FKNMS
Benthic Habitat Monitoring Program

Jim Fourqurean
Sara Wilson
Chris Lopes
Johannes Krause

Institute of Environment, Florida International University

Summer 2021 WQPP steering committee meeting, July 23 2021

Goals for the project

As originally envisioned in 1995, the goal was to address these points at the <u>regional</u> scale:

- **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**

Information being collected

- Distribution & abundance of seagrasses and associated fauna and flora using rapid assessment Braun-Blanquet surveys
  - 40 permanent sites 2 times a year

- Seagrass nutrient availability using tissue concentration assays and stable isotopic analyses
  - 40 permanent sites 2 times a year
  - Ca. 200 mapping sites/year

- Water column physicochemical data
  - Sites co-located with water quality sites
  - 40 permanent sites 2 times a year in addition to quarterly water quality sampling (Briceño)

	Economics	Human health	FKNMS health
Leading indicator	Retail sales	Tobacco use	$\delta^{13}C$ (light availability)
Lagging indicator	GDP	Cancer death	Seagrass areal extent

- **Leading indicators are considered to point toward future events:** retail sales, tobacco use, seagrass $\delta^{13}C$

- **Lagging indicators are seen as confirming a pattern that is in progress:** change in GDP, cancer death, Loss of Seagrass area

- **Leading indicators can help guide choices that can influence the state of laggining indicators before they happen**

Leading indicators of Seagrass status

Property	Indicative of	References
Species composition	Light availability: Species specific light requirements	Wiginton and McMillan 1979
	Nutrient availability: higher nutrient availability favors faster growing taxa	Powell et al. 1989; 1991; Fourqurean et al. 1995
	Selective herbivory: most herbivores prefer high-nutrient, faster-growing taxa	Mariani and Alcoverro 1999; Armitage and Fourqurean 2006; Kelkar et al. 2013;
	Herbivory: Herbivores create conditions that favor faster-growing species	Molina Hernández and van Tussenbroek 2014
Elemental stoichiometry (C:N:P)	Relative availability of nutrients and light: High light drives increases in C:N and C:P, higher nutrient availability drives decreases in C:N, C:P	Duarte 1990; Fourqurean and Rutten 2003; Campbell and Fourqurean 2009
	Herbivory: Herbivores remove older tissues lower in nutrients, leading to decreases in C:N and C:P in grazed plants	Thayer et al. 1984; Moran and Bjorndal 2007; Burkholder et al. 2012; Holzer and McGlathery 2016; Mutchler and Hoffman 2017
$\delta^{13}C$	Light availability: Seagrasses from high light environments have less negative $\delta^{13}C$	Cooper and DeNiro 1989; Abal et al. 1994; Hu et al. 2012; Campbell and Fourqurean 2009
$\delta^{15}N$	N source: Wastewater pollution leads to increased $\delta^{15}N$; fertilizer pollution can decrease $\delta^{15}N$	McClelland et al. 1997
Leaf length	Light availability and Herbivory: Shortens leaves	Fourqurean et al. 2010
Leaf width	Low light and Herbivory: Leaves become narrower on grazed plants, low light narrows leaves	Thayer et al. 1984; Zieman et al. 1984; Moran and Bjorndal 2005; Fourqurean et al. 2010; Holzer and McGlathery 2016;
Area per short shoot	Low light and Herbivory: Grazed plants have less area per shoot, low light results in smaller plants	Fourqurean et al. 2010

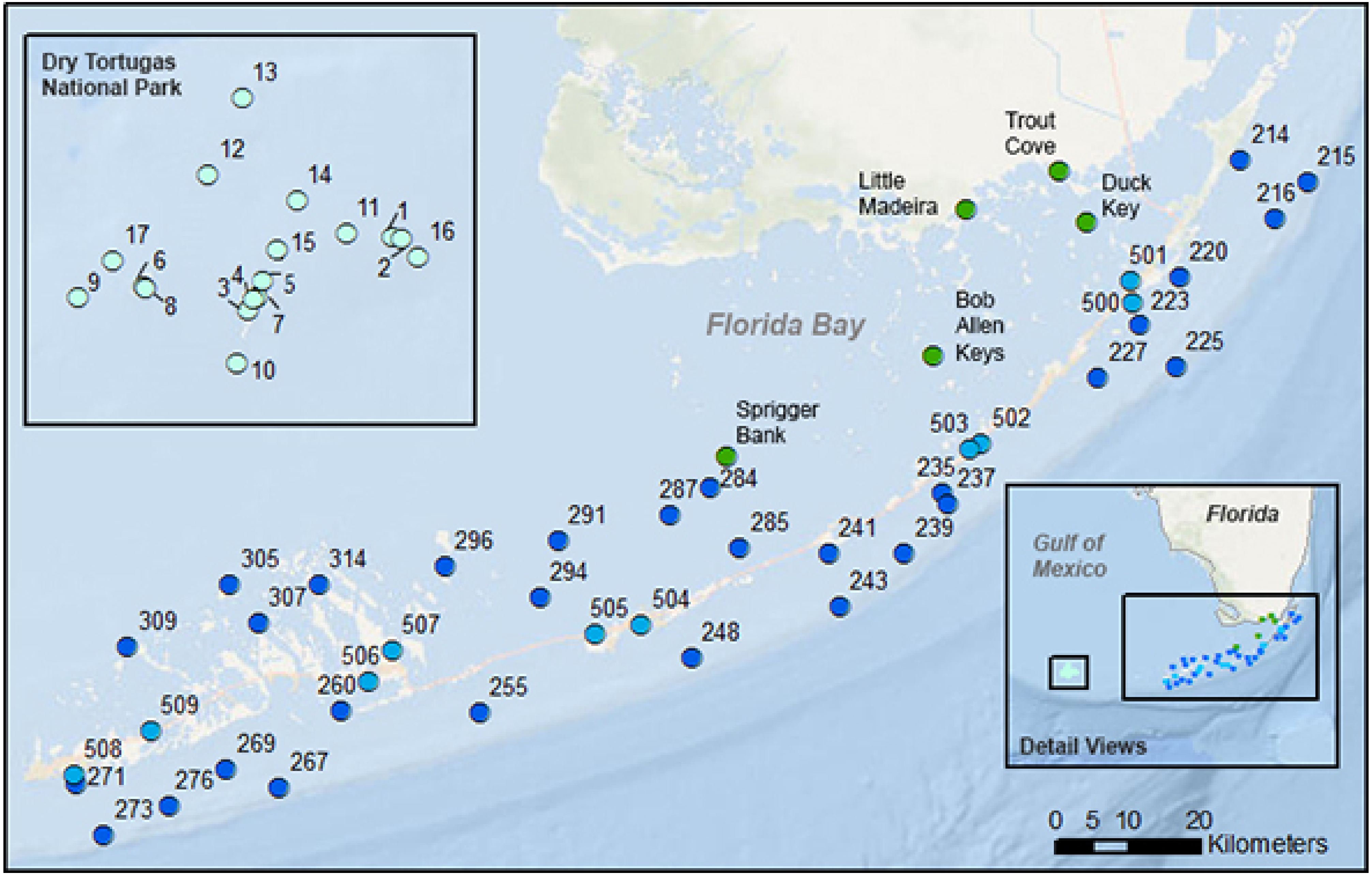
Fourqurean et al. 2019 *Estuaries and Coasts*

