CRCP 9 Report: PAR-NTU-TSS Relationships Coral ECA

Florida Department of Environmental Protection
Coral Reef Conservation Program
Project CRCP 9

CRCP 9 Report: PAR-NTU-TSS Relationships in Coral ECA

Final Report

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Project CRCP 9

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Executive Summary

The CRCP9 report task was the final deliverable of the Coral Reef Conservation Program Turbidity Criterion Team project to understand the relationship of biologically relevant water quality data such as PAR and TSS and its relationship to NTU values used in the current Florida Turbidity Criterion. The project took place across three Phases. Phase I encompassed water quality data collection from Jupiter Island Beach Nourishment Project, Phase II encompassed water quality data collection from Delray Beach Nourishment Project and Ocean Ridge Beach Nourishment Project. Phase III involved the collection of the same data from Port Miami, Port Everglades, and lake Worth Inlet in the absence of beach nourishment projects to serve as “natural background” comparison values. These datasets as well as sediment characteristic data mined from QA/QC documents from each project in Phases I and II were used to understand the relationships among PAR, NTU, and TSS. Although sediment characteristic data did not show statistically significant relationships to these water quality parameters, the relationship between NTU and PAR and TSS and PAR showed similar negative correlation across all sites in Phases I and II. These correlations were absent at the sites from Phase III indicating they likely change during dredging activities. NTU and TSS values also showed positive correlations at all but Lake Worth Inlet, with stronger correlation values for projects in Phases I and II again indicating a change in relationship during dredging. Comparison data among sites in Phases I and II appear to validate a trend of increasing water quality moving away from dredging activities, while comparison among Phase III projects showed site specific variability.

Acknowledgements

We thank partners in Martin County, Palm Beach County, the cities of Jupiter Island, Delray Beach, Ocean Ridge, APTIM, FDEP, and USACE for assistance with site selection, sampling coordination, and data acquisition. We thank Callaway Environmental for sample collection and Broward Labs for laboratory analysis.

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1. BACKGROUND AND INTRODUCTION

The Coral Reef Conservation Program 9 (CRCP 9) report is put forth as a part of the efforts of the Florida Department of Environmental Protection (DEP) Coral Turbidity Criterion Team. The existing turbidity criterion in the State of Florida is a numeric value of 29 nephelometric turbidity units (NTU) above natural background. Turbidity, expressed as NTUs, is the favored measure of suspended sediments by managers given the rapid turnaround time for turbidity analyses, which allows quick adaptive management for dredging and beach nourishment projects. However, NTU is an indirect measure of more biologically relevant measures such as photosynthetically active radiation (PAR), total suspended solids (TSS), and sedimentation. As such, NTUs should be measured with other factors listed in the literature that may be more direct determinants of sedimentation effects on corals and hardbottom communities in Florida. Hence the goal of CRCP 9 was to collect NTU data and other biologically relevant factors such as PAR and TSS across several coastal dredging projects as well as at background levels at several inlets within the Southeast Florida Coral Reef Ecosystem Conservation Area (Coral ECA), and combine that data with sediment characteristic data (where available) in order to investigate: 1) the relationship among NTUs, PAR, and TSS in SE Florida; 2) how these values are influenced by construction and how they contrast with values not under the influence of construction activity; 3) how these values change by sediment type and, 4) the natural variability in these measures in background measurements (both project associated background and ambient background).

DEP began drafting a revision to the Turbidity Criterion in order to better protect the hardbottom communities within the Coral ECA (*Revised Turbidity Criterion to Protect Florida Coral and Hardbottom Communities*, 2019). As part of the work to revise the criterion, the Standards Development Section (SDS) and Coral Reef Conservation Program (CRCP) designed and implemented a light attenuation translator study, and the data from that study became the dataset used in this CRCP 9 report. The ultimate goal of the CRCP 9 process is to determine if there are relationships among TSS, PAR, and NTU and sediment characteristic data.

Many coral species in the nearshore environment in Florida undergo symbiotic relationships with dinoflagellates which provide the corals with nutrients through the byproducts of photosynthesis. As such, availability of light and associated light attenuation from suspended sediments in the water column as well as direct effects of suspended sediments are key in understanding impacts from coastal construction projects on corals and hardbottom communities within the Coral ECA. PAR is a measure of the amount of available radiation for use in photosynthetic processes, and therefore could have a correlation to coral health. As turbidity increases, less light would be able to penetrate the water column and therefore less photosynthetically active radiation would reach the corals. Decreased light availability can reduce a coral's ability to feed autotrophically and ultimately cause hypoxia as a byproduct of the lowered oxygen production brought about by lower rates of photosynthesis (Jones, Bessell-Browne, Fisher, Klonowski, & Slivkoff, 2016). TSS values have been used to quantify turbidity thresholds for corals (Erftemeijer, Riegl, Hoeksema, & Todd, 2012) TSS thresholds for coral reefs in Florida have ranged from 10mgL^{-1} to 165mgL^{-1} in some particularly tolerant species (Rice & Hunter, 1992; Rogers, 1990). Chronic exposure to suspended sediments at 30mgL^{-1} ex situ caused mortality as well as sub lethal effects including reduced growth and tissue lipid content and photosystem II damage in Pacific species (Flores et al., 2012). NTU levels have also been used experimentally to determine threshold levels in Florida corals. NTU levels of 7 or below were found to be optimal in promoting survival of coral recruits as well as showing no deleterious effects when compared to background levels (Fourney & Figueiredo, 2017; Telesnicki & Goldberg, 1995). However, turbidity levels above 29 (the current numeric Florida Turbidity Criterion) were shown to depress photosynthesis to respiration (P:R) ratio and increase mucous production in coral recruits; both are signs of short term stress and greater energy expenditure (Fourney & Figueiredo, 2017; Telesnicki &Goldberg,1995).

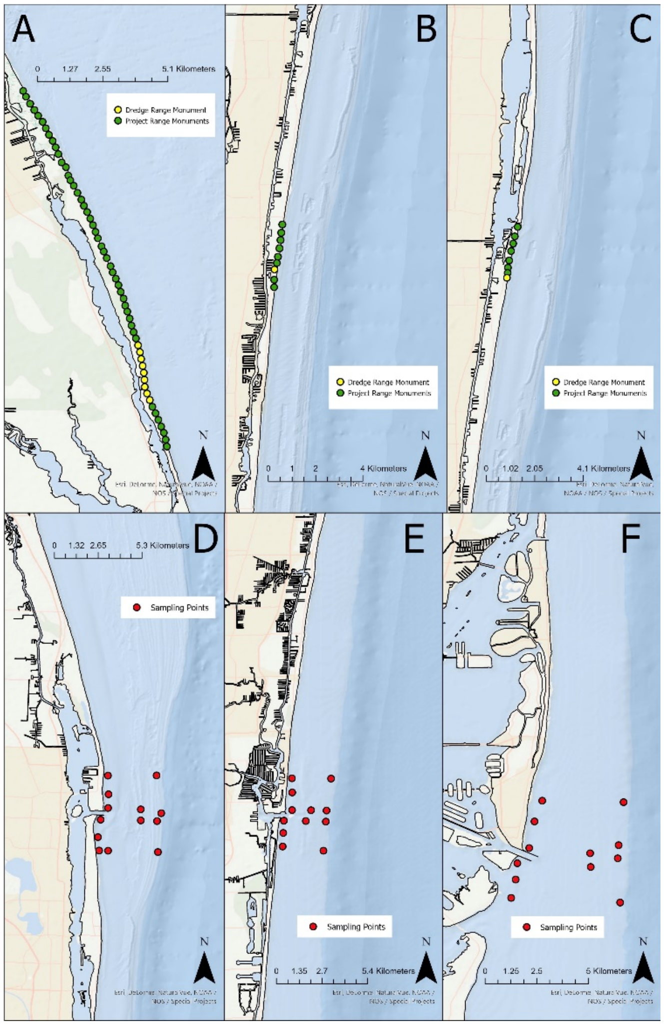

Figure 1 Project Location. *Location of Range Monuments for beach nourishment projects in Phase I and II, and background sampling sites at inlets in Phase III. Dredge range monuments indicate the approximate location of dredge sites offshore, and red dots indicate sampling sites in the absence of construction in Phase III A: Jupiter Island, B: Delray Beach, C: Ocean Ridge, D: Lake Worth Inlet, E: Port Everglades, F: Port Miami*

The CRCP 9 was comprised of three Phases of PAR, NTU, and TSS sampling during three beach nourishment projects within the Coral ECA as well as at three inlets within the Coral ECA. Phase I took place in Martin County during the Jupiter Island Beach Nourishment Project (Permit

0186991-008-JC), which used a hopper dredge. Beach nourishment occurred between monuments R-73 and R-127, with the dredge site approximately three kilometers offshore between R-112 and R-120 (figure 1 A). Phase II occurred in Palm Beach County and encompassed both the Delray Beach Nourishment (Permit 0303553-008-JC) and Ocean Ridge Beach Nourishment (Permit 03113339-008-JC) Projects. Cutter-head dredges were used in both Phase 2 projects. Beach nourishment occurred between R-181 and R-189, with the dredged area offshore of R-187 for Delray Beach (figure 1 B). For Ocean Ridge, the nourishment area was between R-152 and R-159, and the dredged area was offshore of R-159 (figure 1 C). Phase III occurred at Lake Worth Inlet in Palm Beach County (Figure 1 D), Port Everglades Inlet in Broward County (Figure 1 E), and Government Cut in Miami-Dade County (Figure 1 F).

2. METHODS

2.1 Collection of PAR, NTU, and TSS data

Water samples were collected for each variable and categorized based on where the sample was taken with relation to the construction activity (either dredging at the borrow area or beach material placement) during beach renourishment in Phases I and II, as well as background samples collected in all phases with those in Phase III being absent of any construction activity and acting as “spatial background” samples (table 1). Sampling was inherently tied to construction schedules which were beyond the control of the monitoring firm collecting data, in Phases I and II, and therefore the number of sampling days and sampling of construction milestones (pre, during, and post-construction) varied by Phase and project, though the sampling methodology remained consistent. Samples for TSS, NTU, and PAR were taken concurrently. At the same time these samples were taken, tidal cycle, latitude and longitude, water depth, cloud cover, wind speed, current direction, air and water temperature were recorded.

Table 1 Background Types. *Description of the different types of background measurements in CRCP 9*

Background Measurement Type	Description	Phases of Occurrence
Pre-construction	Samples are collected at least a day before construction starts in ambient conditions	Phase II
Post-construction	Samples are collected at least a day after construction ends in ambient conditions	Phases I and II
During construction	Samples are collected during construction upcurrent from and away from the influence of the turbidity plume generated by construction activity, at a distance specified in the permit for the activity	Phases I and II
Ambient Background	Could also be considered “natural” or “ambient” background. Samples are collected in the absence of any construction before or after sampling, and with minimal anthropogenic factors affecting turbidity	Phase III

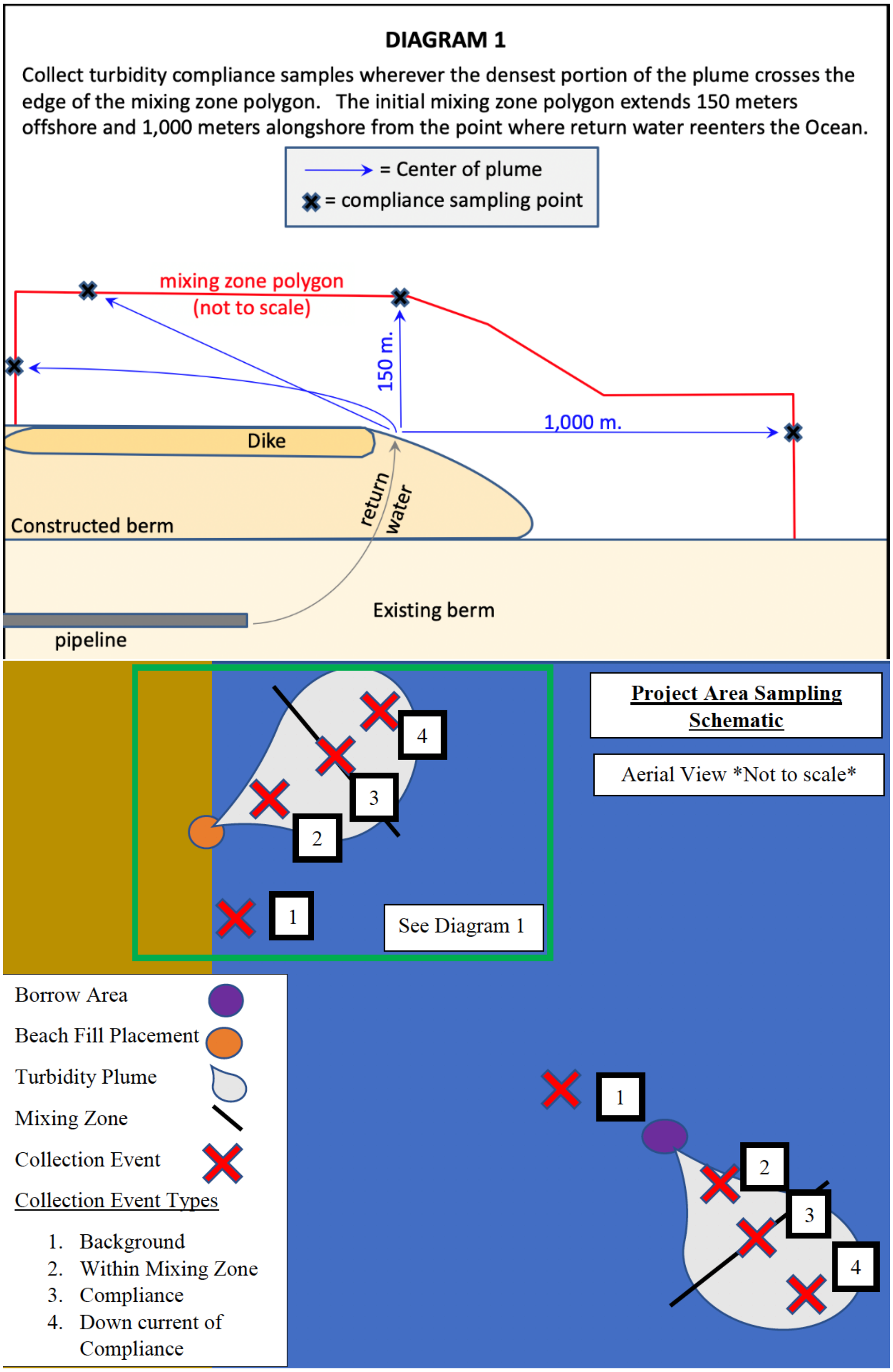

DIAGRAM 1

Collect turbidity compliance samples wherever the densest portion of the plume crosses the edge of the mixing zone polygon. The initial mixing zone polygon extends 150 meters offshore and 1,000 meters alongshore from the point where return water reenters the Ocean.

Figure 2 Sample Collection. *Top: diagram of turbidity compliance sample collection process, Bottom: diagram of sample collection for Phase I and II*

Samples taken during construction in Phases I and II were collected across several days of repeated sampling at both high and low tide and at both the borrow area and beach fill placement sites. Borrow areas were offshore zones where dredges operated to remove sediments from defined locations on the seafloor, while beach fill placement areas were those where the sediments were pumped to ultimately nourish the beach. Samples were taken both at the surface at a depth of 0.5m and at mid-depth. Samples for TSS and readings for PAR and NTU were taken concurrently for both the surface and mid-depth samples (figure 2). All sampling for CRCP9 was performed by contractors in accordance with their scope of work and DEP standard operating procedures including SOPs FC1000 (DEP, 2017), FT1600 for turbidity, FT 1700 for light penetration (DEP, 2017), and FS2100 for surface water sampling (DEP, 2017). PAR data were collected with a Terrestrial Quantum Sensor LI-193 (Serial No. Q108392) and Underwater Spherical Quantum Sensor LI-193 (Serial No. SPQA5768). NTU data was collected using a nephelometer, Hach 2100Q Turbidmeter, calibrated daily. TSS samples were taken with a 2.5L Niskin bottle, and 1L volume samples were sent for laboratory analysis (Callaway Environmental Services, 2020*)*. Contractors tasked with processing the samples ensured proper storage and preservation as per DEP SOP FS1000-4 (DEP, 2017). TSS samples were processed and analyzed based on SOP WLB022, whereby samples were stored at 4°C before being analyzed at room temperature, and calibration was ensured daily for both oven and balance.

During the construction milestone, samples were taken at 4 locations: 1) a background sample outside the influence of the construction project; 2) within the mixing zone of the plume; 3) at a typical compliance point (where the densest portion of the plume crossed the edge of the mixing zone polygon); and 4) down-current of the compliance zone but still within the plume;.

Sample types 2-4 were considered “plume influenced” and referred to as such throughout the study.

Background samples were taken during all Phases and at all construction milestones (pre, during, and post-construction). During pre-construction, samples for PAR, TSS, and NTU were collected at both surface and mid-depth in ambient conditions. During construction, samples were collected up-current and away from construction plumes, at a specified distance (Figure 2). Post-construction, samples were taken at least a day following the end of construction activities in ambient conditions. Pre and post-construction samples were taken in approximately the same locations as those during construction. For Phase III, “natural background” or ambient samples were collected absent of construction at the three inlets in the Coral ECA.

Analysis of TSS samples were conducted using previously established Standard Operating Procedure WLB022 (Broward County Environmental Monitoring Laboratory, 2020).

2.2 Collection of Sediment Data

Sediment data used in the analysis and creation of regressions were collected during June 2020 using the Florida Department of Environmental Protection Electronic Document Management System (OCULUS) and searching by permit number. The nearest range marker, its coordinates, wet Munsell color, size, sorting, percent silt, and percent gravel were mined from documents related to each project in Phases I and II. These characteristics were chosen as they were available in all QA/QC documents.

Table 2 Phase I and II Dates. *Sampling dates for Phases I and II by construction milestone*

Site	Phase	Pre-Construction	Construction	Post-construction
Jupiter Island Beach Nourishment	I	NA	2/28,3/23,4/11,4/24/19	5/15,5/30/19
Delray Beach Nourishment	II	2/20/20	2/27,3/12/20	3/26/20

Ocean Ridge Beach Nourishment	II	NA	3/23-24/20	NA

2.3 Phase I

During Phase I, water quality data were collected between February and May 2019, both during and post-construction. Cloud cover data were not collected in situ during sampling in Phase I. Jupiter Island sediment data were mined from the post-construction document *Project Quality Assurance Material Testing Summary Jupiter Island Nourishment*.

2.4 Phase II

During Phase II, water quality data were collected between February and March 2020, with pre-construction, during, and post-construction for Delray Beach and during construction for Ocean Ridge. Sediment data for Ocean Ridge were taken from post-construction document *Sediment QA/QC Plan Post-Construction Sediment Analysis Report*.

2.5 Phase III

Table 3 Phase III Dates. *Sampling dates for Phase III*

Site	**Phase**	**Ambient Background Sampling Dates**
Port Everglades	III	5/29, 5/30, 6/8/20
Lake Worth Inlet	III	6/9, 6/16, 6/22/20
Port Miami	III	5/6, 5/7, 5/9/20

Phase III took place between May and June 2020, with Port Miami and Port Everglades in May, and Lake Worth Inlet in June. Three days of sampling were performed at all Phase III sites.

2.6 Statistical Analyses

Statistical analyses were performed in Rstudio, a free, open source software for professional data science (*RStudio: Integrated Development for R*). The CRAN R packages are a set of packages provided by Rstudio for data science. The ggplot2 package was used to perform visualizations of the data. The data visualization software ggplot2 is an open source system for creating graphics within Rstudio (Wickham, 2009).

2.7 Summary Statistics

Summary statistics (mean, median, mode, quartiles, minimum and maximum values) were taken for all metrics (TSS, NTU, PAR) for all Phases, both overall and separated by surface or mid-depth and background versus plume influenced samples (compliance, down current of compliance, or within mixing zone). These were used to inform further analyses and to find meaningful trends in the data.

2.8 Phase II Background Comparison

Pre-construction data were only available for the Phase II DBN project. For this project, the background data collected pre-construction were compared to background data collected during construction. A Shapiro-Wilk normality test was performed across all variables in order to determine the appropriate comparison test. An F-test for equal variance was then performed to determine whether a parametric ANOVA or non-parametric equivalent (Kruskal-Wallis rank sum test) was appropriate for the individual comparison. Post-hoc multiple comparison tests used for ANOVAs were Tukey multiple comparison of means and pairwise Wilcoxon rank-sum test for non-parametric tests.

2.9 Phase III Background Comparison

“Natural background” values for NTU, PAR, and TSS were compared to background values from pre, during, and post-construction background values from Phases I and II. Data were initially sorted by surface or mid-depth for comparison, and a Shapiro-Wilk’s test of normality was run on individual sites. Based on results of the normality test, a Kruskal-Wallis was run by depth. Multiple comparison tests were then run dependent on comparison test, with Tukey-Kramer tests used for ANOVA and Wilcoxon signed-rank tests for Kruskal-Wallis.

