Seagrass Monitoring in the Florida Keys National Marine Sanctuary

FY 2008 Annual Report

Executive Summary

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PROJECT OVERVIEW

The general objective of seagrass monitoring in the Florida Keys National Marine Sanctuary (FKNMS) is to measure the status and trends of seagrass communities to evaluate progress toward protecting and restoring the living marine resources of the Sanctuary. The scope and depth of this monitoring effort are without precedent or peer for seagrass ecosystems throughout the world. Specific objectives are: 1) To provide data needed to make unbiased, statistically rigorous statements about the status and temporal trends of seagrass communities in the Sanctuary as a whole and within defined strata; 2) To help define reference conditions in order to develop resource-based water quality standards; and 3) To provide a framework for testing hypothesized pollutant fate/effect relationships through process-oriented research and monitoring. In order to meet these objectives, we have developed these goals for the project:

- Define the present distribution of seagrasses 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
- Determine relationships between water quality and seagrass status
- Detect trends in the distribution and status of the seagrass communities

To reach these goals, four kinds of data are being collected in seagrass beds in the FKNMS:

- Distribution and abundance of seagrasses and other benthic plants and animals using rapid assessment Braun-Blanquet surveys
- Seagrass nutrient availability using tissue concentration assays
- Nutrient quality information using stable isotopic composition of seagrass leaves
- Water quality data collected with the seagrass data

These data are being collected at three different types of sites within the FKNMS:

- Level 1 Stations: Sampled quarterly for seagrass abundance, productivity and nutrient availability. These stations are all co-located with the water quality monitoring project's stations (Figure 1)
- Level 2 Stations: Randomly selected locations within the FKNMS, sampled annually for seagrass abundance and nutrient availability. Each year, new locations for Level 2 stations are chosen.
- Level 3 Stations: Randomly selected locations within the FKNMS, sampled annually for seagrass abundance. Each year, new locations for Level 3 stations are chosen.

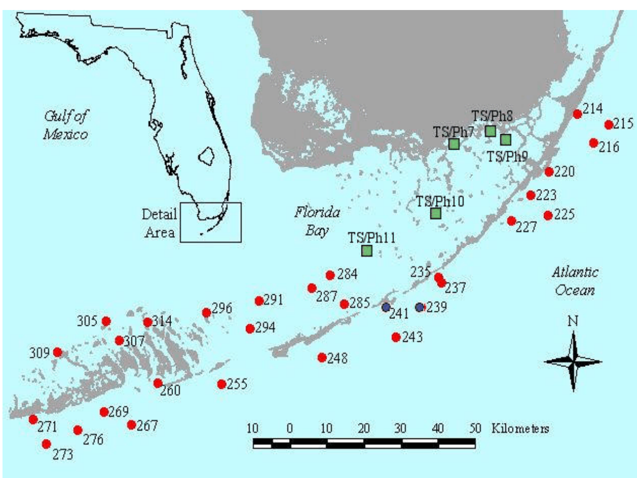

Figure 1. Location of Level 1 stations in the FKNMS (red and blue dots). Green squares indicate the position of similar sites funded by the Florida Coastal Everglades Long Term Ecological Research Program. Site numbers correspond to water quality monitoring locations.

We are assessing both inter-annual and intra-annual trends in seagrass communities. The mix of site types is intended to monitor trends through quarterly sampling at a few permanent locations (Level 1 sites) and to annually characterize the broader seagrass population through less intensive, one-time sampling at more locations (Level 2 and 3 sites).

In addition to the monitoring activities, we take advantage of the vessel time needed to collect the monitoring data to also conduct manipulative experiments that help us understand the spatial and temporal trends in the monitoring data.

PROJECT ACCOMPLISHMENTS FY 2008

The significant changes in seagrass communities at the permanent Level 1 stations that we reported last fiscal year continue to be present after an additional year of sampling. Additional lines of evidence now point towards more geographically widespread, long-term changes in the seagrass communities at the Level 1 stations. These changes are consistent with model predictions of nutrient-induced changes of these systems. There may be reasons for these observations that are unrelated to man's activities in the region, but the spatial pattern of changes and the agreement of the changes with models of the system suggest that there is regional-scale change in nutrient availability that is causing changes in seagrass beds over a wide portion of the FKNMS.

