2013 ANNUAL REPORT
OF THE WATER QUALITY MONITORING PROJECT
FOR THE WATER QUALITY PROTECTION PROGRAM
OF THE FLORIDA KEYS NATIONAL MARINE SANCTUARY

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EXECUTIVE SUMMARY

This report serves as a summary of our efforts to date in the execution of the Water Quality Monitoring Project for the FKNMS as part of the Water Quality Protection Program. The period of record for this report is Mar. 1995 – Dec. 2013 and includes data from 73 quarterly sampling events within the FKNMS. This annual report reflects funding cutbacks in 2012 resulting in reduction of spatial sampling from 155 to 112 sites.

Field parameters measured at each station (surface and bottom at most sites) include salinity (practical salinity scale), temperature (ºC), dissolved oxygen (DO, mg l^{-1}), turbidity (NTU), relative fluorescence, and light attenuation (K_d, m^{-1}). Water quality variables include the dissolved nutrients nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), and soluble reactive phosphorus (SRP). Total unfiltered concentrations include those of nitrogen (TN), organic carbon (TOC), phosphorus (TP), silicate (SiO_2) and chlorophyll *a* (CHLA, µg l^{-1}).

The EPA developed Strategic Targets for the Water Quality Monitoring Project (SP-47) which state that beginning in 2008 through 2012, they shall annually maintain the overall water quality of the near shore and coastal waters of the FKNMS according to 2005 baseline. For reef sites, chlorophyll *a* should be less than or equal to 0.2 µg l^{-1} and the vertical attenuation coefficient for downward irradiance (K_d, i.e., light attenuation) should be less than or equal to 0.13 m^{-1}. For all monitoring sites in FKNMS, dissolved inorganic nitrogen should be less than or equal to 0.75 µM (0.010 ppm) and total phosphorus should be less than or equal to 0.2 µM (0.0077 ppm). Table 1 shows the number of sites and percentage of total sites exceeding these Strategic Targets for 2013.

We must recognize that the reduction of sampling sites in western FKNMS (less human-impacted sites) and the increase in inshore sites (heavily human-impacted sites) introduces a bias to the dataset which results in a reporting problem, perhaps requiring a revision of SP-47 to correct this deviation. To avoid such complications, we have not included the recently added locations (#500 to #509) in the calculation of compliances.

Table 1: EPA WQPP WQ Targets derived from 1995-2005 Baseline

For reef stations, chlorophyll less than or equal to 0.2 micrograms liter^{-1} (ugl^{-1}) and vertical attenuation coefficient for downward irradiance (K_d, i.e., light attenuation) less than or equal to 0.13 per meter; for all stations in the FKNMS, dissolved inorganic nitrogen less than or equal to 0.75 micromolar and total phosphorus less than or equal to 0.2 micromolar; water quality within these limits is considered essential to promote coral growth and overall health. The "number of samples" exceeding these targets is tracked and reported annually. Values in green are those years with % compliance greater than 1995-2005 baseline. Values in yellow are those years with % compliance less than 1995-2005 baseline.

EPA WQPP Water Quality Targets

	REEF Stations		All Stations (excluding SHORE sites)	
Year	CHLA ≤ 0.20 µg l^{-1}	K_d ≤ 0.13 m^{-1}	DIN ≤ 0.75 µM (0.010 ppm)	TP ≤ 0.25 µM (0.0077 ppm)
1995-05	1778 of 2367 (75.1%)	1042 of 1597 (65.2%)	7826 of 10254 (76.3%)	7810 of 10267 (76.1%)
2006	196 of 225 (87.1%)	199 of 225 (88.4%)	432 of 990 (43.6%)	316 of 995 (31.8%)
2007	198 of 226 (87.6%)	202 of 222 (91.0%)	549 of 993 (55.3%)	635 of 972 (65.3%)
2008	177 of 228 (77.6%)	181 of 218 (83.0%)	836 of 1,000 (83.6%)	697 of 1,004 (69.4%)
2009	208 of 228 (91.2%)	189 of 219 (86.3%)	858 of 1,003 (85.5%)	869 of 1,004 (86.6%)
2010	170 of 227 (74.9%)	176 of 206 (85.4%)	843 of 1000 (84.3%)	738 of 1,003 (73.6%)
2011	146 of 215 (67.9%)	156 of 213 (73.2%)	813 of 1012 (80.3 %)	911 of 1013 (89.9 %)
2012	142 of 168 (84.5%)	135 of 168 (80.4%)	489 of 683 (71.6 %)	634 of 684 (92.7 %)
2013	148 of 172 (86.0%)	150 of 172 (87.2%)	496 of 688 (72.1 %)	603 of 688 (87.6 %)

Important Results Realized from this Monitoring Project

1. Land-based Influence on Water Quality

We documented elevated nutrient concentrations (DIN, TN, TP, and SiO_2) in waters close to shore along the Keys, and their corresponding responses from the system, such as higher phytoplankton biomass (CHLA), turbidity, as well as lower salinity and DO in the water column. These changes, associated to human impact, have become even more obvious by the addition of 10 stations (# 500 to #509) located very close to shore, (within the so-called 500 m Halo; FDEP 2011) sampled since Nov 2011 (SHORE).