WQPP 1996-

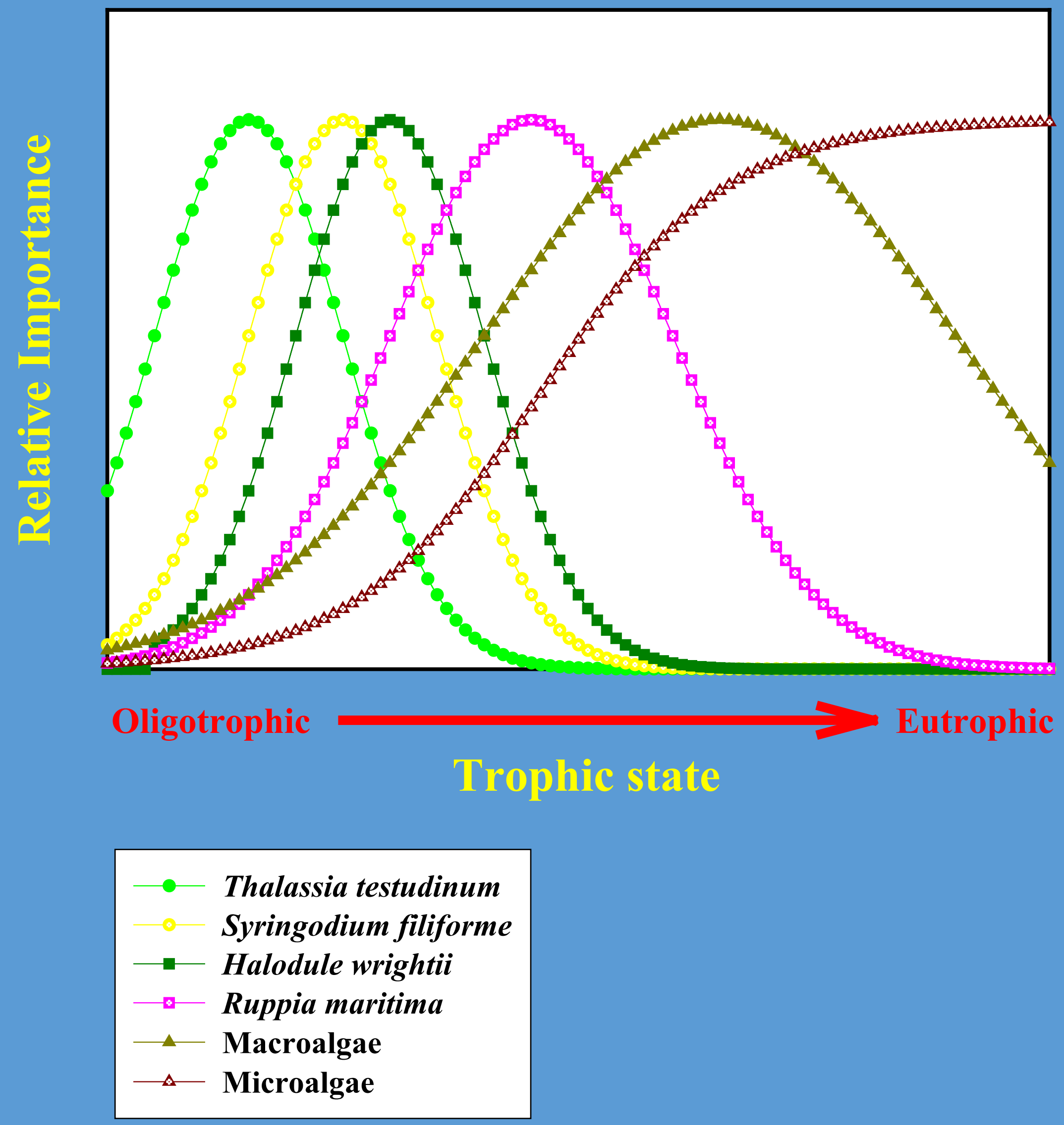
WQPP 2012-

DRTO 2011-

FCE-LTER 2000-

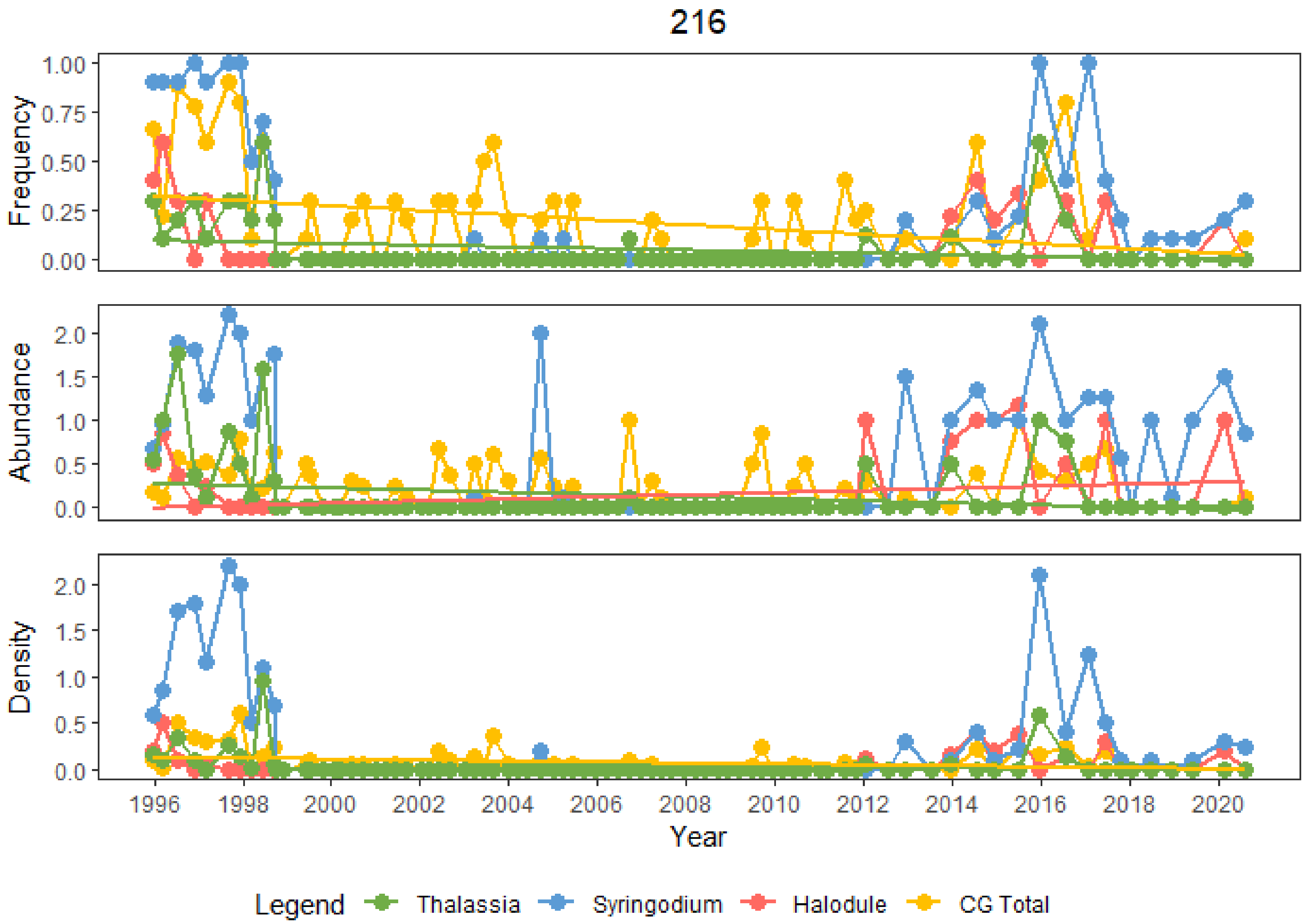


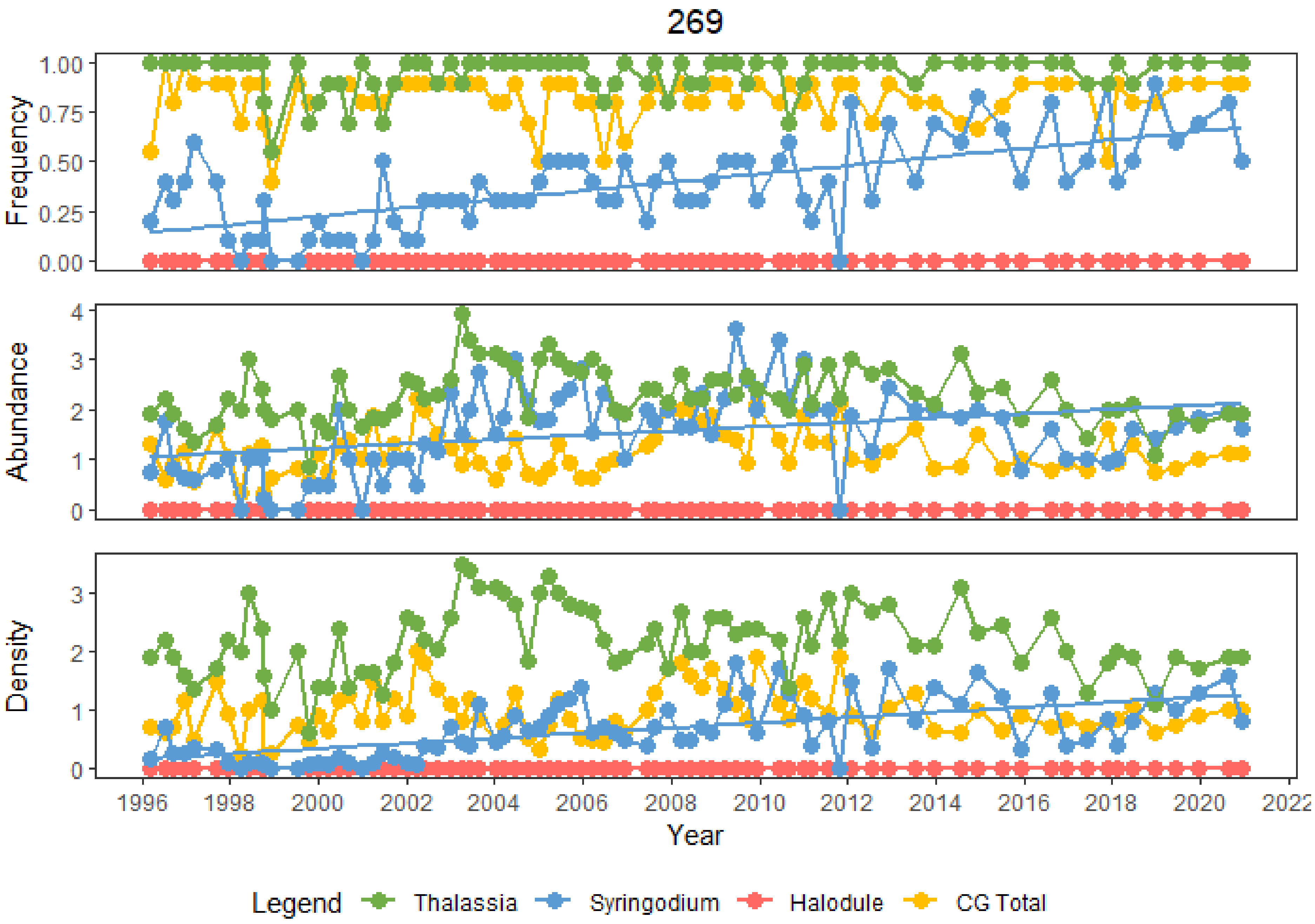
Eutrophication model



Explicit model of ecosystem behavior #1

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

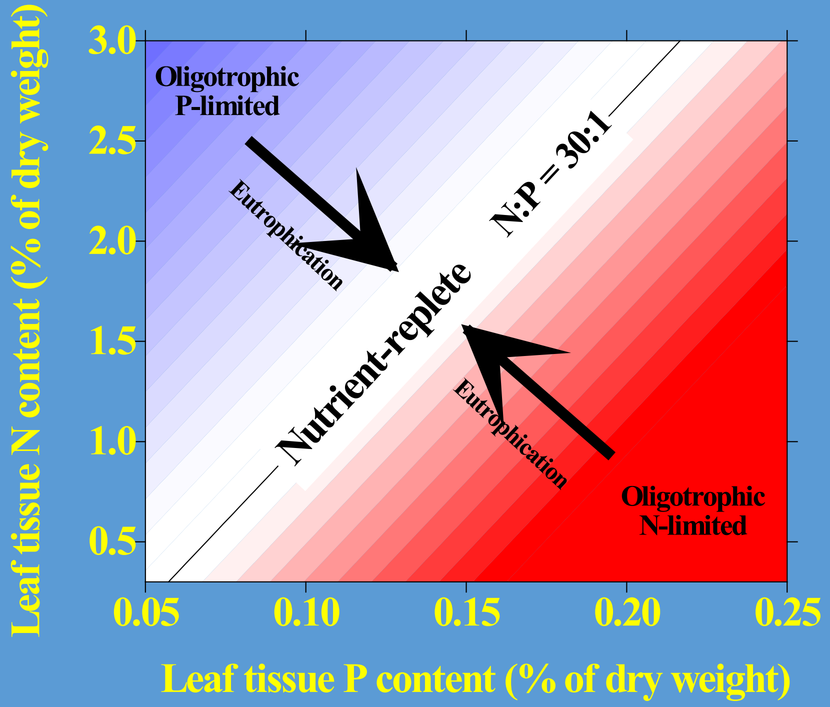

216
Frequency
1.00
0.75
0.50
0.25
0.00
Abundance
2.0
1.5
1.0
0.5
0.0
Density
2.0
1.5
1.0
0.5
0.0
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
Year
Legend
Thalassia
Syringodium
Halodule
CG Total

