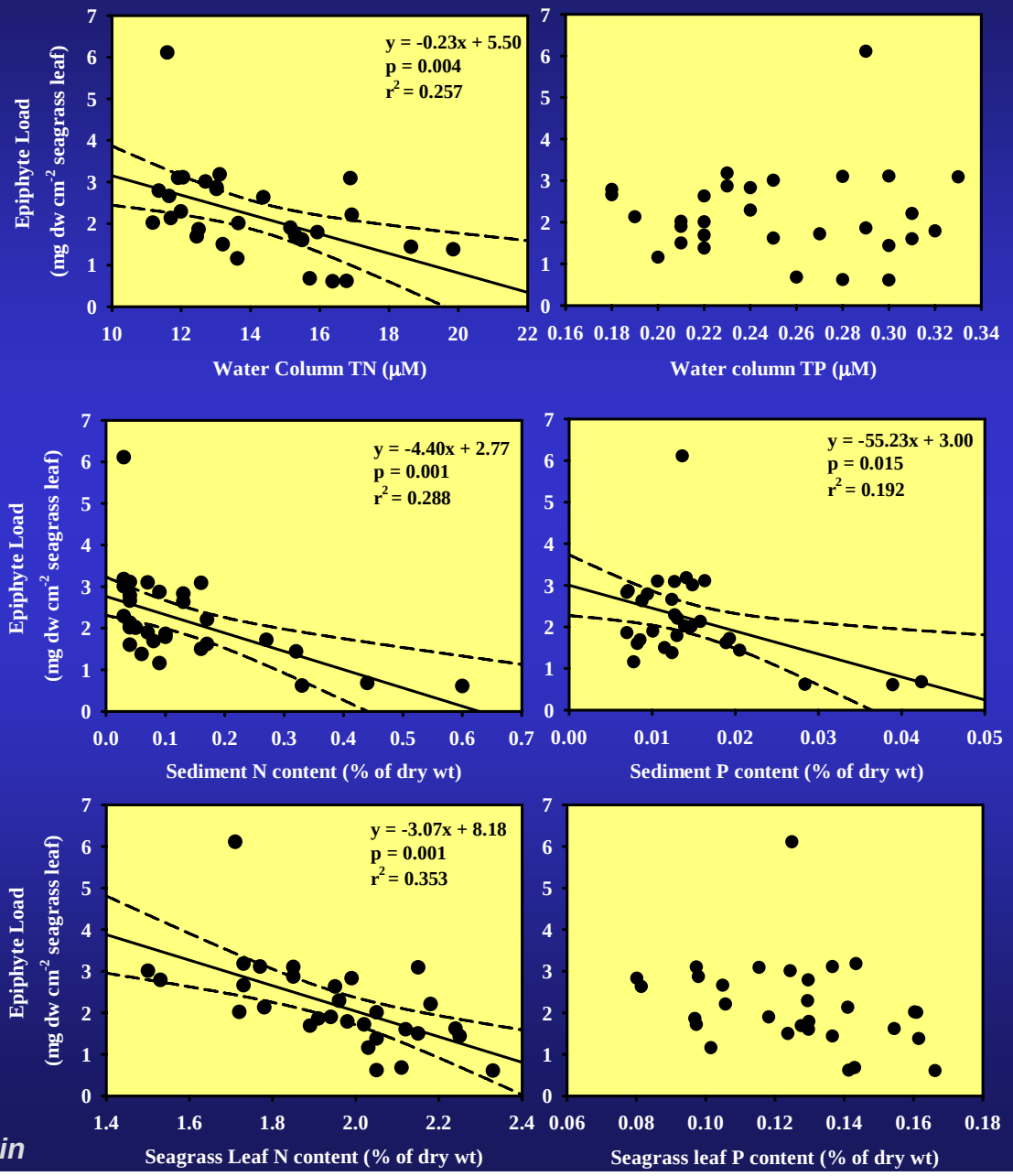
Epiphyte loads are highly seasonal in the FKNMS



Fourqurean et al. 2010 Marine Pollution Bulletin

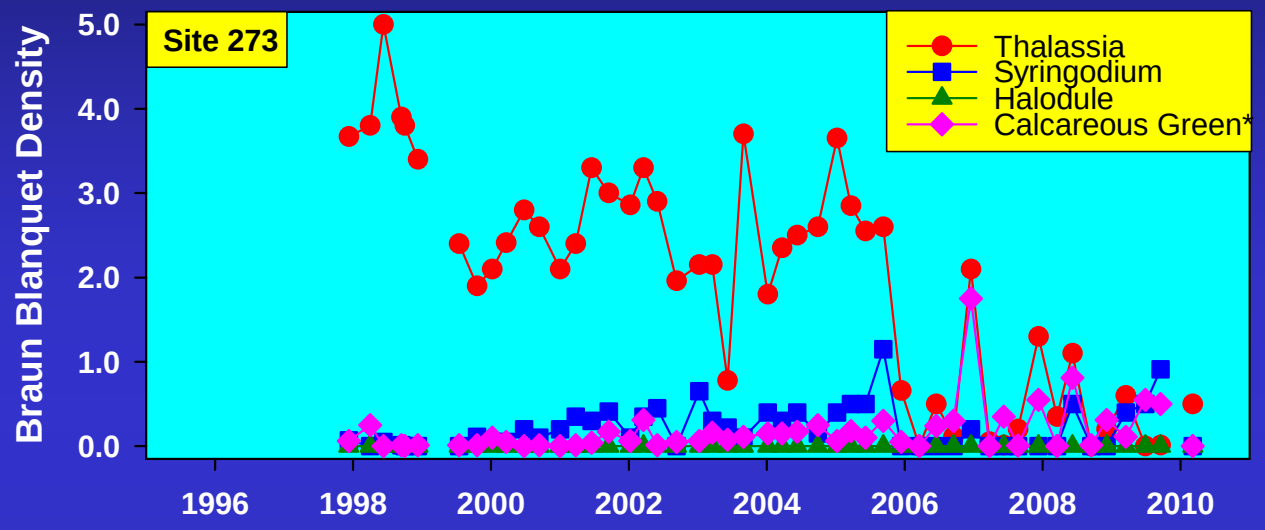
Changes in relative abundance of primary producers #3

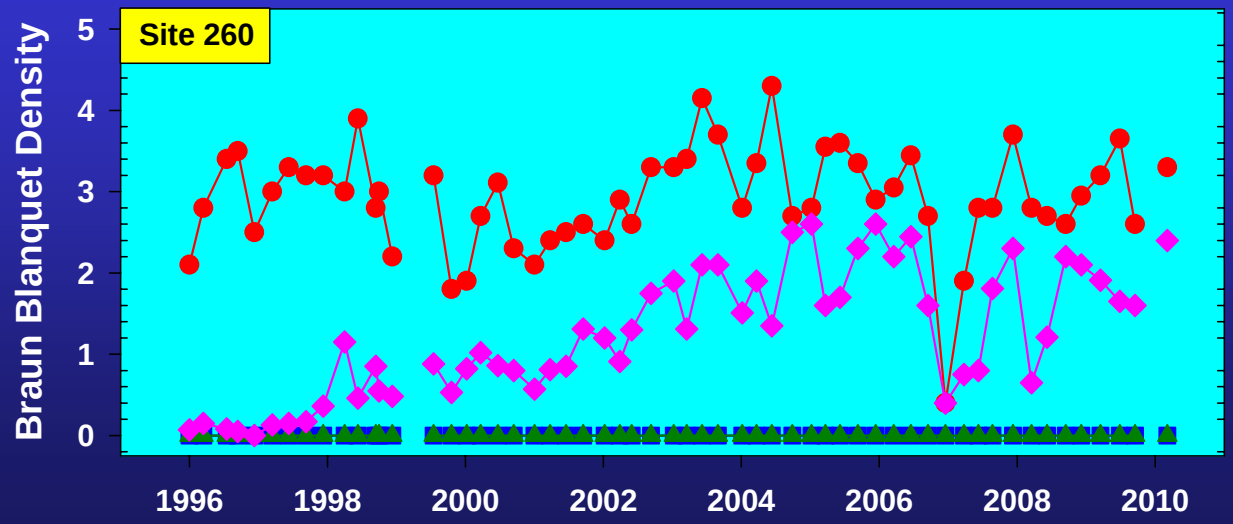
Unlike more eutrophic systems, epiphyte loads are not correlated with increased nutrient loads at the scale of our sampling in the FKNMS