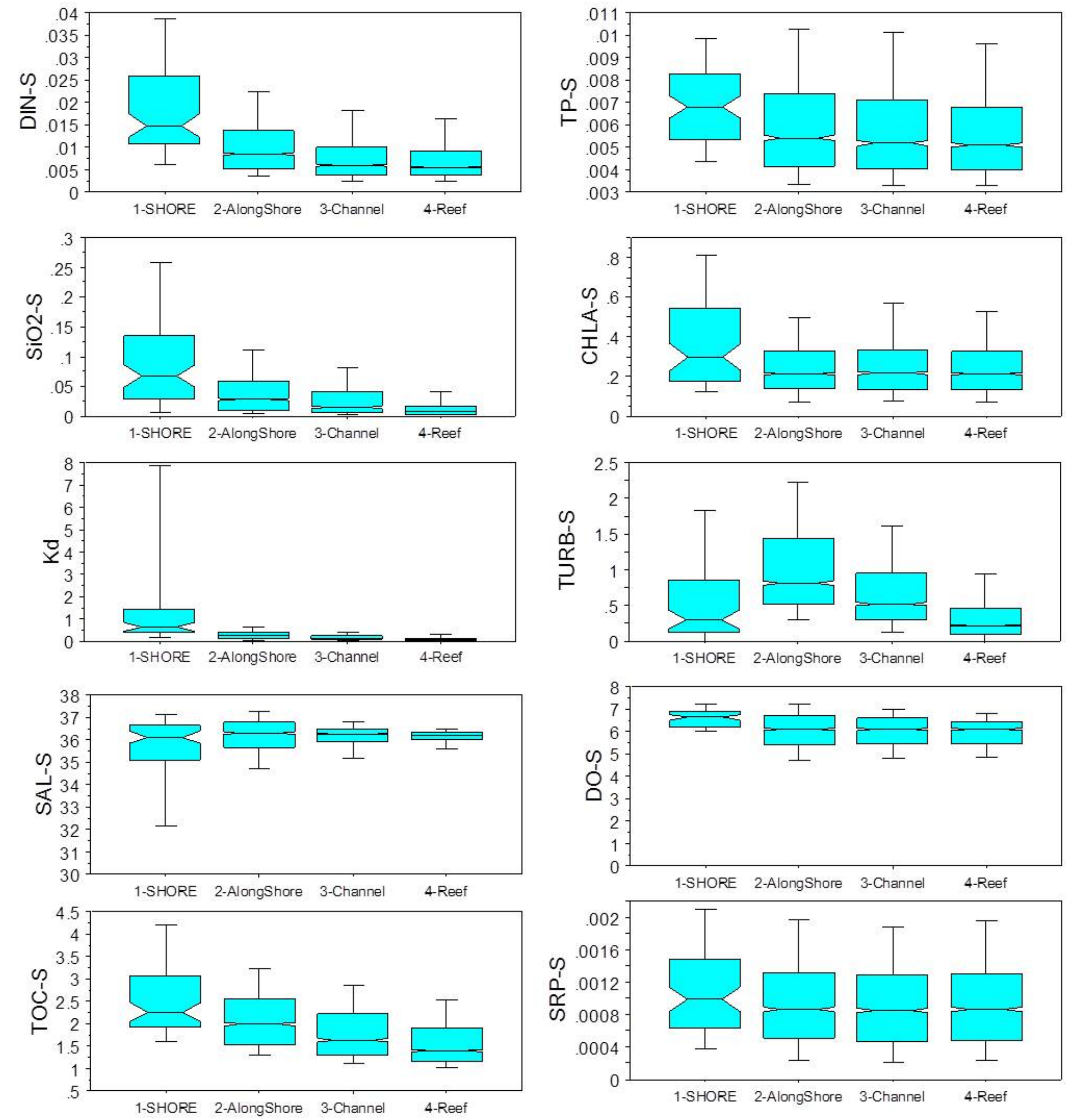

Figure i. *Nutrient and response changes along transect from shore sites to reef-track*

This trend, especially for DIN was evident from our first sampling event in 1995 and was not observed in a comparison transect from the Tortugas (no human impact). This pattern suggests a land-bound, freshwater end-member as the main nutrient source. In summary, this type of distribution would imply a relatively nutrient-rich land source which is diluted by low nutrient Atlantic Ocean waters.

This raises another important point; when looking at what are perceived to be local trends, we find that they seem to occur across the whole region but at more damped amplitudes. This spatial autocorrelation in water quality is an inherent property of highly interconnected systems such as coastal and estuarine ecosystems driven by similar hydrological and climatological forcing. It is clear that trends observed inside the FKNMS are influenced by regional conditions outside the Sanctuary boundaries. Inclusion of new stations close to shore highlights where human impact is more evident.

2. Numeric Nutrient Criteria Development

In order to gain a better understanding of the spatial patterns of water quality of the FKNMS, we attempted to reduce the complicated data matrix into fewer elements which would provide robust estimates of condition and connection. To this end we developed an objective classification analysis procedure which grouped stations according to water quality similarity (Briceño et al. 2013, Fig. ii).