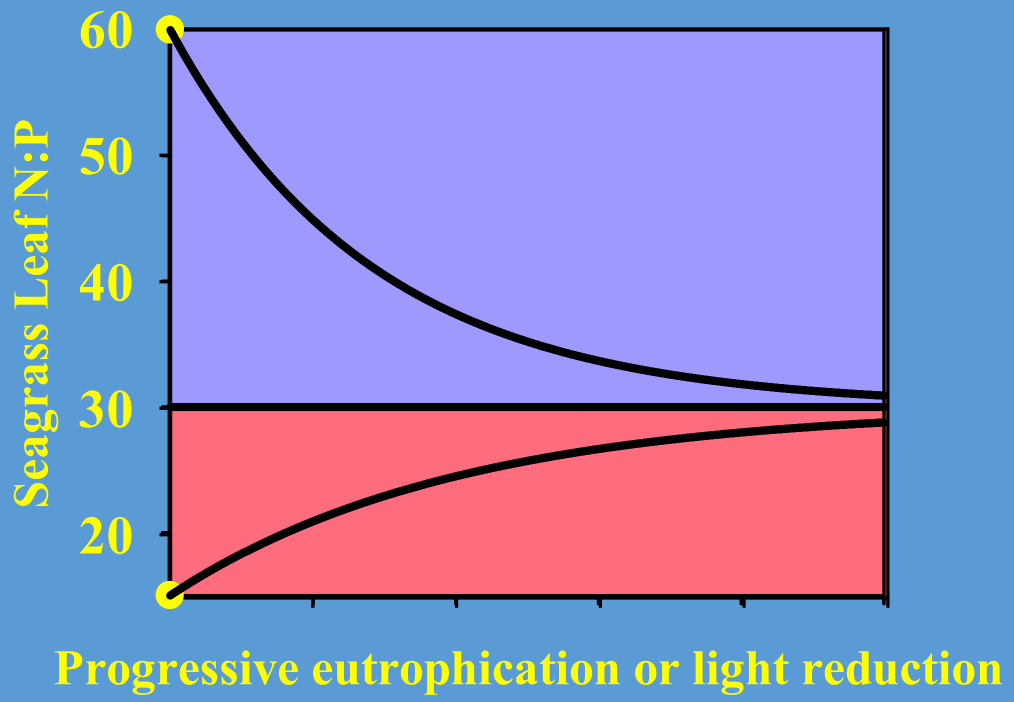


269
Frequency
1.00
0.75
0.50
0.25
0.00
Abundance
4
3
2
1
0
Density
3
2
1
0
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
Year
Legend
Thalassia
Syringodium
Halodule
CG Total