We plan on resuming synoptic sampling at Level 2 and 3 sites in 2010 to maintain the rotating panel design established during the first two cycles of sampling.

In general, nutrient addition to aquatic environments shifts the competitive balance to faster-growing primary producers. The consequences of this generality in seagrass-dominated environments is that seagrasses are the dominant primary producers in oligotrophic conditions. As nutrient availability increases, there is an increase in the importance of macroalgae, both free-living and epiphytic, with a concomitant decrease in seagrasses because of competition for light. Macroalgae lose out to even faster-growing microalgae as nutrient availability continues to increase: first, epiphytic microalgae replace epiphytic macroalgae on seagrasses; then planktonic microalgae bloom and deprive all benthic plants of light under the most eutrophic conditions.

Each species in the species dominance-eutrophication gradient model can potentially dominate over a range of nutrient availability and the model predicts a change in species dominance as nutrient availability changes. These changes are not instantaneous, however. Field evidence suggests that species replacements may take place on a time scale of a decade or more. It is desirable that we be able to predict the tendency of the system to undergo these changes in species dominance before they occur, so that management actions can be taken. Tissue nutrient concentrations can be monitored to assess the relative availability of nutrients to the plants. For phytoplankton communities, this idea is captured in the interpretation of elemental ratios compared to the familiar 'Redfield ratio' of 106C:16N:P. For the seagrass *T. testudinum*, the critical ratio of N:P in green leaves that indicates a balance in the availability of N and P is ca. 30:1, and monitoring deviations from this ratio can be used to infer whether N or P availabilities are limiting this species' growth. Hence, *T. testudinum* is likely to be replaced by faster-growing competitors if nutrient availability is such that the N:P of its leaves is ca. 30:1. A change in the N:P in time to a value closer to 30:1 is indicative of eutrophication.

In addition to species composition and elemental content, the stable isotopic composition of plant tissues change as environmental conditions change. As light availability to the seagrasses is reduced, as occurs when nutrient availability increases and faster growing taxa proliferate, the stable carbon isotopic composition shifts towards values more depleted in the heavier stable C isotope, ^{13}C. Hence, long-term changes in $\delta^{13}C$ values of seagrasses can serve as an indicator of changing light environment. At 6 of the 30 Level 1 sites, there has been a significant long-term decrease in $\delta^{13}C$ over the period 1995-2008 consistent with decreased light availability and eutrophication, while only one site showed significant increases in $\delta^{13}C$. Nitrogen stable isotopic composition can also indicate change in nutrient status; however this indicator is much more complicated to interpret. Sewage-derived nitrogen tends to be enriched in the heavier stable isotope, ^{15}N, while fertilizer-derived nitrogen is depleted of this heavier isotope. Additionally, changes in the availability of light may affect plant stable N contents in a manner similar to the stable carbon isotopic content. While interpretation of patterns in stable N isotope composition are not straightforward, changes in the $\delta^{15}N$ of seagrass tissues does indicate a change in the nutrient environment of those plants. At 7 of the Level 1 sites, there were significant long-term decreases in the $\delta^{15}N$ over the period 1995-2007; while $\delta^{15}N$ significantly increased at 3 of the 30 sites.

In many coastal seagrass ecosystems with higher availability of nutrients than in the FKNMS, epiphyte loads on seagrasses have been shown to increase with increasing nutrient concentration. An analysis of data on water column nutrient concentration, sediment nutrient content, and seagrass elemental content, we found that epiphyte load was highly seasonal in the FKNMS< with peaks in abundance in early Spring and minimum abundance in early Autumn (Figure 2). However, among sites, we found that epiphyte load decreased or remained the same as nutrient availability increased (Figure 3). These results suggest that monitoring epiphyte loads in the FKNMS would be an insensitive indicator of changes in nutrient availability in the seagrass beds.