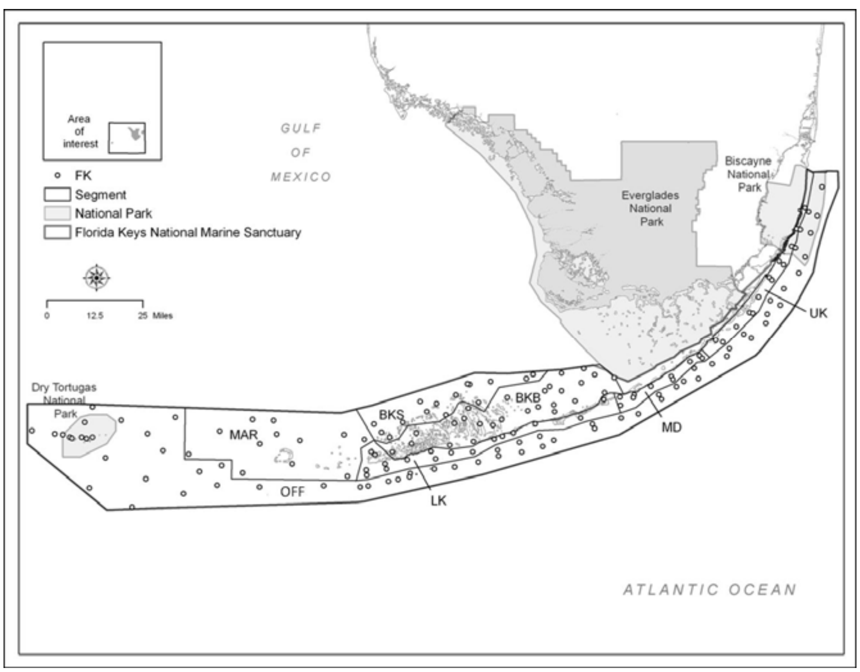

Figure ii. *Map of FKNMS showing segments derived from Factor and Cluster Analysis of biogeochemical data: OFF=Offshore; MAR=Marquesas; BKS=Back Shelf; BKB= Back Bay; LK= Lower Keys; MK= Middle Keys; UK= Upper Keys*

This segmentation was proposed to EPA and FDEP for use in developing numeric nutrient criteria for FL estuaries and coastal waters. The statistical approach was adopted by FDEP and referenced as Eight Maps of FL Marine Nutrient Regions, https://www.flrules.org/Gateway/reference.asp?No=Ref-01215, dated Oct. 19, 2011. The nutrient criteria for this region was subsequently developed using data from this Florida Keys Water Quality Monitoring Project and submitted to EPA in March 2013 as FDEP Implementation of FL Numeric Nutrient Standards, NNC_Implementation_3-11-13.pdf. On June 27, 2013, EPA approved 062713_epa_approval_nnc_implementation_document.pdf, FDEP Rule 62.300 (19) F.A.C. which includes 62.302.532 Estuary-Specific Numeric Interpretations of the Narrative Nutrient Criterion (the Coastal Estuary Rule), 62_302_final.pdf.

We believe that this accomplishment is an important achievement for a Federally-funded, University-operated water quality monitoring program and should be a model for future projects.

3. Trend analysis

Most Atlantic side reef sites experienced increased surface DO over the 18 year period of record (Fig. iii). Declines in surface DO were generally observed on the Gulf side of the Middle and Lower Keys and in some inshore areas on the Atlantic side. Bottom DO trends showed a similar pattern as surface with more increased DO than surface sites (Fig. iv). Increased DO is beneficial for animal life.

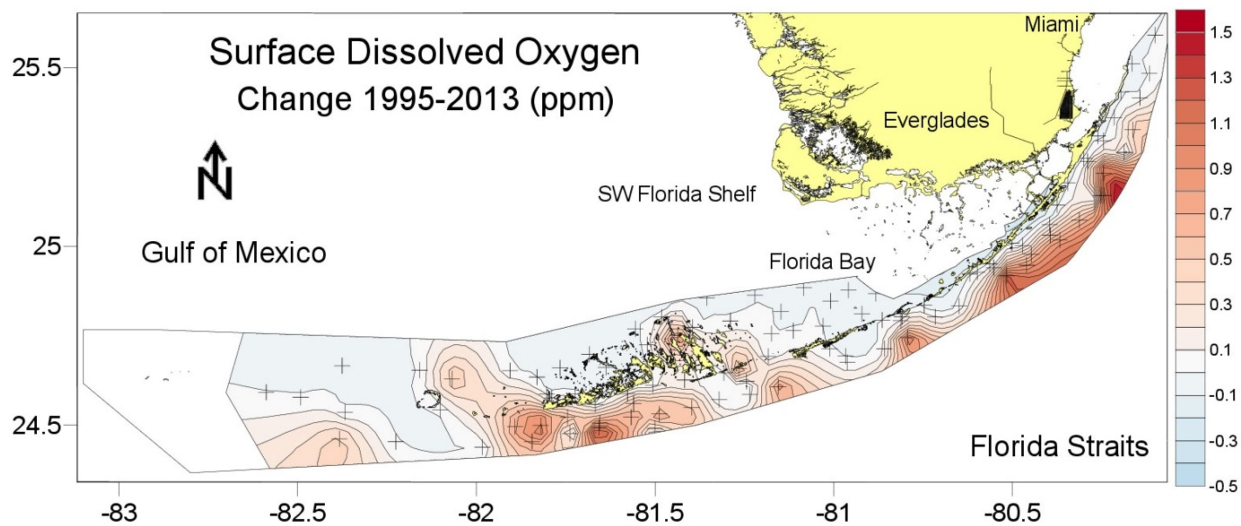

Figure iii. *Total change in DO of surface waters for 18 year period calculated from significant trends (p<0.10).*

