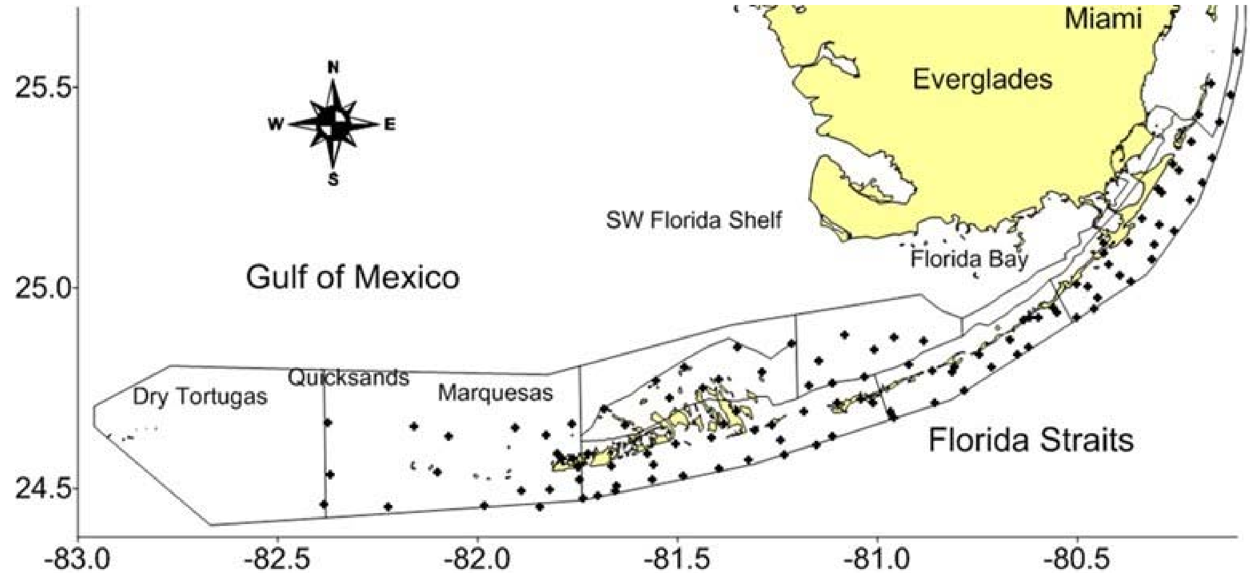
2024 ANNUAL REPORT
OF THE WATER QUALITY MONITORING PROJECT
FOR THE WATER QUALITY PROTECTION PROGRAM
OF THE FLORIDA KEYS NATIONAL MARINE SANCTUARY



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EXECUTIVE SUMMARY

In 1990, President Bush signed into law the Florida Keys National Sanctuary and Protection Act (HR5909) which designated a boundary encompassing >2,800 square nautical miles of islands, coastal waters, and coral reef tract as the Florida Keys National Marine Sanctuary (FKNMS). The Comprehensive Management Plan required the FKNMS to have a Water Quality Protection Plan (WQPP) thereafter developed by EPA and the State of Florida.

This report serves as a **30 year summary** of efforts to date in the execution of the Water Quality Monitoring Project for the FKNMS as part of the WQPP. The period of record for this report is Mar. 1995 – Dec. 2024 and includes data from 118 quarterly sampling events within the FKNMS over those 30 years.

For this year, field measurements and grab samples were collected from 112 fixed stations within the FKNMS boundary. Field measurements from each station (surface and bottom at most sites) included salinity, temperature (°C), dissolved oxygen (DO, mg l^{-1}), turbidity (NTU), and diffuse light attenuation coefficient (K_d, m^{-1}). Water quality variables included the dissolved nutrients nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), and soluble reactive phosphorus (SRP). Total unfiltered concentrations included those of nitrogen (TN), organic carbon (TOC), phosphorus (TP), silicate (SiO_2) and chlorophyll *a* (CHLA, µg l^{-1}). Dissolved inorganic nitrogen (DIN) was calculated as NO_3^-+NO_2^-+NH_4^+ and total organic nitrogen (TON) as TN-DIN. All variables are reported in elemental mg l^{-1} (ppm) unless otherwise noted.

Strategic Targets

The EPA developed Strategic Targets for the Water Quality Monitoring Project (SP-47) which states that beginning in 2008, they shall annually maintain the overall water quality of the near shore and coastal waters of the FKNMS according to the 2005 baseline. For reef sites, CHLA should be less than or equal to 0.35 µg l^{-1} (ppb) and the K_d should be less than or equal to 0.20 m^{-1}. For all monitoring sites in the FKNMS, DIN should be less than or equal to 0.75 µM (10.5 ppb) and TP should be less than or equal to 0.25 µM (7.7 ppb).

The 2011 reduction of sampling sites in Tortugas/western FKNMS (Tortugas, less human-impacted sites) and addition of close in, shore sites (Shore, heavily human-impacted sites) introduced a bias to the dataset which might require a revision of SP-47 to correct this deviation. To avoid complications, we have not included the Tortugas or Shore stations in calculation of compliances after 2010.

The number of sites and percentage of total sites meeting and exceeding these Strategic Targets for the period of record to 2024 are shown in *Table i*. In addition, *Figure i* shows the graphs of percentage of sites meeting the targets in relation to baselines for CHLA, K_d. DIN, and TP.

For the six years prior to 2023, CHLA was elevated relative to the 2005 Target Baseline. 2023 and 2024 showed a return to lower CHLA across the region. TP was elevated for three of the last five years. These are indicators of creeping eutrophication and bear continued vigilance.