2.10 Sampling Type Comparison

Comparisons between the sampling data at each individual site in Phases I and II was compared in order to determine the difference between background samples taken during construction and those taken within the influence of the plume. Site data was separated by depth, and then grouped by water quality parameter sampling type (background, compliance, down current of compliance, or within mixing zone). Shapiro-Wilk's test were run to determine if data were normal. Kruskall-Wallis tests were then run comparing water quality parameters between sampling types. If found to be statistically significant, a Pairwise Wilcoxon Rank-Sum Test was run with a Benjamini and Hochberg adjustment to control the false discovery rate (Benjamini & Hochberg, 1995).

2.11 Surface to Mid-Depth Comparison

Comparisons between water quality parameter sampling data at all sites for Phases I, II, and III were compared in order to determine if there were statistically significant differences between surface and mid-depth NTU, PAR, and TSS values at each site. Data were separated by site and compared among water quality parameter sampling type (background, compliance, down current of compliance, or within mixing zone). A Shapiro-Wilk's test was run on the data to determine if data were normal. A Wilcoxon test was then run comparing aforementioned data between surface and mid-depth.

2.12 Correlation

Correlations and scatterplots were created between NTU values and values for PAR and TSS as determined necessary after reviewing preliminary data. Data were separated by Phase I and II projects as well as the three individual inlets from Phase III. Datasets were tested for normality using a Shapiro-Wilk's test to determine appropriate correlation to use. Correlation tests were then performed as appropriate, with Pearson tests being run for normal data and Spearman rank correlation for non-normal data. Data were then plotted in scatterplots with a linear correlation. This process was repeated for the relationship between TSS and both PAR collected with a spherical quantum sensor and PAR collected with a terrestrial quantum sensor.

2.13 Mapping Analysis

Mapping products were created in ArcGIS Pro to illustrate potential differences in TSS and NTU between all beach nourishment projects for Phases I and II (ESRI 2011). Data were divided by surface or mid-depth and points were displayed with differing symbology based on sampling event type. Symbology was sized based on values in order to reflect the larger or smaller sample values taken closer or further from dredging activities. The mean center of the data was then displayed to display where the mean of plume-influenced and background values was spatially located. Due to the low number of datapoints per site in Phase III, further analysis using mapping was excluded.

2.14 Sediment Characteristic Models

Sediment characteristic data mined as a part of Phase I and II projects were used to create generalized linear models to evaluate relationships between PAR, NTU, TSS measurements and sediment characteristics from individual sites. Analysis aggregated values by site. Analysis focused on size and silt as these values were highlighted as being likely to contribute to relationships. Q-Q plots and Residual versus Fit plots were used to determine data distribution and detect linearity and outliers in the models.

3. RESULTS

3.1 Summary Statistics

Summary statistics for Phases 1 and II are found in supplemental table 1. Overall, data appeared relatively homogeneous across all sampling types for Jupiter Island, with all mean NTU values being below 5. Mean NTU values for both Ocean Ridge and Delray Beach were higher at the surface within the mixing zone (8.72 and 8.17 respectively) and the highest mean NTU values were found at those sides at mid-depth within the mixing zone (21.91 and 12.19). The mixing zone at mid-depth also had the greatest range and highest maximum for both Ocean Ridge (0.54-82) and Delray Beach (0.71-62.7) outside of the aggregated data by site. The lowest NTU values occurred at the surface down current of compliance for Phase I and II sites individually, with all registering 0. For TSS values, the highest mean for Jupiter Island was at the surface within the mixing zone (6.45), while for both Ocean Ridge and Delray Beach, the highest means were found at mid-depth within the mixing zone (23.5 and 12.8 respectively). These trends were also reflected in the ranges, where Jupiter Island had the greatest range in TSS at the surface within the mixing zone (0-39.1) while Ocean Ridge (-1.11-84.5) and Jupiter Island (0.30-48) had greatest ranges at the mid-depth within the mixing zone.

Summary statistics for projects in Phase III can be found in supplemental table 2. Again, overall the summary data from Phase III was relatively homogeneous. Port Everglades had a mean NTU value at the surface (1.37) which was over double that of Lake Worth Inlet (0.63) and Port Miami (0.66). Both Port Everglades and Port Miami had high maximum TSS values at the surface (45.4 and 42.1) as compared to Lake Worth Inlet (13.5), while at mid-depth Port Everglades (17.8) was greater than Lake Worth Inlet (12.0) or Port Miami (7.4).

3.2 Background Data Comparisons

All data for all variables recorded in Delray Beach (Phase II) did not violate normality based on Shapiro-Wilk test, which meant that One-Way ANOVAs were used. Only surface PAR data between pre-construction and construction was found to have a significant difference (One-Way ANOVA, p=0.042) when comparing across background samples.

“Natural backgound” values derived from Phase III compared as aggregates to those in Phases I and II yielded multiple comparisons. Surface background NTU values at Delray Beach were found to be significantly different than at Lake Worth Inlet (p=0.014) and Port Miami (p=0.017). Construction mid-depth NTU background values differed between Ocean Ridge and Lake Worth Inlet (p=0.007) and between Ocean Ridge and Port Everglades (p=0.017).

Across Phase III, surface NTU values from Lake Worth Inlet were significantly different than Port Everglades (p<0.001), and those from Port Everglades were significantly different than Port Miami (p<0.001). Mid-depth NTU values at Lake Worth Inlet were significantly different than Port Everglades (p<0.001). For NTU at mid-depth, Port Everglades was significantly different than Port Miami (p<0.001). Post-construction surface NTU levels were significantly different from Lake Worth Inlet to Port Everglades (p<0.001) and Port Everglades to Port Miami (p<0.001). There was no significant difference in PAR or TSS across all construction Phases and depths for Phase III.

3.3 Sampling Type Comparison

For Ocean Ridge, no water quality parameter showed a statistically significant difference between background samples and those within the influence of the plume (compliance, down current of compliance, or within mixing zone), both at the surface and at mid-depth.

For Delray Beach, several water quality parameters showed statistically significant differences between background samples and those which were plume influenced. At the surface, background NTU values differed from compliance NTU values (p=0.004), although no other groups showed a significant difference in NTU values. Surface TSS values also differed between background samples and compliance samples (p=0.044) and between background and down current samples (p=0.027). At mid-depth, NTU showed significant differences between background samples and those within the mixing zone, down current of compliance and at compliance (p=0.001, 0.004, and <0.001 respectively). TSS sampling values were also significantly different between background and within the mixing zone at mid-depth (p<0.001).

Finally, for Jupiter Island, NTU was the only water quality parameter which showed a significant difference. Background surface NTU values were significantly different to compliance (p=0.014) and within mixing zone (p=0.014) values. For mid-depth comparisons, NTU varied significantly between background and plume influenced samples. Background NTU samples differed from compliance (p=0.017), down current of compliance (p=0.017), and within mixing zone (0.004) samples. Background TSS values were not significantly different at mid-depth.

3.4 Surface to Mid-Depth Comparison

For Phases I and II, data were compared by sampling type and by depth. As with sampling type comparisons, Ocean Ridge showed no significant differences between parameters when comparing between surface and mid-depth by sampling type. For Delray Beach, only PAR collected by spherical quantum sensor differed between surface and mid-depth, and only within the mixing zone of the plume (p=0.021). Jupiter Island showed several significant differences between surface and mid-depth. For background, compliance, down current of compliance, and within mixing zone values, the PAR collected by spherical quantum sensor differed significantly (p<0.001, p=0.001, p<0.001, and p=0.003 respectively). No other water quality parameters differed for Jupiter Island.

For projects in Phase III, several surface to mid-depth comparisons showed statistical significance. At Port Miami, only the PAR collected by spherical quantum sensor differed significantly between surface and mid-depth (p=0.003). At Port Everglades, NTU (p=0.01), PAR collected by spherical quantum sensor (p=0.001) and TSS (p=0.04) differed significantly across surface to mid-depth. Finally, at Lake Worth Inlet, PAR collected by spherical quantum sensor was again the only water quality parameter displaying a significant difference between surface and mid-depth (p<0.001).

3.5 Correlation

No dataset across all sites and Phases was normal according to the Shapiro test, therefore a Spearman rank correlation was used for all tests. This outputted a Rho value (table 4) which showed significant relationships between aggregated NTU data versus water quality parameters separated by site. NTU and TSS showed a positive correlation of varying degrees for all sites except Lake Worth Inlet. NTU and PAR collected by spherical quantum sensors showed negative correlations of very similar value for sites in Phase I and II, although none were significantly different for Phase III. PAR collected by terrestrial quantum sensor showed very little correlation, with only a slight negative correlation for Jupiter Island and Port Miami.

Table 4 NTU-PAR-TSS Rho. *Rho values (correlation) for NTU versus water quality parameters by site*

	PAR (Spherical Quantum Sensor)	**PAR (Terrestrial Quantum Sensor)**	**TSS**
Jupiter Island	-0.3940 (p=0.001)	-0.2182 (p=0.002)	0.4697 (p<0.001)
Delray Beach	-0.3644 (p<0.001)	NC (p=0.18)	0.7769 (p<0.001)
Ocean Ridge	-0.3940 (p=0.001)	NC (p=0.97)	0.6695 (p<0.001)
Port Everglades	NC (p=0.24)	NC (p=0.10)	0.2688 (p=0.001)
Port Miami	NC (p=0.87)	-0.2729 (p=0.001)	0.3166 (p<0.001)
Lake Worth Inlet	NC (p0.75)	NC (p=0.33)	NC (p=0.73)

Scatterplots were also created at the request of CRCP9 team members to reflect the correlations seen in table 4. Figures 3-8 show the relationships by sampling site and water quality parameter.

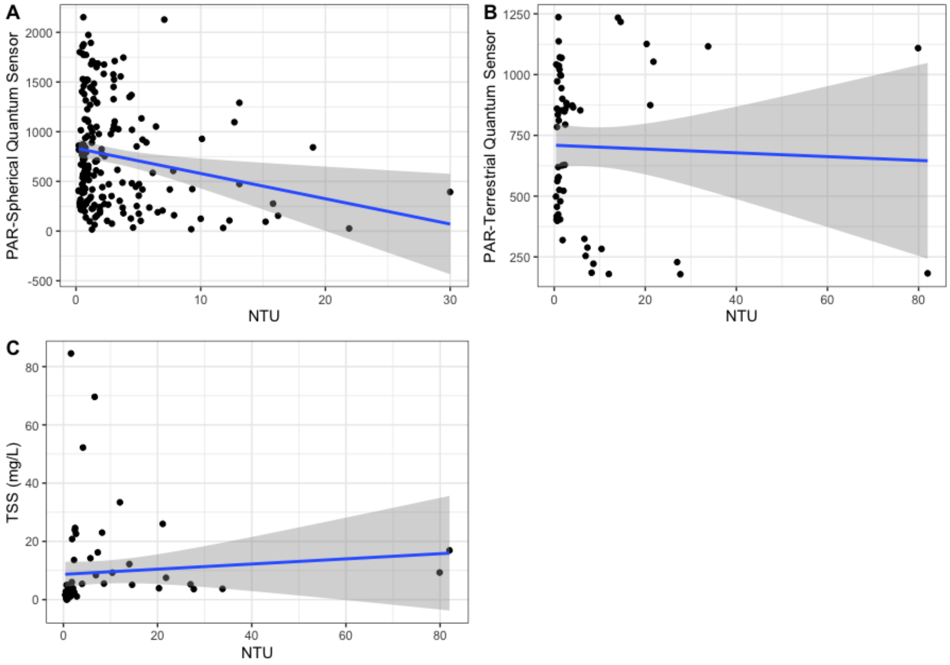

Figure 3 Jupiter Island NTU-PAR-TSS. *Scatterplots showing correlation between NTU and water quality parameters for Jupiter Island*

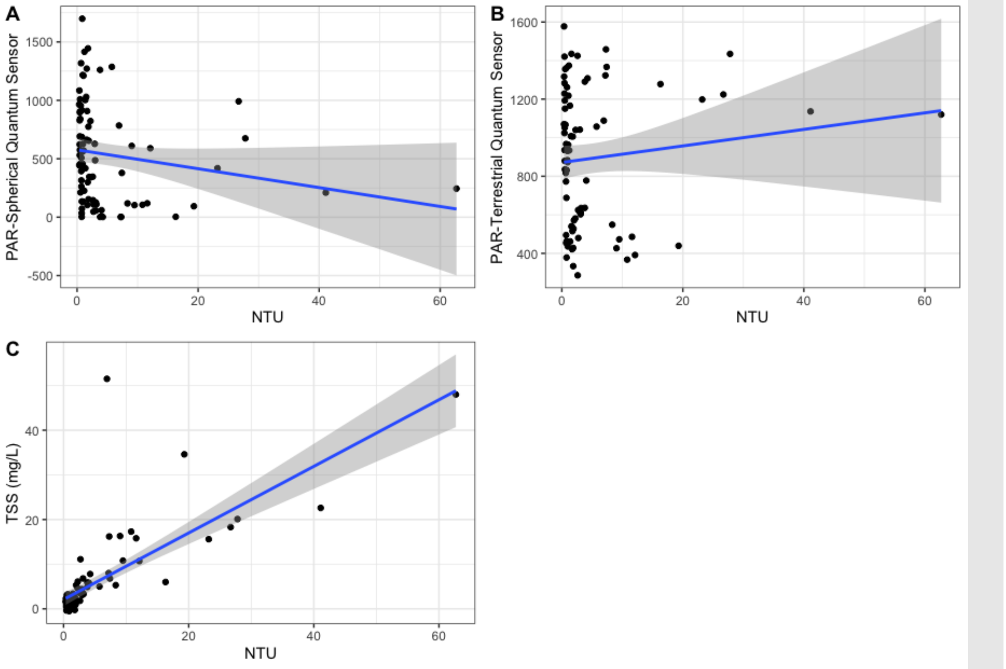

Figure 4 Delray Beach NTU-PAR-TSS. *Scatterplots showing correlation between NTU and water quality parameters for Delray Beach*

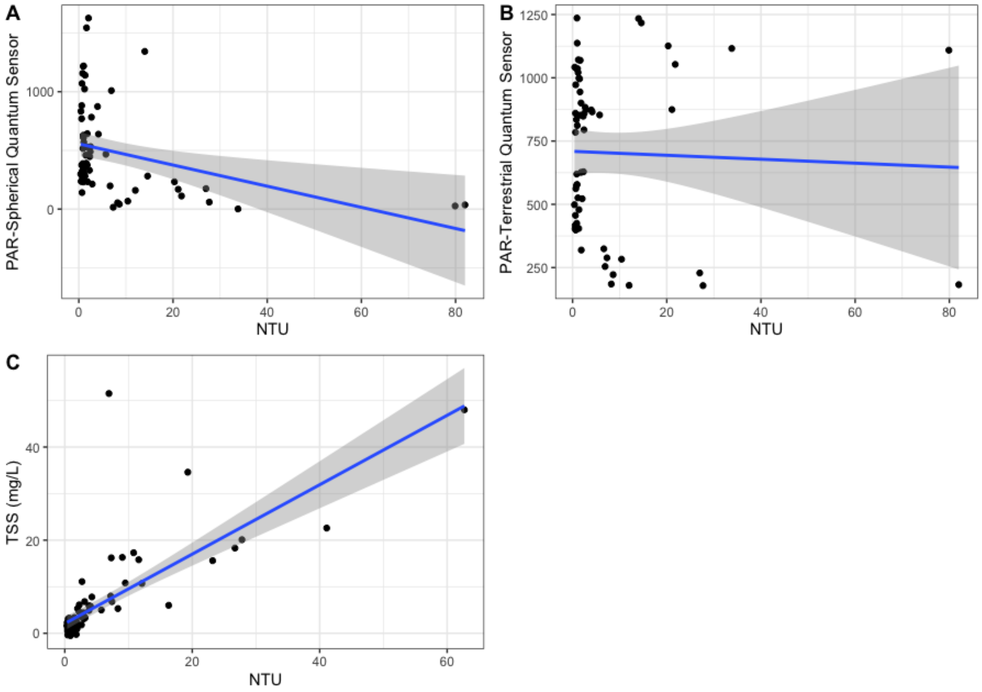

Figure 5 Ocean Ridge NTU-PAR-TSS. *Scatterplots showing correlation between NTU and water quality parameters for Ocean Ridge*

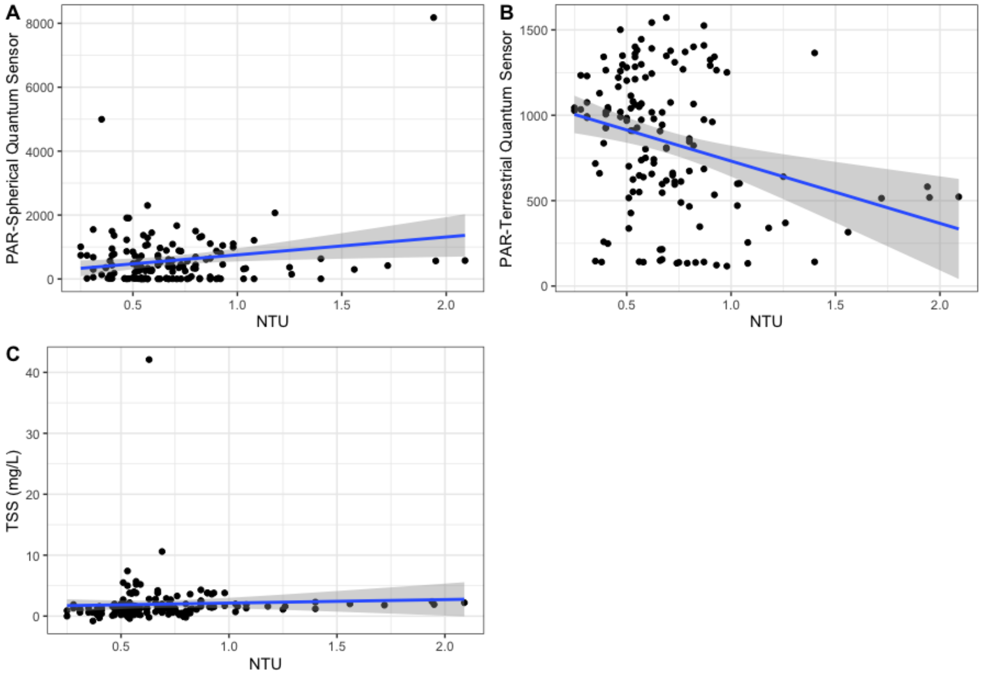

Figure 6 Port Miami NTU-PAR-TSS. *Scatterplots showing correlation between NTU and water quality parameters for Port Miami*

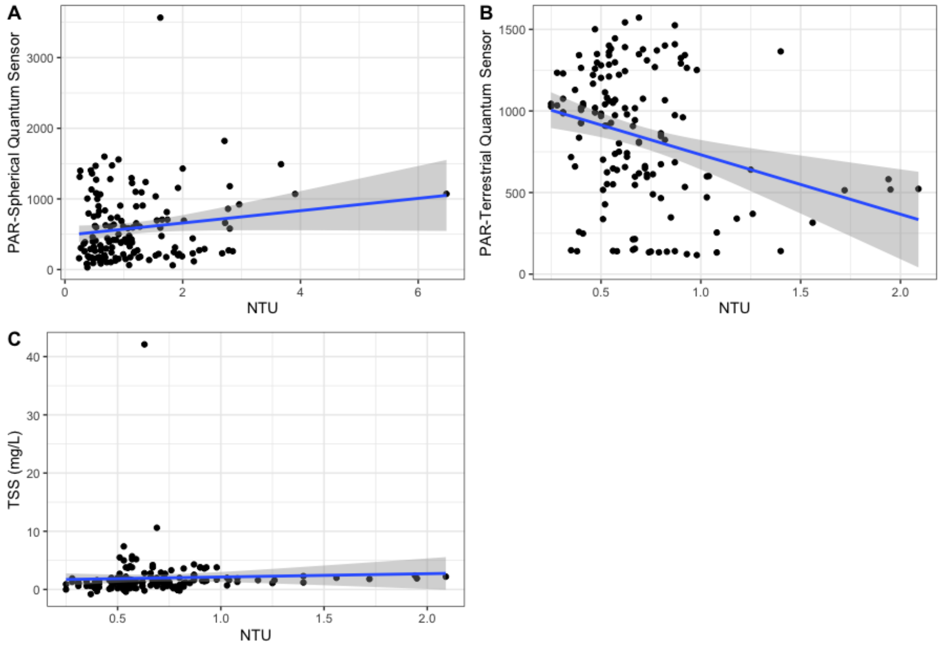

Figure 7 Port Everglades NTU-PAR-TSS. *Scatterplots showing correlation between NTU and water quality parameters for Port*

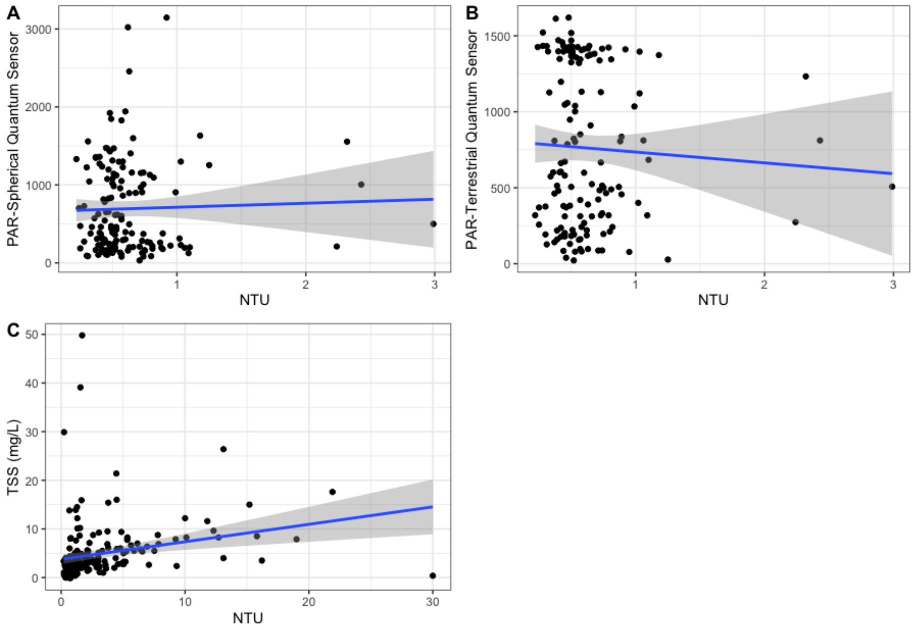

Figure 8 Lake Worth Inlet NTU-PAR-TSS.. *Scatterplots showing correlation between NTU and water quality parameters for Lake*

The relationship between TSS and PAR was also analyzed as above, with correlation values showing a similar negative correlation between TSS and PAR collected by spherical quantum sensor for all sites from Phases I and III but absent from sites in Phase III (table 5). For PAR collected using a terrestrial quantum sensor, only Jupiter Island showed a negative correlation with TSS, with all other sites having no correlation (table 5).