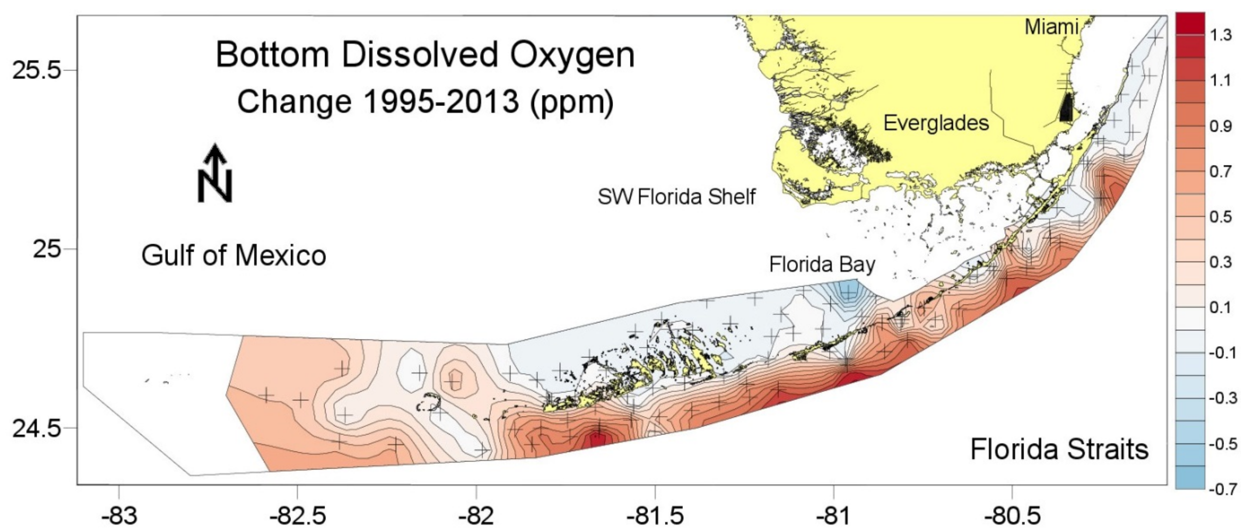

Figure iv. *Total change in DO of bottom waters for 18 year period calculated from significant trends (p<0.10).*

Water column turbidity, or cloudiness, declined throughout the FKNMS during the 18 year period (Fig v). There was no significant change in turbidity in bottom waters. The largest declines in turbidity occurred in western Florida Bay and Marquesas.

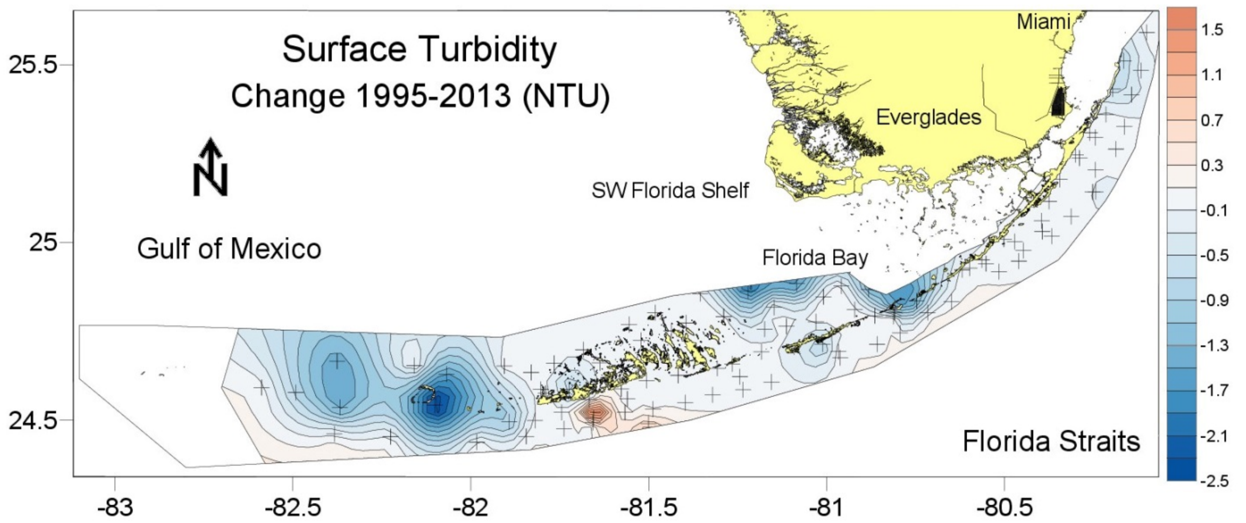

Figure v. *Total change in Turbidity in surface waters for 18 year period calculated from significant trends ($p<0.10$).*

Light extinction in the water column (K_d) also declined throughout most of the FKNMS, mostly as a result of decreased turbidity (Fig. vi). The smaller the K_d, the clearer the water column. This trend was the result of a general decrease in turbidity throughout the Keys (Fig. v).