***Table i*: EPA WQPP Water Quality Targets derived from 1995-2005 Baseline**

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 ≤ 0.35 ppb	$K_d \leq 0.20\ m^{-1}$	DIN ≤ 10.5 ppb	TP ≤ 7.7 ppb
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 1,000 (84.3%)	738 of 1,003 (73.6%)
2011	146 of 215 (67.9%)	156 of 213 (73.2%)	813 of 1,012 (80.3 %)	911 of 1,013 (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 %)
2014	141 of 172 (82.0%)	133 of 172 (77.3%)	426 of 690 (61.7%)	540 of 690 (78.3%)
2015	122 of 172 (70.9%)	135 of 172 (78.5%)	487 of 688 (70.8%)	613 of 688 (89.1%)
2016	131 of 172 (76.2%)	129 of 170 (75.9%)	427 of 687 (62.2%)	549 of 688 (79.8%)
2017	106 of 172 (61.6%)	120 of 170 (70.6%)	440 of 575 (76.5 %)	581 of 683 (85.1 %)
2018	92 of 170 (54.1%)	108 of 152 (71.7%)	558 of 689 (81.0 %)	573 of 689 (82.3 %)
2019	112 of 171 (65.5%)	133 of 168 (79.2%)	669 of 684 (97.8 %)	587 of 686 (85.6 %)
2020	129 of 172 (75.0%)	141 of 169 (83.4%)	617 of 688 (89.7%)	466 of 688 (67.7%)
2021	123 of 172 (71.5%)	141 of 172 (82.0%)	611 of 688 (88.8%)	527 of 688 (76.6%)
2022	98 of 172 (57.0%)	129 of 171 (75.4%)	533 of 686 (77.7%)	458 of 688 (66.6%)
2023	129 of 170 (75.9%)	125 of 166 (75.3%)	624 of 684 (91.2%)	294 of 684 (43.0%)
2024	138 of 171 (80.7%)	127 of 169 (75.1%)	570 of 687 (83.0%)	584 of 688 (84.9%)

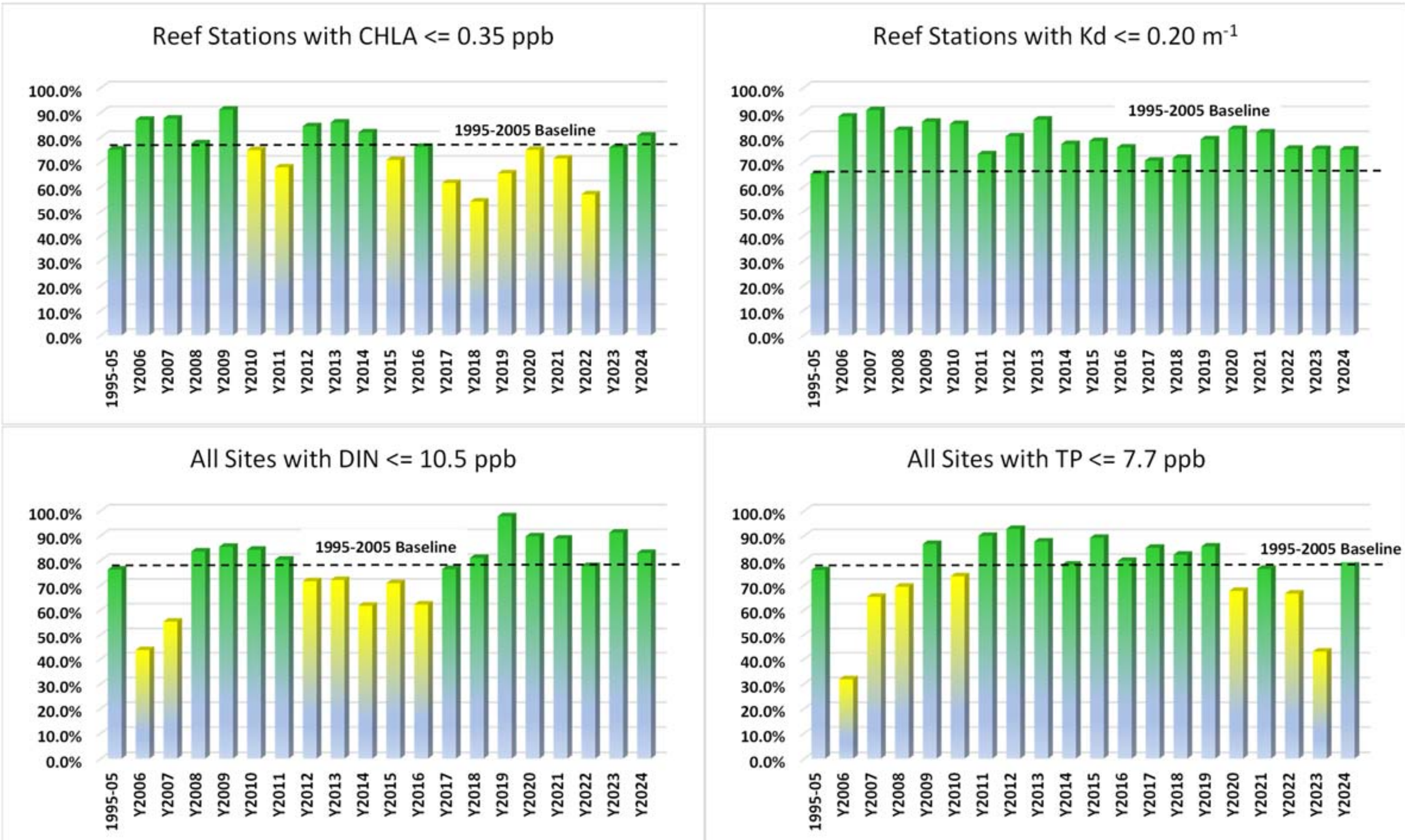

Figure i. *EPA targets expressed as percent of sites meeting baseline criteria by year.*

Trend Analysis – 30 years

The nonparametric Mann-Kendall Test was used to detect monotonic trends without the requirement that measurements be normally distributed. To quantify temporal trends, we used Sen slope regressions for each water quality variable over the period of record. Some of the Sen slopes were very small so to get a better idea of change over the period of record, the Sen slopes were multiplied by the number of years sampled and plotted as contour maps of potential <u>total change</u> in measured variable for the period of record (change maps). Only statistically significant M-K trends ($p<0.05$) were used to show directional tendencies in variables across the hydroscape (non-significant trends were coded as zero). We also included Shore stations located within the Halo Zone sampled since 2011.

The photosynthetic pigment, chlorophyll a, is a proxy measure of phytoplankton biomass. CHLA concentrations have increased in 35 of 112 sites in the FKNMS (*Fig. ii*). Significant increases ranged 0.08-0.19 ppb (median = 0.11 ppb) or ~39% increase over 1995 levels. Strongest increases seem to be associated with shallow stations near land but there were increases at offshore Reef sites and in major passes. Although ambient concentrations remain low relative to other coastal areas in the US, these increases are evidence of slow eutrophication of the FKNMS.