Table 5 PAR-TSS Rho. *Rho values (correlation) for TSS versus PAR by site*

	PAR (Spherical Quantum Sensor)	**PAR (Terrestrial Quantum Sensor)**
Jupiter Island	-0.3175 (p=0.011)	-0.2109 (p=0.003)
Delray Beach	-0.3634 (p<0.001)	NC (p=0.9746)
Ocean Ridge	-0.3175 (p=0.011)	NC (p=0.1558)
Port Everglades	NC (p=0.5286)	NC (p=0.4672)
Port Miami	NC (p=0.64)	NC (p=0.0.195)
Lake Worth Inlet	NC (p=0.8384)	NC (p=0.1469)

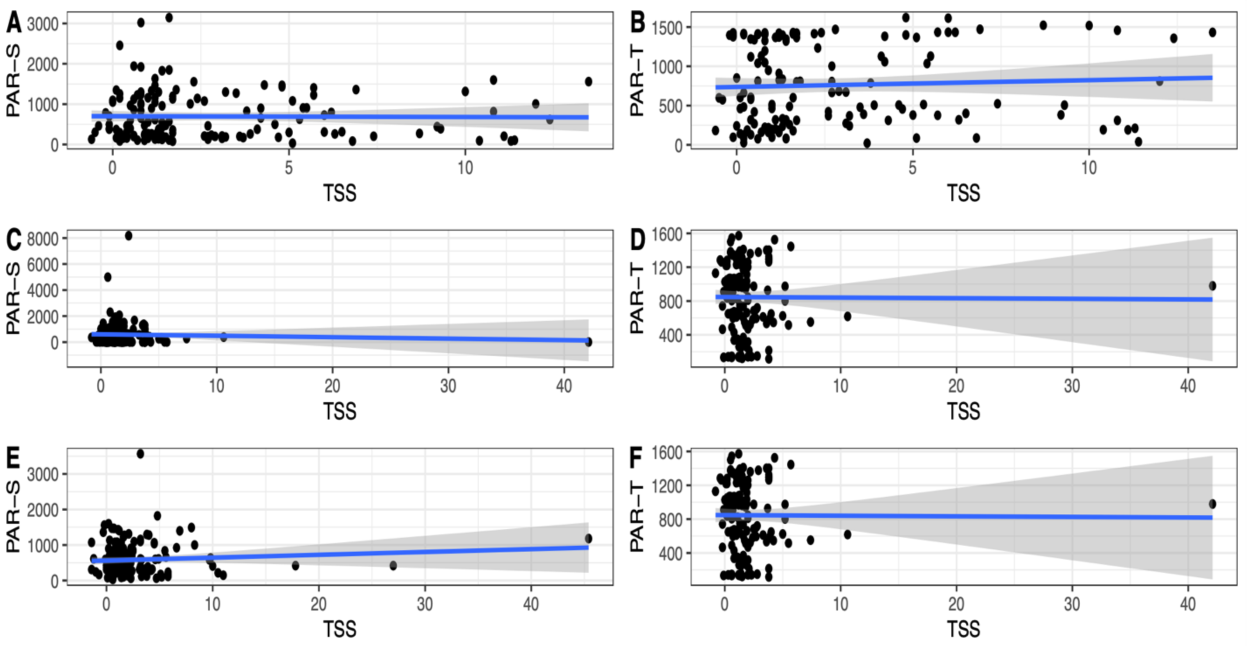

Figure 9 TSS-PAR Phases I and II. *Scatterplots showing correlation between TSS and PAR for Phase I and II PAR-S: Spherical Quantum Sensor, PAR-T: Terrestrial Quantum Sensor. A-B: Jupiter Island, C-D: Delray Beach, E-F: Ocean Ridge.*

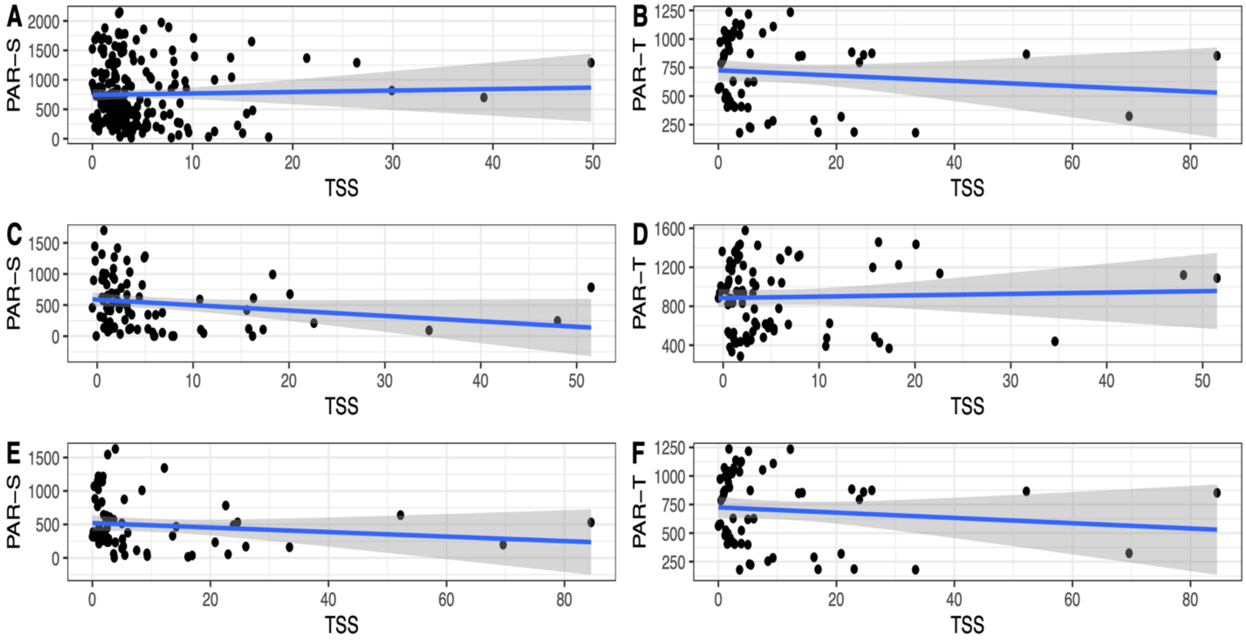

Figure 10 TSS-PAR Phase III. *Scatterplots showing correlation between TSS and PAR for Phases III. PAR-S: Spherical Quantum Sensor, PAR-T: Terrestrial Quantum Sensor. A-B: Lake Worth Inlet, C-D: Port Miami, E-F: Port Everglades.*

3.6 Sediment Characteristic Models

Sediment characteristic models run for water quality parameter relationships by site yielded no significant p-values for any of the models. Adjusted R^2 values (Table 6) indicated that recommended sediment characteristic performance as a predictor was poor whether singularly or added to each other. No single model met significance level at alpha level 0.05.

Table 6 R-Squared Sediment. *Adjusted R^2 values for generalized linear models run on sediment characteristics by site*

	NTU	**PAR (Spherical Quantum Sensor)**	**PAR (Terrestrial Quantum Sensor)**	**TSS (mg/L)**
Jupiter Island				
Silt	-0.0136	-0.0282	-0.0212	-0.0261
Size	-0.0296	-0.0114	-0.0293	-0.0274
Silt+Size	-0.0450	-0.0413	-0.0293	-0.0549
Delray Beach				
Silt	-0.2988	-0.0423	-0.4673	0.1509
Size	-0.3552	-0.4993	-0.4286	-0.0609
Silt+Size	-1.5960	0.5829	-1.338	-0.6982
Ocean Ridge				
Silt	0.3214	0.2397	-0.0017	0.1803
Size	-0.1029	0.1522	-0.1790	0.1467
Silt+Size	0.1102	-0.3260	-1.338	0.1343

3.7 Mapping Analysis

Mapping products were created for individual sites by construction phase and collated between surface and mid-depth in the display. Shapefile layers were displayed in such a way that no data was lost by the overlap of points on the maps.

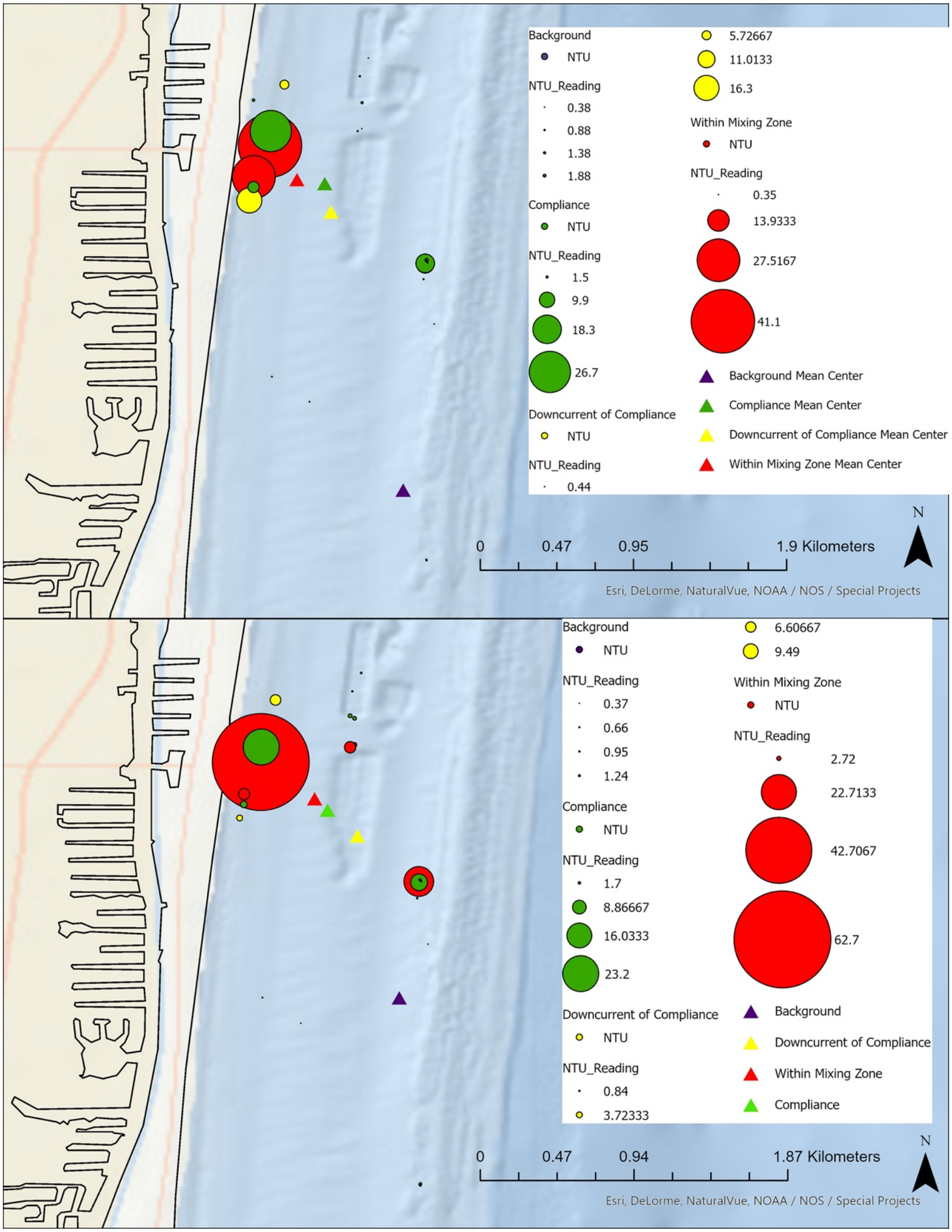

Figure 11 NTU Map Delray Beach. *Mapping product showing Nephelometric Turbidity Unit (NTU) values from Delray Beach by sampling type with symbology to reflect value size. Top: surface values, Bottom: mid-depth values*

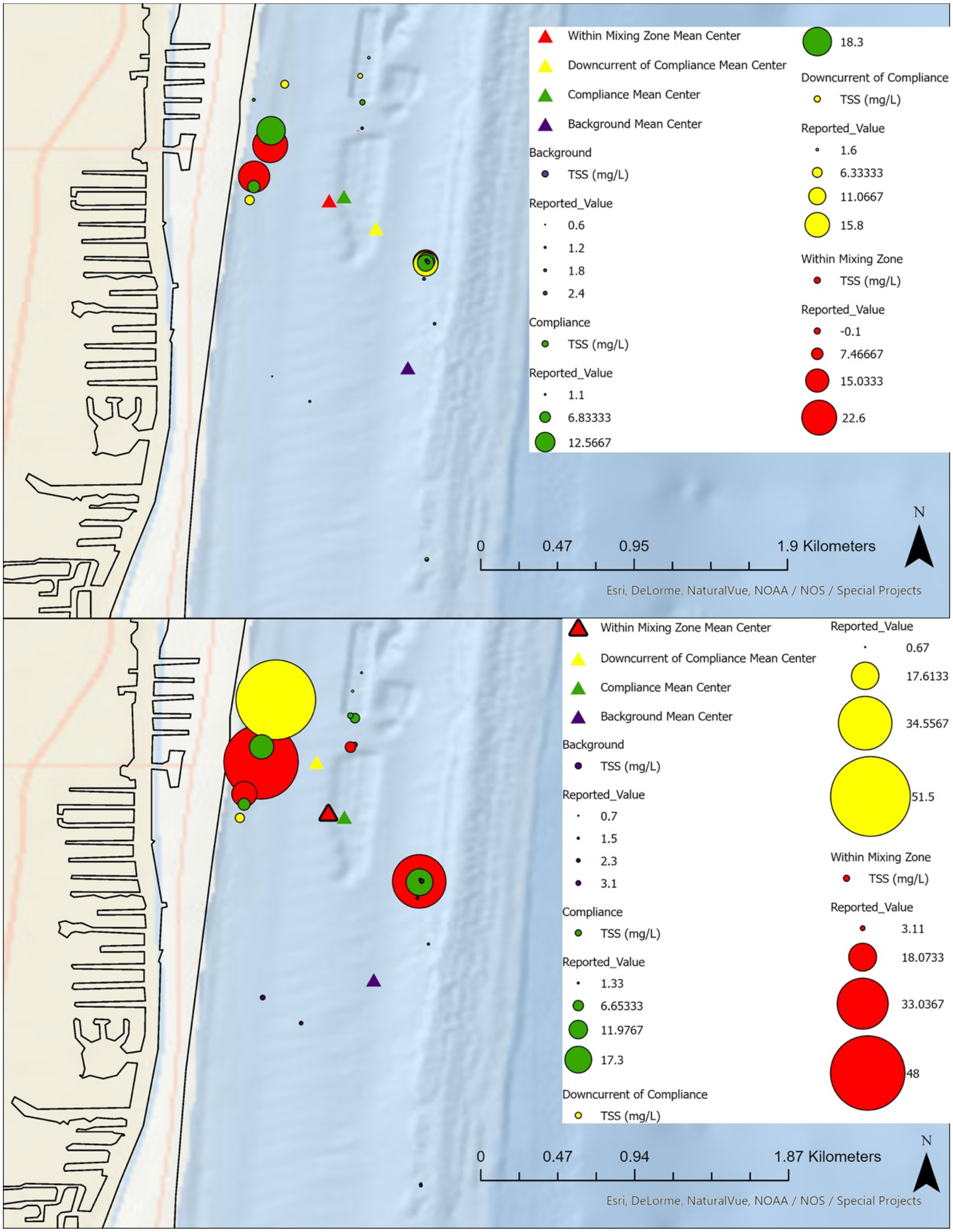

Figure 12 TSS Map Delray Beach. *Mapping product showing Total Suspended Solids (TSS) values in mg/L from Delray Beach by sampling type with symbology to reflect value size. Top: surface values, Bottom: mid-depth values*

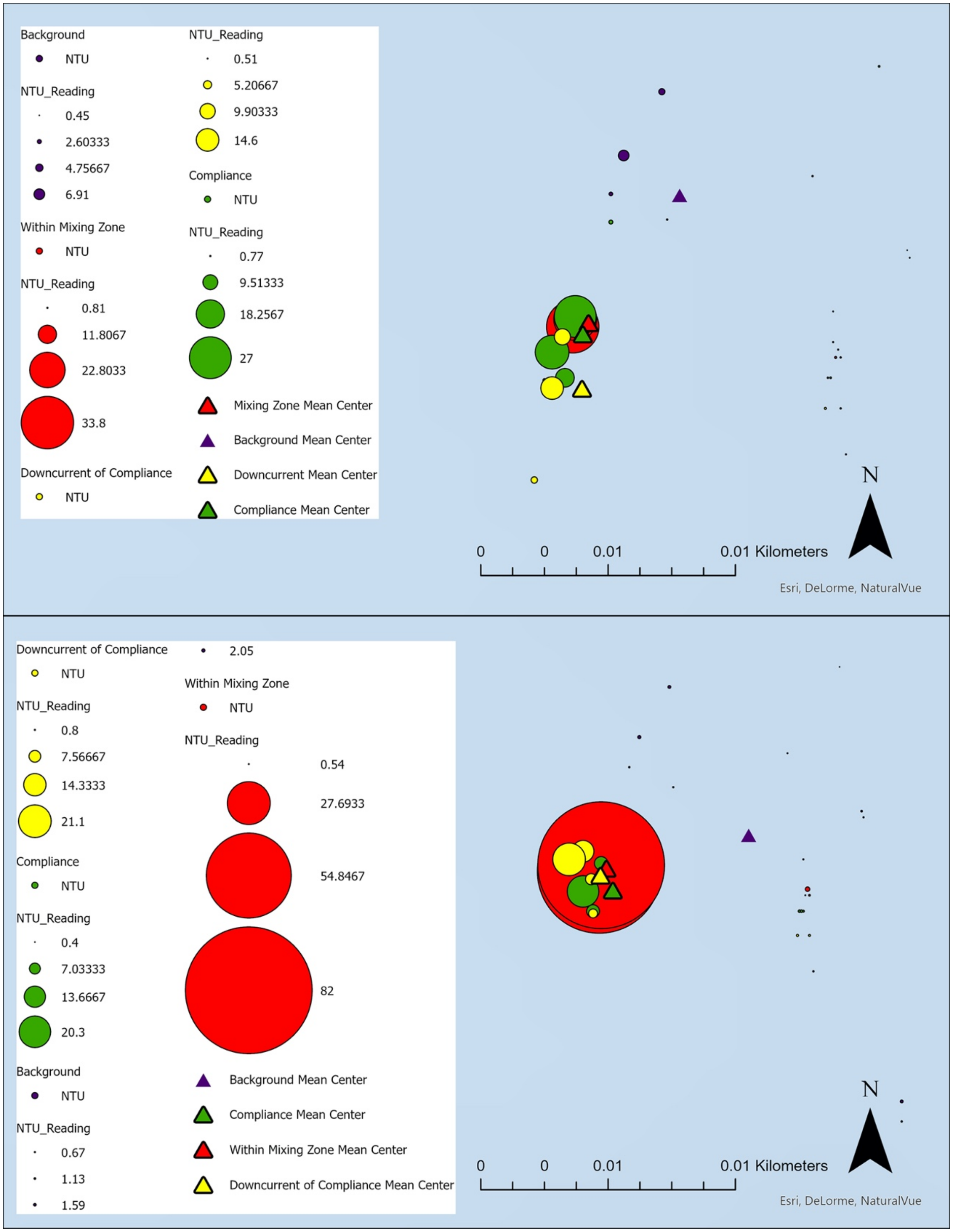

Figure 13 NTU Map Ocean Ridge. *Mapping product showing Nephelometric Turbidity Unit (NTU) values from Ocean Ridge by sampling type with symbology to reflect value size. Top: surface values, Bottom: mid-depth values*