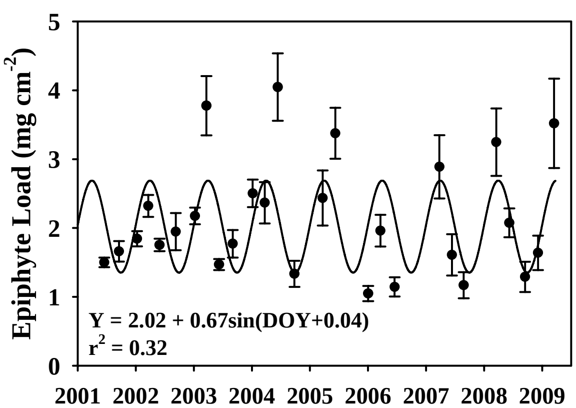

Figure 2. Seasonality of epiphyte load, averaged across all 30 level 1 sites, for the period 2001-2009)

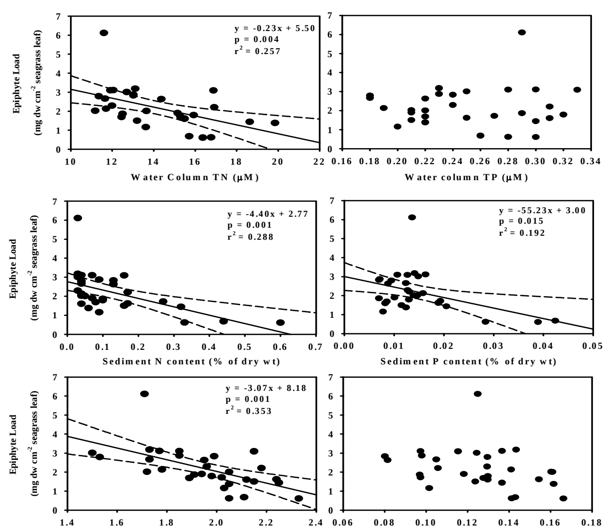

Figure 3. Seagrass epiphyte load was not positively correlated with water column, sediment or seagrass measures of nutrient availability.

At 19 of the 30 Level 1 sites in the Florida Keys, there have been changes in the relative abundance of seagrasses and macroalgae over the period 1995 - 2008 that are consistent with increased nutrient availability (Figure 4); the number of sites showing such changes is up from

13 in FY2007. At two of these sites there has been a decrease in seagrass abundance, but at most of the sites we are seeing increases in fast-growing macroalgae should precede decreases in seagrass abundance. One example, from site 235 near Islamorada, shows how macroalgae steadily increased in abundance from 1995-2006, but in recent years there has been a decrease in the importance of macroalgae (Figure 5).

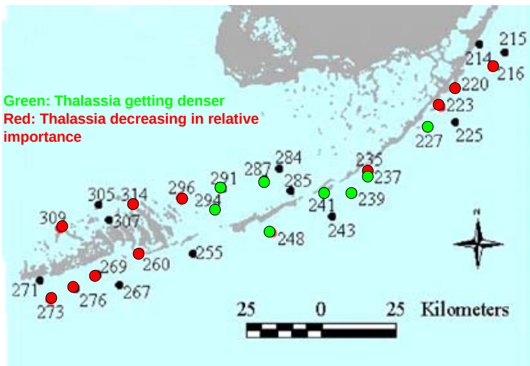

Figure 4. Map of sites showing changes in relative abundance of species consistent with the eutrophication model.

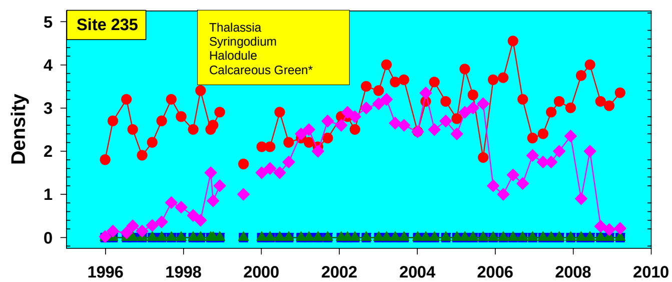

Figure 5. Long-term change in relative abundance of seagrasses and macroalage. Note the decrease in the relative importance of calcareous green algae (pink) relative to Thalassia testudinum (red) beginning in 2006)

In addition to these sites where relative abundance of primary producers has changed, at 10 of 30 Level 1 sites there have been long-term shifts in the ratio of nitrogen to phosphorus in seagrass leaves that are consistent with increases in nutrient availability (Figure 6). It is important to note that only 5 sites showed statistically significant trends in N:P for the period ending 2007. An example data set from one site, offshore of Key Largo, shows data from a previously P-limited site where N:P of *Thalassia* leaves has decreased, consistent with increased availability of P over the period 1995-2008 (Figure 7). Two sites that were heavily effected by the passage of hurricanes (309 and 314) displayed trends in N:P away from Redfield over the monitoring period, suggesting that nutrient availability has decreased at these sites over the monitoring period.