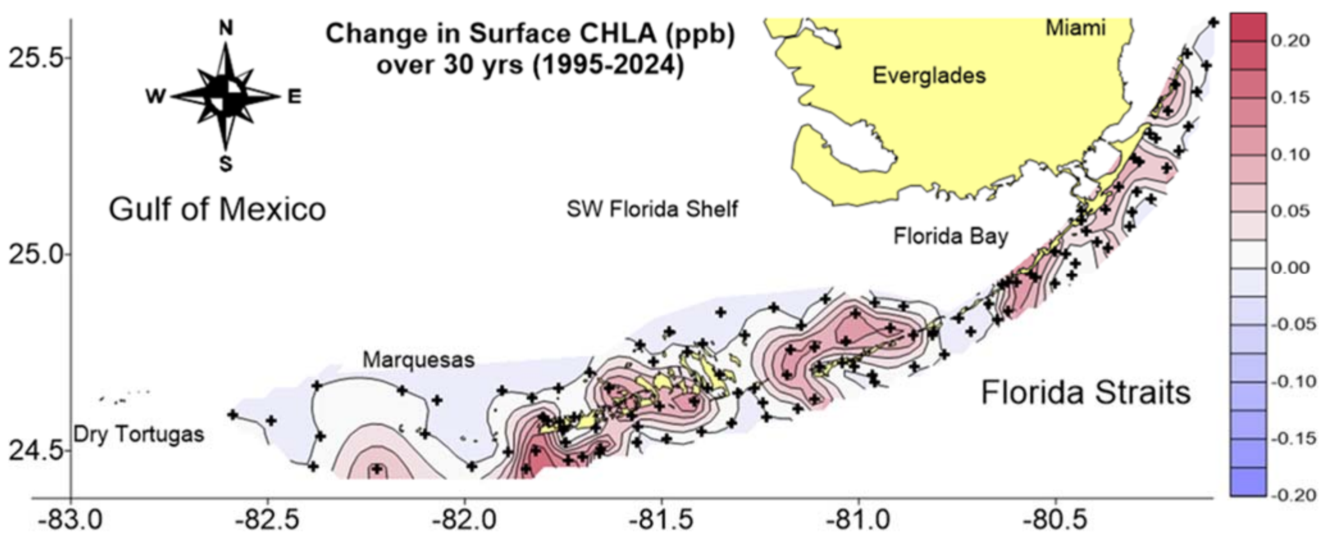

Figure ii. *Net change in CHLA in surface waters over the 30-year period.*

Total phosphorus (TP) is an important driver of primary production in South Florida inland and nearshore waters. Significant increases in TP (median = 0.002 ppm) occurred at 40 sites in the Keys primarily close to land, indicating potential terrestrial sources (*Fig. iii*). This is a 43.5% increase over 1995 levels. In contrast, TP declined in some of the deeper surrounding waters. Note the spatial similarity in changes in TP and CHLA (*Fig. ii*). These trends bear watching, given that we expect future TP concentrations to decline inshore in response to central sewer installation.

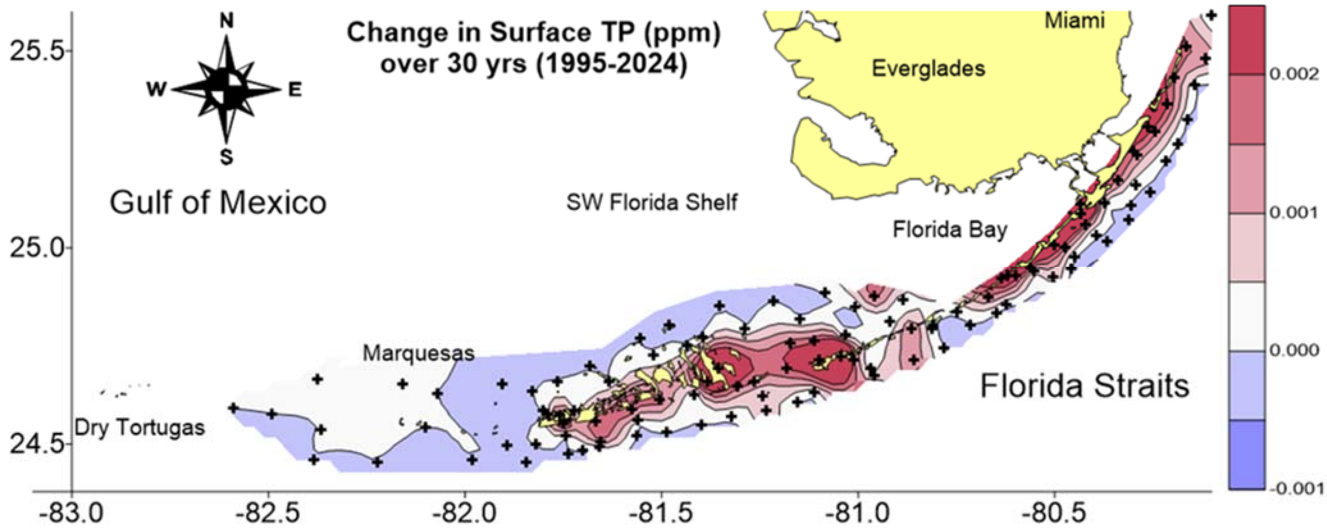

Figure iii. *Net change in surface TP over the 30-year period.*

Soluble reactive phosphorus (SRP) is the inorganic dissolved fraction of TP. SRP concentrations are generally an order of magnitude lower than TP in South Florida waters and may be below the kinetic threshold for uptake by phytoplankton. Contrary to TP, SRP concentrations have declined in the FKNMS (*Fig. iv*), which was not expected.