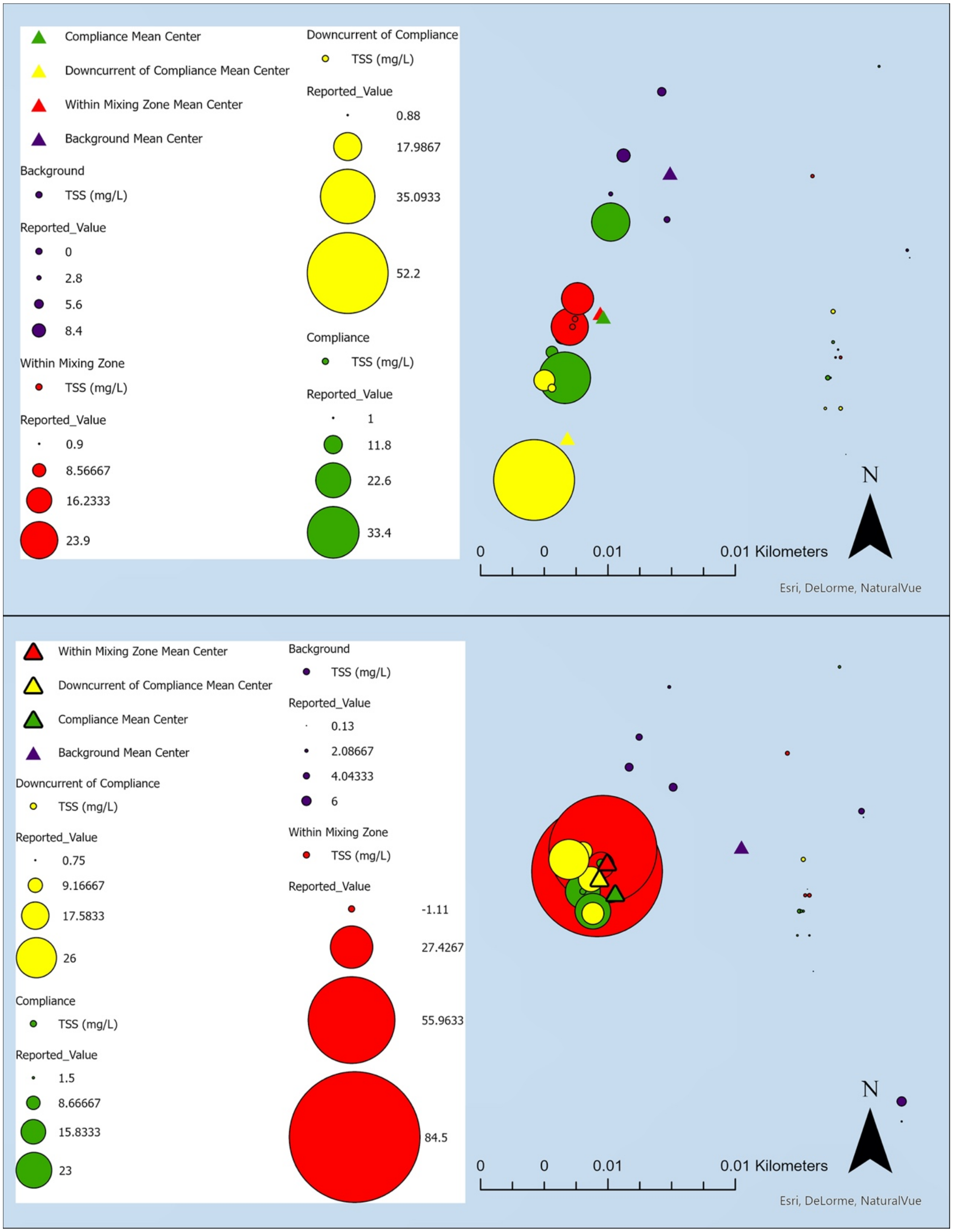

Figure 14 TSS Map Ocean Ridge. *Mapping product showing Total Suspended Solids (TSS) values in mg/L from Ocean Ridge by sampling type with symbology to reflect value size. Top: surface values, Bottom: mid-depth values*

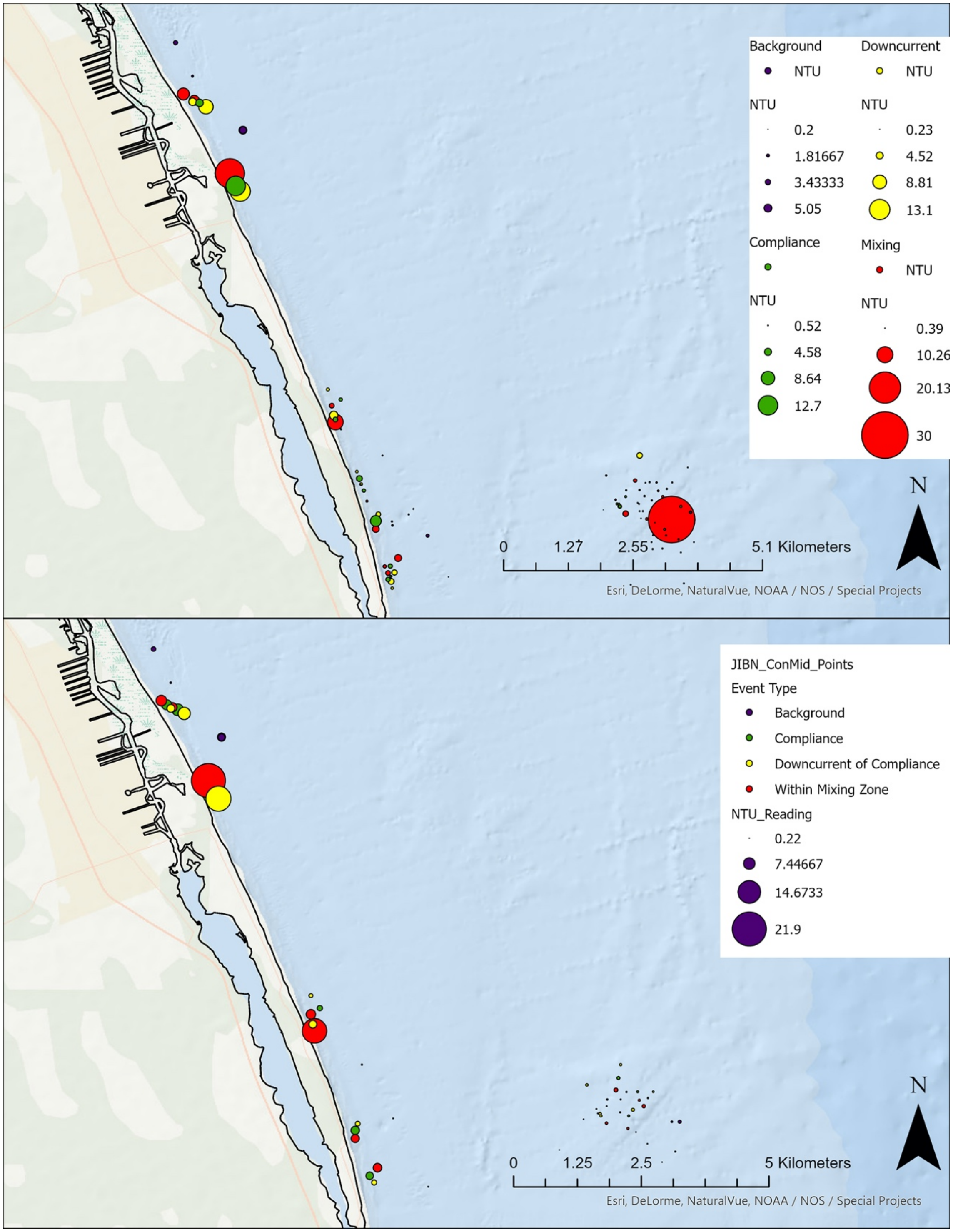

Figure 16 NTU Map Jupiter Island. *Mapping product showing Nephelometric Turbidity Unit (NTU) values for Jupiter Island by sampling type with symbology to reflect value size. Top: surface values, Bottom: mid-depth values*

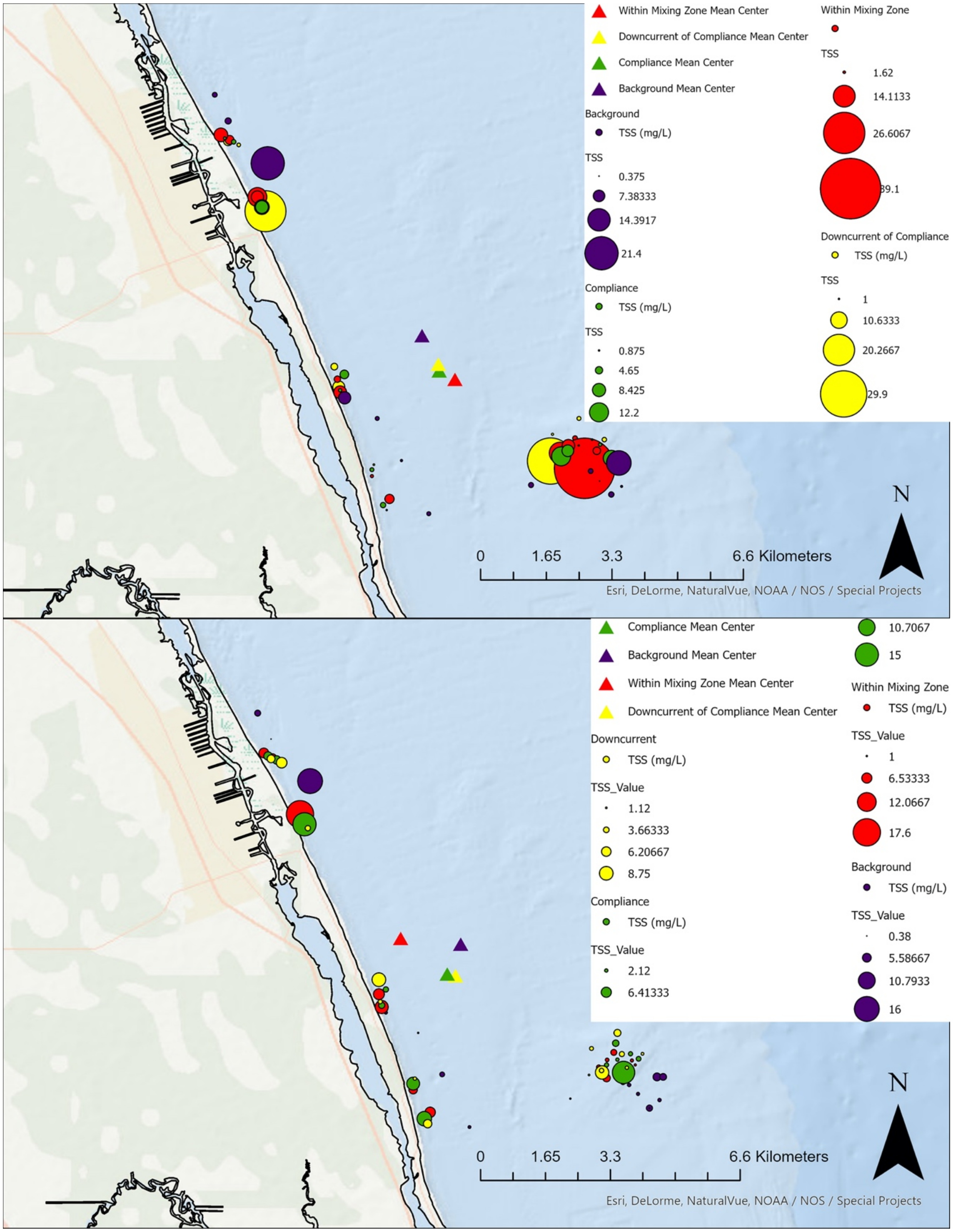

Figure 17 TSS Map Jupiter Island. *Mapping product showing Total Suspended Solids (TSS) values in mg/L for Jupiter Island by sampling type with symbology to reflect value size. Top: surface values, Bottom: mid-depth values*

For Delray Beach (figure 11), trends in mapping reflected other analysis as mixing zone NTU values at mid-depth were greater than those at the surface. This was also reflected in TSS values for both down current of compliance and the mixing zone at Delray Beach (figure 12). For Ocean Ridge, NTU values were again highest at the mid-depth within the mixing zone of the plume (figure 13). TSS values within the mixing zone of the plume peaked at significantly higher levels at the mid-depth versus those at the surface at Ocean Ridge (figure 14). Jupiter Island values appeared similar between mid-depth and surface NTU (figure 15), while TSS values were much higher at surface within the mixing zone, compliance, and background than at mid depth (figure 16).

4. DISCUSSION

Several meaningful conclusions can be drawn from the analysis of water quality parameters and sediment data from CRCP9. Although some caveats exist as noted in the following sections, the data presented here provide evidence of relationships which could be explored through further, more concentrated analysis if desired.

4.1 Relationship Among Water Quality Parameters

Understanding the possible relationships among TSS, PAR, NTU, and their interactions with covariates such as construction activities and sediment characteristics were a key question for the CRCP9 project. Several relationships among these parameters have appeared through analysis, with scope for continued experimentation and further calibration in future. For the relationship between NTU and PAR or TSS, several relationships appeared during correlation testing and creation of scatterplots.

The most consistent among these appeared to be the relationship between NTU and PAR collected with a spherical quantum sensor which had a very similar negative correlation between all sites and Phases I and II (table 4). The negative correlation would be expected in this case as increasing NTU values would be linked to increased turbidity and therefore lower light transmittance through the water column. This correlation was not reflected in any sites from Phase III, perhaps indicating that the relationship between NTU and PAR changes during dredging activity. This relationship was not reflected in PAR data taken with a terrestrial quantum sensor, with only Jupiter Island and Port Miami showing similar negative correlations (table 4). As such, further studies should likely prioritize use of a spherical quantum sensor over a terrestrial one.

The relationship between NTU and TSS also showed some amount of correlation at all but Lake Worth Inlet. All other sites across Phases I, II, and III showed positive correlation of varying degrees. This would be expected as an increase in total suspended solids in the water column would increase turbidity readings. Most notably, correlation Rho values for sites in Phases I and II were higher than those for sites in Phase III indicating a possible effect of dredging activity on the strength of the relationship between NTU and TSS.

The relationship between TSS and PAR appeared similar to that of NTU and PAR based on correlations (table 5). All sites for Phases I and II again showed close negative correlation between TSS and PAR collected by spherical quantum sensor, with these correlations not being statistically significant for any sites from Phase III (5. This negative correlation would again be expected as higher suspended solids would attenuate light penetration. This could also indicate a change in the relationship between TSS and PAR collected with a spherical quantum sensor during construction activities. The lack of statistically significant correlation for TSS and PAR collected with a terrestrial quantum sensor at all except Jupiter Island may further demonstrate that future studies should concentrate on spherical quantum sensors.

Lake Worth Inlet uniquely showed no significant correlation for both NTU and all water quality parameters as well as TSS and PAR, perhaps indicating site specific effects.

Recommended sediment characteristics did not have a clear relationship with water quality parameters across sites. No relationship with any of the parameters was shown whether characteristics were pooled or applied in a model singularly. Mainly negative adjusted R-squared values indicated little to no relationship among the parameters and sediment characteristics. The major caveat of this analysis was the low amount of sediment characteristic datapoints for Delray Beach, Ocean Ridge, and Jupiter Island (4, 6 and 34 respectively) which would greatly reduce the power of any statistical model. No imputation was used in the models so as not to further reduce power. The relationship of sediment characteristics to water quality parameters should be explored further, although experimentation in a closed setting could yield more statistically rigorous results.

A major caveat of the relationships involving PAR are the high variability in the PAR data as a result of sampling methodology. During the course of this study, contractors collected PAR data throughout the sampling days for Phases I, II, and III. This became problematic with regards to consistency, as PAR values were dependent on time of day, yearly irradiance and cloud cover. As calculations involving corrections for these factors were outside the scope of this study, PAR results should be interpreted carefully due to variability in the data introduced by these outside factors. For future studies, PAR data could be collected at a set time point each day or used only from specific time points to compare across studies.

A second caveat of these relationships is the high number of NTU values below five and TSS values below ten. Background NTU values were expected to be below five, and the dataset used in this report contained a high proportion of background samples. The large number of low TSS and NTU values makes relationships hard to visualize as seen in the scatterplots (figures 3-10). More targeted sampling of the sediment plume may be necessary in future studies in order to better capture higher NTU and TSS values if they are present.

4.2 Change in Water Quality Parameters Across Projects

A second goal of the CRCP9 process was to understand how samples taken within construction activities varied to those taken as background samples and whether there was a clear trend of improving water quality moving away from dredging activities. The trends and variances for these analyses were mixed, although differences were found across multiple types of statistical comparisons.

Initially, "natural background" values from sites in Phase III were compared to background samples from sites in Phases I and II separated by construction milestone in order to inform whether dredging activity had any effect on background values as compared to what would be expected to be "natural" values from Phase III. For Delray Beach, surface NTU background samples were significantly different than both those at Lake Worth Inlet and Port Miami, perhaps showing an effect of dredging activities on background samples in their immediate vicinity. This was also demonstrated at Ocean Ridge where during construction milestone NTU values were found to be significantly different at mid-depth to "natural background" samples at Lake Worth Inlet and Port Everglades. However, comparing pre-construction milestone samples to those during construction at Delray Beach (Phase II), on surface PAR taken with a spherical quantum sensor showed statistical difference, indicating that at background sampling sites at least water quality parameter values were not being greatly affected by dredge activity.

Beyond this, differences between background samples and those taken within the influence of the plume and therefore dredging activities appeared site specific based on Analysis. Surprisingly, no water quality parameter showed a statistically significant difference when background values were compared to those in the influence of the plume (compliance, down current of compliance, or within mixing zone) by sampling depth. This is not to say that there is no trend present here, and perhaps the dredge plume was missed during sampling or high variability in the data did not allow trends to be seen. Despite this, mid-depth NTU and TSS readings had the highest means and highest maximums at the surface within the mixing zone at Ocean Ridge, similar to the significant relationships seen at the other sites in Phases I and II. Delray Beach showed a significant difference in NTU at the surface between background and compliance samples, which would be expected given this is where the densest portion of the plume crosses the mixing zone polygon. This was also the case for TSS values at the surface, as well as those down current of compliance. This would again be expected and would indicate a trend of improving water quality away from dredging activity. Delray Beach also showed significant differences at mid-depth, where NTU differed from all plume influenced samples (compliance, down current of compliance, and within mixing zone) further bolstering the trend of improving water quality away from dredging activity. Delray Beach TSS values also echoed this at mid depth, with a significant difference between background values and those within the mixing zone. Jupiter Island surface background NTU values differed significantly from those at compliance points and within the mixing zone, while at mid-depth they differed significantly to all plume influenced samples as they had at Delray Beach.

Both comparisons from Delray Beach and Jupiter Island seem to indicate a trend of increasing water quality as sampling was moved away from dredging activity. This trend is most evident at mid-depth as evidenced by Jupiter Island and Delray Beach, as well as in the summary statistics (Supplemental Table 1) where background NTU and TSS had the lowest means overall as well as the lowest maximum values. Despite background values also having the lowest means for NTU and TSS at Ocean Ridge, they did not have the lowest maximums, indicating the variability in the data may have confounded the trend above, although a trend cannot be discounted given the evidence above. Given the greater significance of values taken at mid-depth, future sampling should prioritize capturing data at mid-depth if there is a risk of the dredge plume dispersing.

4.3 Variability in Water Quality Parameters

The final major goal of the CRCP9 process was to determine the overall variability in the data and determine possible explanations for the variability. Several of the analyses performed provided insight into the source of variability in the data, as well as possible sampling issues which may have inadvertently increased variability.

The type of background sample whether true background or plume influenced plume (compliance, down current of compliance, and within mixing zone) showed differing variability based on sampling type. Since plume influenced samples were only taken in Phases I and II, these were focused on when determining overall variability. Across all sites in Phases I and II, surface and mid-depth values within the mixing zone of the plume had the highest variability in NTU. Looking at the summary statistics for all three projects (supplemental table 1) clearly demonstrates this with NTU standard deviations being the highest of any sampling type at both surface and mid-depth for all three sites. For TSS, standard deviations were highest for surface compliance at Jupiter Island (9.88). At Delray Beach and Ocean Ridge, highest TSS standard deviation was again mid-depth within the mixing zone. Interestingly, this was not true of PAR values for any site.

Site specific factors appeared to cause much of the variability in the data, particularly for projects in Phase III. Comparing background values between sites in Phase III showed significant statistical differences for several water quality parameters that were to be considered "natural background", indicating site specific variability. Surface NTU values from Lake Worth Inlet were significantly different than Port Everglades, and those from Port Everglades were significantly different than Port Miami. For NTU at mid-depth, Port Everglades was significantly different than Port Miami and at Lake Worth Inlet were significantly different than Port Everglades. This was also reflected in Phase II at Ocean Ridge, whereby comparisons between background sample values and those taken at the influence of the dredge plume (compliance, down current of compliance, and within mixing zone) were not found to be significantly different, likely due to great variability in the data not reflected at the other sites in Phase I and II. Referring to the aggregated range data for the sites from Phase I and II (supplemental table 1), Ocean Ridge had a much higher range of NTU (0.4-82) and TSS (-1.11-84.5) than either Jupiter Island (02.-30 and -0.13-49.8) or Delray Beach (0.35-62.7 and -0.5-51.5).