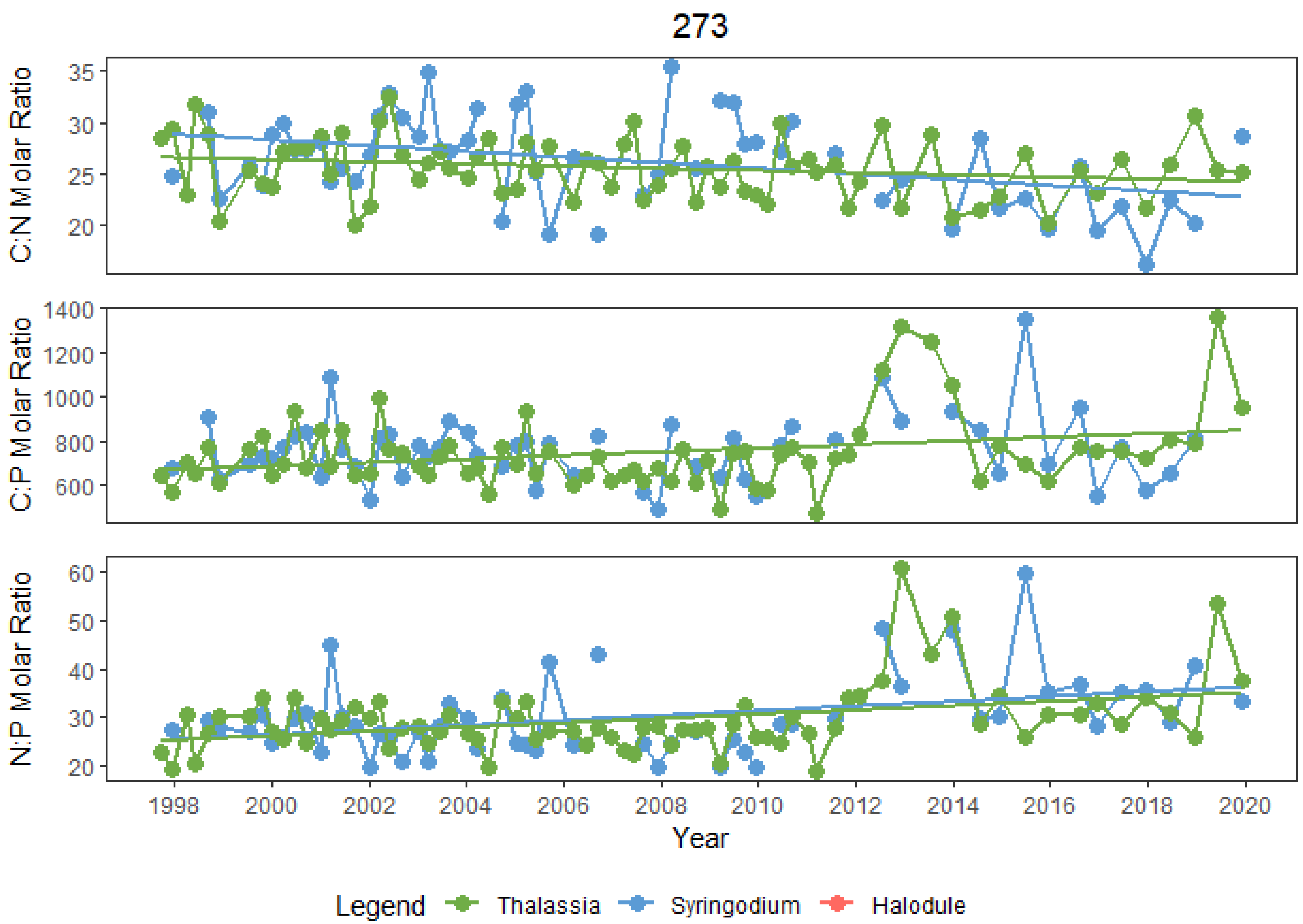
Explicit model of ecosystem behavior #2

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

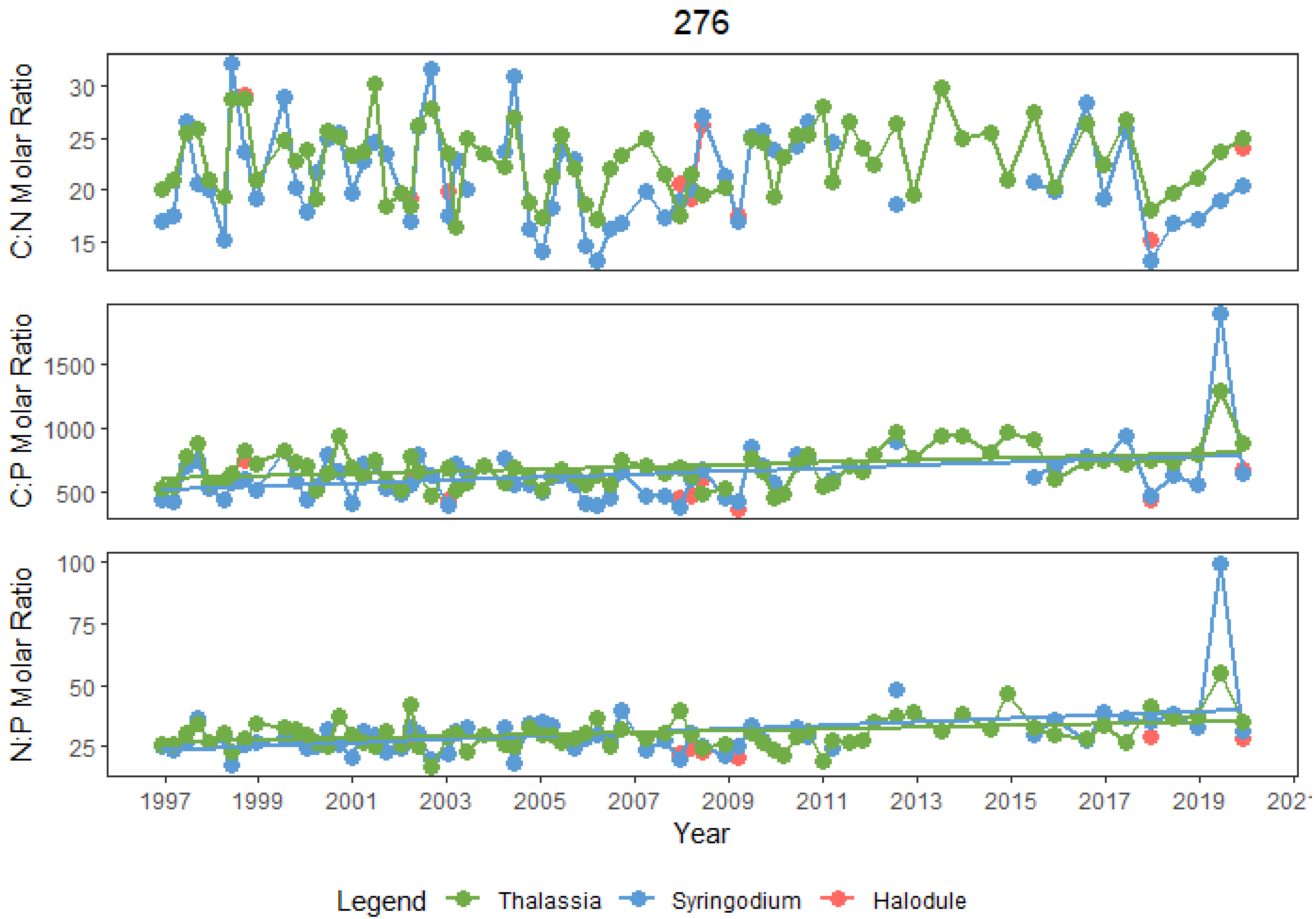


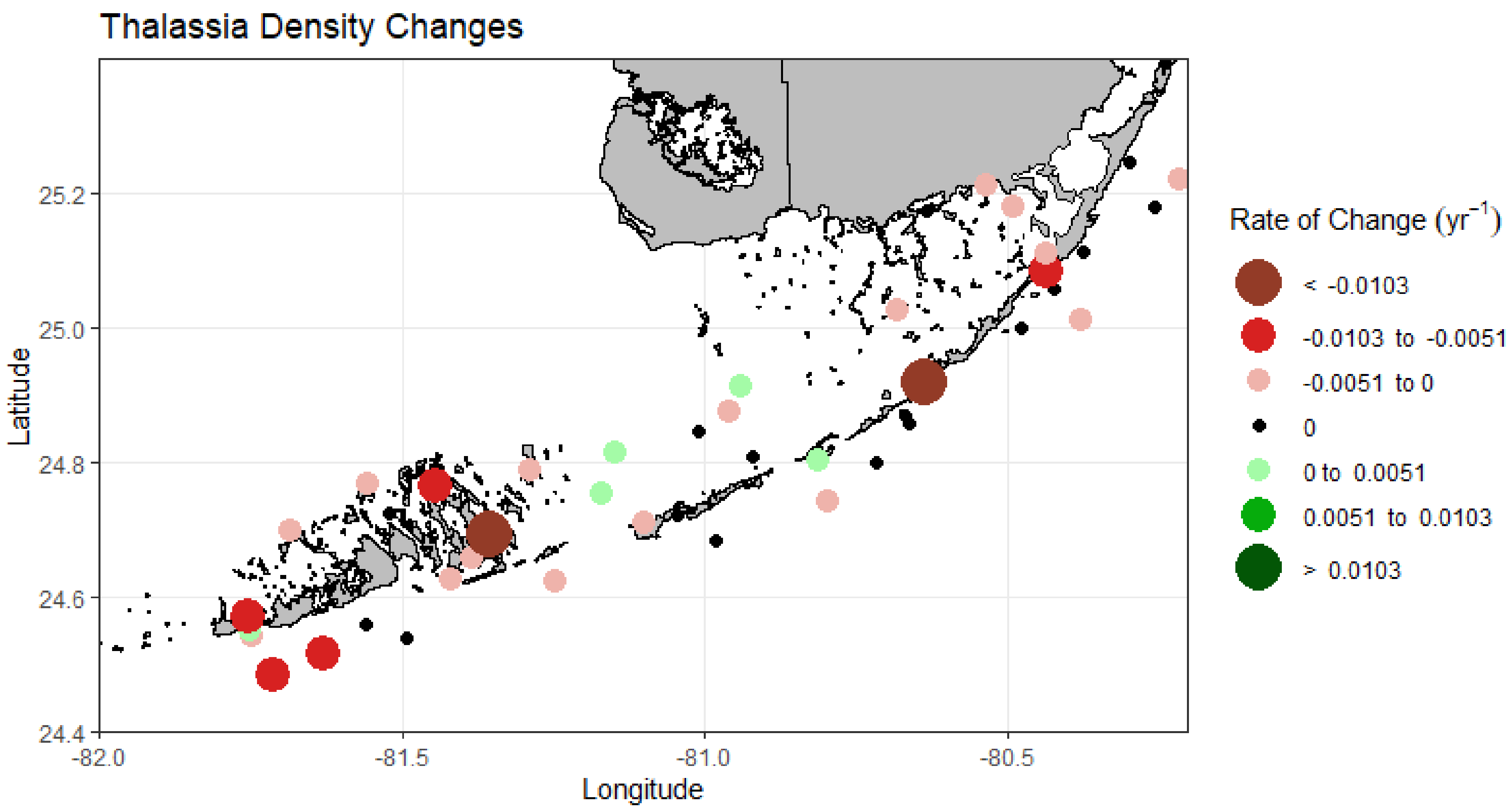


Changes in N:P of primary producers



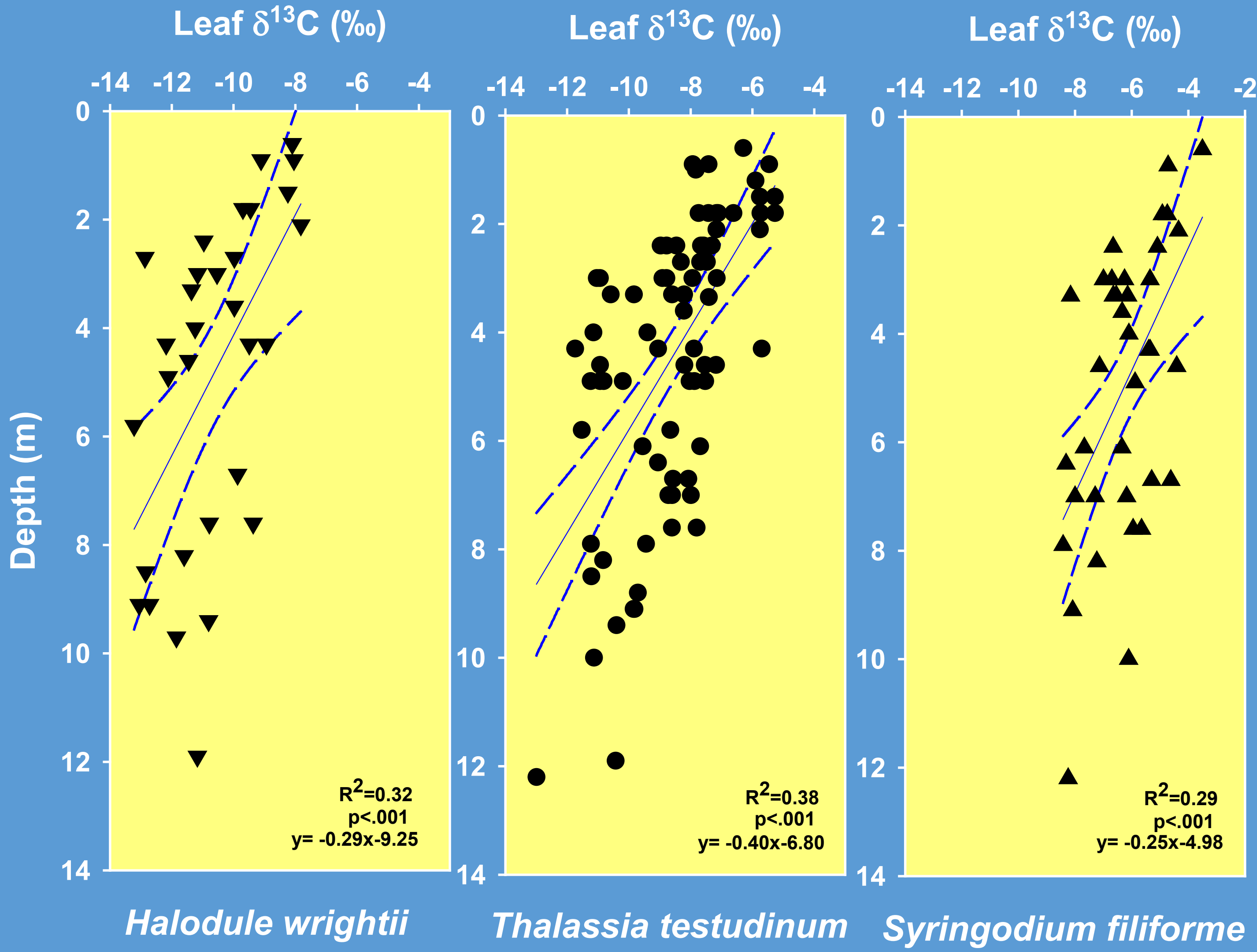
Changes in N:P of primary producers




Thalassia Density Changes
Latitude
25.2
25.0
24.8
24.6
24.4
-82.0
-81.5
-81.0
-80.5
Longitude
Rate of Change (yr^{-1})
< -0.0103
-0.0103 to -0.0051
-0.0051 to 0
0
0 to 0.0051
0.0051 to 0.0103
> 0.0103