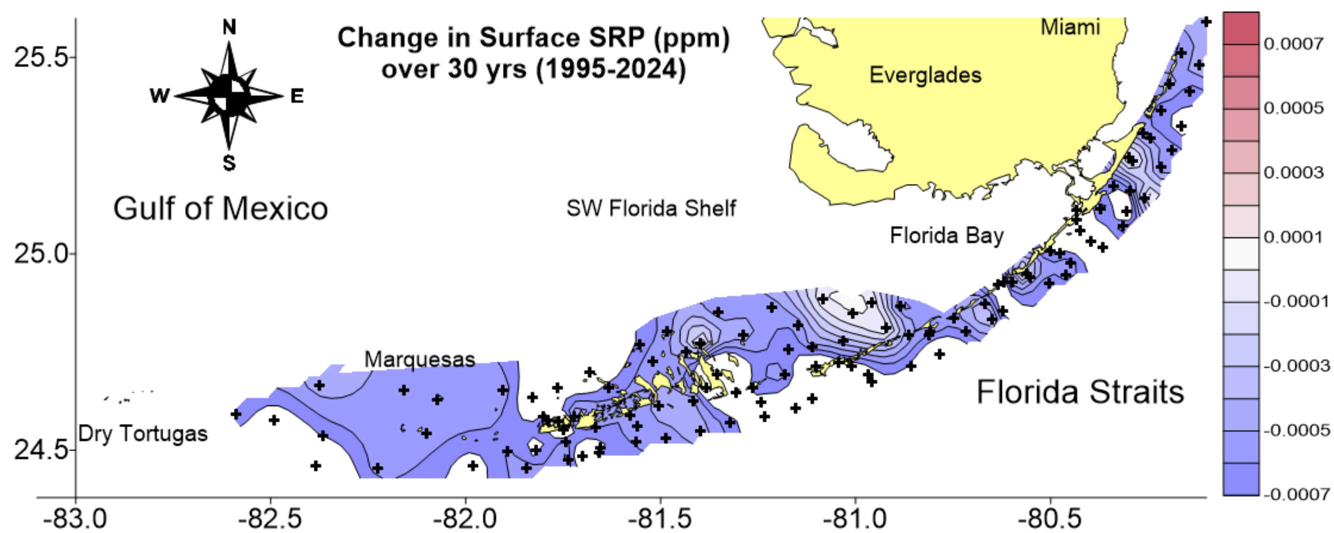

Figure iv. *Net change in surface SRP over the 30-year period.*

Keys-wide declining trends in DIN (NH_4^+, NO_2^-, NO_3^-) were small but widespread (*Fig. v*). Decreasing trends in NH4+ were observed across the FKNMS. Interestingly, these declines occurred at many of the same sites where TP increased. We are unsure if such trends are stoichiometrically related - whether increases in TP act to drive down NH_4^+ through biological uptake or whether declines in DIN allow more TP to be released to the water column.

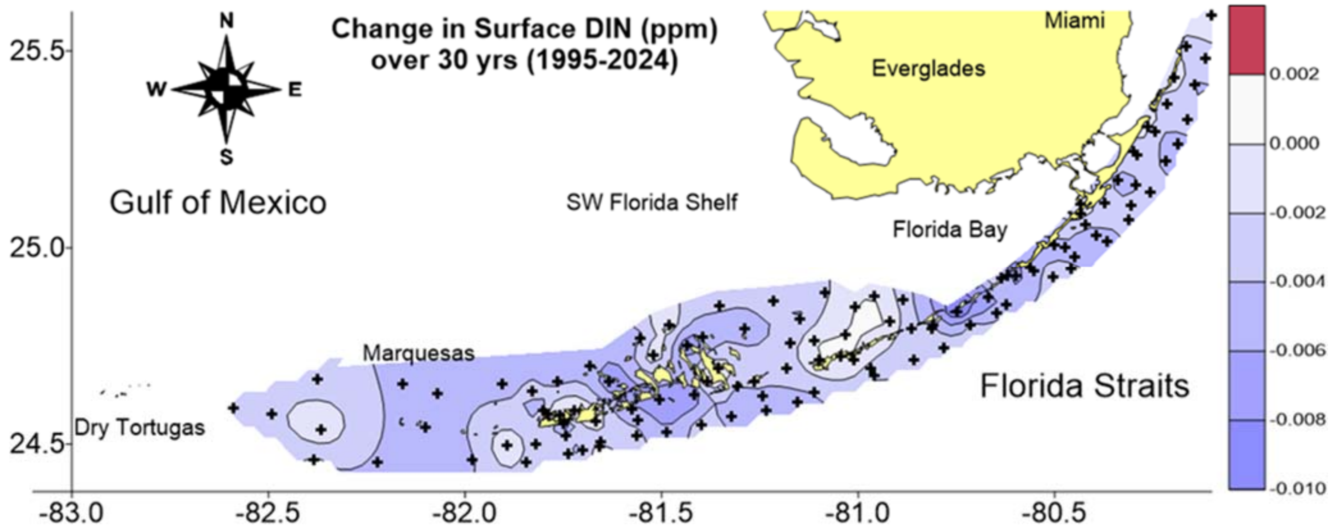

Figure v. *Net change in surface DIN over the 30-year period.*

The largest sustained monotonic trend has been the decline in surface TOC throughout the FKNMS (*Fig. vi*). This trend may be considered favorable given that TOC corresponds with CDOM (chromophoric dissolved organic matter), an important driver of light penetration. Declines in TOC are typically an indication of decreased terrestrial inputs to the region.

