Goals for the project

At the **regional** 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
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 (REMAP).
- **Temporal sensitivity** assured by concentrating some of the sampling effort on randomly-selected, permanent sites.
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
  • Ca. 200 mapping sites/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
  • 40 permanent sites 2 times a year
  • Ca. 200 mapping sites/year
Describing spatial pattern in monitoring data – Stratified-random sampling
Synoptic Surveys: Species distributions

**Thalassia testudinum**

**Halophila decipiens**

**Syringodium filiforme**

**Halodule wrightii**
Nutrient pollution will lead to changes in relative abundances of primary producers in a predictable way.
Changes in relative abundance of primary producers

Site 273

- Thalassia
- Syringodium
- Halodule
- Calcareous Green

Decimal Year

Density

Changes in relative abundance of primary producers

At 19 of 30 sites, species composition has shifted in a manner consistent with increased nutrient availability.

Green: Thalassia getting denser
Red: Thalassia decreasing in relative importance
Changes in N:P of primary producers #1:

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

*Thalassia testudinum*

N:P of leaves

Fourquean et al Estuaries 2005
Changes in N:P of primary producers
At 13 of 30 sites, N:P is trending towards “seagrass Redfield ratio”

Site 267

\[ Y = 1032.6 - 0.5x \]

\[ r^2 = 0.171, \ p = 0.002 \]
Changes in N:P of primary producers

Green: shift away from RR
Red: shift towards RR
Changes in $\delta^{13}C$ of primary producers

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

\[ Y = 221 - 0.115x \]
\[ r^2 = 0.242, p < 0.001 \]
Changes in δ¹³C of primary producers #2

Long-term changes in δ¹³C consistent with eutrophication model
## Site-specific indicator summary
### 1995-2009

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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:

$$SLOW = \frac{A_{Ti}}{A_{Ti} + A_{Sf} + A_{Hw} + A_{Macroalgae}}$$

$$SCI = \frac{\sum_{i=1}^{30} SLOW_i}{30}$$

• 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.
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
Major project accomplishments:

• We have defined the spatial extent and species composition of the largest documented seagrass bed on earth, and solidly defined a baseline to assess change.

• We have defined the spatial and temporal pattern of seagrass community dynamics in the FKNMS and made predictions about future trajectories.

• We have identified long-term trends at stations in the FKNMS that are consistent with increases in nutrient availability.

• We have defined the effects of changing water quality on seagrass communities in south Florida.

• We have documented the effects of storms on seagrass communities.

• We have experimentally confirmed the role of nitrogen, and of phosphorus near shore and in Florida Bay, in controlling seagrass bed structure and productivity near the reef tract in the FKNMS.

• We have provided data for the analysis of potential human impacts on benthic communities to other groups and agencies.

• 23 scientific publications have resulted from this monitoring project to date.
• Not all environmental threats can be monitored in a given monitoring program
• The original monitoring program design was regional in scope
Benthic Habitat Permanent Monitoring Sites

Original 30 sites (1995)
New sites (10) for nearshore emphasis (2012)
New nearshore sites – Key Largo

Site 501

Site 500

Decimal Year

N:P (mol/mol)

Thalassia

Syringodium

Pelican Key

Sunset Cove

Key Largo

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Imagery Date: 12/23/2010

at 25 097679.165 -80 439967.914 elev 6 ft

Eye alt 16945 ft
New nearshore sites – Islamorada

Site 503
Thalassia

Site 502
Halodule
New nearshore sites – Marathon

Site 504
Thalassia

Site 505
Syringodium
Halodule

N:P (mol:mol)

Decimal Year
New nearshore sites – Key West
Are we describing locally-induced changes, responses to larger-scale processes, or natural cycles?

Our redesigned sampling program will contribute to answering this question.
Explicit model of ecosystem behavior #2

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

**Graph**

- **Y-axis**: Leaf tissue N content (% of dry weight)
- **X-axis**: Leaf tissue P content (% of dry weight)
- **Legend**:
  - Oligotrophic P-limited
  - Nutrient-replete
  - Eutrophication
  - Oligotrophic N-limited
- **Axes**:
  - X-axis: 0.05 to 0.25
  - Y-axis: 0.05 to 3.0
  - Color gradient from light blue (Oligotrophic) to red (Eutrophication)

**Axes**

- **X-axis**: Progressive eutrophication or light reduction
- **Y-axis**: Seagrass Leaf N:P

**Equation**

N:P = 30:1
Nutrient pollution will shift seagrass $\delta^{13}C$ towards more negative values because of increased discrimination against $^{13}C$ in low light conditions.
Nutrient pollution will cause some kind of change in $\delta^{15}N$ of primary producers.
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 $-0.03 \ \mu g \ l^{-1} y^{-1}$)

Data from FKNMS water quality monitoring program
Changes in relative abundance of primary producers #2

Epiphyte loads are highly seasonal in the FKNMS

\[ Y = 2.02 + 0.67\sin(\text{DOY}+0.04) \]

\[ r^2 = 0.32 \]
Unlike more eutrophic systems, epiphyte loads are not correlated with increased nutrient loads at the scale of our sampling in the FKNMS.
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
Spatial patterns in stable isotope ratios in south Florida

Thalassia testudinum
\( \delta^{13}C \) of leaves (I )

Thalassia testudinum
\( \delta^{15}N \) of leaves (I )

Limit of Thalassia distribution

Fourquarean et al Estuaries 2005
Changes in $\delta^{13}C$ of primary producers #1:

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

- **Halodule wrightii**
  - $R^2=0.32$
  - $p<.001$
  - $y=-0.29x-9.25$

- **Thalassia testudinum**
  - $R^2=0.38$
  - $p<.001$
  - $y=-0.40x-6.80$

- **Syringodium filiforme**
  - $R^2=0.29$
  - $p<.001$
  - $y=-0.25x-4.98$

Campbell and Fourqurean, 2009, MEPS
Changes in $\delta^{15}$N of primary producers #2

Long-term changes in $\delta^{15}$N:
Increase
Decrease
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?
Oil Spills in Seagrass beds

- Seagrasses are the most extensive of the marine habitats of south Florida
- Seagrass beds have a high ecological and economic value
- WQPP monitoring sites are providing baseline data for assessing ecological effects of Deepwater Horizon oil spill
Oil Spills in Seagrass beds

- GOOD NEWS: Seagrasses are relatively insensitive to oil and dispersants.
- BAD NEWS: The animals that live in seagrass beds are very sensitive to oil and dispersants.
Web accessibility of data and reports: www.fiu.edu/~seagrass