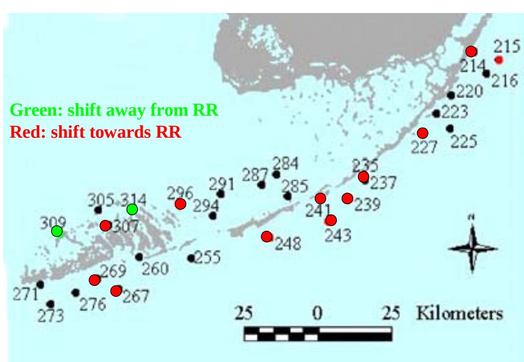

Figure 6. Location of sites showing shift in seagrass N:P

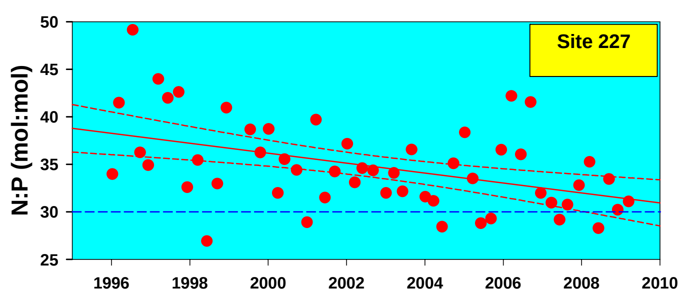

Figure 7. Long term trend in N:P of Thalassia testudinum leaves from site 227. Blue line is 30:1 seagrass redfield value indicating no nutrient limitation

While the trends in indicators we present are consistent with model predictions of nutrient-induced changes of these systems, there may be reasons for these observations that are unrelated to man's activities in the region. However, the spatial pattern of changes and the agreement of the changes with models of the system suggest that there is regional-scale change in nutrient availability that is causing changes in seagrass beds over a wide portion of the FKNMS.

Definition of Seagrass Status Criteria for FKNMS

The diversity of sites, and the differing ways that spatially distinct sites could respond to nutrient addition, make it difficult to extract a single indicator criterion to assess the trends in the health of the seagrass beds of the FKNMS. In a attempt to extract such indicators, we developed two indicator criteria to annually assess the status and trends in the seagrass communities of south Florida. The first of these is based on elemental content of the seagrass tissues, and the second is based on the species composition of the seagrass communities.

As discussed above, seagrasses have an ideal ratio of N:P of 30:1 if they are growing in an environment in which some factor other than nutrients limit their growth. So, in a way that may at first seem counter-intuitive, seagrasses with the “ideal” N:P are ones that are growing in either high nutrient or low light environments. Both of these conditions represent poor water quality in the south Florida marine ecosystem. Statistically significant temporal trends in N:P of leaves of seagrasses towards 30:1 indicates a decrease in light and/or an increase in nutrient supply. Nearshore in the Florida Keys, P is in short supply and a decrease in N:P is an indicator of worsening water quality; while offshore, N is in short supply and an increase in N:P is cause for alarm. Currently, long term trends in the seagrass *Thalassia* N:P indicate decreases in water quality at 10 of the 30 monitored sites (Figure 6), while increases in water quality were indicated at 2 sites. To summarize these trends into a single indicator metric which we term *EI* (Elemental Indicator), we calculate the mean absolute difference in N:P from the ideal 30:1 for the 30 permanent monitoring sites based on the 10-year mean N:P at each of those sites:

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

The long-term average mean absolute difference in the N:P of *Thalassia* leaves at the 30 sites is 8.28 ± 1.47 (± 1 standard error). A decrease in *EI* from this long term value will indicate a Sanctuary-wide decrease in water quality.