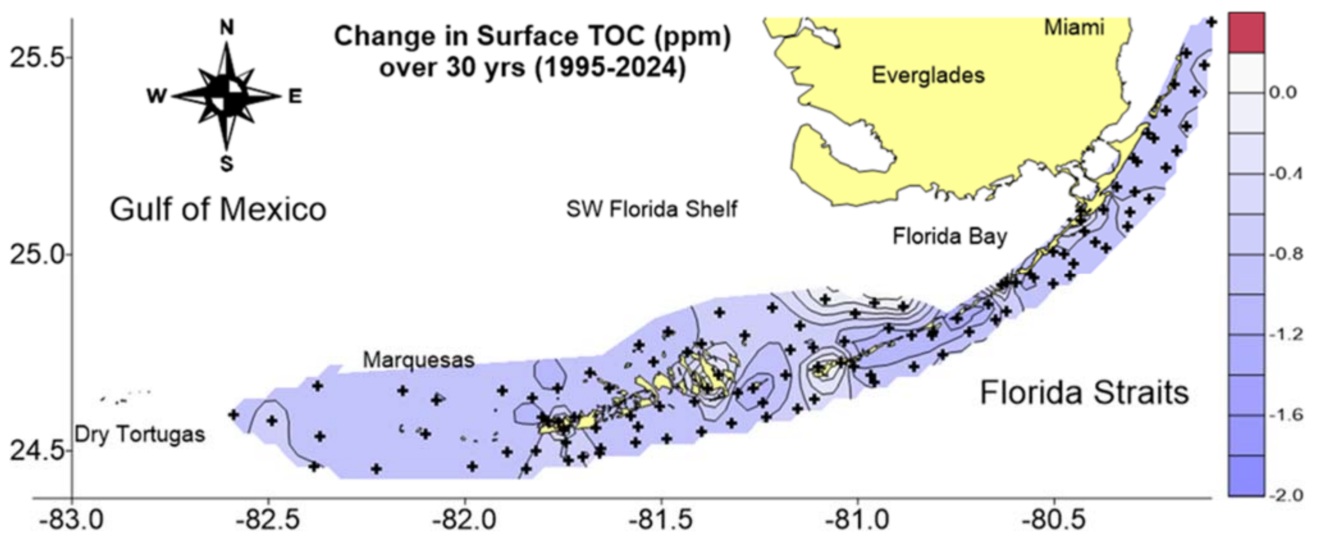

Figure vi. *Net change in TOC in surface waters over the 30-year period.*

Total nitrogen declined overall except for the Sluiceway region contiguous to Florida Bay (*Fig. vii*). Most of this is due to declines in the organic N fraction as it makes up ~96% of the TN pool.

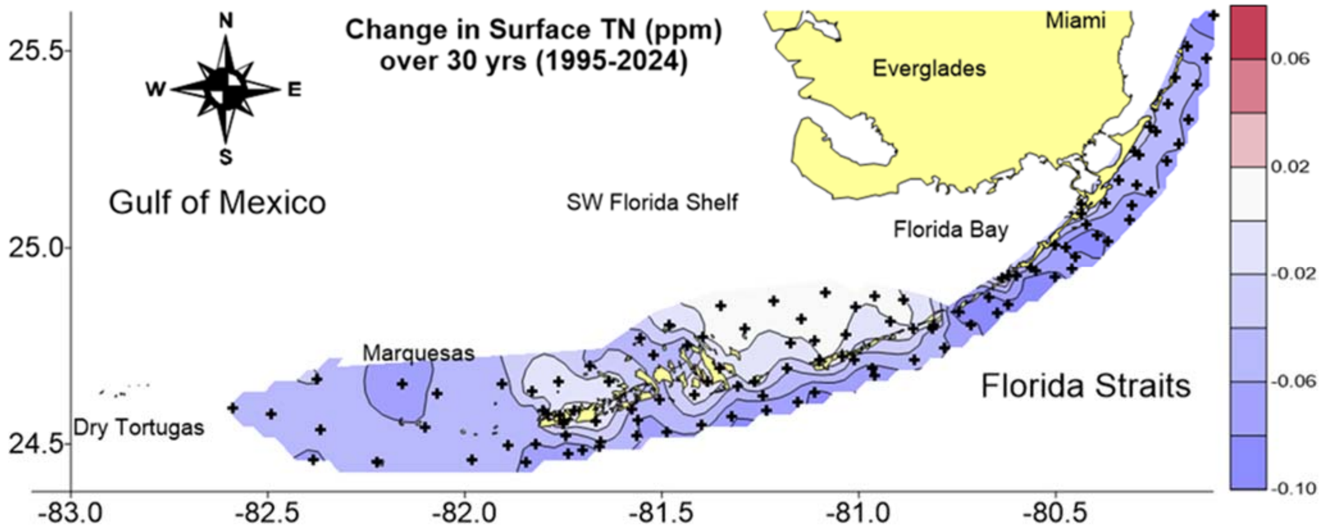

Figure vii. *Net change in TN in surface waters over the 30-year period.*

The TN:TP ratio (molar) is useful in assessing phytoplankton nutrient limitation (Redfield ratio). TN:TP declined in most areas (*Fig. viii*) implying that primary production is becoming less P-limited throughout the FKNMS. This trend is driven by concurrent minor declines in TN and significant increases in TP.

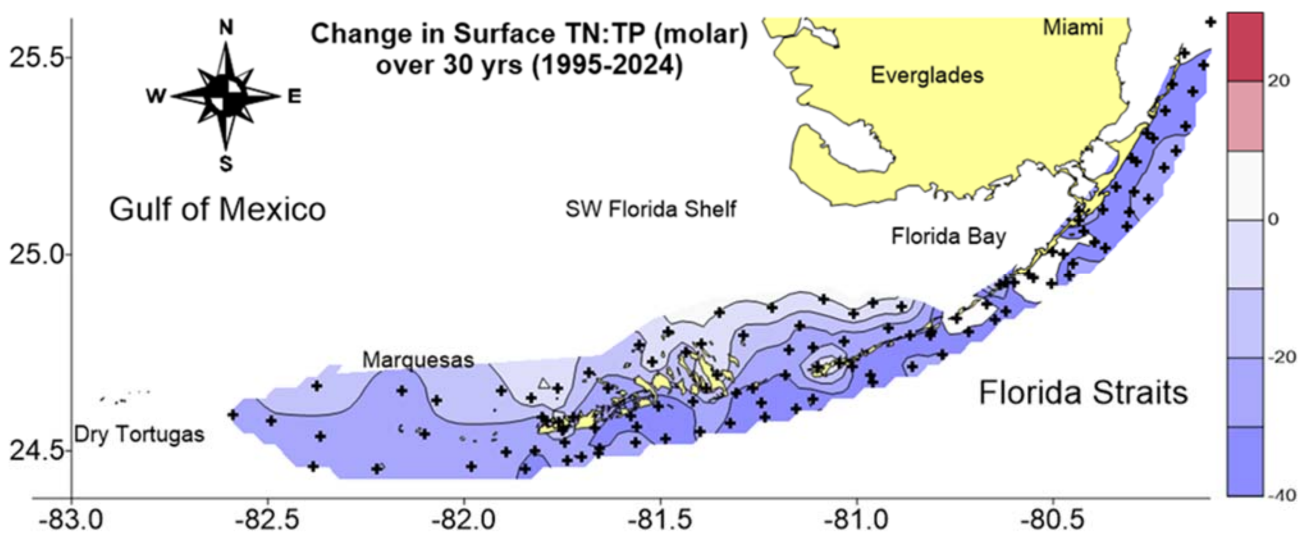

Figure viii. *Net change in TN:TP ratio in surface waters over the 30-year period.*

Diatoms require silicate to form their external frustules (shells). Si:DIN ratios >1 promote diatom growth in the phytoplankton community. Si:DIN <1 indicates growth limitation conditions for diatoms. The northern Sluiceway shows an increase towards fostering diatom community development (*Fig. ix*).