Fourqurean et al. 2010 Marine Pollution Bulletin

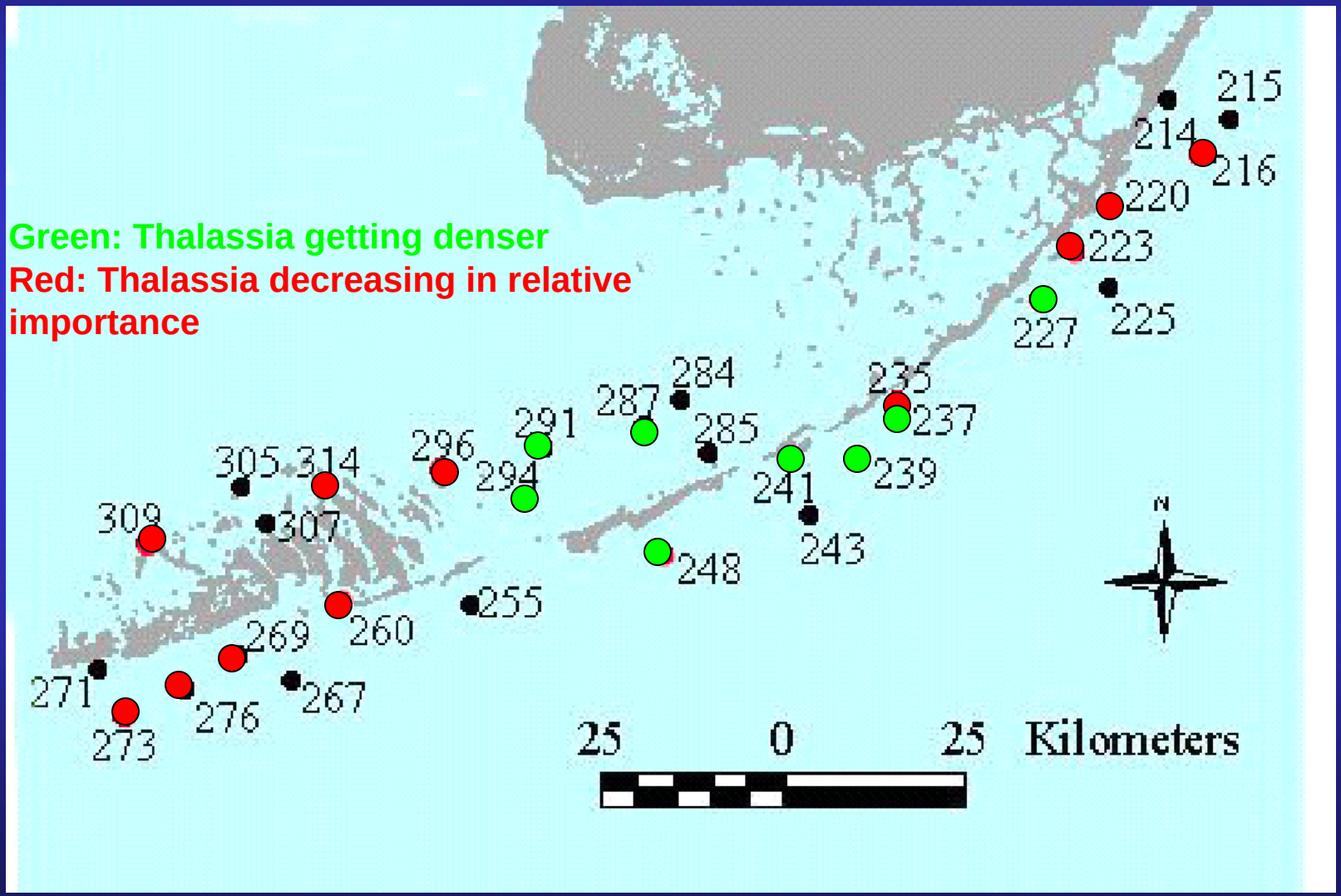
Changes in relative abundance of primary producers #4



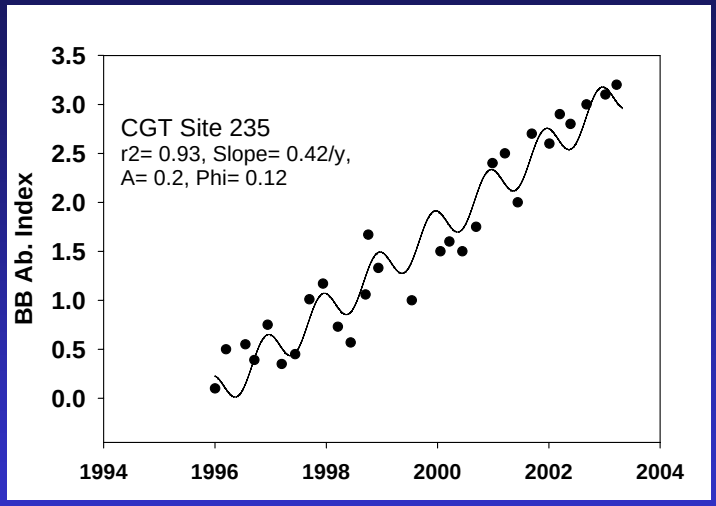


Changes in relative abundance of primary producers #2

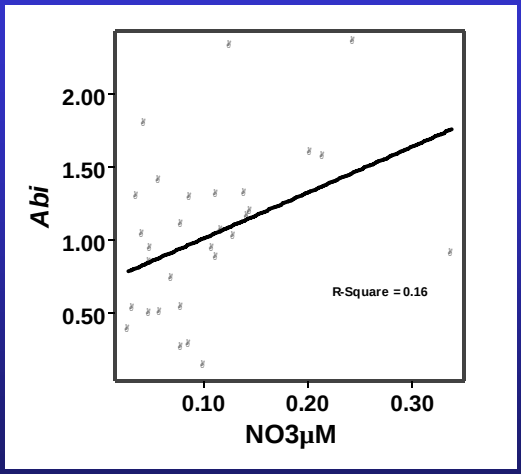
At 19 of 30 sites, species composition has shifted in a manner consistent with increased nutrient availability (19 of 30 in 2008, 13 of 30 in 2007)



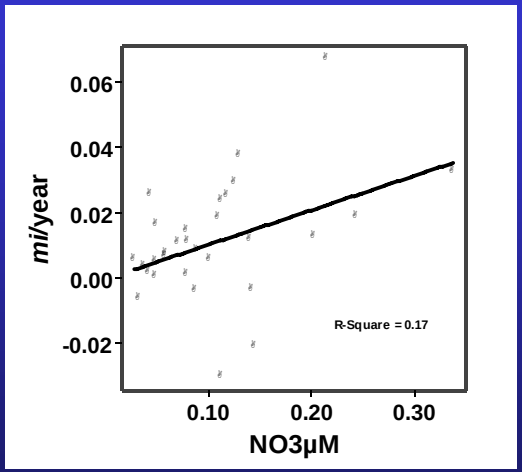
What do the stations with increasing abundance of fast-growing algae have in common?