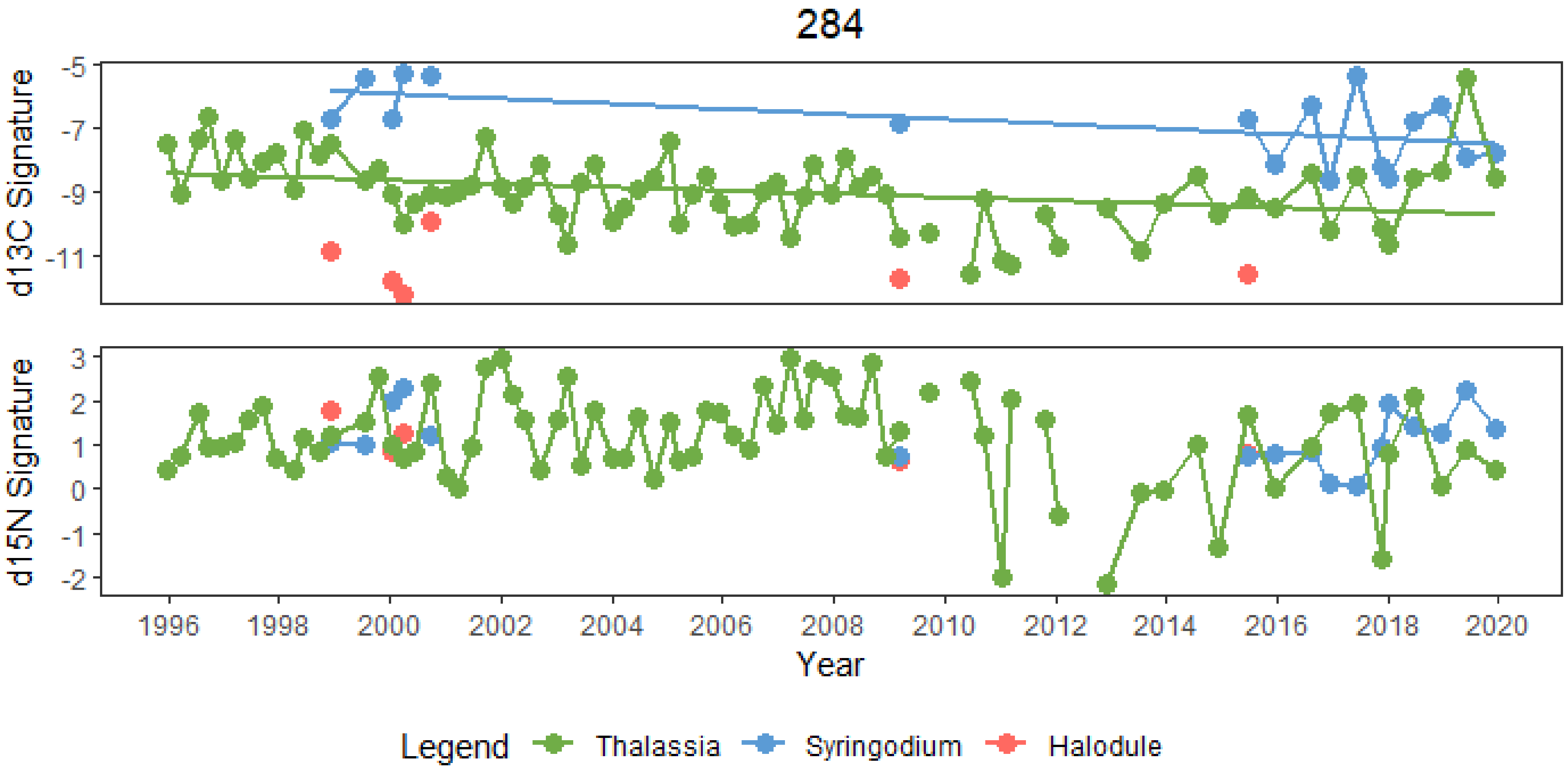
Explicit model of ecosystem behavior #3:

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

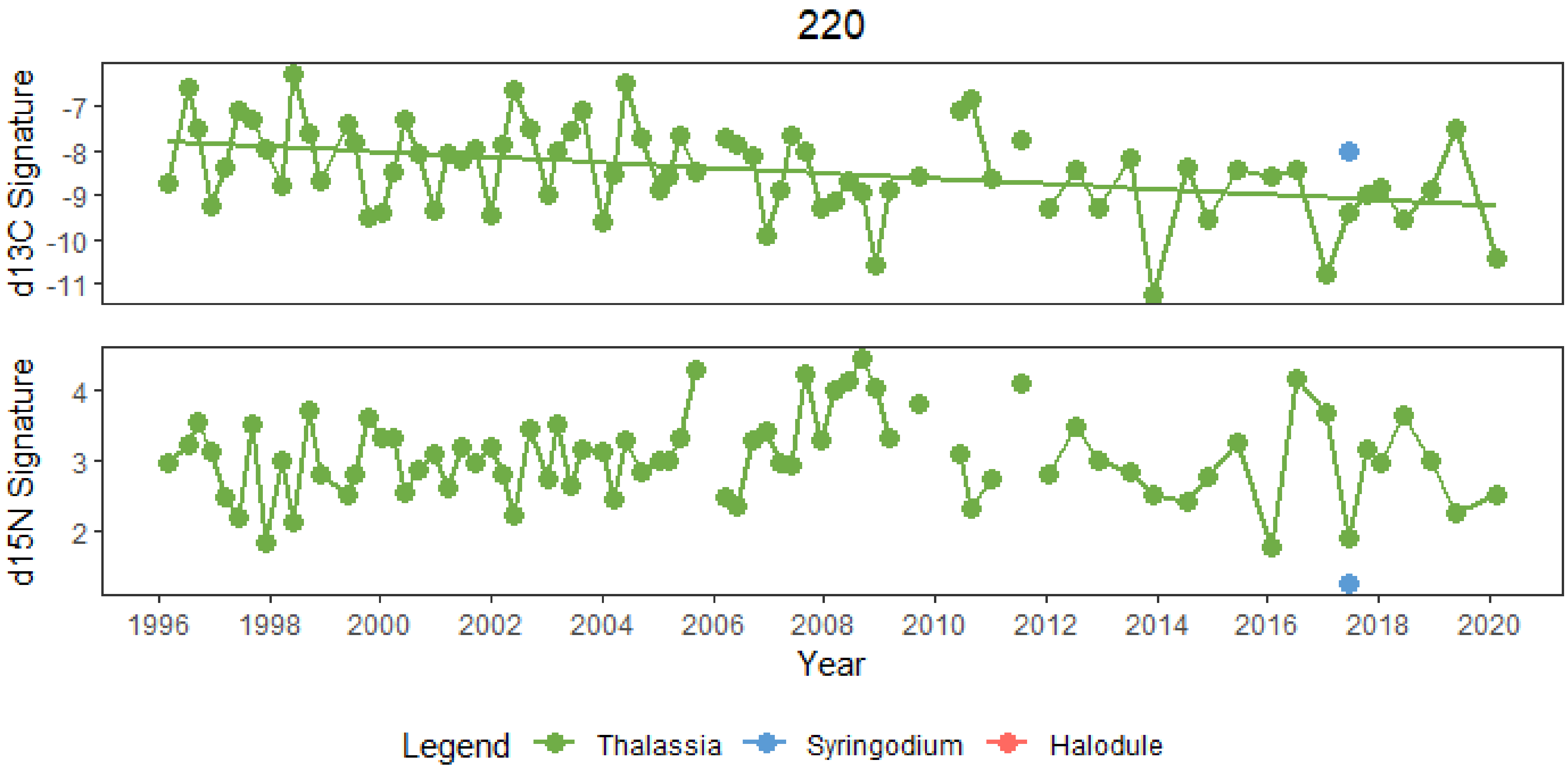


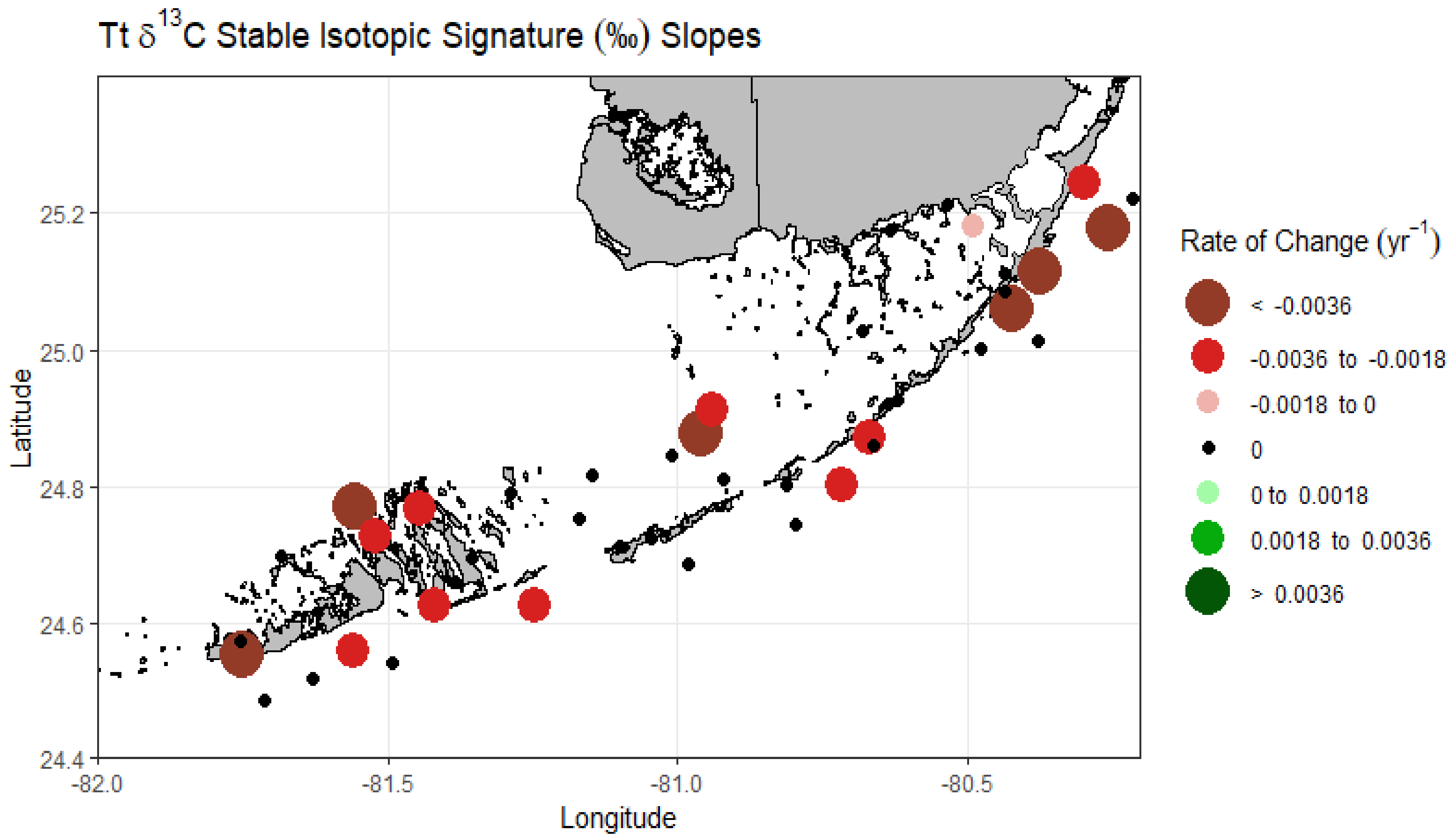
Campbell and Fourqurean, 2009, MEPS

Changes in light availability of primary producers as indicated by $\delta^{13}C$ of seagrass leaves