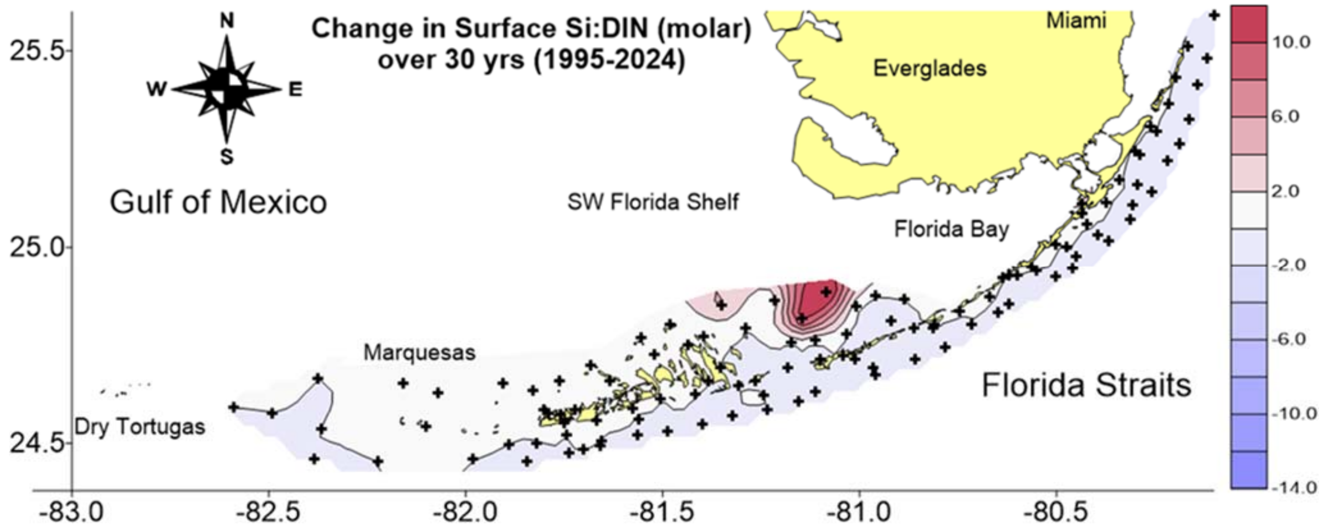

Figure ix. *Net change in Si:DIN ratio in surface waters over the 30-year period.*

No significant trends were observed in either surface or bottom salinity across the FKNMS (*Fig. x*).

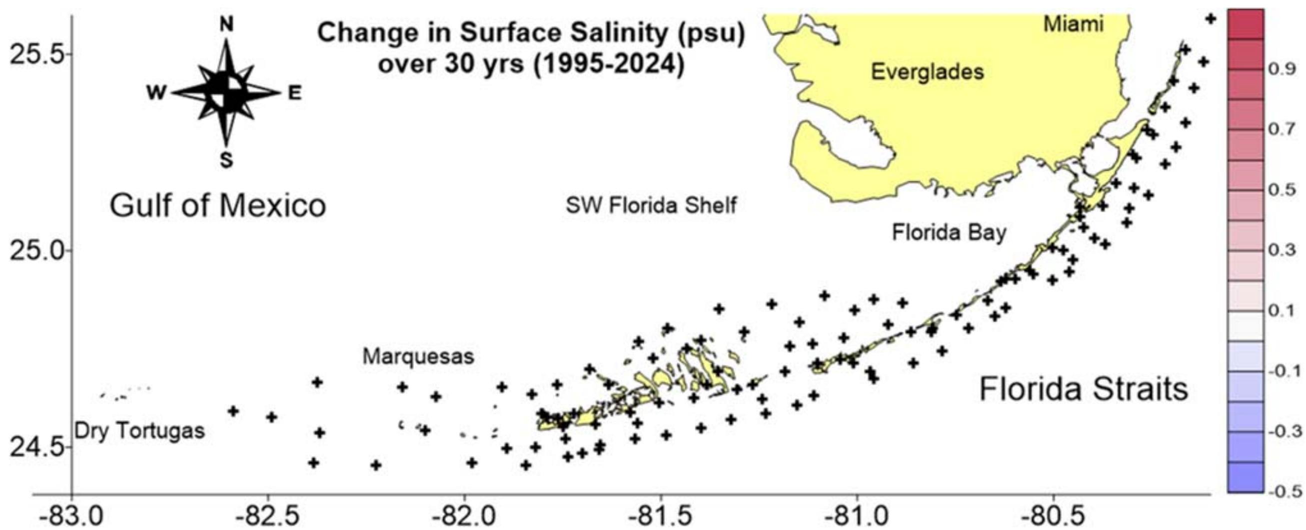

Figure x. *Net change in surface salinity over the 30-year period.*

Temperature displayed marginally significant long-term trends as well, but the change map does show some differences across regions (*Fig. xi*). The Bay zone and offshore areas tended to decline; only one Shore site off Marathon increased. Interestingly, with data from 2024, we observed increased surface temperature at three offshore reef sites. Quarterly collection of temperature over 30 years cannot be expected to resolve the small changes in subtropical water temperature expected under global climate change. Daily temperature measurements from three other research programs have shown that the waters of the Florida Keys have warmed ~0.8°C for the period 1878-2012 (Kuffner et al. 2015). However, there were generally increasing trends in water temperatures in the Backcountry, Bay, and Shore areas since 2011.