The second status indicator is based on species composition of seagrass beds. A significant long-term decrease in the ratio of the abundance of the slowest growing species at a site compared to the sum of abundances of species at a site indicates an increase in nutrient availability at that site. We have defined the quantity *SLOW* for each site:

$$SLOW = \frac{A_{Tt}}{A_{Tt} + A_{Sf} + A_{Hw} + A_{Macroa\lg ae}}$$

Where A_{Tt} = long term mean Abundance of *Thalassia testudinum*, A_{Sf} = long term mean Abundance of *Syringodium filiforme*, A_{Hw} = long term mean Abundance of *Halodule wrightii*, and $A_{macroalgae}$ is the sum of the long term mean abundances of the macroalgal taxa.

From the site=specific values of *SLOW*, we define the Species Composition Indicator (*SCI*) as the mean *SLOW* across the 30 monitoring sites:

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

Based on the long-term mean abundances established during the first 10 years of monitoring, *SCI* = 0.48 ± 0.04 (± 1 standard error). Any decrease in this *SCI* will be interpreted as a decrease in water quality across the Sanctuary.

Both the EI and SCI changed in 2008 compared to previous years. The EI in 2006 was 9.5 +/- 1.4 in 2006; 7.8 +/- 1.2 in 2007, and decreased to 6.9 +/- 1.1 in 2008 (+/- 1 standard error); this small decrease is consistent with an increase in nutrient availability or a decrease in light availability, but the EI values from 2006-2008 were within the long-term average value of the EI of 8.3 +/- 1.5 (Figure 9). The SCI values decreased from 0.55 +/- 0.04 in 2006 to 0.48 +/- 0.04 in 2007, to 0.47 +/- 0.04 in 2008; despite the trend of decreasing SCI, none of the values measured over the period 2006-2008 were outside of the confidence estimate of the long-term arerage established over the period 1995-2005 (Figure 10).

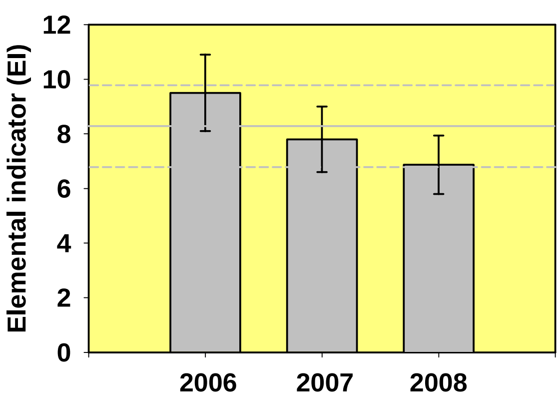

Figure 9. The Elemental Indicator of status of seagrasses in the FKNMS has declined for 3 years running, consistent with increases in nutrient availability.

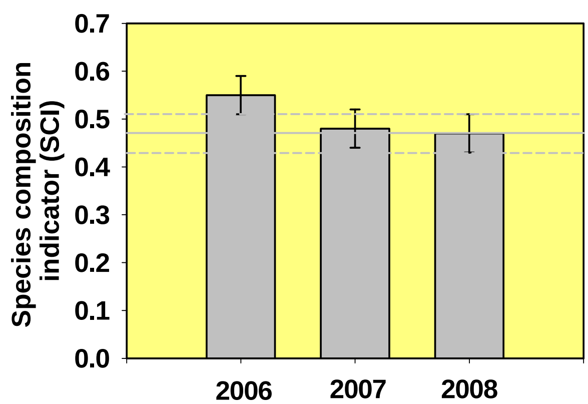

Figure 10. The Species Composition Indicator has also decreased three years running, consistent with a shift towards faster-growing plants due to eutrophication.

Our surveys have provided clear documentation of the distribution and importance of seagrasses in the FKNMS. The seagrass bed that carpets 80% of the FKNMS is part of the largest documented contiguous seagrass bed on earth. These extensive meadows are vital for the ecological health of the FKNMS and the marine ecosystems of all of south Florida. Maps of spatial distributions and time series of species composition, seagrass productivity, nutrient availability and physical parameters can be found for each permanent monitoring site on the web site, www.fiu.edu/~seagrass .