Changes in light availability of primary producers as indicated by $\delta^{13}C$ of seagrass leaves





Tt $\delta^{13}C$ Stable Isotopic Signature (‰) Slopes
Latitude
25.2
25.0
24.8
24.6
24.4
-82.0
-81.5
-81.0
-80.5
Longitude
Rate of Change (yr^{-1})
< -0.0036
-0.0036 to -0.0018
-0.0018 to 0
0
0 to 0.0018
0.0018 to 0.0036
> 0.0036

FKNMS Seagrass Status Criteria

- We have defined 2 criteria to track the status of seagrasses Sanctuary-wide, based on our conceptual models

- The first is based on the relative dominance of slow-growing species:

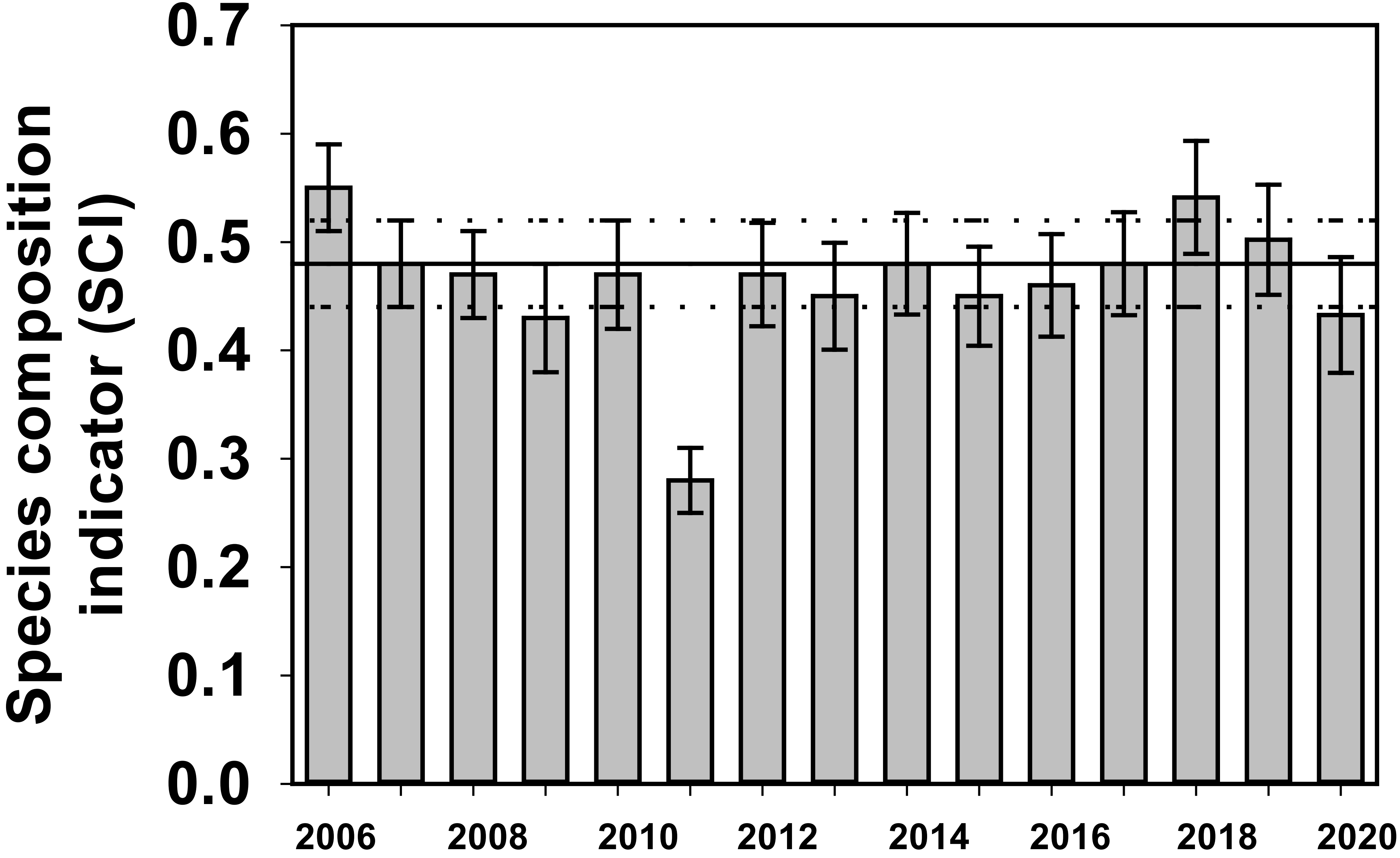
$$SLOW = \frac{A_{Tt}}{A_{Tt} + A_{Sf} + A_{Hw} + A_{Macroalgae}} \qquad SCI = \frac{\sum_{i=1}^{30} SLOW_i}{30}$$

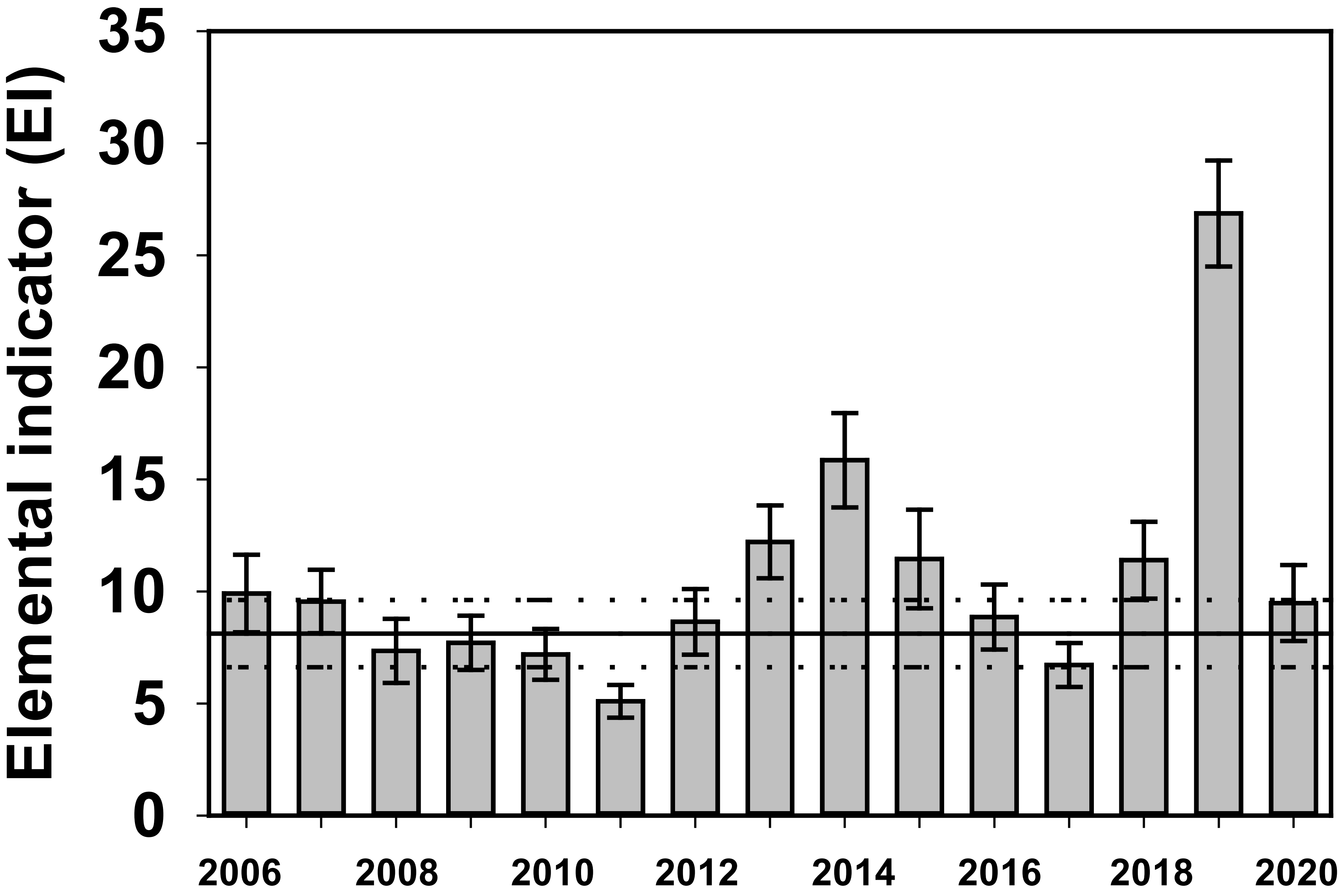
- The baseline SCI, calculated from data collected between 1995-2005, was 0.48 ± 0.04. Any decrease in SCI indicates declining water quality