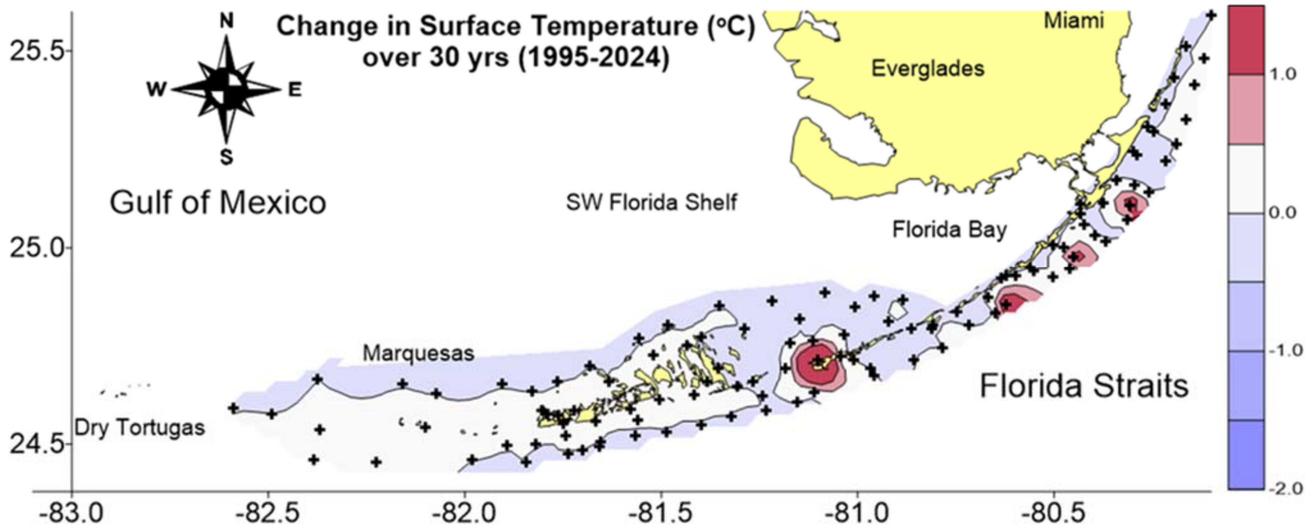

Figure xi. *Net change in surface temperature over the 30-year period.*

DO saturation increased at most sites in the FKNMS, which is generally considered a benefit to aquatic biota (*Fig. xii*). Measurements taken during daylight hours may be influenced by the amount of primary production in the water column and benthos and are offset by comparable drops at night. Greatest increases in DO_{sat} were observed offshore, indicating non-terrestrial influence. Some areas in the Sluiceway closest to Florida Bay and north Backcountry also showed small decreasing trends.

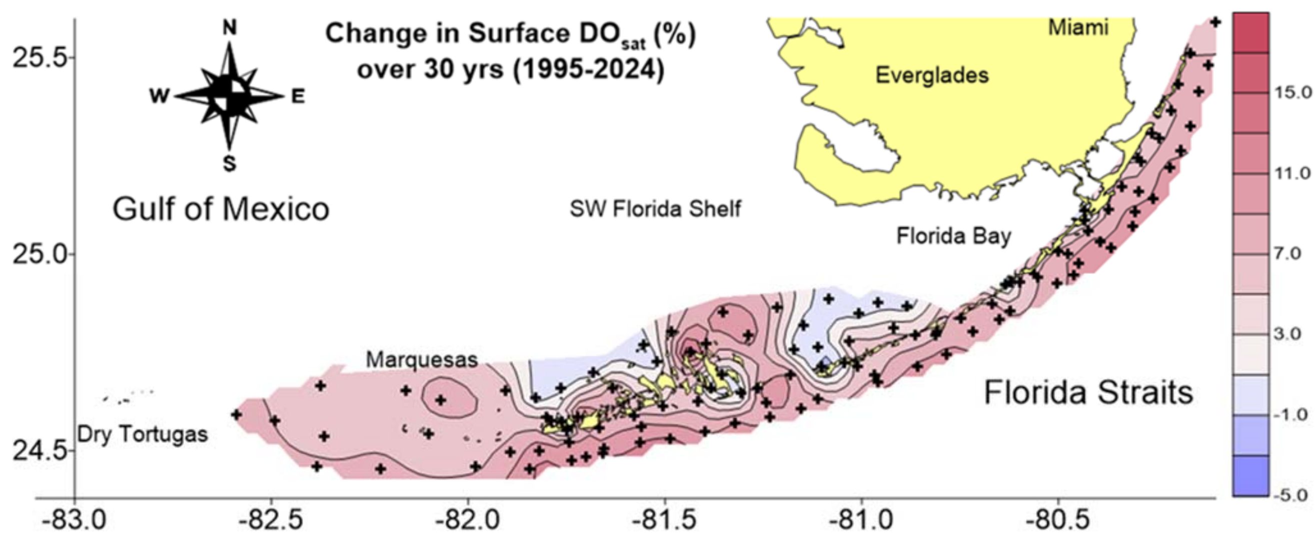

Figure xii. *Net change in surface DO saturation over the 30-year period.*

Water column turbidity declined throughout the FKNMS (a beneficial result, *Fig. xiii*). The largest declines occurred in northern Sluiceway/Backcountry and Marquesas. However, there were increases in surface turbidity at specific Shore sites in Upper Keys.