One inadvertent source of variability in PAR values may have been the aforementioned sampling methodology. By not controlling for factors such as time of day, monthly irradiance, and cloud cover, PAR data was made more variable and therefore difficult to extrapolate from. Also due to the problems with power resulting from the sediment characteristic models and the lack of statistical significance, it is impossible to determine if sediment characteristics were responsible for variability in water quality parameters from this report.

4.4 Mapping Discussion

Mapping products created for this project ultimately reflected trends seen in the data visually, both from simple descriptive statistics (supplemental table 1) as well as some comparative statistics. For example, Jupiter Island mapping products reflected the large range of TSS values at the surface versus the mid-depth (figure 16). Visually, both the TSS and NTU maps for Ocean Ridge and Delray beach (figures 11-14) appeared to show a trend in greater mixing zone values at the mid depth, even if direct statistical comparison did not necessarily find this relationship evident. The low number of datapoints per site precluded further analysis such as Hot-Spot analysis where minimum datapoints required are 30. Future sampling should take this into account if mapping analysis of visual trends is desired.

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6.0 Addendum

CRCP 9 Report Addendum: Kd(PAR)-NTU-TSS Relationships in Coral ECA

Prepared By: Shelby Wedelich

January 27, 2021

With special acknowledgements to Claire Burgett, Ken Weaver, Daryll Joyner, Joey Massa, Wilson Mendoza, Henry Briceno, Jack Stamates, Phil Dustan, and others for updated correlations and figures, calculations of extinction coefficient, comments on the report, and suggestions to improve future work. Thank you!

6.1.0 Need for an Addendum

The original Coral Reef Conservation Program (CRCP) Project 9 report was submitted in September 2020. Within a week of submission, it came to the attention of Department staff that Photosynthetically Active Radiation (PAR) data, while collected and analyzed according to the specifications outlined within the contractors' respective scopes of work, was presented incorrectly in the data set and the report. We apologize for this oversight in the writing of the scope of work and interpretation of submitted data and analyses. Here, we present our attempts to more appropriately analyze the data that was collected, while also acknowledging the shortcomings of this approach and suggestions for future work.

6.2.0 PAR Collection and Reporting Methods

In all phases of CRCP 9, PAR was collected at surface and mid-depth, during high and low tide, on days and locations that were driven by the timing and location of beach nourishment projects (Phases I and II) or conditions absent construction at inlets and surrounding reef within the Coral ECA (Phase III). PAR was collected at these discrete locations using the following appropriately calibrated sensors: a LI-1500 light sensor logger, a LI-109R Quantum Sensor (Serial No. Q108392) terrestrial sensor which stayed on the surface of the boat, and a LI-193 Spherical

Quantum Sensor (Serial No. SPQA5768) spherical sensor which was submerged 0.5 m below the surface for surface measurements and at half the depth of each site for mid-depth measurements. Samples were not collected at noon due to the importance of evaluating flux in turbidity (measured in Nephelometric Turbidity Units, or NTU) and total suspended solids (TSS in mg/L) at high and low tide. Irradiance and seasonal corrections were not conducted at the time of sampling and were not introduced in the corrections or addendum due to the complexity of the equations. The readings of the terrestrial quantum sensor and the spherical quantum sensor were both recorded for surface and mid-depth for each sample, and data was submitted to the Department in .pdf reports. Department staff then entered the data into Excel spreadsheets and matched light readings from the spherical and terrestrial quantum sensor and NTU readings to TSS results from laboratory analysis of the same water sample.

This data was subsequently analyzed by a contractor in the CRCP Project 9 report. One of the contractor's tasks was to provide correlations and plots between PAR, NTU, and TSS data collected for each phase of CRCP 9. Since PAR data was split up into terrestrial and spherical readings, correlations and plots were created for PAR terrestrial to NTU, PAR spherical to NTU, and PAR terrestrial to TSS, and PAR spherical to TSS.

6.2.1 Calculating Extinction Coefficient and Updated Analysis

Upon realizing the analysis error, Department staff coordinated internally, as well as with contractors and members of the Southeast Florida Coral Reef Initiative Technical Advisory Committee (SEFCRI TAC). The solution put forward in this addendum was to approximate extinction coefficient (Kd) from the light readings using the following formula:

$$\mathrm{Kd} = \mathrm{Ln}\left(\frac{PARTerr}{PARSpher}\right) * \frac{1}{m}$$

where Kd = extinction coefficient, PARTerr = light reading from the terrestrial quantum sensor, PARSpher = light reading from the underwater spherical quantum sensor, and m = light reading depth in meters. For surface, m = 0.5. For mid-depth m = ½ total depth in meters at each site. In tables, this is referred to as “Kd”. In figures, this is referred to as “Kd(PAR)”.

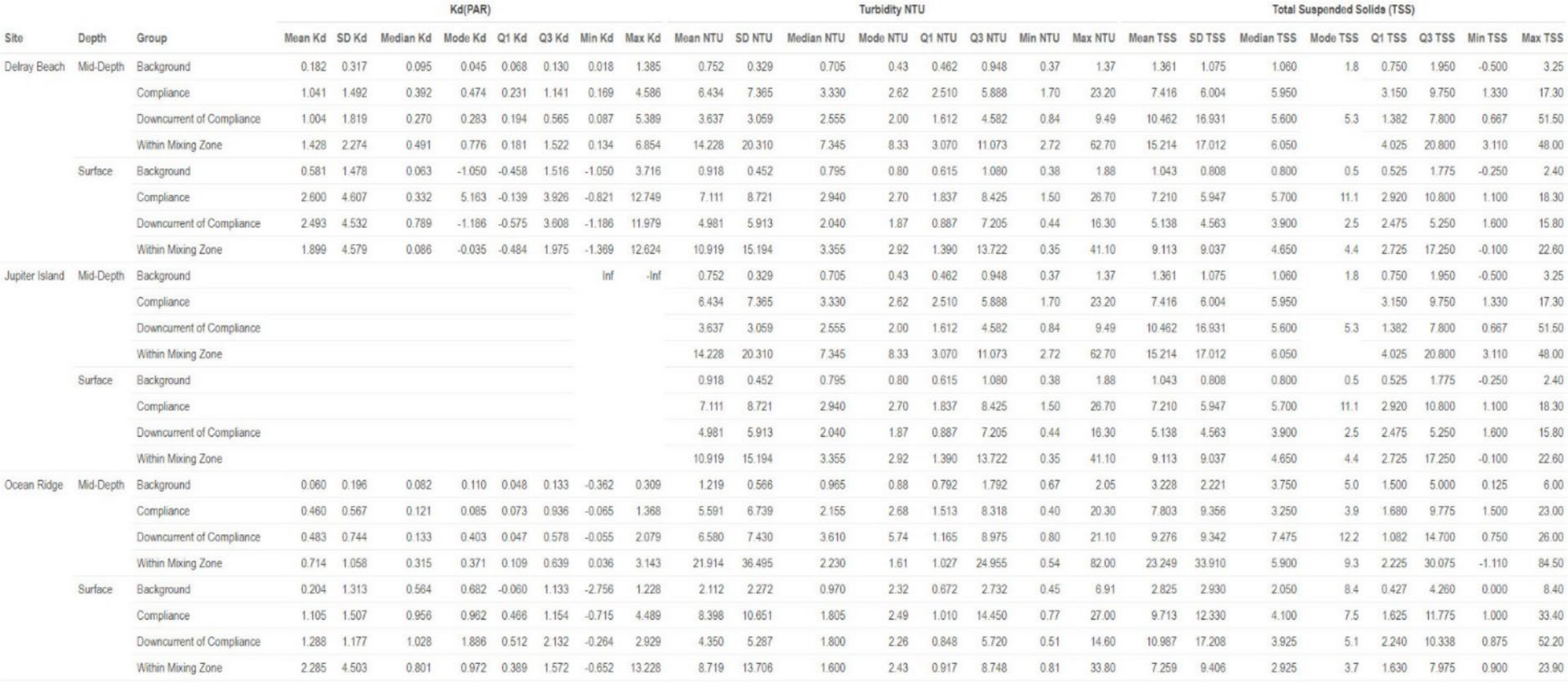
The analyses and work detailed in the original CRCP Project 9 report include summary statistics, background comparisons within and among phases, construction sampling type comparisons, surface to mid-depth comparisons, correlations of PAR, NTU, and TSS, mapping analysis of turbidity in Phases I and II, and sediment characteristic models. The methods in Sections 2.13 and 2.14, NTU and TSS results and maps detailed in Sections 3.1 – 3.7, and much of the discussion stand alone in the original report and are not replicated here. The methods detailed in Sections 2.3 – 2.12 are revised to include Kd, and results pertaining to Kd in Sections 3.1-3.5 are included in this addendum. Exceptions include work pertaining to Phase I (due to an unfortunate loss of depth data) and sediment characteristic models (since they were initially insignificant and less related to Kd than NTU or TSS). A transcript of the updated Rmarkdown (Appendix A) and of the original Rscript (Appendix B) are included at the end of this addendum.

6.3.0 Updated Results

6.3.1 Summary Statistics

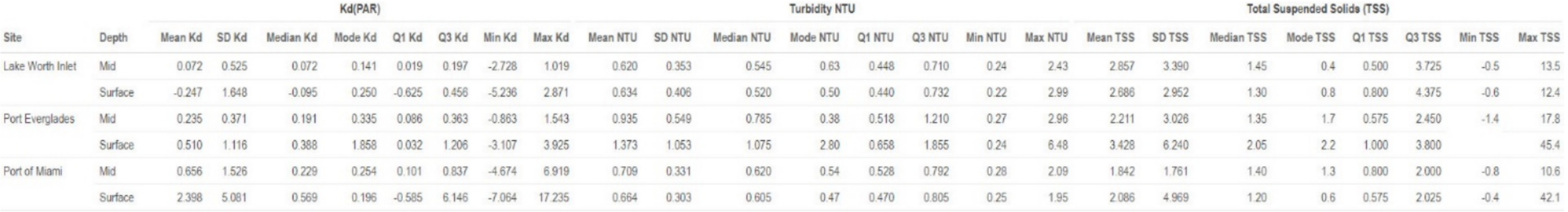
For ease of reference, summary statistic tables with all parameters are included below, but refer to the original report for discussion of NTU and TSS.

Table 7 Summary Statistics Phase II. *Summary statistics for Kd, NTU, and TSS for Delray Beach and Ocean Ridge (Phase II). Jupiter Island (Phase I) does not have corrected Kd data, but NTU and TSS values are incorporated for reference.*



			Kd(PAR)								Turbidity NTU								Total Suspended Solids (TSS)							
Site	Depth	Group	Mean Kd	SD Kd	Median Kd	Mode Kd	Q1 Kd	Q3 Kd	Min Kd	Max Kd	Mean NTU	SD NTU	Median NTU	Mode NTU	Q1 NTU	Q3 NTU	Min NTU	Max NTU	Mean TSS	SD TSS	Median TSS	Mode TSS	Q1 TSS	Q3 TSS	Min TSS	Max TSS
Delray Beach	Mid-Depth	Background	0.182	0.317	0.095	0.045	0.068	0.130	0.018	1.385	0.752	0.329	0.705	0.43	0.462	0.948	0.37	1.37	1.361	1.075	1.060	1.8	0.750	1.950	-0.500	3.25
		Compliance	1.041	1.492	0.392	0.474	0.231	1.141	0.169	4.586	6.434	7.365	3.330	2.62	2.510	5.888	1.70	23.20	7.416	6.004	5.950		3.150	9.750	1.330	17.30
		Downcurrent of Compliance	1.004	1.819	0.270	0.283	0.194	0.565	0.087	5.389	3.637	3.059	2.555	2.00	1.612	4.582	0.84	9.49	10.462	16.931	5.600	5.3	1.382	7.800	0.667	51.50
		Within Mixing Zone	1.428	2.274	0.491	0.776	0.181	1.522	0.134	6.854	14.228	20.310	7.345	8.33	3.070	11.073	2.72	62.70	15.214	17.012	6.050		4.025	20.800	3.110	48.00
	Surface	Background	0.581	1.478	0.063	-1.050	-0.458	1.516	-1.050	3.716	0.918	0.452	0.795	0.80	0.615	1.080	0.38	1.88	1.043	0.808	0.800	0.5	0.525	1.775	-0.250	2.40
		Compliance	2.600	4.607	0.332	5.163	-0.139	3.926	-0.821	12.749	7.111	8.721	2.940	2.70	1.837	8.425	1.50	26.70	7.210	5.947	5.700	11.1	2.920	10.800	1.100	18.30
		Downcurrent of Compliance	2.493	4.532	0.789	-1.186	-0.575	3.608	-1.186	11.979	4.981	5.913	2.040	1.87	0.887	7.205	0.44	16.30	5.138	4.563	3.900	2.5	2.475	5.250	1.600	15.80
		Within Mixing Zone	1.899	4.579	0.086	-0.035	-0.484	1.975	-1.369	12.624	10.919	15.194	3.355	2.92	1.390	13.722	0.35	41.10	9.113	9.037	4.650	4.4	2.725	17.250	-0.100	22.60
Jupiter Island	Mid-Depth	Background							Inf	-Inf	0.752	0.329	0.705	0.43	0.462	0.948	0.37	1.37	1.361	1.075	1.060	1.8	0.750	1.950	-0.500	3.25
		Compliance									6.434	7.365	3.330	2.62	2.510	5.888	1.70	23.20	7.416	6.004	5.950		3.150	9.750	1.330	17.30
		Downcurrent of Compliance									3.637	3.059	2.555	2.00	1.612	4.582	0.84	9.49	10.462	16.931	5.600	5.3	1.382	7.800	0.667	51.50
		Within Mixing Zone									14.228	20.310	7.345	8.33	3.070	11.073	2.72	62.70	15.214	17.012	6.050		4.025	20.800	3.110	48.00
	Surface	Background									0.918	0.452	0.795	0.80	0.615	1.080	0.38	1.88	1.043	0.808	0.800	0.5	0.525	1.775	-0.250	2.40
		Compliance									7.111	8.721	2.940	2.70	1.837	8.425	1.50	26.70	7.210	5.947	5.700	11.1	2.920	10.800	1.100	18.30
		Downcurrent of Compliance									4.981	5.913	2.040	1.87	0.887	7.205	0.44	16.30	5.138	4.563	3.900	2.5	2.475	5.250	1.600	15.80
		Within Mixing Zone									10.919	15.194	3.355	2.92	1.390	13.722	0.35	41.10	9.113	9.037	4.650	4.4	2.725	17.250	-0.100	22.60
Ocean Ridge	Mid-Depth	Background	0.060	0.196	0.082	0.110	0.048	0.133	-0.362	0.309	1.219	0.566	0.965	0.88	0.792	1.792	0.67	2.05	3.228	2.221	3.750	5.0	1.500	5.000	0.125	6.00
		Compliance	0.460	0.567	0.121	0.085	0.073	0.936	-0.065	1.368	5.591	6.739	2.155	2.68	1.513	8.318	0.40	20.30	7.803	9.356	3.250	3.9	1.680	9.775	1.500	23.00
		Downcurrent of Compliance	0.483	0.744	0.133	0.403	0.047	0.578	-0.055	2.079	6.580	7.430	3.610	5.74	1.165	8.975	0.80	21.10	9.276	9.342	7.475	12.2	1.082	14.700	0.750	26.00
		Within Mixing Zone	0.714	1.058	0.315	0.371	0.109	0.639	0.036	3.143	21.914	36.495	2.230	1.61	1.027	24.955	0.54	82.00	23.249	33.910	5.900	9.3	2.225	30.075	-1.110	84.50
	Surface	Background	0.204	1.313	0.564	0.682	-0.060	1.133	-2.756	1.228	2.112	2.272	0.970	2.32	0.672	2.732	0.45	6.91	2.825	2.930	2.050	8.4	0.427	4.260	0.000	8.40
		Compliance	1.105	1.507	0.956	0.962	0.466	1.154	-0.715	4.489	8.398	10.651	1.805	2.49	1.010	14.450	0.77	27.00	9.713	12.330	4.100	7.5	1.625	11.775	1.000	33.40
		Downcurrent of Compliance	1.288	1.177	1.028	1.886	0.512	2.132	-0.264	2.929	4.350	5.287	1.800	2.26	0.848	5.720	0.51	14.60	10.987	17.208	3.925	5.1	2.240	10.338	0.875	52.20
		Within Mixing Zone	2.285	4.503	0.801	0.972	0.389	1.572	-0.652	13.228	8.719	13.706	1.600	2.43	0.917	8.748	0.81	33.80	7.259	9.406	2.925	3.7	1.630	7.975	0.900	23.90

Table 8 Summary Statistics Phase III. *Summary statistics for Kd, NTU, and TSS for Port of Miami, Port Everglades, and Lake Worth Inlet (Phase III).*



		Kd(PAR)								Turbidity NTU								Total Suspended Solids (TSS)							
Site	Depth	Mean Kd	SD Kd	Median Kd	Mode Kd	Q1 Kd	Q3 Kd	Min Kd	Max Kd	Mean NTU	SD NTU	Median NTU	Mode NTU	Q1 NTU	Q3 NTU	Min NTU	Max NTU	Mean TSS	SD TSS	Median TSS	Mode TSS	Q1 TSS	Q3 TSS	Min TSS	Max TSS
Lake Worth Inlet	Mid	0.072	0.525	0.072	0.141	0.019	0.197	-2.728	1.019	0.620	0.353	0.545	0.63	0.448	0.710	0.24	2.43	2.857	3.390	1.45	0.4	0.500	3.725	-0.5	13.5
	Surface	-0.247	1.648	-0.095	0.250	-0.625	0.456	-5.236	2.871	0.634	0.406	0.520	0.50	0.440	0.732	0.22	2.99	2.686	2.952	1.30	0.8	0.800	4.375	-0.6	12.4
Port Everglades	Mid	0.235	0.371	0.191	0.335	0.086	0.363	-0.863	1.543	0.935	0.549	0.785	0.38	0.518	1.210	0.27	2.96	2.211	3.026	1.35	1.7	0.575	2.450	-1.4	17.8
	Surface	0.510	1.116	0.388	1.858	0.032	1.206	-3.107	3.925	1.373	1.053	1.075	2.80	0.658	1.855	0.24	6.48	3.428	6.240	2.05	2.2	1.000	3.800		45.4
Port of Miami	Mid	0.656	1.526	0.229	0.254	0.101	0.837	-4.674	6.919	0.709	0.331	0.620	0.54	0.528	0.792	0.28	2.09	1.842	1.761	1.40	1.3	0.800	2.000	-0.8	10.6
	Surface	2.398	5.081	0.569	0.196	-0.585	6.146	-7.064	17.235	0.664	0.303	0.605	0.47	0.470	0.805	0.25	1.95	2.086	4.969	1.20	0.6	0.575	2.025	-0.4	42.1

6.3.2 Background Data Comparisons

Originally, background data comparisons were made between Phases I, II, and III. Given that Phase I had a loss of depth data, Kd could not be calculated for Phase I and thus this analysis was not re-done.

6.3.3 Sampling Type Comparison (Effect of Event Type)

For Ocean Ridge, no water quality parameter showed a statistically significant difference between background samples and those within the influence of the plume (compliance, down current of compliance, or within mixing zone), both at the surface and at mid-depth.

For Delray Beach, several water quality parameters showed statistically significant differences between background samples and those which were plume influenced, which are replicated here for all parameters since the new results yielded similar significance but different p-values. At the surface, background NTU values differed from compliance NTU values ($p=0.002$), although no other groups showed a significant difference in NTU values. Surface TSS values also differed between background samples and compliance samples ($p=0.003$), between background and down current samples ($p=0.002$), and between background and within mixing zone samples ($p=0.01$). There were no significant differences between Kd at the surface. At mid-depth, NTU showed significant differences between background samples and those within the mixing zone, down current of compliance and at compliance ($p<0.001$, $p=0.001$, and $p<0.0001$ respectively). At mid-depth, background Kd was significantly different from compliance, downcurrent, and within mixing zone ($p=0.002$, $p=0.0147$, $p=0.002$ respectively). At mid-depth, background TSS was significantly different from compliance, downcurrent, and within mixing zone ($p=0.004$, $p = 0.04$, $p < 0.001$ respectively).

6.3.4 Surface to Mid-Depth Comparison (Effect of Depth)

For Delray Beach, there was no significant difference between parameters when comparing solely between surface and mid-depth. For Ocean Ridge, Kd was significantly different between surface and mid-depth (p=0.01). For Lake Worth Inlet, there was no significant difference in parameters between surface and mid-depth. For Port of Miami, there was no significant difference in parameters between surface and mid-depth. For Port Everglades, NTU (p=0.01), Kd (p = 0.01), and TSS (p=0.04) differed significantly across surface to mid-depth.

6.3.5 Correlation (Relationships Between NTU, TSS, and Kd)

NTU and Kd showed a positive correlation of varying degrees for all sites except Port Miami. TSS and Kd showed a positive correlation at Delray Beach and Ocean Ridge, but no correlation at any of the port/inlet sites in Phase III (Table 2). Figures 1-7 show the relationships by sampling site and water quality parameter.