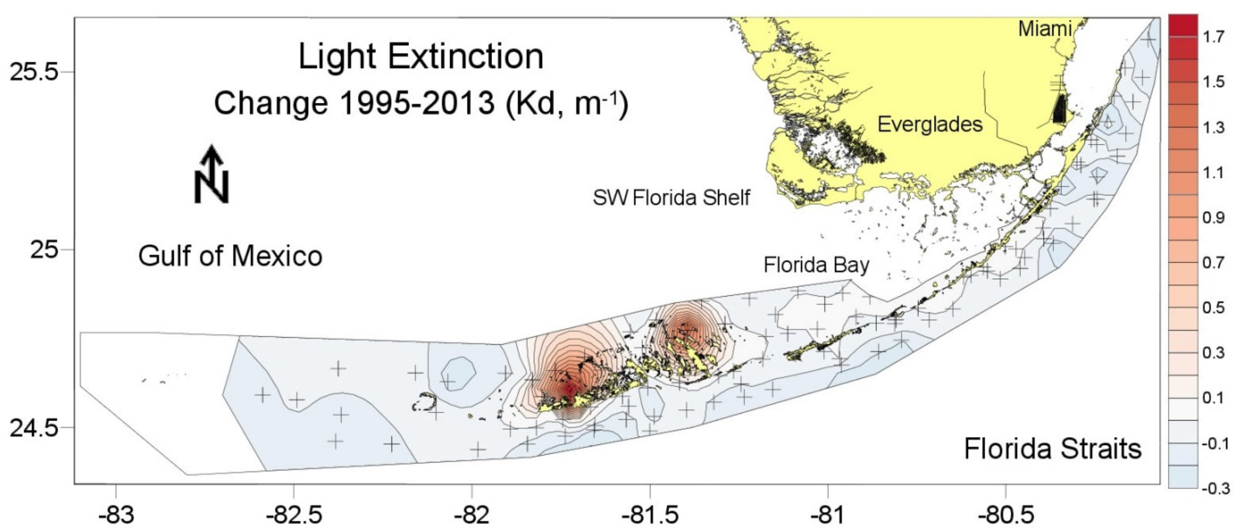

Figure vi. *Total change in K_d of water column for 18 year period calculated from significant trends ($p<0.10$).*

As a further consequence, the percent of ambient light reaching the bottom (I_o) increased at most reef sites throughout the Keys (Fig. vii). More light on the bottom is beneficial to corals, seagrass, and algae. Interestingly, the Backcountry area of the lower Keys experienced increases in K_d which lead to corresponding decreases in I_o (Fig vii).

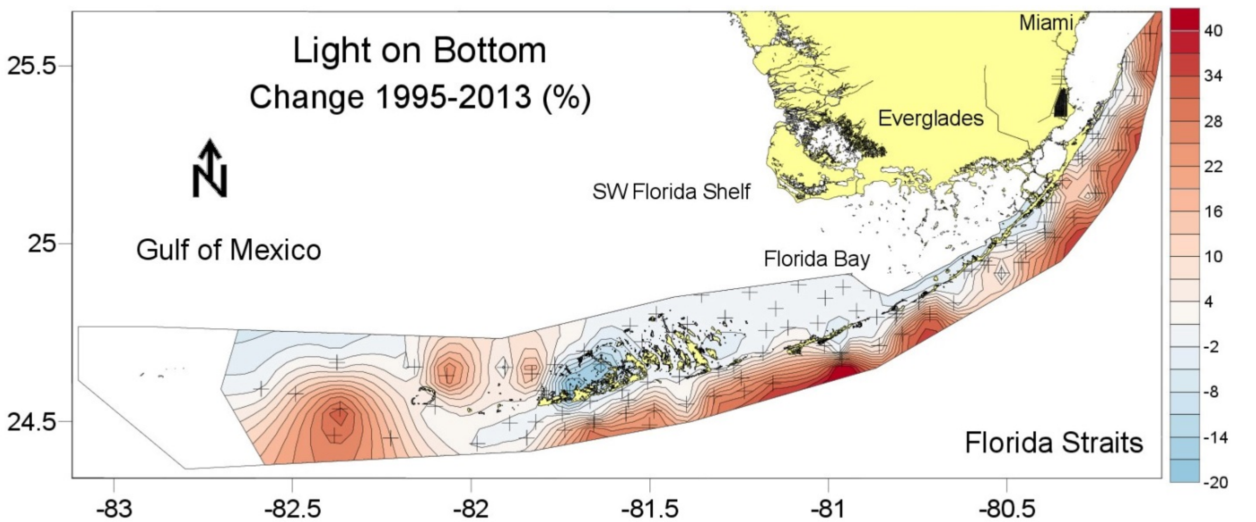

Figure vii. *Total change in bottom I_o for 18 year period calculated from significant trends ($p<0.10$).*

<u>Nitrate in the surface waters declined</u> significantly, especially along Middle and Lower Keys (Fig. viii). NO_3^- was the only N variable which showed any significant trend (NO_2^- concentrations are too small to be of any significance). Declines were greatest in surface waters of the Backcountry and inshore of Middle Keys.