- The second is based on nutrient content of the slowest growing species:

$$EI = \frac{\sum_{i=1}^{30} \left| NP_i - 30 \right|}{30}$$

- The long-term average EI of *Thalassia* leaves at the 30 sites is 8.28 ± 1.47


0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Species composition indicator (SCI)
2006
2008
2010
2012
2014
2016
2018
2020



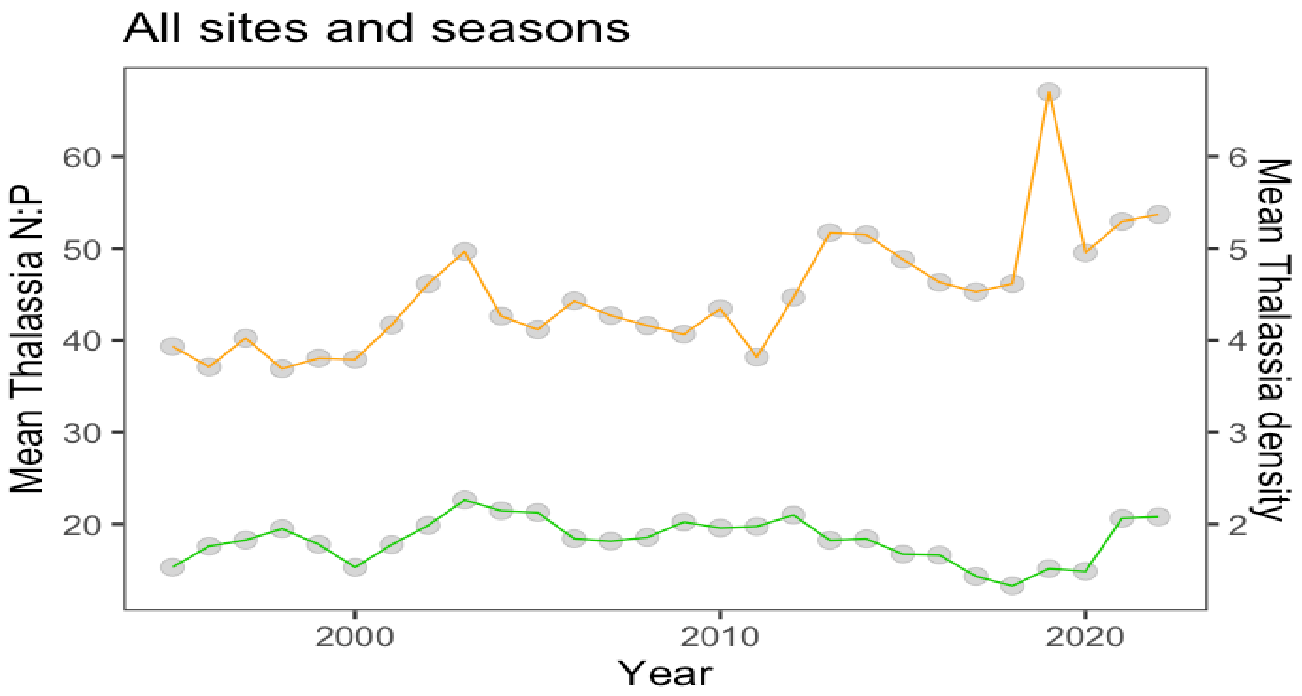
Elemental indicator (EI)
35
30
25
20
15
10
5
0
2006
2008
2010
2012
2014
2016
2018
2020

Summary of numbers of sites with long-term trends in leading water quality indicators (number of sites from 40 total)

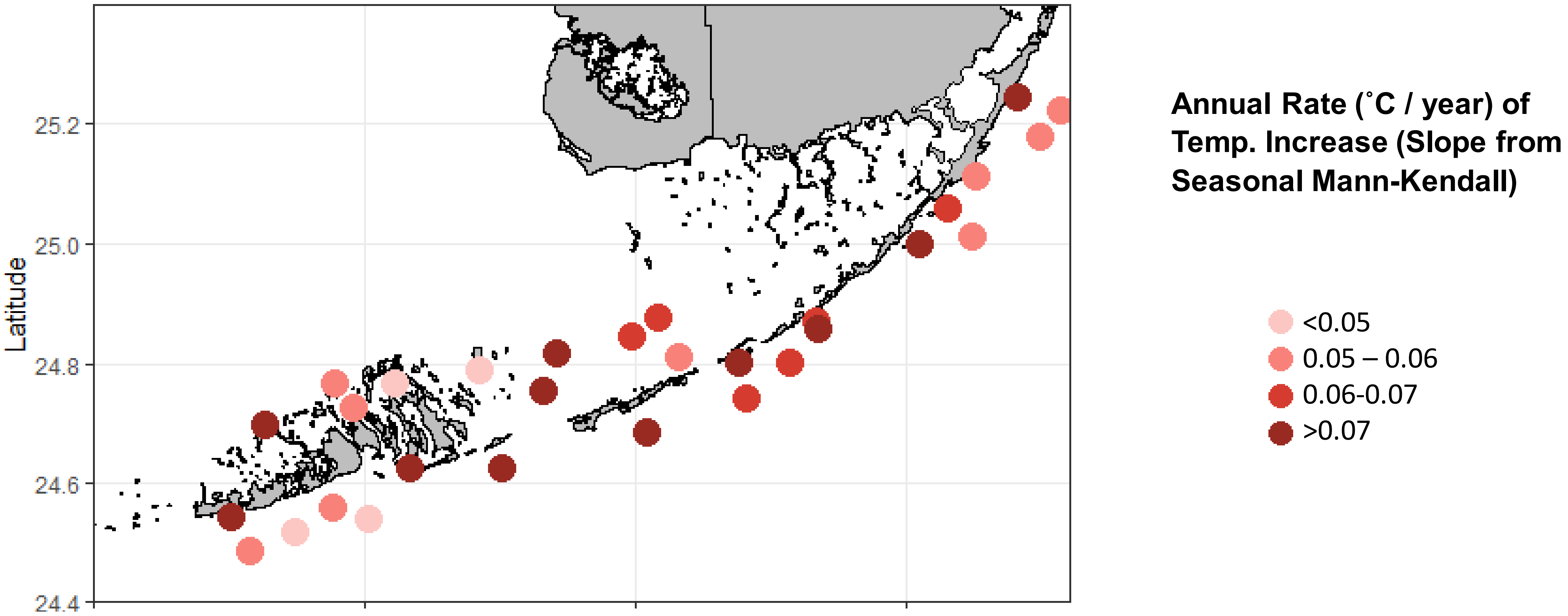
Indicator	Decreasing	No trend	Increasing
Thalassia density	20	16	4
Thalassia leaf area/shoot	8	31	1
Thalassia N:P	13	27	0
Thalassia $\delta^{13}C$	15	25	0
Thalassia $\delta^{15}N$	6	32	2

Granger causality is a statistical concept of causality that is based on prediction. According to Granger causality, if a signal X_1 "Granger-causes" (or "G-causes") a signal X_2, then past values of X_1 should contain information that helps predict X_2 above and beyond the information contained in past values of X_2 alone.

- **_Thalassia_ tissue N:P is a leading indicator of _Thalassia_ density across all sites and seasons (_p_ = 0.02). This trend is driven by data from the Florida Keys in Q2 (_p_ = 0.04) and Q3 (_p_ = 0.005).**