Algae are more abundant in high nitrogen areas



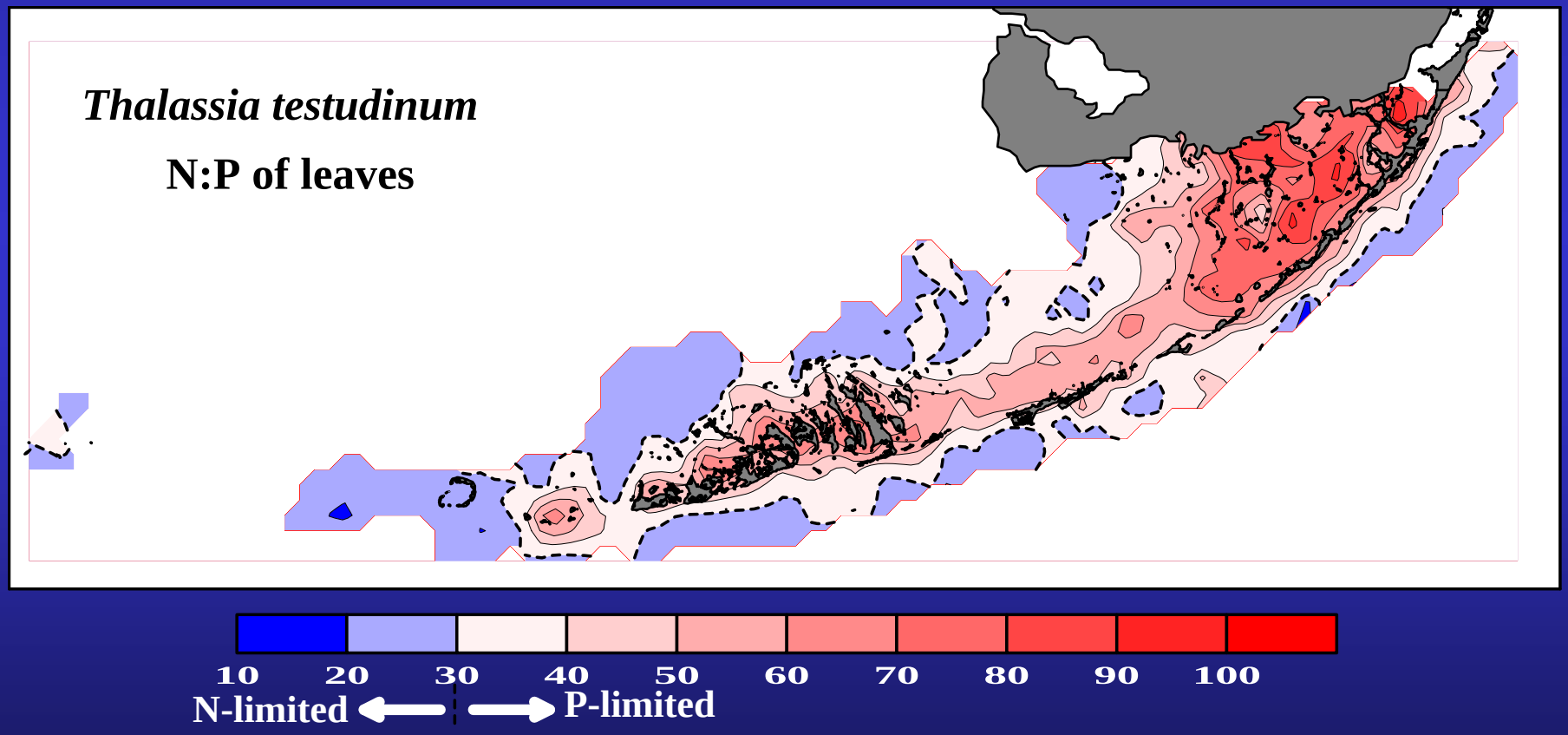
…and high-N stations have higher increases in algae



Collado-Vides et al. 2007, Estuarine Coastal and Shelf Science

Changes in N:P of primary producers #1:

There is a spatial pattern in the relative availability of N and P

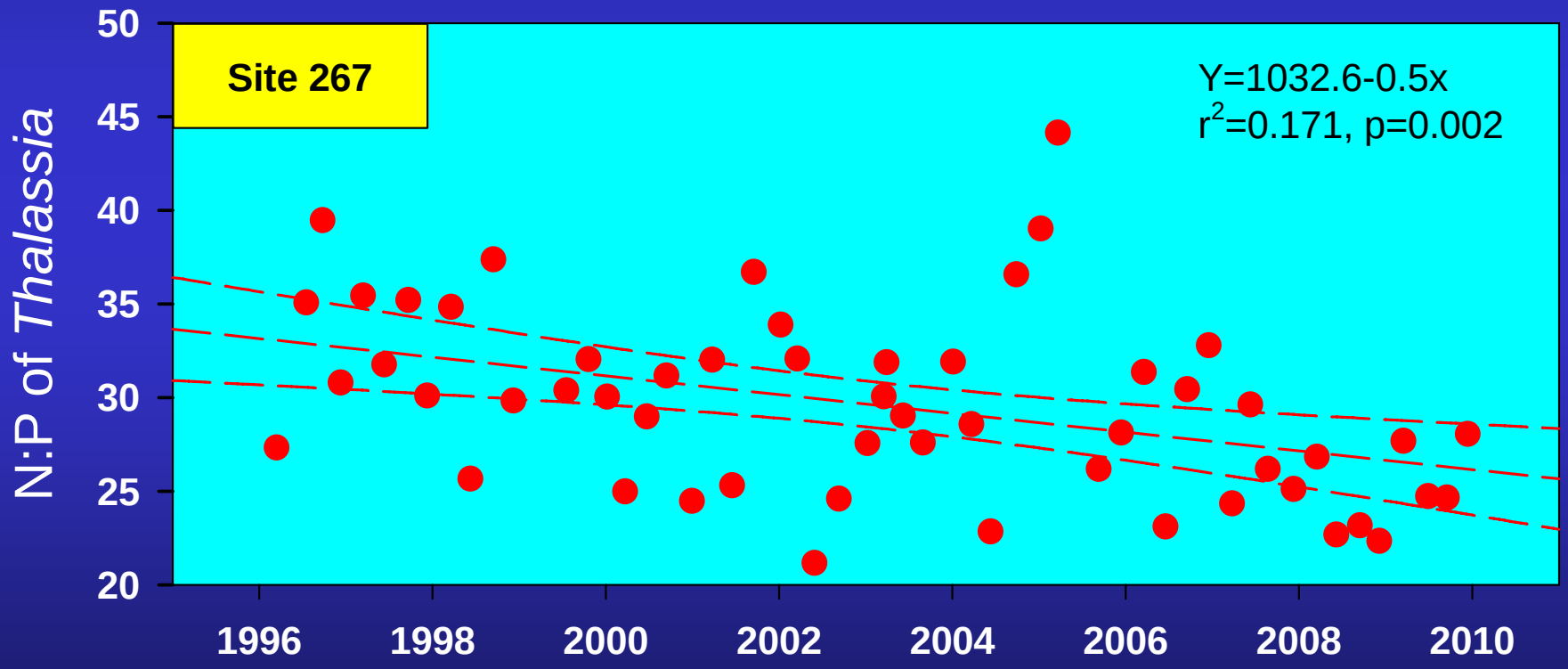


Fourqurean et al Estuaries 2005

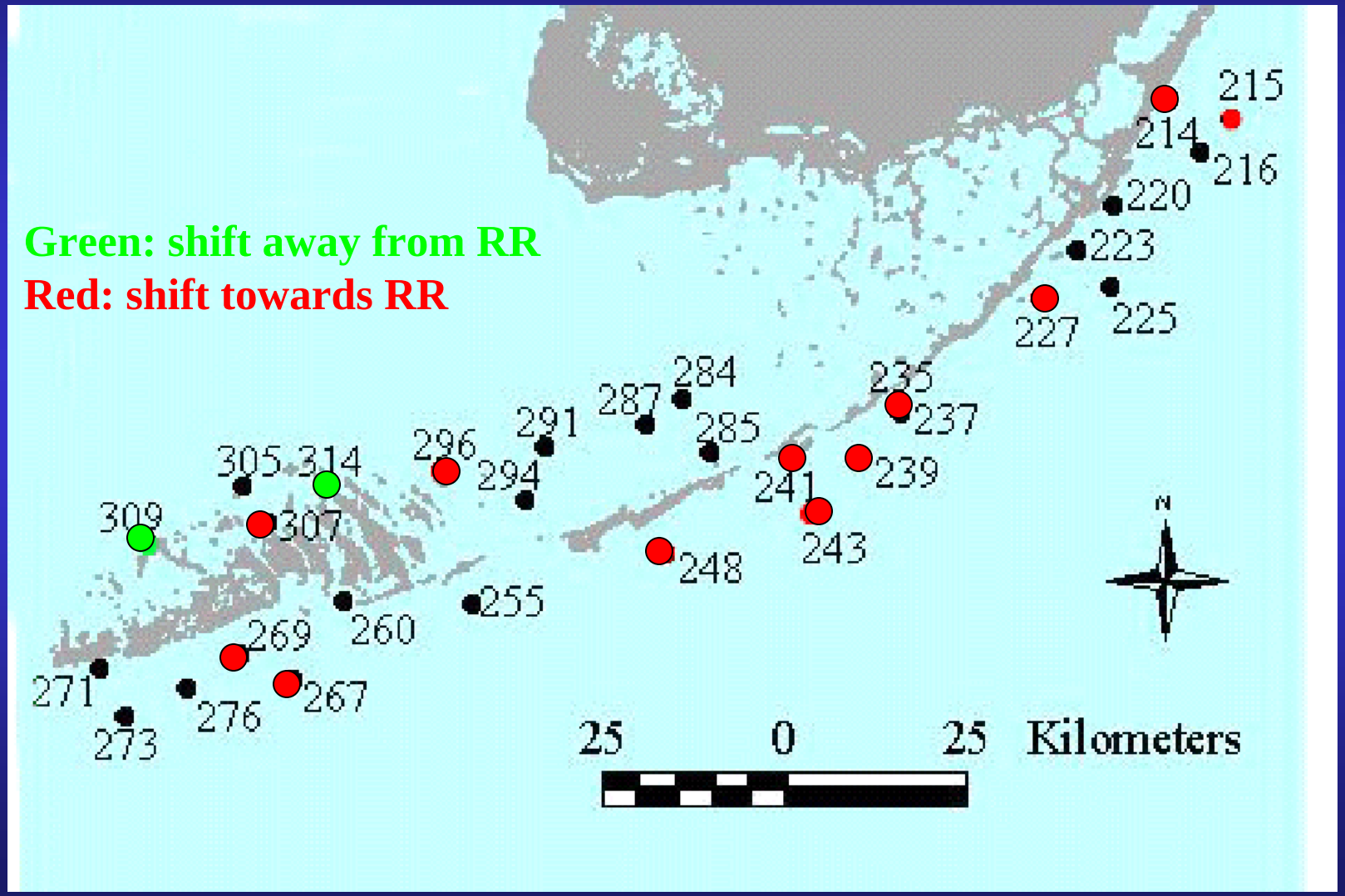
Changes in N:P of primary producers #2:

At 13 of 30 sites, N:P is trending towards “seagrass Redfield ratio”

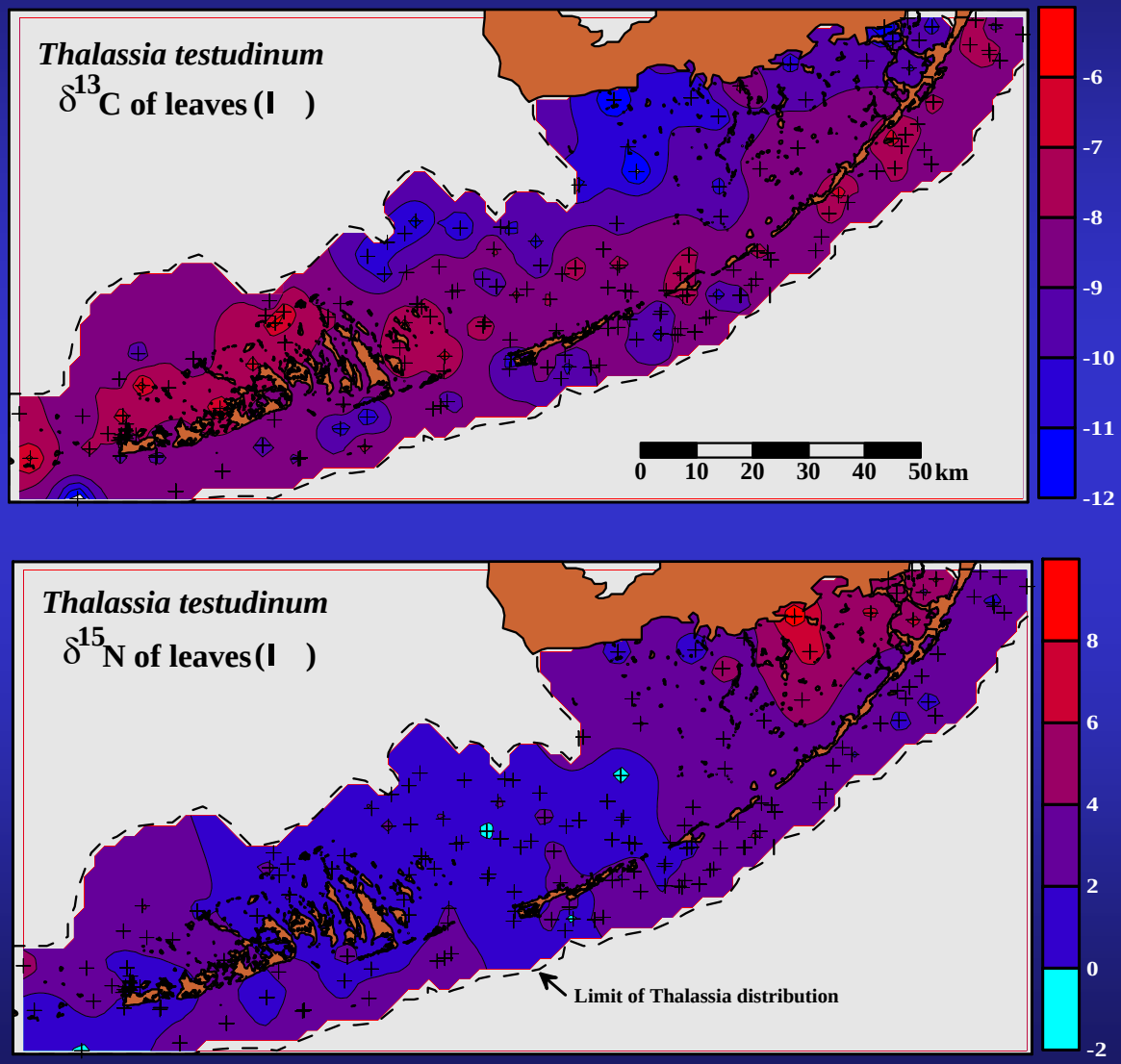
(10 of 30 in 2008, 5 of 30 in 2007)