Table 9 Rho NTU-Kd-TSS. *Spearman rank correlation Rho values (correlation) for Nephelometric Turbidity Units (NTU) vs extinction coefficient calculated from photosynthetically active radiation (Kd) and Kd vs Total Suspended Solids (TSS) in mg/L by site (see report for NTU-TSS rho and correlation. NC = no correlation.*

Location	**NTU and Kd**	**Kd and TSS**
Delray Beach	0.2404 (p = 0.02)	0.3277 (p = 0.002)
Ocean Ridge	0.4173 (p<0.001)	0.5271 (p < 0.001)
Port Everglades	0.2344 (p = 0.004)	NC (p = 0.2)
Port Miami	NC (p = 0.4)	NC (p = 0.3)
Lake Worth Inlet	0.1867 (p = 0.02)	NC (p = 0.07)

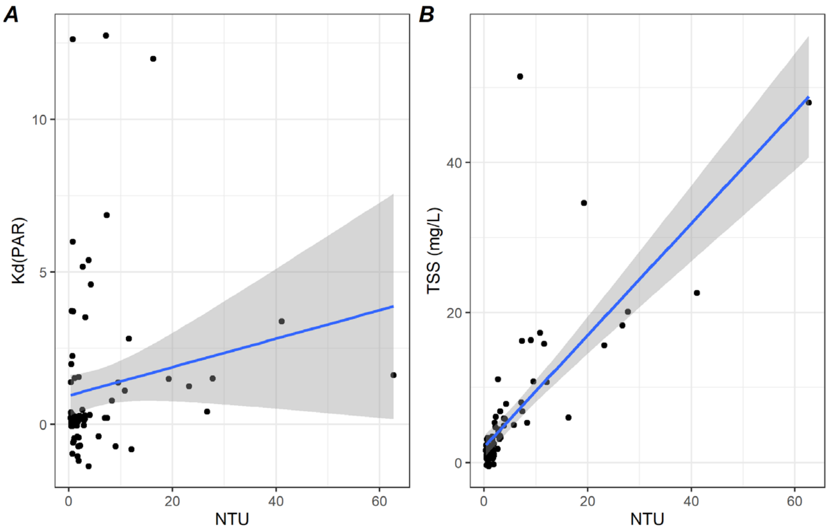


Figure 18 Delray Beach NTU-Kd(PAR)-TSS: *Scatterplots showing correlation between Nephelometric Turbidity Units (NTU) and A: extinction coefficient calculated from photosynthetically active radiation (Kd(PAR)) B: Total Suspended Solids (TSS) in mg/L, both at Delray Beach*

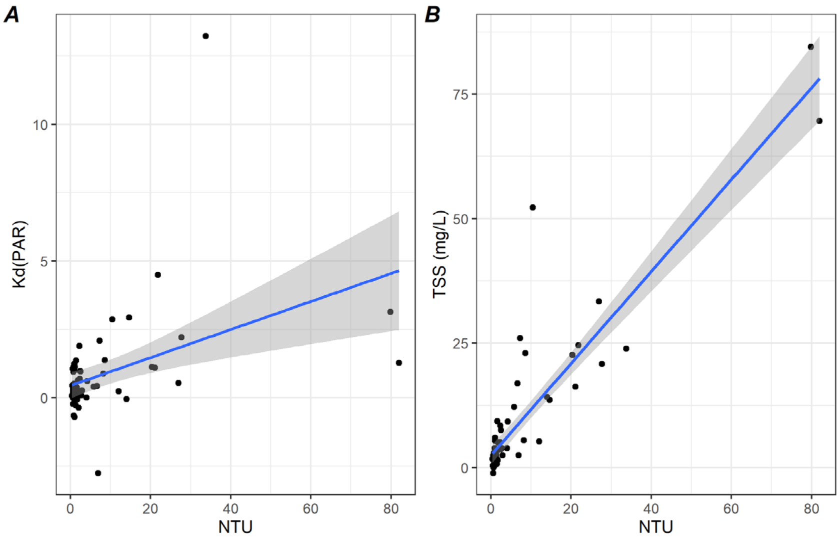


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Figure 19 Ocean Ridge NTU-Kd(PAR)-TSS. *Scatterplots showing correlation between Nephelometric Turbidity Units (NTU) and A: extinction coefficient calculated from photosynthetically active radiation (Kd(PAR)) B: Total Suspended Solids (TSS) in mg/L, both at Ocean Ridge*

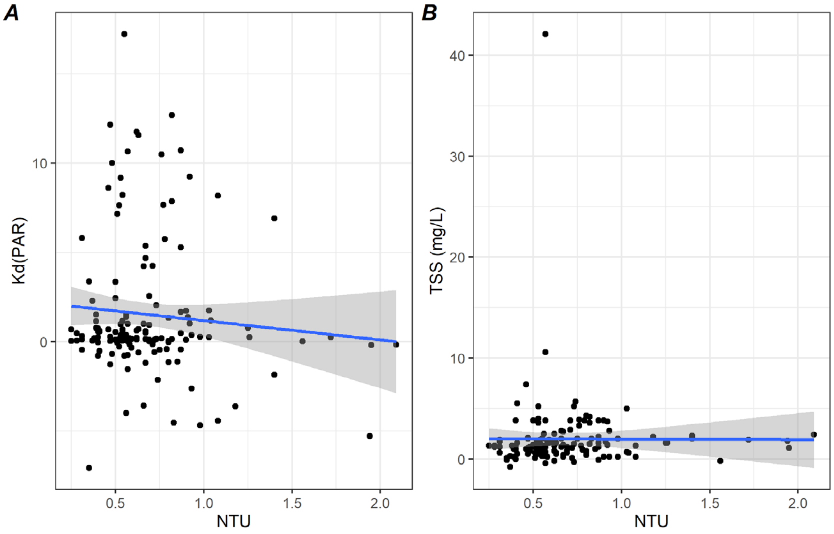

Figure 20 Port Miami NTU-Kd(PAR)-TSS. *Scatterplots showing correlation between Nephelometric Turbidity Units (NTU) and A: extinction coefficient calculated from photosynthetically active radiation (Kd(PAR)) B: Total Suspended Solids (TSS) in mg/L, both at Port Miami*

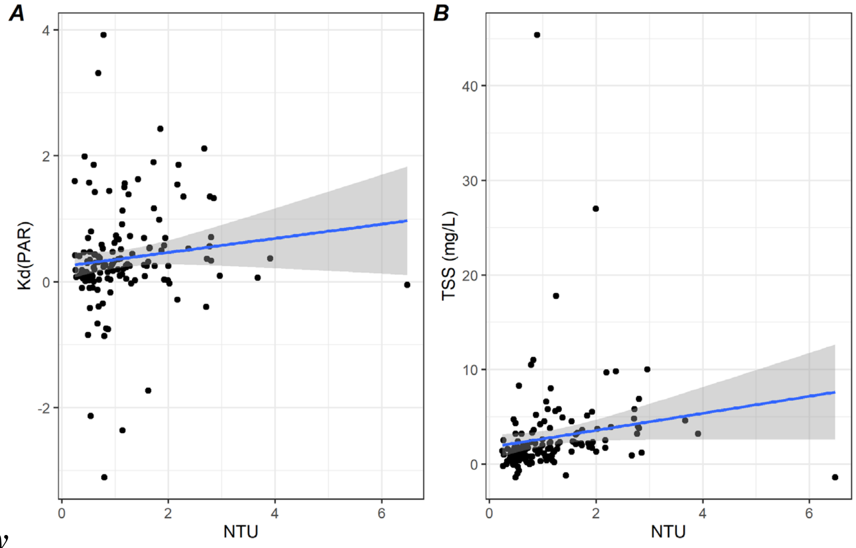

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Figure 21 Port Everglades NTU-Kd(PAR)-TSS. *Scatterplots showing correlation between Nephelometric Turbidity Units (NTU) and A: extinction coefficient calculated from photosynthetically active radiation (Kd(PAR)) B: Total Suspended Solids (TSS) in mg/L, both at Port Everglades*

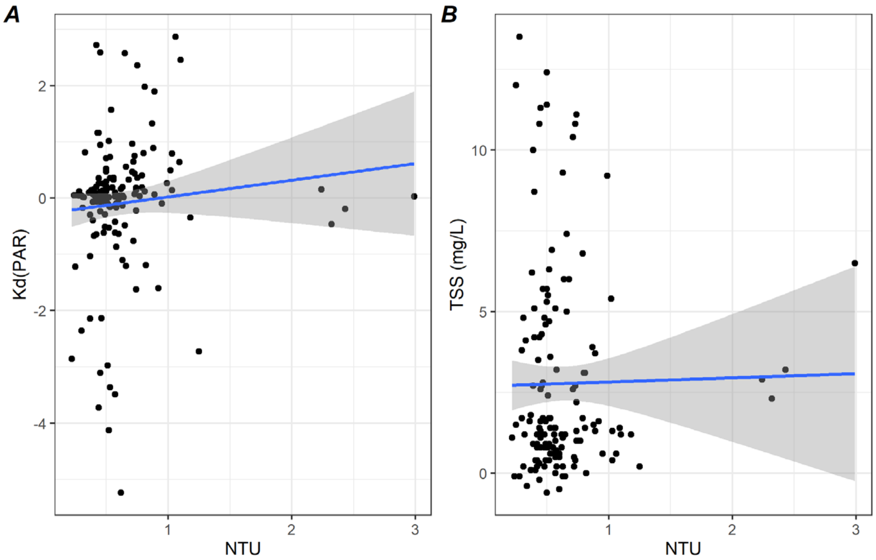


Figure 22 Lake Worth Inlet NTU-Kd(PAR)-TSS . *Scatterplots showing correlation between Nephelometric Turbidity Units (NTU) and A: extinction coefficient calculated from photosynthetically active radiation (Kd(PAR)) B: Total Suspended Solids (TSS) in mg/L, both at Lake Worth Inlet*

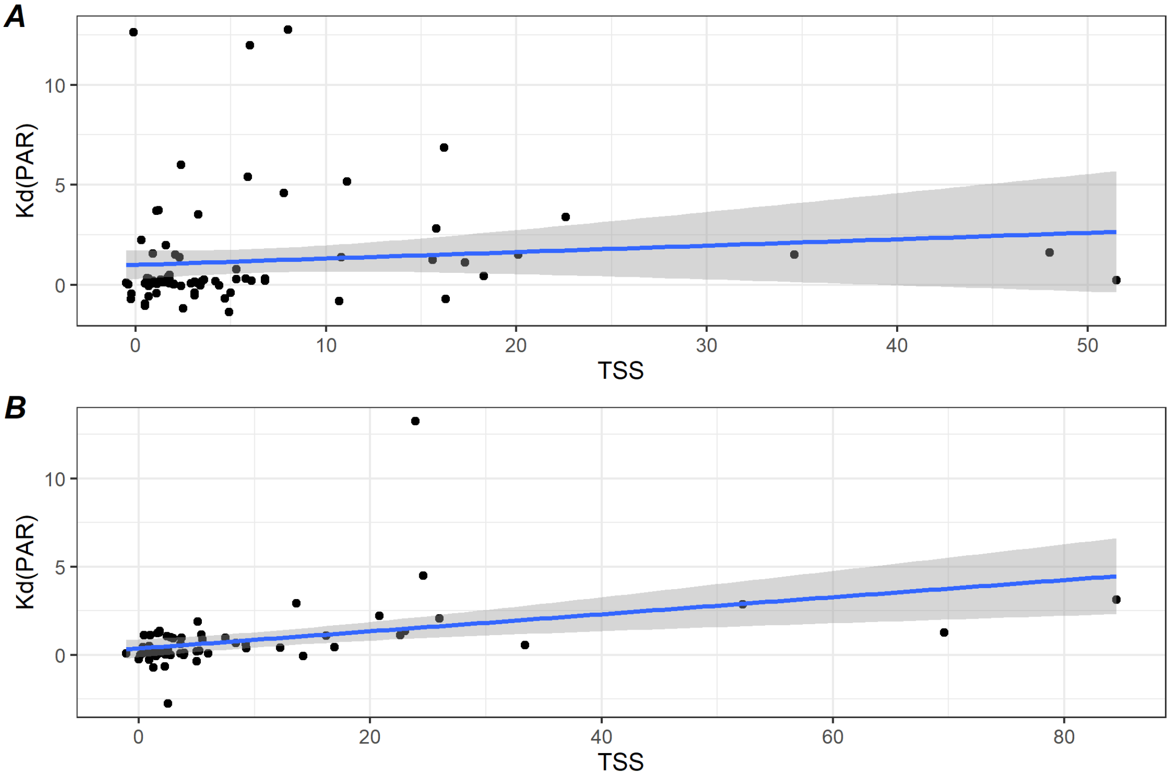


Figure 23 Phase II TSS-Kd(PAR). *Scatterplots showing correlation between Total Suspended Solids (TSS) in mg/L and extinction coefficient calculated from photosynthetically active radiation (Kd(PAR)) for Phase II A: Delray Beach B: Ocean Ridge*

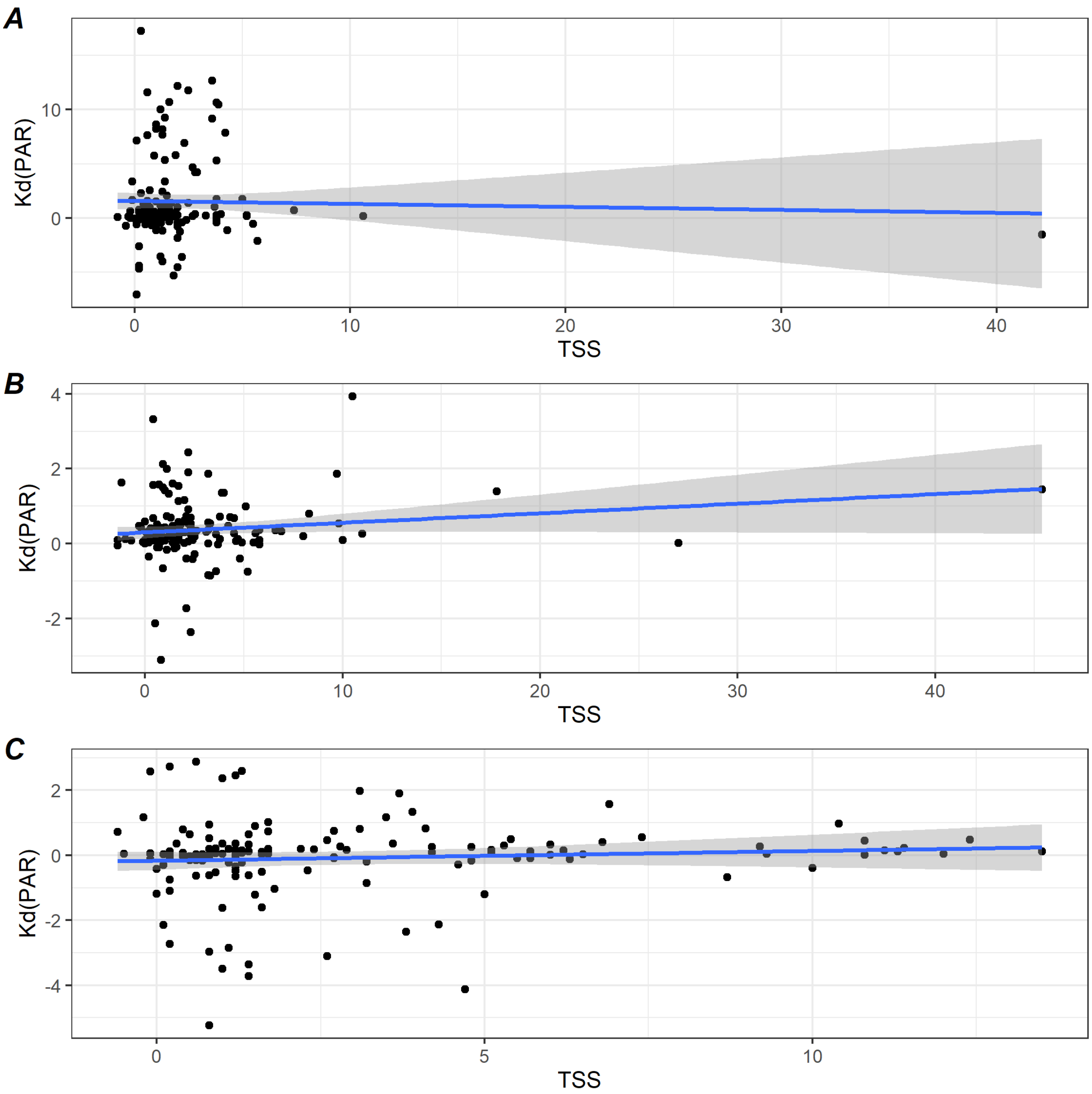


Figure 24 Phase III TSS-Kd(PAR). *Scatterplots showing correlation between Total Suspended Solids (TSS) in mg/L and extinction coefficient calculated from photosynthetically active radiation (Kd(PAR)) for Phase III. A: Port Miami, B: Port Everglades, C: Lake Worth Inlet.*

6.4.0 Updated Discussion

In contrast to the original report, NTU and Kd appear to have significant positive correlations in Phases I and II, and at Lake Worth Inlet and Port Everglades in Phase III, however these correlations appear to be weak. This perhaps indicating that the relationship between NTU and Kd changes during dredging activity. Or, perhaps the utilization of a spherical quantum sensor overemphasized the effects of light scattering, and a flat cosine sensor similar to the one used on the boat would have been more appropriate for this study design. Instances of negative extinction coefficient indicate that aspects of this approach may be flawed. In addition, the lack of an irradiance correction on light data, both to reflect season and time of day, may contribute to this unusual result. For future studies, light data could be collected at a set time point each day or used only from specific (irradiance and cloud cover corrected) time points to compare across studies. While there is a degree of confidence in NTU and TSS values obtained, Kd values have enough caveats that they should be interpreted carefully.

7.0 Appendix A – Updated Rmarkdown

CRCP9_Addendum_with_Kd

```
#Note if you need to install packages you can use the install button in R stu
dio or assign packages in a list and tell it to install the list
#packages <- c(readxl, tidyverse, egg, stats)
#install.packages(packages)

#R Packages used
library(readxl)
library(tidyverse)
library(egg)
library(stats)
library(pander)

#This just sets working directory to folder script is saved in. Any outputs w
ill go directly to this folder and you can just call files by their filename
from this folder.
path <- dirname(rstudioapi::getActiveDocumentContext()$path)
setwd(path)
```

```
#Pulled each sheet from the data document
#Had to change Kd to values in excel first, it was reading the formula in as
a date
#Reminder that the first sheet was JIBN which had no depth data and therefore
no Kd
DBBNraw <- read_xlsx("CRCP9_Data_Kd_Corrections_12.28.2020.xlsx", sheet = 2)
```

```
ORBNraw <- read_xlsx("CRCP9_Data_Kd_Corrections_12.28.2020.xlsx", sheet = 3)
POMraw <- read_xlsx("CRCP9_Data_Kd_Corrections_12.28.2020.xlsx", sheet = 4)
PEraw <- read_xlsx("CRCP9_Data_Kd_Corrections_12.28.2020.xlsx", sheet = 5)
LWIraw <- read_xlsx("CRCP9_Data_Kd_Corrections_12.28.2020.xlsx", sheet = 6)

#Formatted these objects to fit existing variable names
#Had made a new Kd column name in excel due to import issue, otherwise would
be Kd = "Kd (Estimated assuming 1/2 Depth)"
DBBN <- rename(DBBNraw, Depth = "Surface or Mid-Depth Sample", Group = "Event
Type", NTU = "NTU Reading", TSS = "TSS Reported Value (mg/L)") %>% mutate(Kd
= as.numeric(Kd))
ORBN <- rename(ORBNraw, Depth = "Surface or Mid-Depth Sample", Group = "Event
Type", NTU = "NTU Reading", TSS = "TSS Reported Value (mg/L)")
POM <- rename(POMraw, Depth = "Surface or Mid-Depth Sample", NTU = "NTU\r\nRe
ading", TSS = "TSS Value (mg/L)") #No event type
PE <- rename(PEraw, Depth = "Surface or Mid- Depth Sample", NTU = "NTU\r\nRea
ding", TSS = "TSS Reported Value") #No event type
LWI <- rename(LWIraw, Depth = "Surface or Mid-Depth Sample", NTU = "NTU\r\nRe
ading", TSS = "Reported Value TSS mg/L") #No event type

#Filtered to recreate objects for each group and depth within OR and DB, opti
onally can select specific columns as well
ORSurf <- filter(ORBN, Depth == "Surface") #%>% select("Sample Collection Dat
e and Time", "Sample ID", "Sample Code on Bottle for Lab", Group, Depth, TSS,
NTU, Kd)
ORMid <- filter(ORBN, Depth == "Mid-Depth")
ORBG <- filter(ORBN, Group == "Background") #Was no background from ORBN on p
urpose from original code?
ORCOM <- filter(ORBN, Group == "Compliance")
ORMIX <- filter(ORBN, Group == "Within Mixing Zone")
ORDC <- filter(ORBN, Group == "Downcurrent of Compliance")

DBSurf <- filter(DBBN, Depth == "Surface")
DBMid <- filter(DBBN, Depth == "Mid-Depth")
DBBG <- filter(DBBN, Group == "Background")
DBCOM <- filter(DBBN, Group == "Compliance")
DBMIX <- filter(DBBN, Group == "Within Mixing Zone")
DBDC <- filter(DBBN, Group == "Downcurrent of Compliance")
```