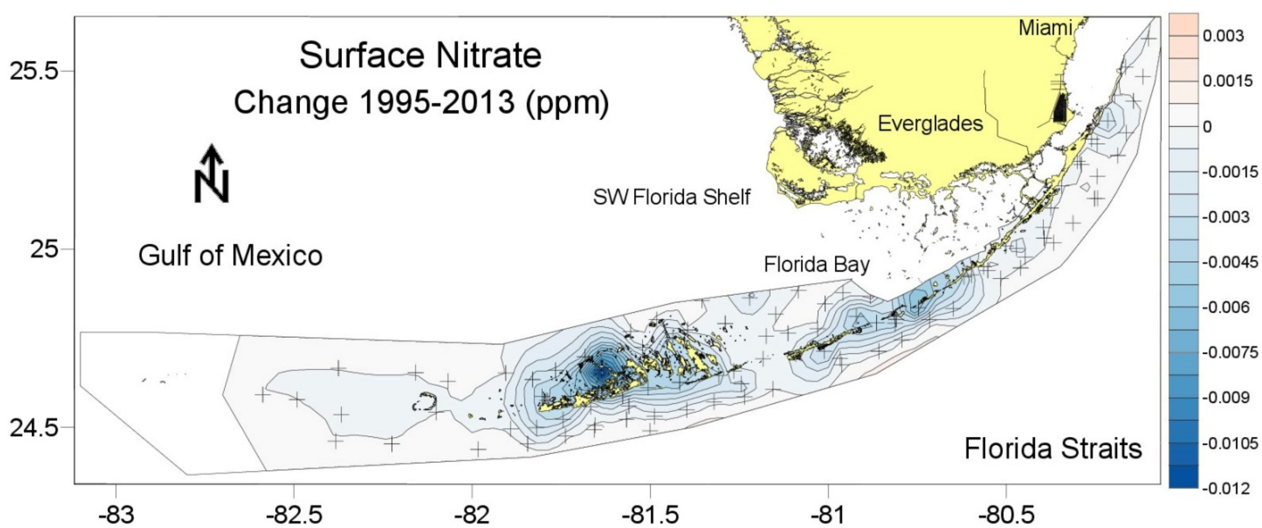

Figure viii. *Total change in NO_3^- in surface waters for 18 year period calculated from significant trends ($p<0.10$).*

<u>Silicate in surface waters increased</u> mostly in western Florida Bay/Sluiceway but declined slightly across the region (Fig ix). The source of SiO_2 in this region is Everglades runoff (diatomaceous periphyton). Overall results in bottom waters have slightly declined with a local exception offshore the Middle Keys (Fig. x).

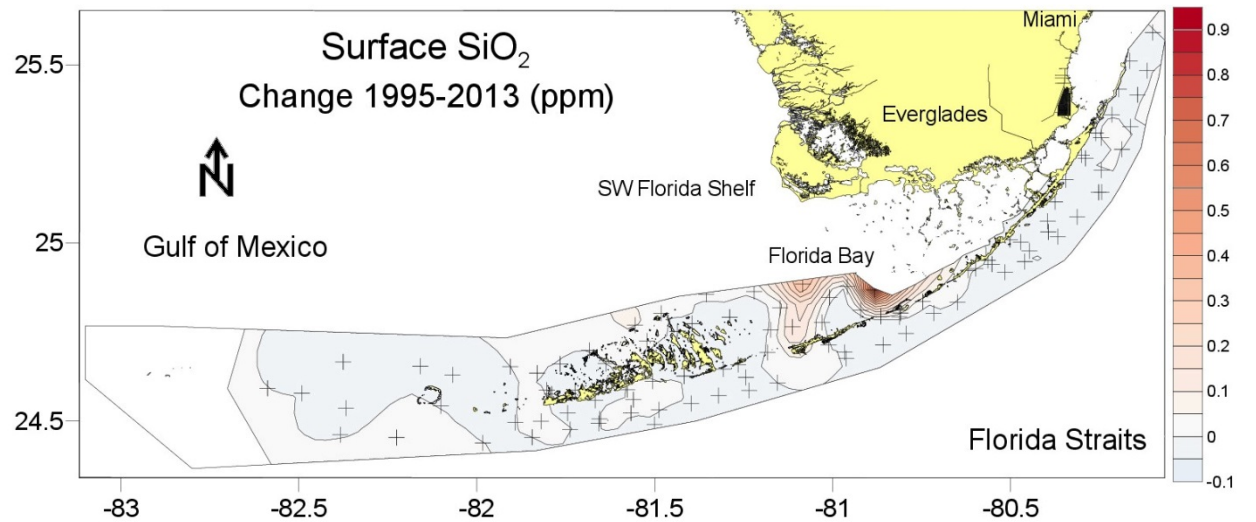

Figure ix. *Total change in SiO_2 in surface waters for 18 year period calculated from significant trends ($p<0.10$).*