Changes in N:P of primary producers #3:



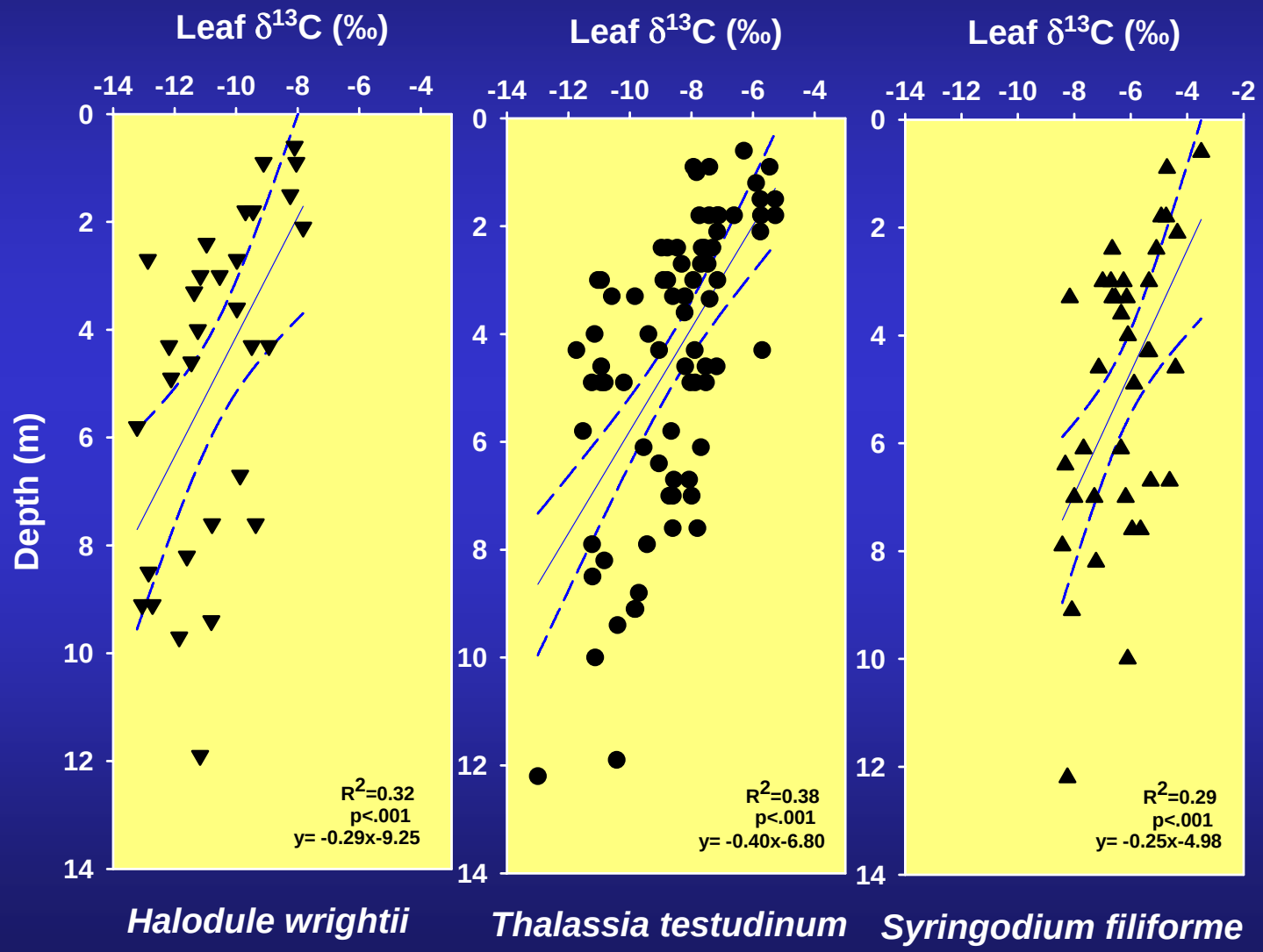
Spatial patterns in stable isotope ratios in south Florida



Fourqurean et al Estuaries 2005

Changes in $\delta^{13}C$ of primary producers #1:

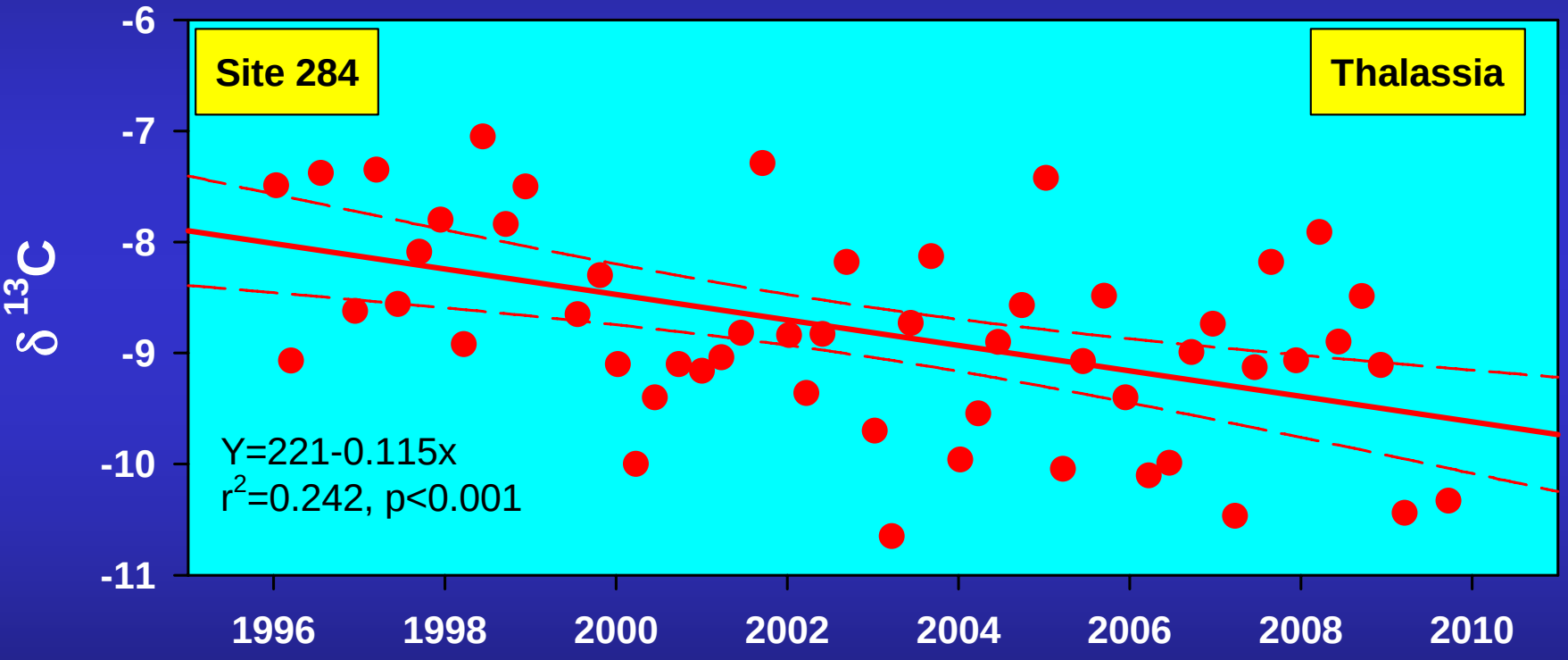
As light decreases with depth, $\delta^{13}C$ decreases