Summary Statistics

Delray Beach Kd Summary Statistics

```
Mode <- function(x) {
  ux <- unique(x)
  ux[which.max(tabulate(match(x, ux)))]
}
```

```
DBBN %>% group_by(Depth, Group) %>%
  summarise(Mean_Kd = mean(Kd, na

.rm = T),
            SD_Kd = sd(Kd, na.rm = T),
            Median_Kd = median(Kd, na.rm = T),
            Mode_Kd = Mode(Kd), #mode isn't a stats function, so needed code
above
            Q1_Kd = quantile(Kd, na.rm = T, probs = 0.25),
            Q3_Kd = quantile(Kd, na.rm = T, probs = 0.75),
            Min_Kd = min(Kd, na.rm = T),
            Max_Kd = max(Kd, na.rm = T)) %>%
      pander()
```

`summarise()` regrouping output by 'Depth' (override with `.groups` argument)

Table continues below

Depth	Group	Mean_Kd	SD_Kd	Median_Kd	Mode_Kd	Q1_Kd	Q3_Kd	Min_Kd	Max_Kd
Mid-Depth	Background	0.1822	0.3169	0.09516	0.04497	0.06803	0.1299	0.01779	1.385
Mid-Depth	Compliance	1.041	1.492	0.3917	0.4739	0.2314	1.141	0.1687	4.586
Mid-Depth	Downcurrent of Compliance	1.004	1.819	0.27	0.283	0.1945	0.5654	0.08724	5.389
Mid-Depth	Within Mixing Zone	1.428	2.274	0.4911	0.7762	0.1806	1.522	0.1338	6.854
Surface	Background	0.5811	1.478	0.06299	-1.05	-0.4581	1.516	-1.05	3.716
Surface	Compliance	2.6	4.607	0.3317	5.163	-0.1387	3.926	-0.8208	12.75
Surface	Downcurrent of Compliance	2.493	4.532	0.7889	-1.186	-0.5749	3.608	-1.186	11.98
Surface	Within Mixing Zone	1.899	4.579	0.08602	-0.03504	-0.4843	1.975	-1.369	12.62
NA	NA	NA	NA	NA	NA	NA	NA	Inf	-Inf

Delray Beach NTU Summary Statistics (to compare)

```
#Test with NTU
DBBN %>% group_by(Depth, Group) %>%
  summarise(Mean_NTU = mean(NTU, na.rm = T),
            SD_NTU = sd(NTU, na.rm = T),
            Median_NTU = median(NTU, na.rm = T),
            Mode_NTU = Mode(Kd),
            Q1_NTU = quantile(NTU, na.rm = T, probs = 0.25),
            Q3_NTU = quantile(NTU, na.rm = T, probs = 0.75),
            Min_NTU = min(NTU, na.rm = T),
```

```
            Max_NTU = max(NTU, na.rm = T)) %>%
      pander()
```

`summarise()` regrouping output by 'Depth' (override with `.groups` argument)

Table continues below

Depth	Group	Mean_NTU	SD_NTU	Median_NTU	Mode_NTU	Q1_NTU	Q3_NTU	Min_NTU	Max_NTU
Mid-Depth	Background	0.7517	0.3286	0.705	0.04497	0.4625	0.9475	0.37	1.37
Mid-Depth	Compliance	6.434	7.365	3.33	0.4739	2.51	5.888	1.7	23.2
Mid-Depth	Downcurrent of Compliance	3.637	3.059	2.555	0.283	1.613	4.582	0.84	9.49
Mid-Depth	Within Mixing Zone	14.23	20.31	7.345	0.7762	3.07	11.07	2.72	62.7
Surface	Background	0.9178	0.4517	0.795	-1.05	0.615	1.08	0.38	1.88
Surface	Compliance	7.111	8.721	2.94	5.163	1.837	8.425	1.5	26.7
Surface	Downcurrent of Compliance	4.981	5.913	2.04	-1.186	0.8875	7.205	0.44	16.3
Surface	Within Mixing Zone	10.92	15.19	3.355	-0.03504	1.39	13.72	0.35	41.1
NA	NA	NA	NA	NA	NA	NA	NA	Inf	-Inf

Ocean Ridge Kd Summary Statistics

```
ORBN %>% group_by(Depth, Group) %>%
  summarise(Mean_Kd = mean(Kd, na.rm = T),
            SD_Kd = sd(Kd, na.rm = T),
            Median_Kd = median(Kd, na.rm = T),
            Mode_Kd = Mode(Kd),
```

```
            Q1_Kd = quantile(Kd, na.rm = T, probs = 0.25),
            Q3_Kd = quantile(Kd, na.rm = T, probs = 0.75),
            Min_Kd = min(Kd, na.rm = T),
            Max_Kd = max(Kd, na.rm = T)) %>%
    pander()
```

`summarise()` regrouping output by ‘Depth’ (override with `.groups` argument)

Table continues below

Depth	Group	Mean_Kd	SD_Kd	Median_Kd	Mode_Kd	Q1_Kd	Q3_Kd	Min_Kd	Max_Kd
Mid-Depth	Background	0.0599	0.1964	0.08219	0.1101	0.04797	0.1334	-0.3621	0.309
Mid-Depth	Compliance	0.4605	0.5668	0.1208	0.08548	0.07283	0.9361	-0.06485	1.368
Mid-Depth	Downcurrent of Compliance	0.4829	0.7439	0.1329	0.4034	0.04747	0.5781	-0.05499	2.079
Mid-Depth	Within Mixing Zone	0.7135	1.058	0.3147	0.3712	0.109	0.6391	0.03552	3.143
Surface	Background	0.2038	1.313	0.5641	0.6822	-0.05989	1.133	-2.756	1.228
Surface	Compliance	1.105	1.507	0.9556	0.9616	0.4658	1.154	-0.7145	4.489
Surface	Downcurrent of Compliance	1.288	1.177	1.028	1.886	0.5116	2.132	-0.2641	2.929
Surface	Within Mixing Zone	2.285	4.503	0.8005	0.9715	0.3893	1.572	-0.6515	13.23
NA	NA	NA	NA	NA	NA	NA	NA	Inf	-Inf

Port of Miami Kd Summary Statistics

```
POM %>% group_by(Depth) %>%
  summarise(Mean_Kd = mean(Kd, na.rm = T),
            SD_Kd = sd(Kd, na.rm = T),
            Median_Kd = median(Kd, na.rm = T),
```

```
            Mode_Kd = Mode(Kd),
            Q1_Kd = quantile(Kd, na.rm = T, probs = 0.25),
            Q3_Kd = quantile(Kd, na.rm = T, probs = 0.75),
            Min_Kd = min(Kd, na.rm = T),
            Max_Kd = max(Kd, na.rm = T)) %>%
      pander()
```

`summarise()` ungrouping output (override with `.groups` argument)

Depth	Mean_Kd	SD_Kd	Median_Kd	Mode_Kd	Q1_Kd	Q3_Kd	Min_Kd	Max_Kd
Mid	0.6559	1.526	0.2286	0.2542	0.1006	0.8368	-4.674	6.919
Surface	2.398	5.081	0.5692	0.1962	-0.5848	6.146	-7.064	17.24

Port Everglades Kd Summary Statistics

```
PE %>% group_by(Depth) %>%
  summarise(Mean_Kd = mean(Kd, na.rm = T),
            SD_Kd = sd(Kd, na.rm = T),
            Median_Kd = median(Kd, na.rm = T),
            Mode_Kd = Mode(Kd),
            Q1_Kd = quantile(Kd, na.rm = T, probs = 0.25),
            Q3_Kd = quantile(Kd, na.rm = T, probs = 0.75),
            Min_Kd = min(Kd, na.rm = T),
            Max_Kd = max(Kd, na.rm = T)) %>%
  pander()
```

`summarise()` ungrouping output (override with `.groups` argument)

Table continues below

Depth	Mean_Kd	SD_Kd	Median_Kd	Mode_Kd	Q1_Kd	Q3_Kd	Min_Kd	Max_Kd
Mid	0.2352	0.3706	0.1909	0.335	0.08611	0.3626	-0.8627	1.543
Surface	0.5099	1.116	0.3885	1.858	0.03187	1.206	-3.107	3.925

Lake Worth Inlet Kd Summary Statistics

```
LWI %>% group_by(Depth) %>%
  summarise(Mean_Kd = mean(Kd, na.rm = T),
            SD_Kd = sd(Kd, na.rm = T),
            Median_Kd = median(Kd, na.rm = T),
            Mode_Kd = Mode(Kd),
            Q1_Kd = quantile(Kd, na.rm = T, probs = 0.25),
            Q3_Kd = quantile(Kd, na.rm = T, probs = 0.75),
            Min_Kd = min(Kd, na.rm = T),
            Max_Kd = max(Kd, na.rm = T)) %>%
      pander()
```

`summarise()` ungrouping output (override with `.groups` argument)

Depth	Mean_Kd	SD_Kd	Median_Kd	Mode_Kd	Q1_Kd	Q3_Kd	Min_Kd	Max_Kd
Mid	0.07154	0.5251	0.07218	0.1407	0.0191	0.1973	-2.728	1.019
Surface	-0.2473	1.648	-0.09482	0.2495	-0.6249	0.4558	-5.236	2.871

```
#This is some example code to create some plots check for normality, but only
showing Delray Beach Surface at the moment as original analyst provided norma
lity checks in excel justifying using non-parametric. At the top of this code
chunk it is shown as eval = F so it will not run unless told. These outputs d
id show non-normality.

ntu_lm <- lm(NTU~Group, data = DBSurf)
plot(ntu_lm)

#This creates a histogram to view the distribution of the data. Can look at o
ne specifically by filtering (must hash out or remove facet wrap and plus sig
n above). Facet grap shows all groups together separately. To view all groups
together can hash out filter and facet wrap.
DBSurf %>%
  #filter(Group == "Background") %>%
  ggplot() +
  geom_histogram(aes(x = NTU)) +
  facet_wrap(.~Group)

#This tests normality. If p less than chosen alpha (0.05), then the null hypo
thesis of normality is rejected. So significant p value means non-normal data
.
shapiro.test(DBSurf$NTU)
```

Tests for the Effect of Event Type

These tests look at the effect of the event type groups: background, compliance, downcurrent of compliance, and within mixing zone. Kruskal test is a non-parametric test that can look at the effect of groups. The pairwise wilcox test is a post-hoc test looking pairwise comparisons only done here after significant kruskal test. BH in pairwise wilcox method stands for Benjami and Hochberg correction, also known as false discovery rate.

Ocean Ridge Surface

```
#Surface Values
kruskal.test(NTU~Group,data=ORSurf)

##
##  Kruskal-Wallis rank sum test
##
## data:  NTU by Group
## Kruskal-Wallis chi-squared = 2.3233, df = 3, p-value = 0.5081

#No significant difference in NTU between groups
kruskal.test(Kd~Group,data=ORSurf)

##
##  Kruskal-Wallis rank sum test
##
```

```
## data:  Kd by Group
## Kruskal-Wallis chi-squared = 1.4915, df = 3, p-value = 0.6842

#No significant difference in Kd between groups
kruskal.test(TSS~Group,data=ORSurf)

##
##  Kruskal-Wallis rank sum test
##
## data:  TSS by Group
## Kruskal-Wallis chi-squared = 2.5142, df = 3, p-value = 0.4727

#No significant difference in TSS between groups
```

Ocean Ridge Mid-Depth

```
kruskal.test(NTU~Group,data=ORMid)

##
##  Kruskal-Wallis rank sum test
##
## data:  NTU by Group
## Kruskal-Wallis chi-squared = 3.233, df = 3, p-value = 0.3571

#No significant difference in NTU between groups
kruskal.test(Kd~Group,data=ORMid)

##
##  Kruskal-Wallis rank sum test
##
## data:  Kd by Group
## Kruskal-Wallis chi-squared = 3.4347, df = 3, p-value = 0.3293

#No significant difference in Kd between groups
kruskal.test(TSS~Group,data=ORMid)

##
##  Kruskal-Wallis rank sum test
##
## data:  TSS by Group
## Kruskal-Wallis chi-squared = 1.1958, df = 3, p-value = 0.754

#No significant difference in TSS between groups
```

Delray Beach Surface

```
kruskal.test(NTU~Group,data=DBSurf)

##
##  Kruskal-Wallis rank sum test
##
## data:  NTU by Group
## Kruskal-Wallis chi-squared = 14.607, df = 3, p-value = 0.002185
```

```
#***Significant difference for NTU across groups, p = 0.002185
pairwise.wilcox.test(DBSurf$NTU,DBSurf$Group,p.adjust.method = "BH")

##
##  Pairwise comparisons using Wilcoxon rank sum test with continuity correct
ion
##
## data:  DBSurf$NTU and DBSurf$Group
##
##                            Background Compliance Downcurrent of Compliance
## Compliance                 0.0016     -          -
## Downcurrent of Compliance  0.0743     0.5734     -
## Within Mixing Zone         0.0732     0.9591     0.8090
##
## P value adjustment method: BH

#***Background NTU was significantly different to Compliance NTU p=0.0016
##Previously Reported: Background NTU differed to Compliance NTU p=0.0037

kruskal.test(Kd~Group,data=DBSurf)

##
##  Kruskal-Wallis rank sum test
##
## data:  Kd by Group
## Kruskal-Wallis chi-squared = 0.94866, df = 3, p-value = 0.8137

#No significant difference in Kd between groups

kruskal.test(TSS~Group,data=DBSurf)

##
##  Kruskal-Wallis rank sum test
##
## data:  TSS by Group
## Kruskal-Wallis chi-squared = 19.712, df = 3, p-value = 0.0001947

#***Significant difference for TSS across groups, p = 0.0001947
pairwise.wilcox.test(DBSurf$TSS,DBSurf$Group,p.adjust.method = "BH")

##
##  Pairwise comparisons using Wilcoxon rank sum test with continuity correct
ion
##
## data:  DBSurf$TSS and DBSurf$Group
##
##                            Background Compliance Downcurrent of Compliance
## Compliance                 0.0034     -          -
## Downcurrent of Compliance  0.0018     0.7632     -
## Within Mixing Zone         0.0119     0.8785     0.7632
```

```
##
## P value adjustment method: BH
```

```
#***Background TSS was significantly different from compliance, downcurrent,
and within mixing zone (p=0.034, 0.0018, 0.0119)
##Previously Reported: Background TSS differed to compliance and downcurrent
(p=0.044, 0.027)
```

Delray Beach Mid-Depth

```
kruskal.test(NTU~Group, data=DBMid)
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  NTU by Group
## Kruskal-Wallis chi-squared = 29.28, df = 3, p-value = 1.956e-06
```

```
#***Significant difference for NTU across groups, p = 1.956e-06
pairwise.wilcox.test(DBMid$NTU,DBMid$Group,p.adjust.method = "BH")
```

```
##
##  Pairwise comparisons using Wilcoxon rank sum test with continuity correct
ion
##
## data:  DBMid$NTU and DBMid$Group
##
##                            Background Compliance Downcurrent of Compliance
## Compliance                 0.00021    -          -
## Downcurrent of Compliance  0.00127    0.32821    -
## Within Mixing Zone         0.00021    0.23385    0.12448
##
## P value adjustment method: BH
```

```
#***Background NTU was significantly different from compliance, downcurrent,
and within mixing zone (p=0.00021,p=0.00127,0.00021)
##Previously Reported: Significant difference between Background and Mixing,
Downcurrent and Compliance (P=0.0005,p=0.004,p=0.0005)

kruskal.test(Kd~Group,data=DBMid)
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  Kd by Group
## Kruskal-Wallis chi-squared = 17.215, df = 3, p-value = 0.0006383
```

```
#***Significant difference for Kd across groups, p = 0.0006383
pairwise.wilcox.test(DBMid$Kd,DBMid$Group,p.adjust.method = "BH")
```

```
##
##  Pairwise comparisons using Wilcoxon rank sum exact test
```

```
##
## data:  DBMid$Kd and DBMid$Group
##
##                            Background Compliance Downcurrent of Compliance
## Compliance                 0.0026     -          -
## Downcurrent of Compliance  0.0147     0.8606     -
## Within Mixing Zone         0.0026     0.8785     0.8651
##
## P value adjustment method: BH

#***Background Kd was significantly different from compliance, downcurrent, a
nd within mixing zone (p=0.0026,p=0.0147,0.0026)

kruskal.test(TSS~Group,data=DBMid)

##
##  Kruskal-Wallis rank sum test
##
## data:  TSS by Group
## Kruskal-Wallis chi-squared = 20.093, df = 3, p-value = 0.0001624

#***Significant difference for TSS across groups, p = 0.0001624
pairwise.wilcox.test(DBMid$TSS,DBMid$Group,p.adjust.method = "BH")

##
##  Pairwise comparisons using Wilcoxon rank sum test with continuity correct
ion
##
## data:  DBMid$TSS and DBMid$Group
##
##                            Background Compliance Downcurrent of Compliance
## Compliance                 0.00416    -          -
## Downcurrent of Compliance  0.04214    0.67420    -
## Within Mixing Zone         0.00053    0.67420    0.67420
##
## P value adjustment method: BH

#***Background TSS was significantly different from compliance, downcurrent,
and within mixing zone (p=0.00416,0.04214,0.00053)
##Previously Reported: Background was significantly different to mixing (p=0.
0056)
```

Tests for the Effect of Depth

These tests look at the effect of the depth categories: surface or mid-depth. Wilcox test is a non-parametric pairwise test, used because there are two depth categories.

Delray Beach All Events

```
#This wasn't included in the original analysis, but seemed like it could be i
nteresting

wilcox.test(NTU~Depth, data=DBBN)

##
##  Wilcoxon rank sum test with continuity correction
##
## data:  NTU by Depth
## W = 930, p-value = 0.6709
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in background NTU between surface and mid depth

wilcox.test(Kd~Depth, data=DBBN)

##
##  Wilcoxon rank sum exact test
##
## data:  Kd by Depth
## W = 937, p-value = 0.3753
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in background Kd between surface and mid depth

wilcox.test(TSS~Depth, data=DBBN)

##
##  Wilcoxon rank sum test with continuity correction
##
## data:  TSS by Depth
## W = 974, p-value = 0.4129
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in background TSS between surface and mid depth
```

Delray Beach Background

```
wilcox.test(NTU~Depth, data=DBBG)

##
##  Wilcoxon rank sum test with continuity correction
##
## data:  NTU by Depth
## W = 126, p-value = 0.2613
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in background NTU between surface and mid depth

wilcox.test(Kd~Depth, data=DBBG)
```

```
##
##  Wilcoxon rank sum exact test
##
## data:  Kd by Depth
## W = 153, p-value = 0.7857
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in background Kd between surface and mid depth

wilcox.test(TSS~Depth, data=DBBG)

##
##  Wilcoxon rank sum test with continuity correction
##
## data:  TSS by Depth
## W = 192.5, p-value = 0.3419
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in background TSS between surface and mid depth
```

Delray Beach Compliance

```
wilcox.test(NTU~Depth,data=DBCOM)

##
##  Wilcoxon rank sum exact test
##
## data:  NTU by Depth
## W = 34, p-value = 0.8785
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in compliance NTU between surface and mid depth

wilcox.test(Kd~Depth,data=DBCOM)

##
##  Wilcoxon rank sum exact test
##
## data:  Kd by Depth
## W = 35, p-value = 0.7984
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in compliance Kd between surface and mid depth

wilcox.test(TSS~Depth,data=DBCOM)

##
##  Wilcoxon rank sum exact test
##
## data:  TSS by Depth
## W = 33, p-value = 0.9591
## alternative hypothesis: true location shift is not equal to 0
```

```
#No significant difference in compliance TSS between surface and mid depth
```

Delray Beach Within Mixing Zone

```
wilcox.test(NTU~Depth,data=DBMIX)

##
##  Wilcoxon rank sum exact test
##
## data:  NTU by Depth
## W = 40, p-value = 0.4418
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in mixing zone NTU between surface and mid depth

wilcox.test(Kd~Depth,data=DBMIX)

##
##  Wilcoxon rank sum exact test
##
## data:  Kd by Depth
## W = 39, p-value = 0.5054
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in mixing zone Kd between surface and mid depth

wilcox.test(TSS~Depth,data=DBMIX)

##
##  Wilcoxon rank sum exact test
##
## data:  TSS by Depth
## W = 40, p-value = 0.4418
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in mixing zone Kd between surface and mid depth
```

Delray Beach Downcurrent of Compliance

```
wilcox.test(NTU~Depth,data=DBDC)

##
##  Wilcoxon rank sum exact test
##
## data:  NTU by Depth
## W = 34, p-value = 0.8785
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in downcurrent NTU between surface and mid depth

wilcox.test(Kd~Depth,data=DBDC)
```

```
##
##  Wilcoxon rank sum exact test
##
## data:  Kd by Depth
## W = 34, p-value = 0.8785
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in downcurrent Kd between surface and mid depth

wilcox.test(TSS~Depth,data=DBDC)

##
##  Wilcoxon rank sum exact test
##
## data:  TSS by Depth
## W = 34, p-value = 0.8785
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in downcurrent TSS between surface and mid depth
```