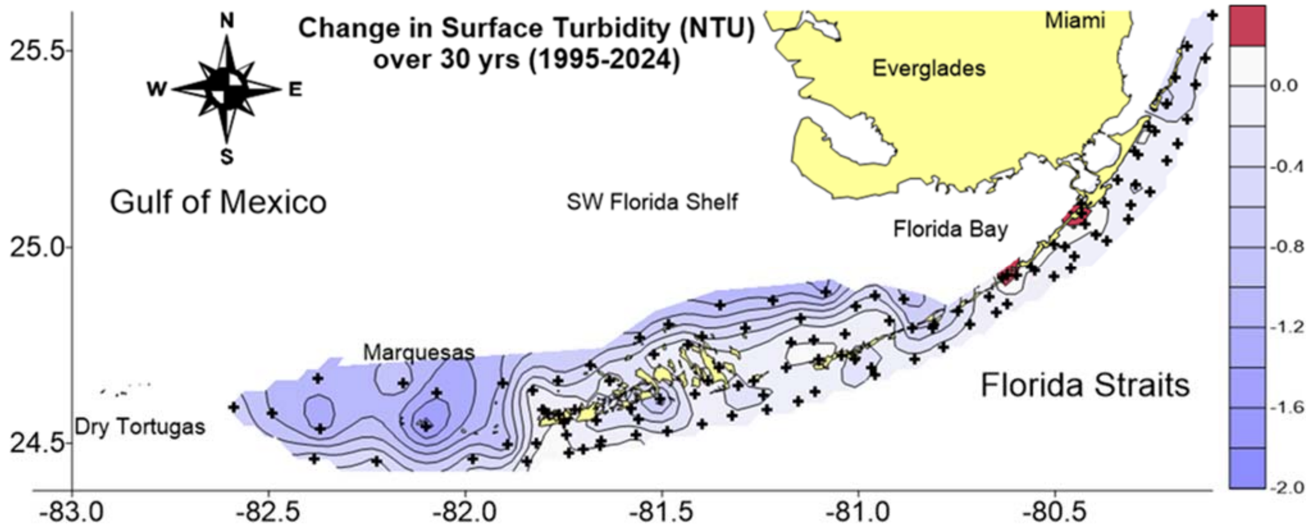

Figure xiii. *Net change in surface turbidity over the 30-year period.*

The diffuse light attenuation coefficient (K_d), a measure of light penetration, also declined (a beneficial result) in some offshore areas and Marquesas (*Fig. xiv*). There were isolated increases in the Backcountry, Sluiceway, and some Shore and Inshore sites.

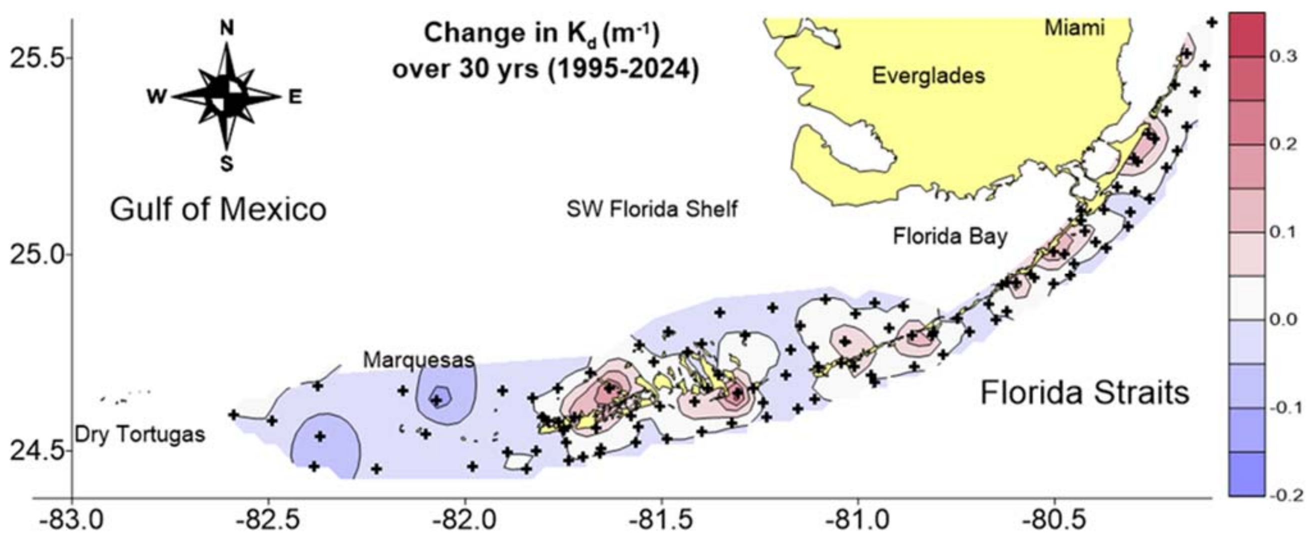

Figure xiv. *Net change in K_d over the 30-year period.*

Lower K_d tends to increase the proportion of surface irradiance reaching the bottom (I_o). More light on the bottom is beneficial to corals, seagrass, and algae. Increases in I_o were observed mostly in the Marquesas and isolated offshore Reef sites (*Fig. xv*). The Backcountry experienced decreases in I_o (with increases in K_d) resulting in less light penetrating to the bottom.

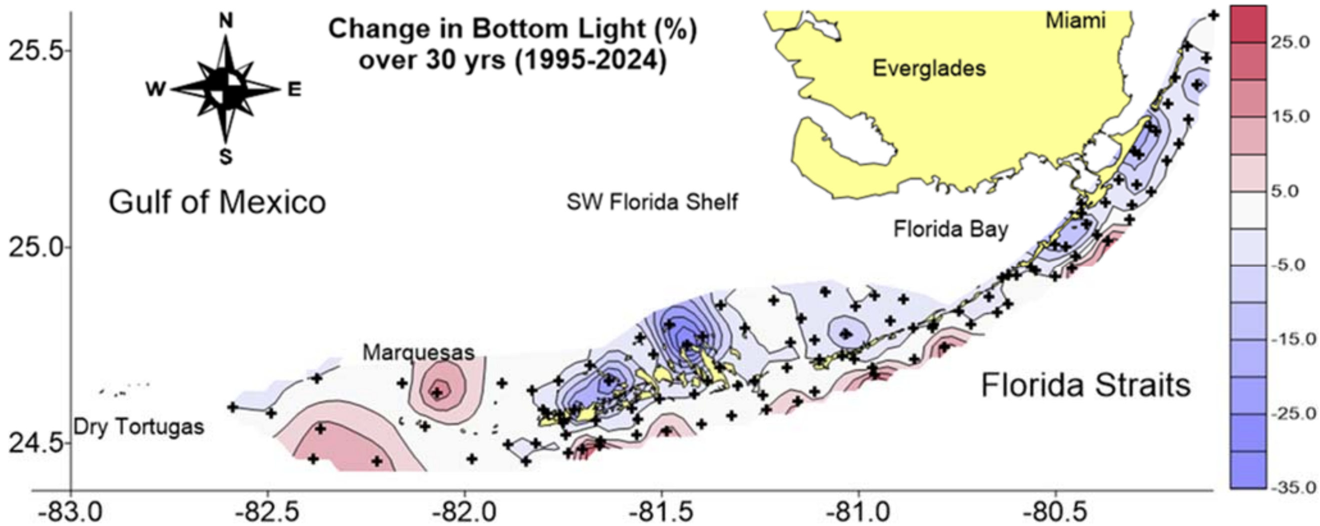

Figure xv. *Net change in incident bottom light over the 30-year period.*

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 FKNMS hydroscape. These results confirm the concept that monitoring is an important tool for addressing management questions and for developing new scientific hypotheses. We continue to maintain a website where data and reports from this project are accessible to the public, http://serc.fiu.edu/wqmnetwork/.