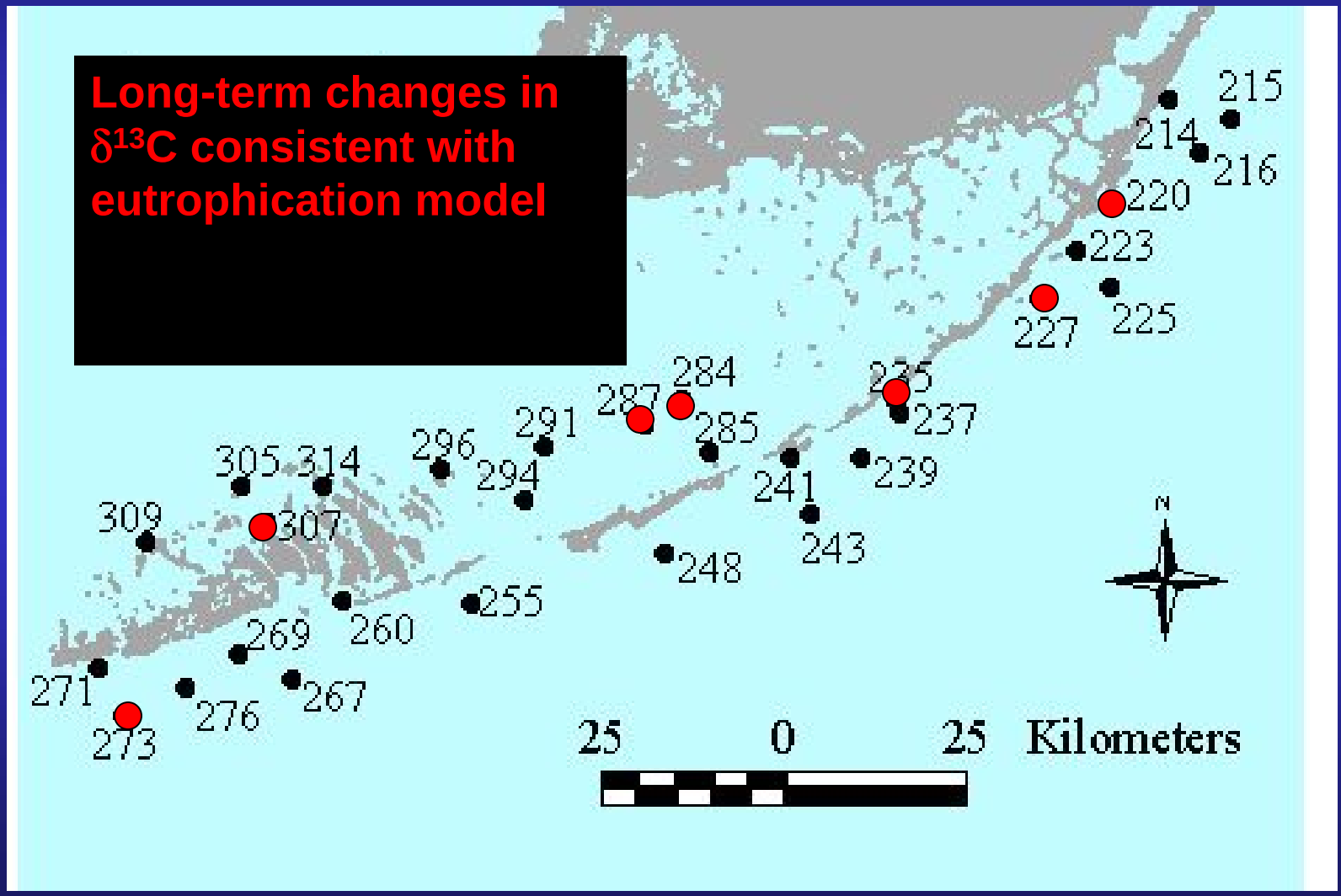
Campbell and Fourqurean, 2009, MEPS

Changes in $\delta^{13}C$ of primary producers #2:

At 7 of 30 sites, significant $\delta^{13}C$ trends consistent with eutrophication (7 of 30 last year)