Detailed analyses of the monitoring data have led to 23 peer-reviewed publications in the scientific literature (listed below). These publications address aspects of the functioning, status and trends of benthic communities as well as lay the groundwork for forecasting future anthropogenic impacts on this ecosystem.

Publications

1. Sea urchin overgrazing of a large seagrass bed in outer Florida Bay. Rose, C.D., W.C. Sharp, W.J. Kenworthy, J.H. Hunt, W.G. Lyons, E.J. Prager, J.F. Valentine, M.O. Hall, P. Whitfield, and J.W. Fourqurean. 1999. Marine Ecology Progress Series 190:211-222.

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3. Competition between the tropical alga, Halimeda incrassata, and the seagrass, Thalassia testudinum. Davis, B.C. and J.W. Fourqurean. 2001. Aquatic Botany 71(3):217-232.

4. Large-scale patterns in seagrass (*Thalassia testudinum*) demographics in south Florida. Peterson, B. J. and J. W. Fourqurean. 2001, Limnology and Oceanography 46(5):1077-1090.

5. Seagrass distribution in south Florida: a multi-agency coordinated monitoring program. Fourqurean, J. W., M. J. Durako, M. O. Hall and L. N. Hefty. 2002. Pp 497-522 in: Porter, J.W. and K.G. Porter, eds. The Everglades, Florida Bay, and the coral reefs of the Florida Keys. CRC Press LLC, Boca Raton. 1000pp.

6. Disturbance and recovery following catastrophic grazing: studies of a successional chronosequence in a seagrass bed. Peterson, B. J., C. D. Rose, L. M. Rutten and J. W. Fourqurean. 2002. Oikos 97: 361-370.

7. Seagrass nutrient content reveals regional patterns of relative availability of nitrogen and phosphorus in the Florida Keys, FL, USA, Fourqurean, J. W. and J. C. Zieman. 2002. Biogeochemistry 61: 229-245.

8. Monitoring of soft-bottom marine habitat on the regional scale: the competing goals of spatial and temporal resolution. Fourqurean, J.W. and L.M. Rutten. 2003. Pp 257-288 in: Busch, D. and J.C. Trexler, eds. Ecological Monitoring of Ecosystem Initiatives. Island Press, Washington, D.C.

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10. Intra- and interannual variability in seagrass carbon and nitrogen stable isotopes from south Florida, a preliminary study. Anderson, W.T. and J.W. Fourqurean. 2003. Organic Geochemistry 34:185-194.

11. Spatial and seasonal variability in elemental content, $\delta^{13}C$ and $\delta^{15}N$ of *Thalassia testudinum* from south Florida. Fourqurean, J.W. S.P. Escorcia, W.T. Anderson and J.C. Zieman. Estuaries. 2005. 28(3):447-461.

12. The impact of Hurricane Georges on soft-bottom, backreef communities: site- and species-specific effects in south Florida seagrass beds. Fourqurean, J. W. and L. M. Rutten. Bulletin of Marine Science. 2004. 75(2):239-257.

13. Nutrient limitation of benthic primary production in the upper Florida Keys. Ferdie, M., Masters of Science Thesis, Florida International Universtiy, Biology Department, 2002.

14. An assessment of nearshore benthic communities of the Florida Keys. Rutten, L.M., Masters of Science Thesis, Florida International University, Biology Department, 2002.

15. Elucidating seagrass population dynamics: theory, constraints and practice. Fourqurean, J.W., N. Marbà, and C.M. Duarte. 2003. Limnology and Oceanography 48(5):2070-2074.

16. Differential responses of benthic primary producers to nitrogen and phosphorus enrichment in a carbonate coastal marine system. Ferdie, M. and J.W. Fourqurean. 2004. Limnology and Oceanography 49(6):2082-2094.

17. Spatiotemporal variation of the abundance of calcareous green macroalgae in the Florida Keys: A study of synchrony within a macroalgal functional-form group. Collado-Vides, L., L.M. Rutten and J.W. Fourqurean. 2005. Journal of Phycology 41(4):742-752.

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21. Phenology, sexual reproduction, and the factors affecting sexual reproduction of the marine angiosperm, *Thalassia testudinum*, in the Florida Keys National Marine Sanctuary (FKNMS). Cunniff, K. M. Masters of Science Thesis, Florida International University, Biology Department. 2006.

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