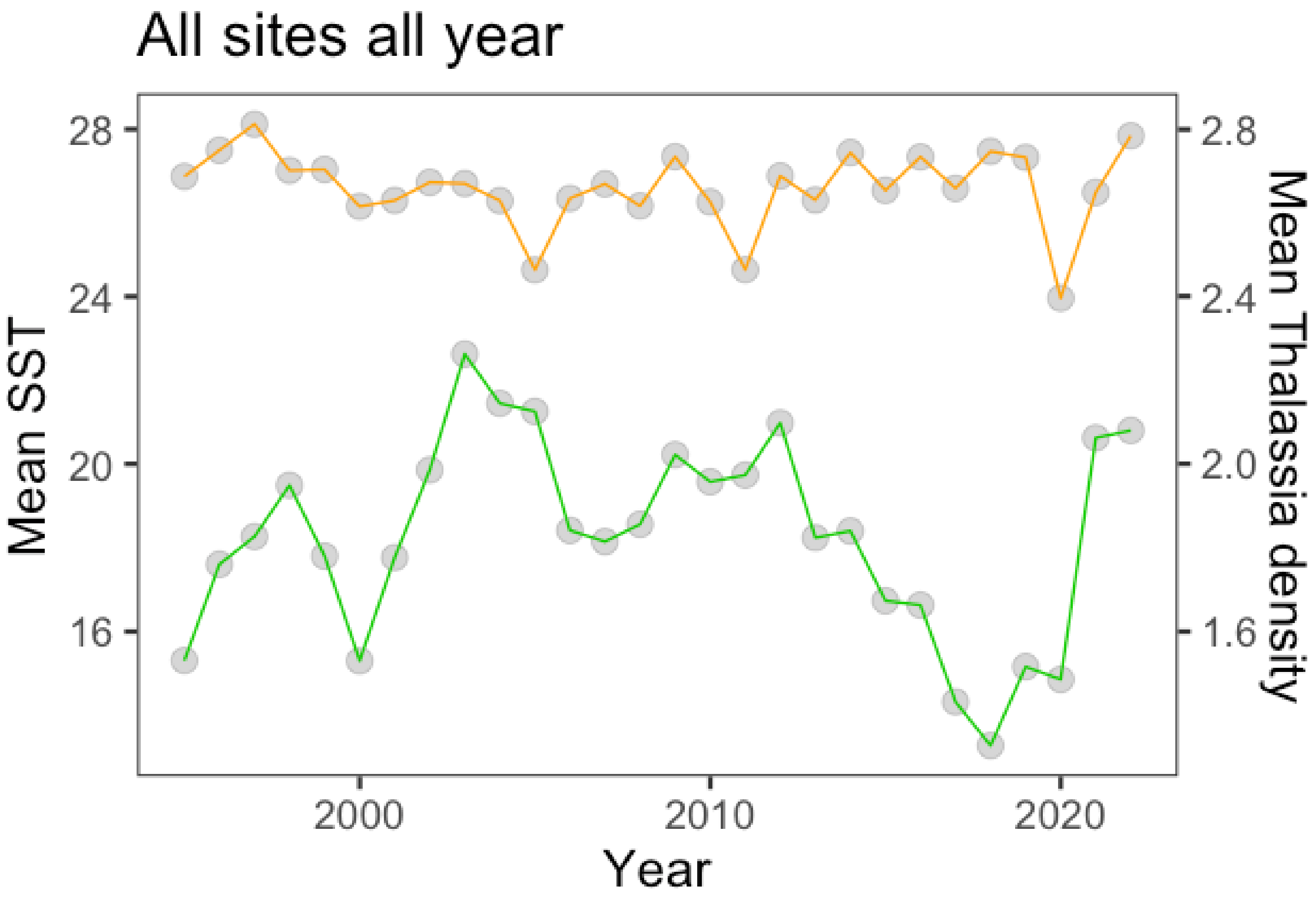


Annual Rate of Temp. Increase across FKNMS, 2003-



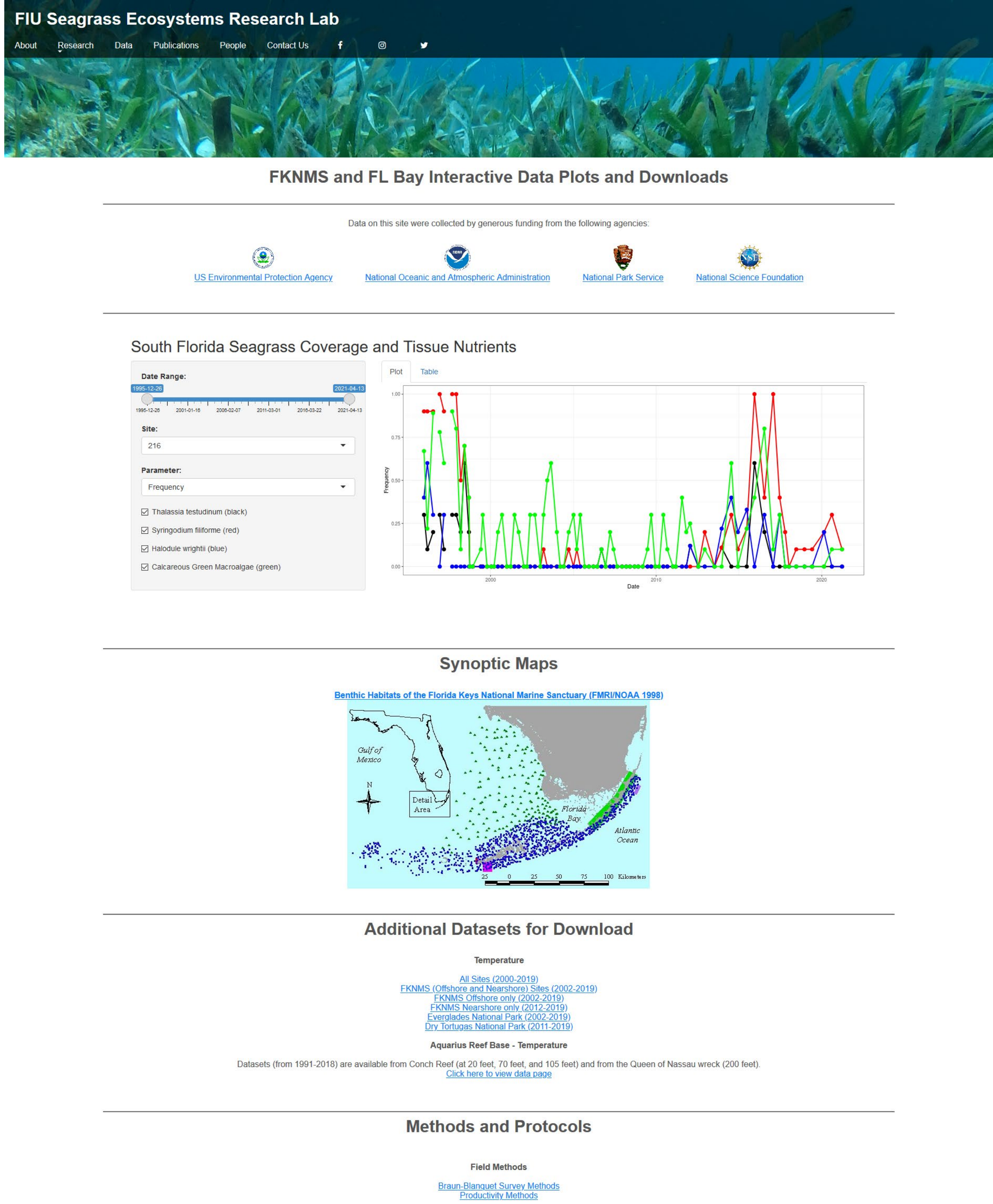
Mean rate of global sea surface temperature warming = 0.013 ˚C / year (NOAA 2019)

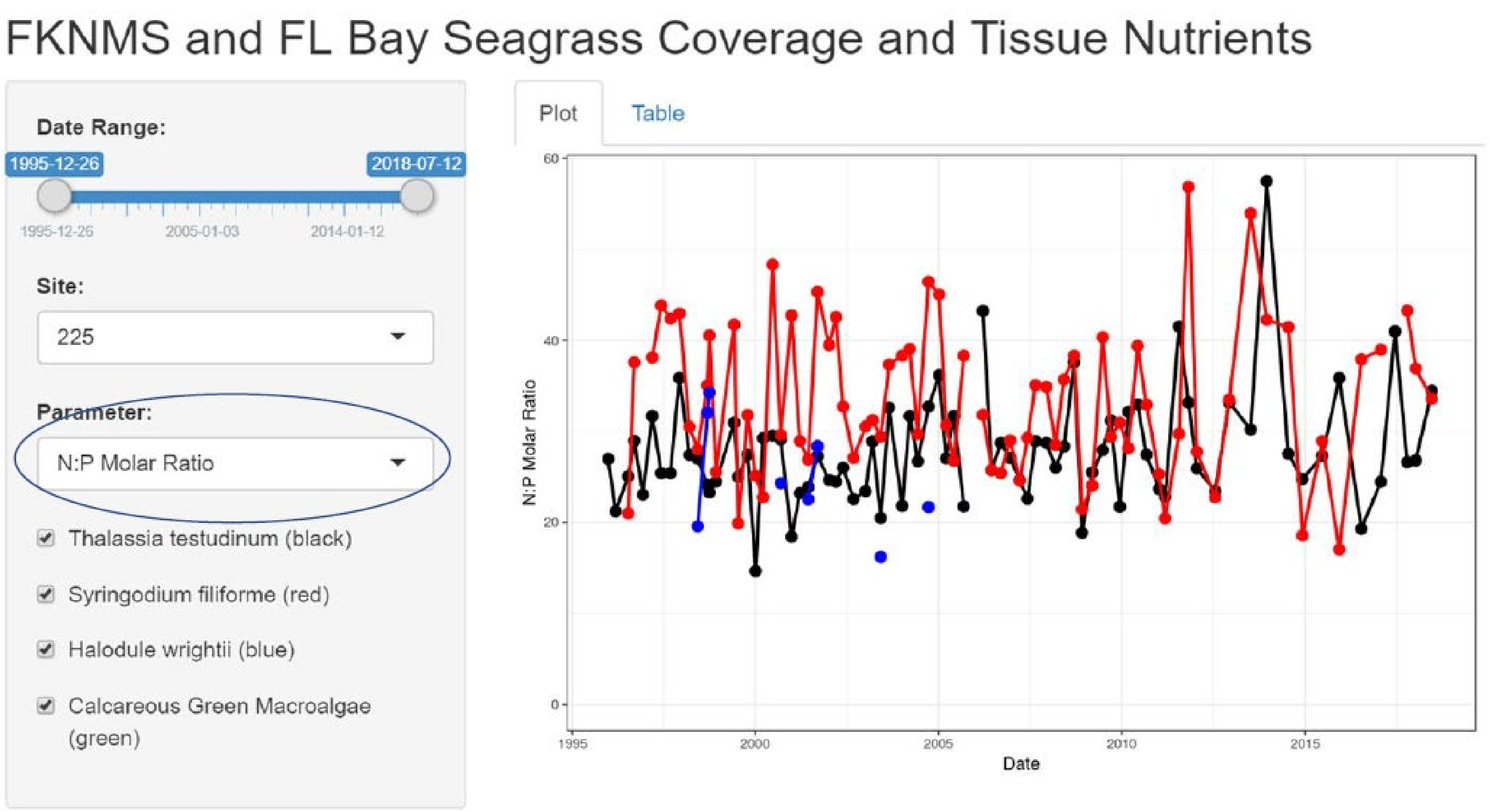
- **Sea Surface Temperature is a leading indicator for *Thalassia* density across all sites and seasons (p = 0.01). By region, this pattern is detected for the Florida Keys all year (p = 0.04) and in Q3 (p = 0.04). By season, this relationship exists across all sites for Q3 (p = 0.03).**



All data made easily accessible and downloadable:

https://seagrass.fiu.edu/data.htm





seagrass.fiu.edu

Summary:

The seagrass monitoring component of the WQPP is measuring proven leading indicators of the impact of water quality on seagrass status

***Most* sites show long term changes in at least one leading indicator of negative changes consistent with declining water quality**

These changes are occurring in the absence of any violations of FDEP water-body specific numeric nutrient criteria

The waters of the Sanctuary are warming 5-7 times faster than the global ocean over the last 20 years, and high temperatures are linked to seagrass decline.

Looking to the future:

- **Maintaining the permanent site monitoring**
- **Resample the synoptic mapping of seagrass distributions done in the early days of the seagrass monitoring program:**

Synoptic Surveys: Species distributions