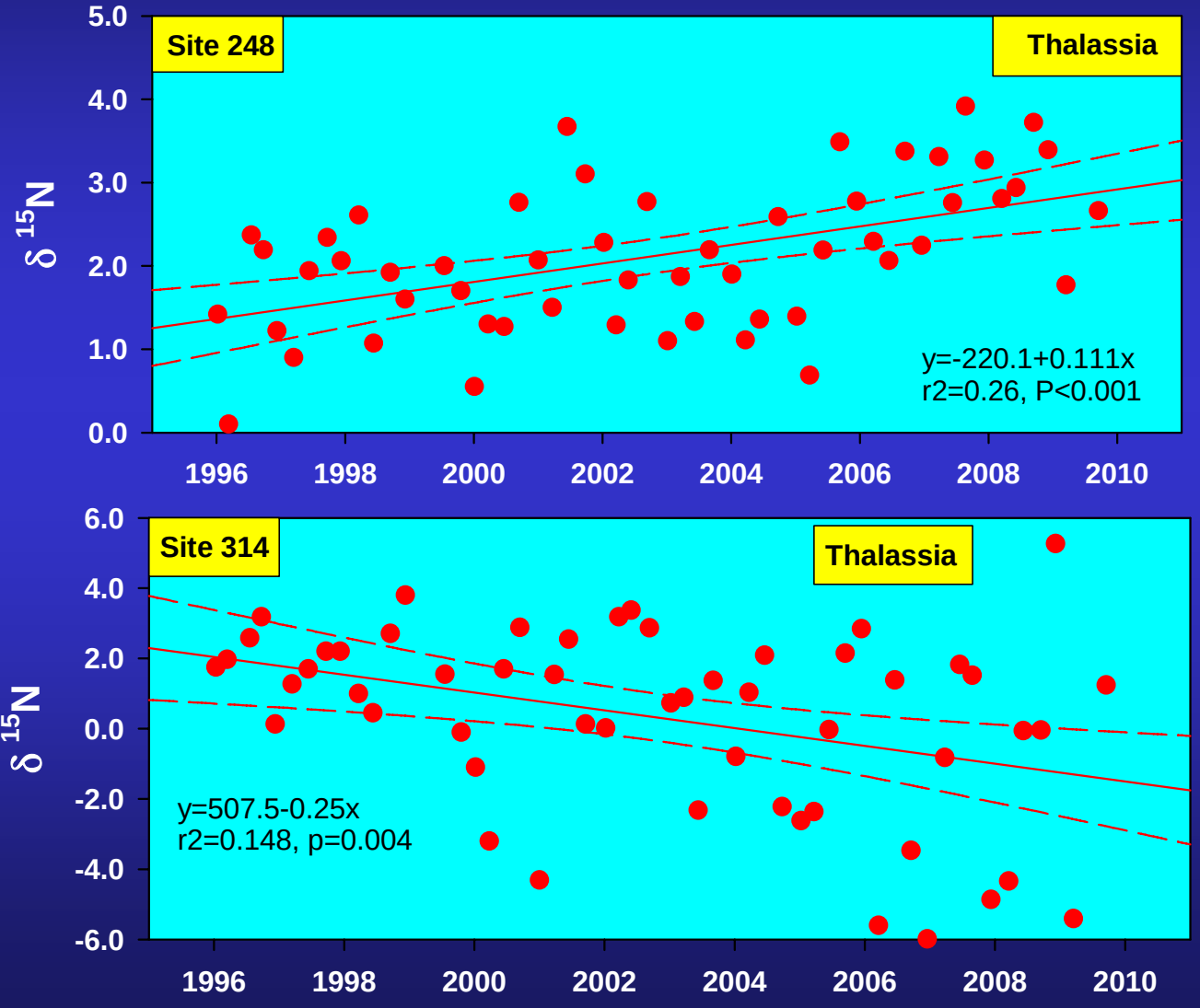


Changes in $\delta^{13}C$ of primary producers #2

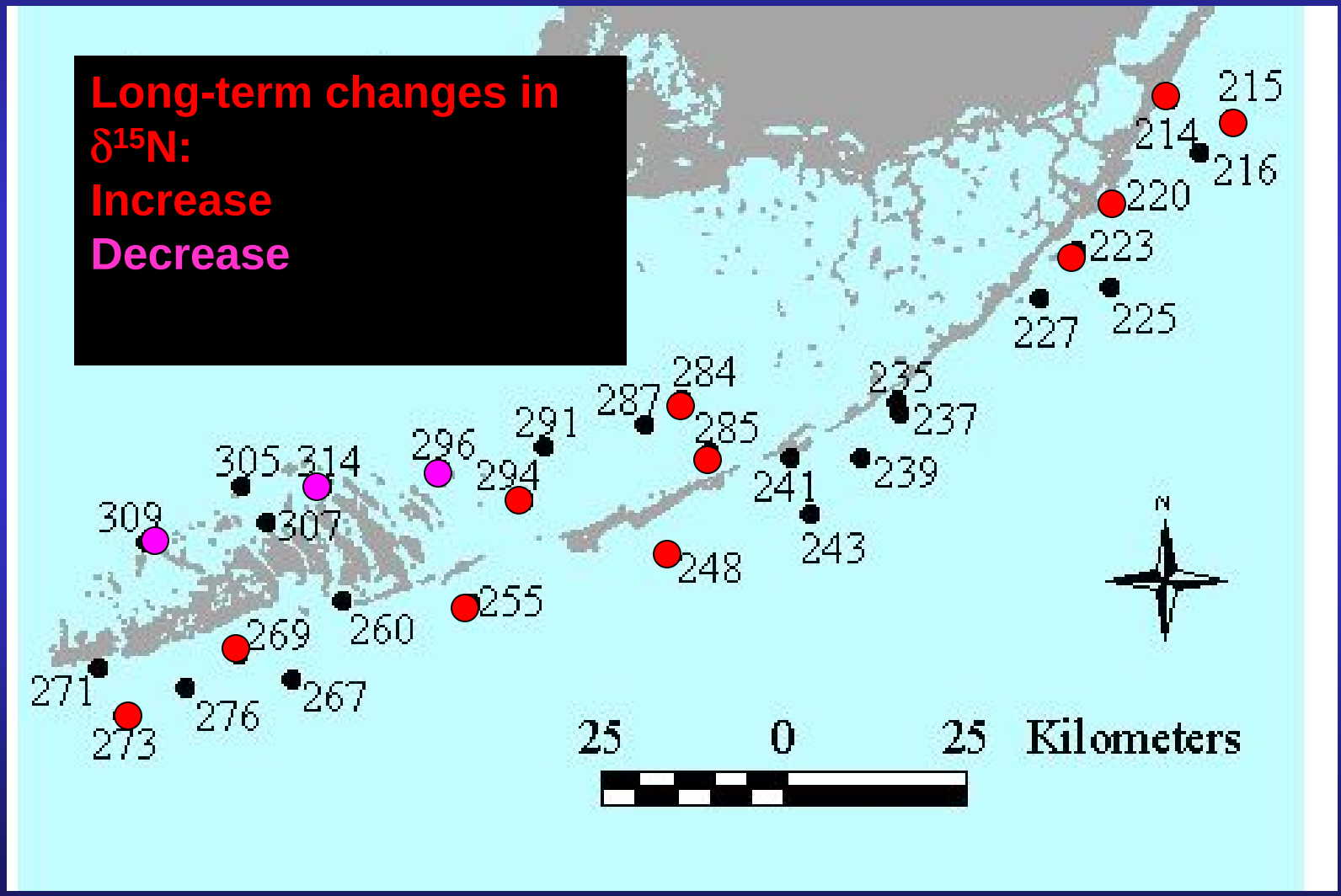


Changes in $\delta^{15}N$ of primary producers #1:

14 of 30 sites show significant trends in $\delta^{15}N$ (15 of 30 last year)



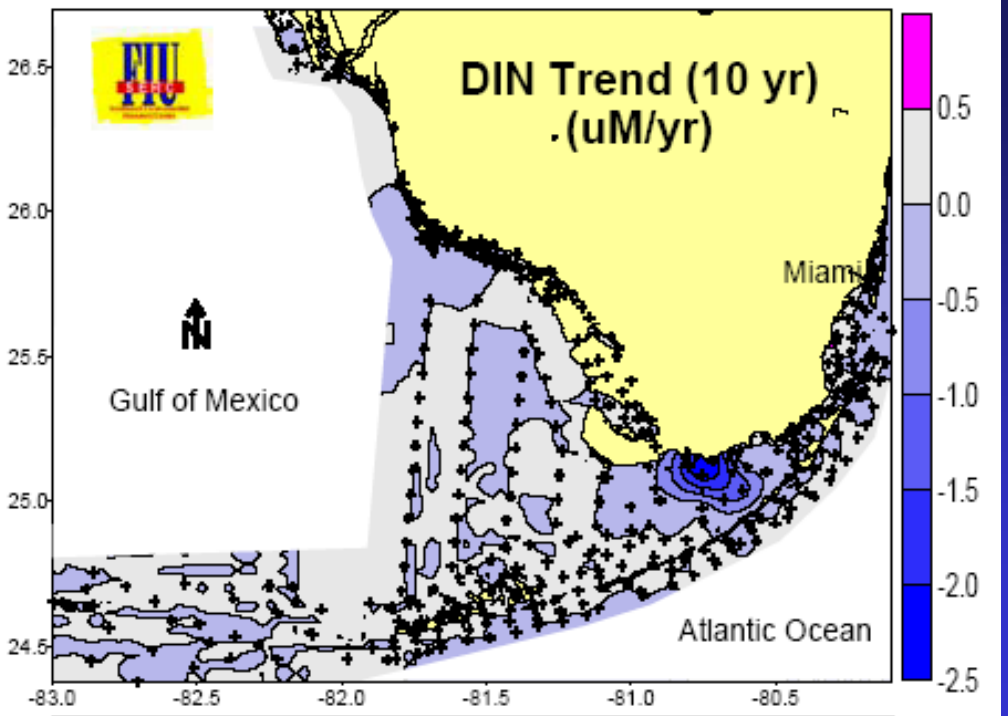
Changes in $\delta^{15}N$ of primary producers #2