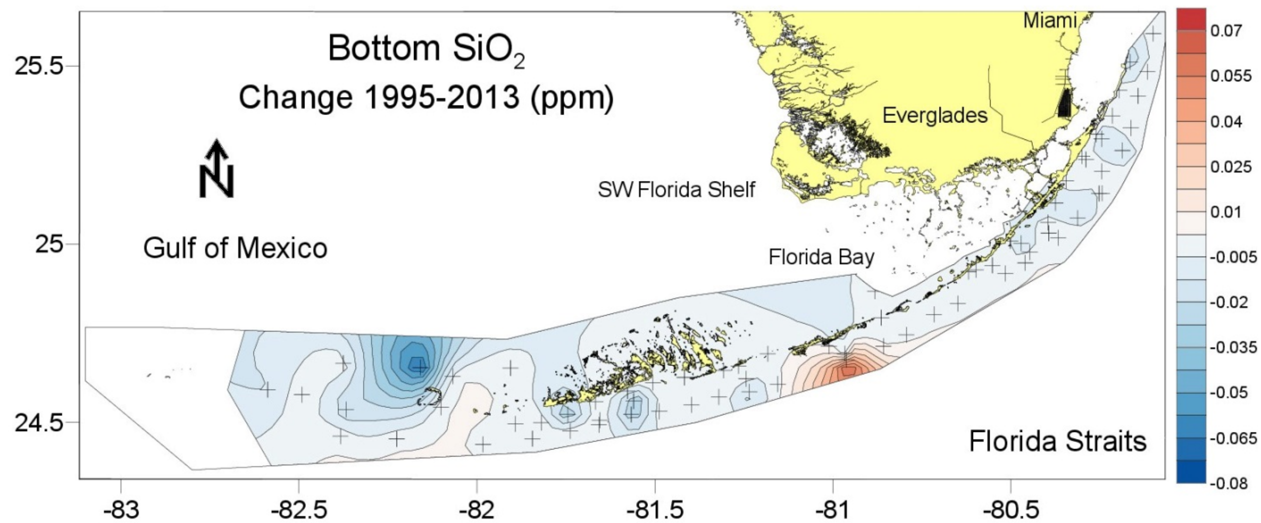

Figure x. *Total change in SiO_2 in bottom waters for 18 year period calculated from significant trends ($p<0.10$).*

No significant trends in TP were observed, however concentrations of SRP did increase in most surface and bottom waters (Fig. xi & xii). It must be noted that concentrations of SRP are generally an order of magnitude lower than TP and are usually below kinetic uptake threshold of phytoplankton, meaning it is not all that accessible.

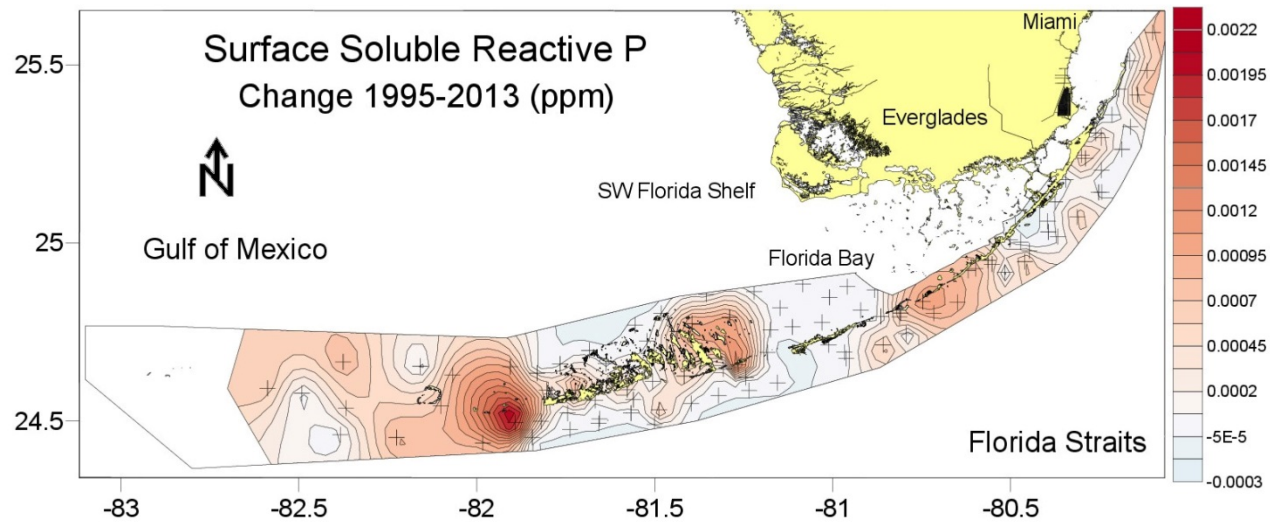

Figure xi. *Total change in SRP in surface waters for 18 year period calculated from significant trends (p<0.10).*