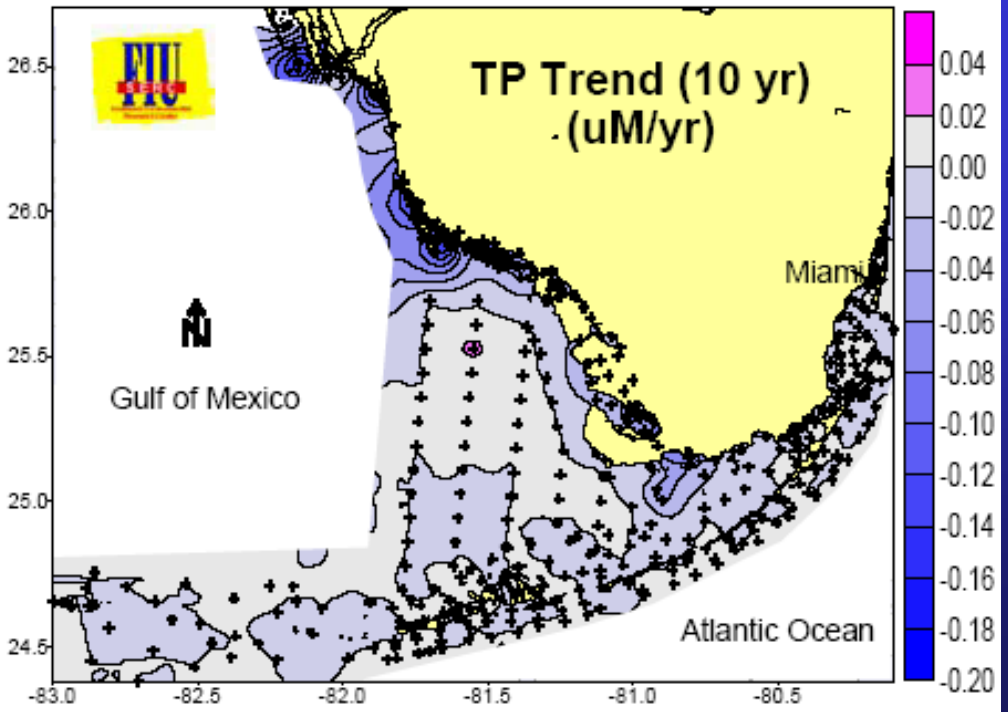


Site-specific indicator summary 1995-2009

Site	N:P	SCI	$\delta^{13}C$	$\delta^{15}N$
214				+
215				+
216				
220			-	+
223				+
225				
227			-	
235			-	
237				
239				
241				
243				
248				+
255				+
260				

Site	N:P	SCI	$\delta^{13}C$	$\delta^{15}N$
267				
269				+
271				
273				+
276				
284			-	+
285				+
287			-	
291				
294				+
296				-
305				
307			-	
309				-
314	+			-

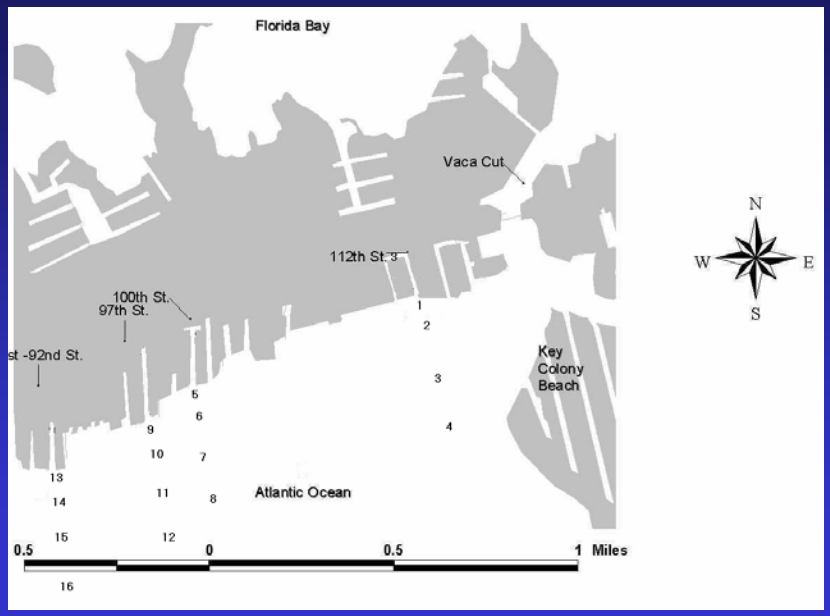




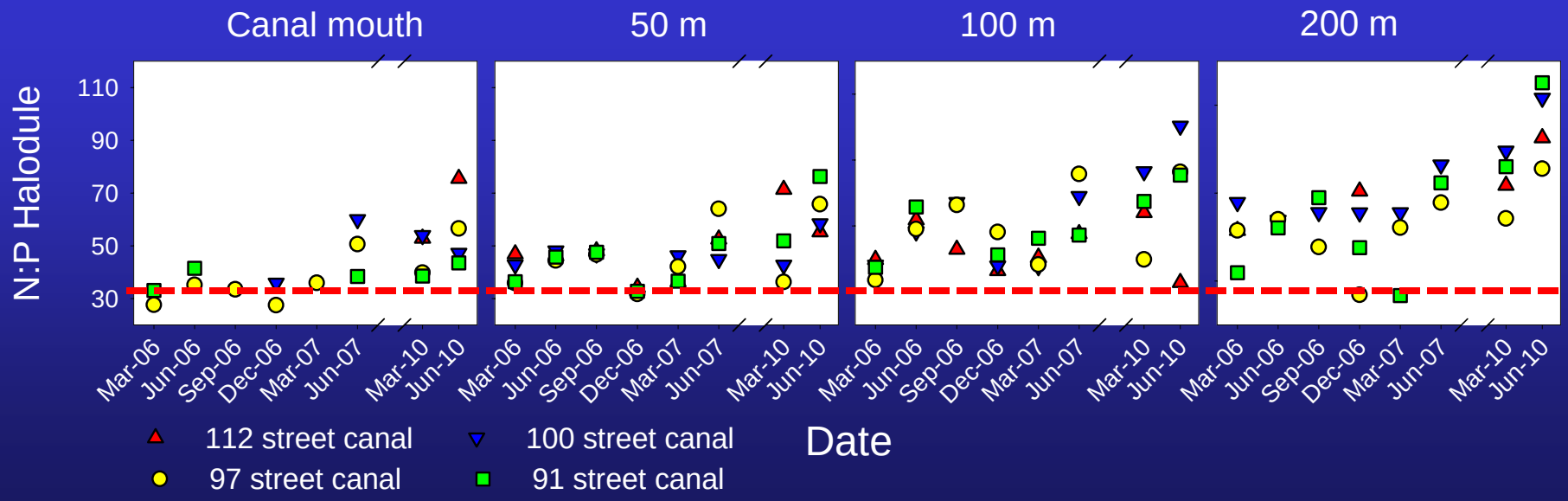
Our benthic indicators of eutrophication of the system are measuring troubling changes, even in the absence of trends in water quality

Is the benthos more sensitive to changes in nutrient loading than water column nutrient concentrations?

Are we perhaps merely measuring a long-term cyclicity of the seagrasses of south Florida?



Little Venice demonstration project Sewered in 2004



Summary points

- **Rapid population increases adjacent to oligotrophic marine ecosystems in south Florida *may* have deleterious effects on those ecosystems**
- **Changes are occurring in south Florida seagrass beds that are consistent with increased nutrient availability in the system – *but few increases have been observed in the water column***
- **These changes are relatively subtle, we have not witnessed loss of seagrass beds in this regional and decadal scale program. *There is time to act!***
- **Many different factors can influence our indicators that are independent of the main management concern – anthropogenic nutrient enrichment**
- **Congruence of patterns among independent indicators increases confidence in the observations**
- **Replacement of septic tanks by sewage collection will decrease nutrientetn availability in nearshore waters**

Web accessibility of data and reports: www.fiu.edu/~seagrass