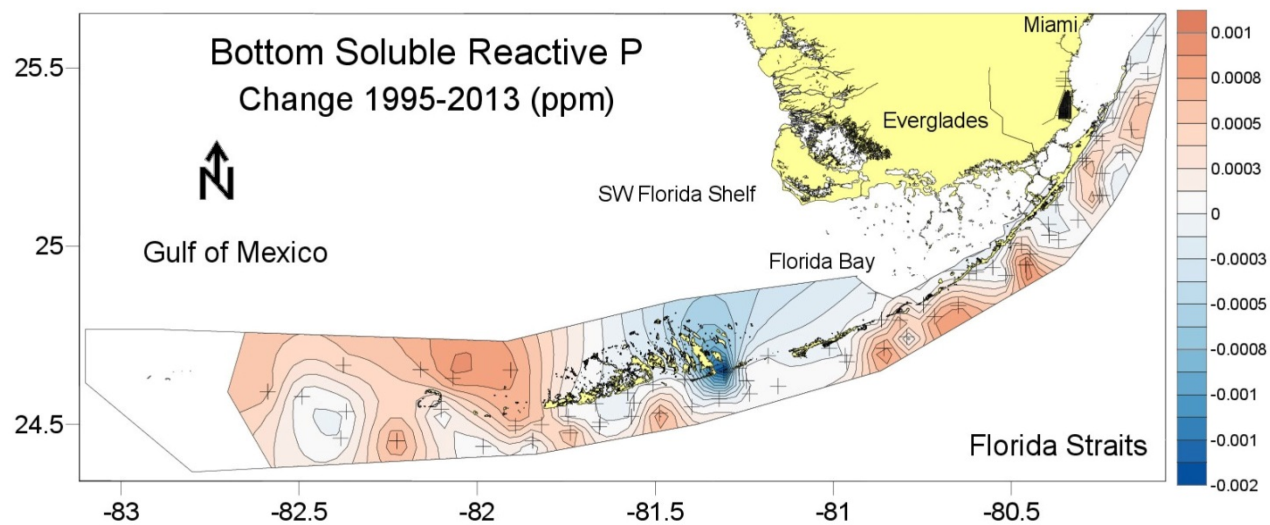

Figure xii. *Total change in SRP in bottom waters for 18 year period calculated from significant trends (p<0.10).*

Clearly, there have been some changes in the FKNMS water quality over time, but the largest sustained monotonic trend has been the decline in surface TOC concentration. There were strong declines in surface TOC throughout the FKNMS, especially in the Backcountry and the Marquesas (Fig. xiii). This is part of a regional trend in TOC observed on the SW Shelf, Florida Bay, and the mangrove estuaries draining the Everglades. This decline could be considered favorable given that TOC corresponds with CDOM (an important driver of water color and light penetration), but could also be an indication of decreased upstream primary production.

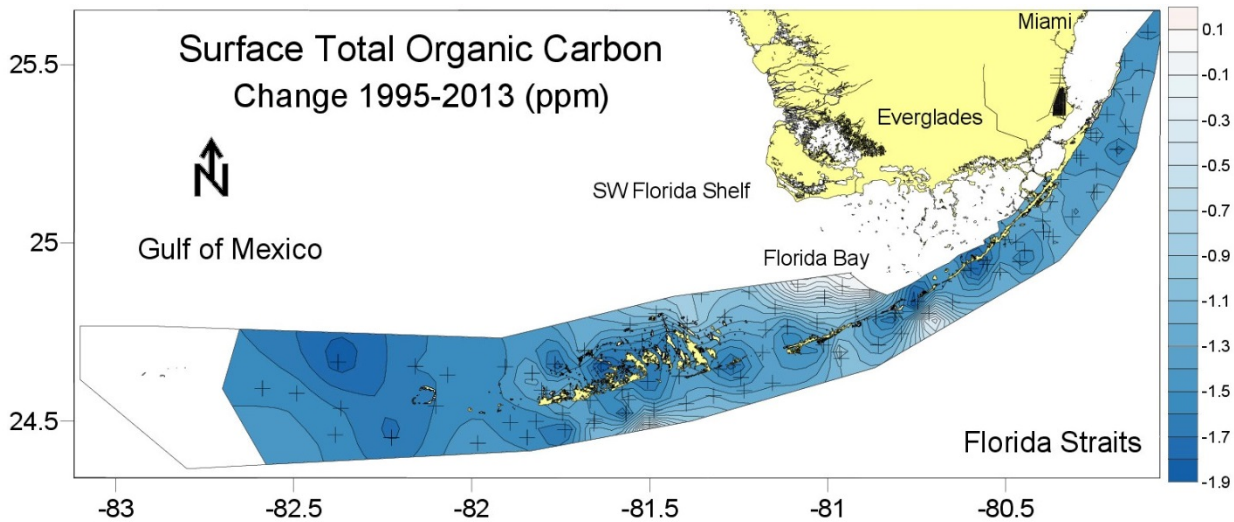

Figure xiii. *Total change in TOC in surface waters for 18 year period calculated from significant trends ($p<0.10$).*

The large scale of this monitoring program has allowed us to assemble a much more holistic view of broad physical/chemical/biological interactions occurring over the South Florida hydroscape. This confirms that rather than thinking of water quality monitoring as being a static, non-scientific pursuit it should be viewed as a tool for answering management questions and developing new scientific hypotheses.

We continue to maintain a website (http://serc.fiu.edu/wqmnetwork/) where data and reports from the FKNMS are integrated with other available programs.