Ocean Ridge All Events

```
#This wasn't included in the original analysis, but seemed like it could be i
nteresting

wilcox.test(NTU~Depth,data=ORBN)

##
##  Wilcoxon rank sum test with continuity correction
##
## data:  NTU by Depth
## W = 539, p-value = 0.722
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in background NTU between surface and mid depth

wilcox.test(Kd~Depth,data=ORBN)

##
##  Wilcoxon rank sum exact test
##
## data:  Kd by Depth
## W = 338, p-value = 0.0191
## alternative hypothesis: true location shift is not equal to 0

#***Kd was significantly different between surface and mid depth (p = 0.0191)

wilcox.test(TSS~Depth,data=ORBN)

##
##  Wilcoxon rank sum test with continuity correction
##
```

```
## data:  TSS by Depth
## W = 551.5, p-value = 0.6005
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in background TSS between surface and mid depth
```

Ocean Ridge Background

```
#Tests for ORBG were not included in original code for unknown reason

wilcox.test(NTU~Depth,data=ORBG)

## 
##  Wilcoxon rank sum exact test
## 
## data:  NTU by Depth
## W = 30, p-value = 0.8785
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in background NTU between surface and mid depth

wilcox.test(Kd~Depth,data=ORBG)

## 
##  Wilcoxon rank sum exact test
## 
## data:  Kd by Depth
## W = 21, p-value = 0.2786
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in background Kd between surface and mid depth

wilcox.test(TSS~Depth,data=ORBG)

## 
##  Wilcoxon rank sum test with continuity correction
## 
## data:  TSS by Depth
## W = 36, p-value = 0.713
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in background TSS between surface and mid depth
```

Ocean Ridge Compliance

```
wilcox.test(NTU~Depth,data=ORCOM)

## 
##  Wilcoxon rank sum exact test
## 
## data:  NTU by Depth
## W = 33, p-value = 0.9591
## alternative hypothesis: true location shift is not equal to 0
```

```
#No significant difference in compliance NTU between surface and mid depth

wilcox.test(Kd~Depth,data=ORCOM)

##
##  Wilcoxon rank sum exact test
##
## data:  Kd by Depth
## W = 21, p-value = 0.2786
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in compliance Kd between surface and mid depth

wilcox.test(TSS~Depth,data=ORCOM)

##
##  Wilcoxon rank sum exact test
##
## data:  TSS by Depth
## W = 30, p-value = 0.8785
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in compliance TSS between surface and mid depth
```

Ocean Ridge Mixing

```
wilcox.test(NTU~Depth,data=ORMIX)

##
##  Wilcoxon rank sum exact test
##
## data:  NTU by Depth
## W = 35, p-value = 0.7984
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in mixing NTU between surface and mid depth

wilcox.test(Kd~Depth,data=ORMIX)

##
##  Wilcoxon rank sum exact test
##
## data:  Kd by Depth
## W = 24, p-value = 0.4418
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in mixing Kd between surface and mid depth

wilcox.test(TSS~Depth,data=ORMIX)

##
##  Wilcoxon rank sum exact test
```

```
##
## data:  TSS by Depth
## W = 39, p-value = 0.5054
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in mixing TSS between surface and mid depth
```

Ocean Ridge Downcurrent of Compliance

```
wilcox.test(NTU~Depth,data=ORDC)

##
##  Wilcoxon rank sum exact test
##
## data:  NTU by Depth
## W = 39, p-value = 0.5054
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in downcurrent NTU between surface and mid depth

wilcox.test(Kd~Depth,data=ORDC)

##
##  Wilcoxon rank sum exact test
##
## data:  Kd by Depth
## W = 18, p-value = 0.1605
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in downcurrent Kd between surface and mid depth

wilcox.test(TSS~Depth,data=ORDC)

##
##  Wilcoxon rank sum test with continuity correction
##
## data:  TSS by Depth
## W = 32.5, p-value = 1
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in downcurrent TSS between surface and mid depth
```

Lake Worth Inlet

```
wilcox.test(NTU~Depth,data=LWI)

##
##  Wilcoxon rank sum test with continuity correction
##
## data:  NTU by Depth
## W = 2631.5, p-value = 0.8761
## alternative hypothesis: true location shift is not equal to 0
```

```
#No significant difference in NTU between surface and mid depth

wilcox.test(Kd~Depth,data=LWI)

##
##  Wilcoxon rank sum test with continuity correction
##
## data:  Kd by Depth
## W = 2938, p-value = 0.1235
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in Kd between surface and mid depth

wilcox.test(TSS~Depth,data=LWI)

##
##  Wilcoxon rank sum test with continuity correction
##
## data:  TSS by Depth
## W = 2573, p-value = 0.941
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in TSS between surface and mid depth
```

Port Everglades

```
wilcox.test(NTU~Depth,data=PE)

##
##  Wilcoxon rank sum test with continuity correction
##
## data:  NTU by Depth
## W = 1947, p-value = 0.01002
## alternative hypothesis: true location shift is not equal to 0

#***NTU was significantly different between surface and mid depth (p = 0.0100
2)
##Previously Reported: significant difference in NTU by depth P=0.01

wilcox.test(Kd~Depth,data=PE)

##
##  Wilcoxon rank sum test with continuity correction
##
## data:  Kd by Depth
## W = 2008, p-value = 0.01973
## alternative hypothesis: true location shift is not equal to 0

#***Kd was significantly different between surface and mid depth (p = 0.01973
)

wilcox.test(TSS~Depth,data=PE)
```

```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  TSS by Depth
## W = 2091.5, p-value = 0.04567
## alternative hypothesis: true location shift is not equal to 0

#***TSS was significantly different between surface and mid depth (p = 0.0456
7)
##Previously Reported: Significant difference in TSS by depth p=0.04
```

Port of Miami

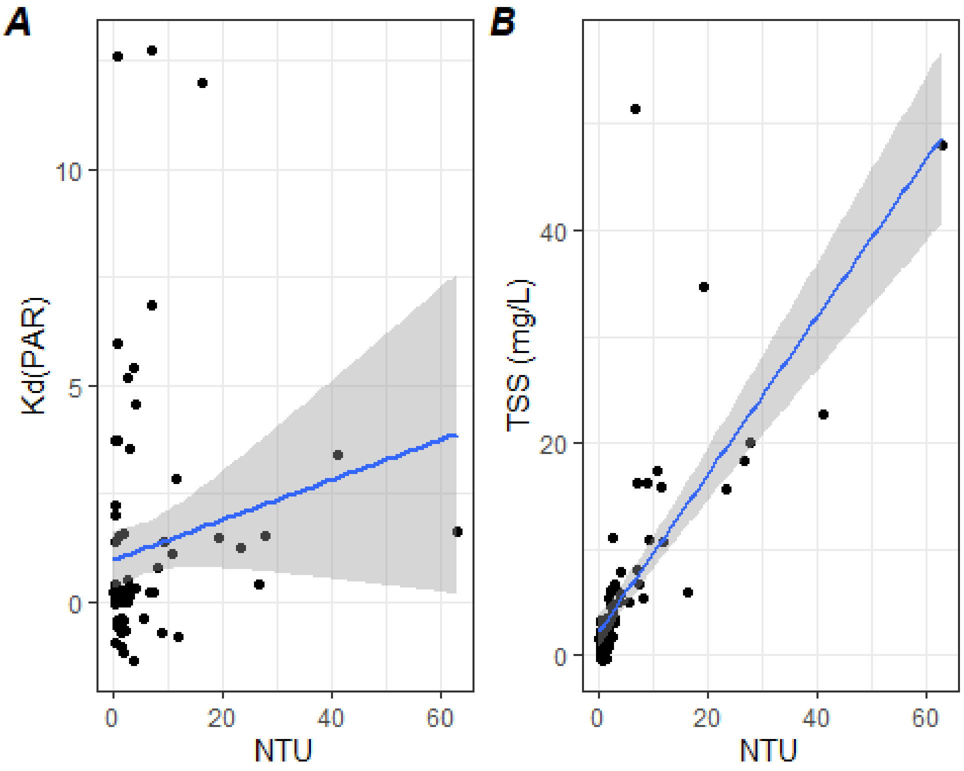
```
wilcox.test(NTU~Depth,data=POM)

##
##  Wilcoxon rank sum test with continuity correction
##
## data:  NTU by Depth
## W = 2777.5, p-value = 0.4597
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in NTU between surface and mid depth

wilcox.test(Kd~Depth,data=POM)

##
##  Wilcoxon rank sum test with continuity correction
##
## data:  Kd by Depth
## W = 2449, p-value = 0.5691
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in Kd between surface and mid depth

wilcox.test(TSS~Depth,data=POM)

##
##  Wilcoxon rank sum test with continuity correction
##
## data:  TSS by Depth
## W = 2925, p-value = 0.1836
## alternative hypothesis: true location shift is not equal to 0

#No significant difference in TSS between surface and mid depth
```

Relationships Between NTU, TSS, and Kd

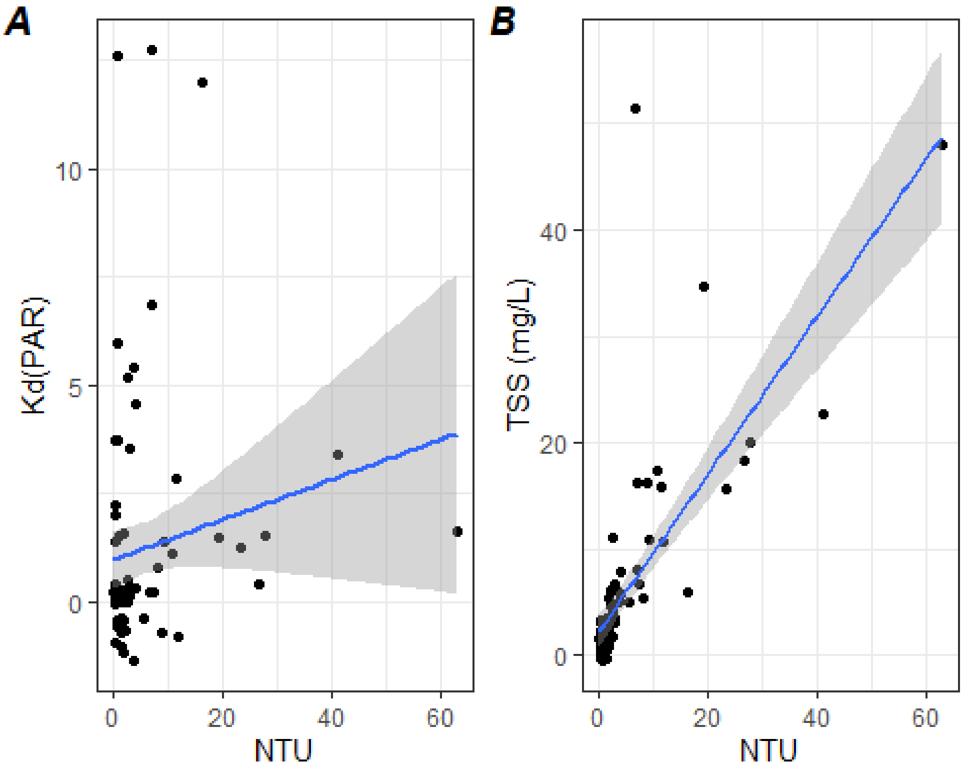
These include Spearman’s rank order correlation tests looking at relationships between pairs of values and associated plots of those relationships. For Spearman’s test, p tells you if relationship is significant and rho tells you directionality and strength of association.

Delray Beach

```
cor.test(DBBN$NTU, DBBN$Kd,method = "spearman")

##
##  Spearman's rank correlation rho
##
## data:  DBBN$NTU and DBBN$Kd
## S = 69790, p-value = 0.02957
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##       rho
## 0.2404358

#***Significant relationship between NTU and Kd (p = 0.02957, rho = 0.2404358
)

cor.test(DBBN$NTU,DBBN$TSS, method = "spearman")

##
##  Spearman's rank correlation rho
##
## data:  DBBN$NTU and DBBN$TSS
## S = 22034, p-value < 2.2e-16
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##       rho
## 0.7769204

#***Significant relationship between NTU and TSS (p < 2.2e-16, rho = 0.776920
4)

DBN_NTU_Kd<-ggplot(DBBN, aes(x=NTU, y=Kd))+geom_point()+geom_smooth(method=lm
)+labs(x="NTU",y="Kd(PAR)")+theme_bw()

DBN_NTU_TSS<-ggplot(DBBN, aes(x=NTU, y=TSS))+geom_point()+geom_smooth(method=
lm)+labs(x="NTU",y="TSS (mg/L)")+theme_bw()

DB_Plot<-ggarrange(DBN_NTU_Kd,DBN_NTU_TSS,ncol=2,nrow=1,labels = c("A","B"))
```

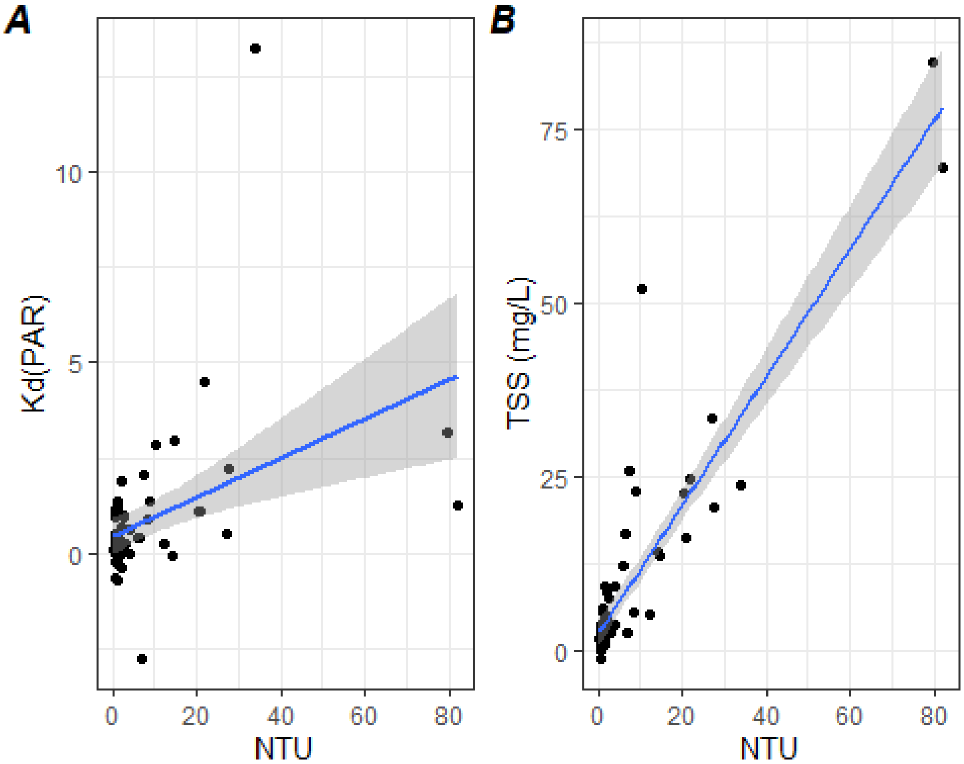

A
Kd(PAR)
10
5
0
0
20
40
60
NTU
B
TSS (mg/L)
40
20
0
0
20
40
60
NTU

```
DB_Plot
```

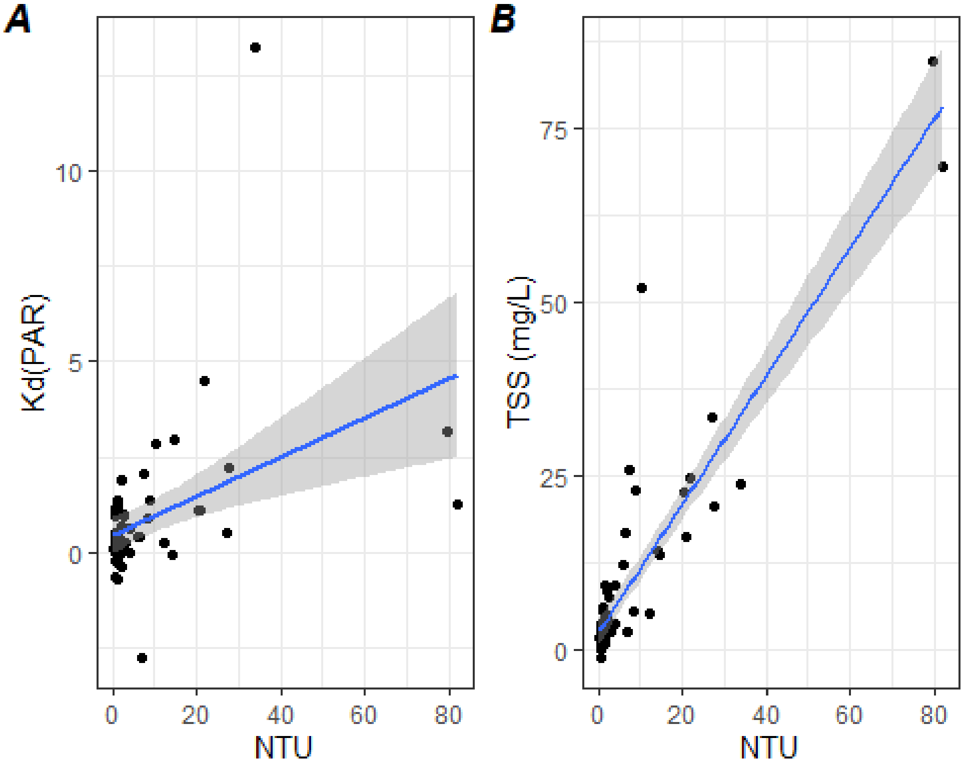

A
Kd(PAR)
10
5
0
0
20
40
60
NTU
B
TSS (mg/L)
40
20
0
0
20
40
60
NTU

Ocean Ridge

```
cor.test(ORBN$NTU,ORBN$Kd, method = "spearman")

##
##  Spearman's rank correlation rho
##
## data:  ORBN$NTU and ORBN$Kd
## S = 25451, p-value = 0.0006018
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##       rho
## 0.4173268

#***Significant relationship between NTU and Kd (p = 0.0006018, rho = 0.41732
68)

cor.test(ORBN$NTU,ORBN$TSS, method = "spearman")

##
##  Spearman's rank correlation rho
##
## data:  ORBN$NTU and ORBN$TSS
## S = 7871, p-value < 2.2e-16
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##       rho
## 0.8198033

#***Significant relationship between NTU and TSS (p < 2.2e-16, rho = 0.819803
3)

ORN_NTU_Kd<-ggplot(ORBN, aes(x=NTU, y=Kd))+geom_point()+geom_smooth(method=lm
)+labs(x="NTU",y="Kd(PAR)")+theme_bw()

ORN_NTU_TSS<-ggplot(ORBN, aes(x=NTU, y=TSS))+geom_point()+geom_smooth(method=
lm)+labs(x="NTU",y="TSS (mg/L)")+theme_bw()

OR_Plot<-ggarrange(ORN_NTU_Kd,ORN_NTU_TSS, ncol=2,nrow=1,labels = c("A","B"))
```

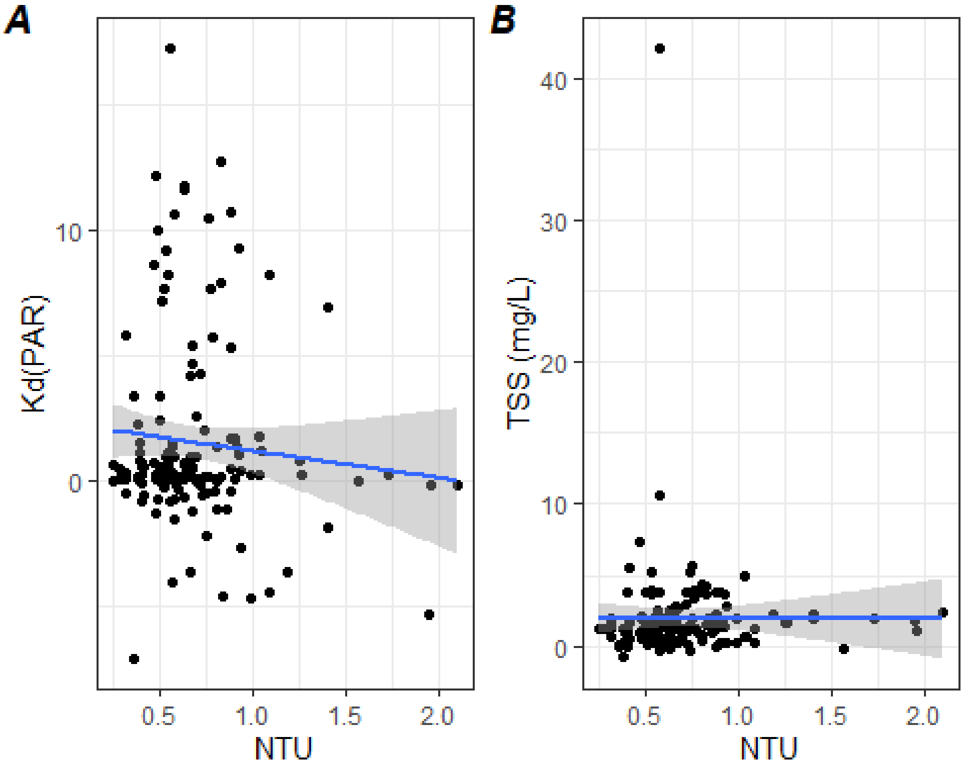

A
Kd(PAR)
10
5
0
0
20
40
60
80
NTU
B
TSS (mg/L)
75
50
25
0
0
20
40
60
80
NTU

```
OR_Plot
```

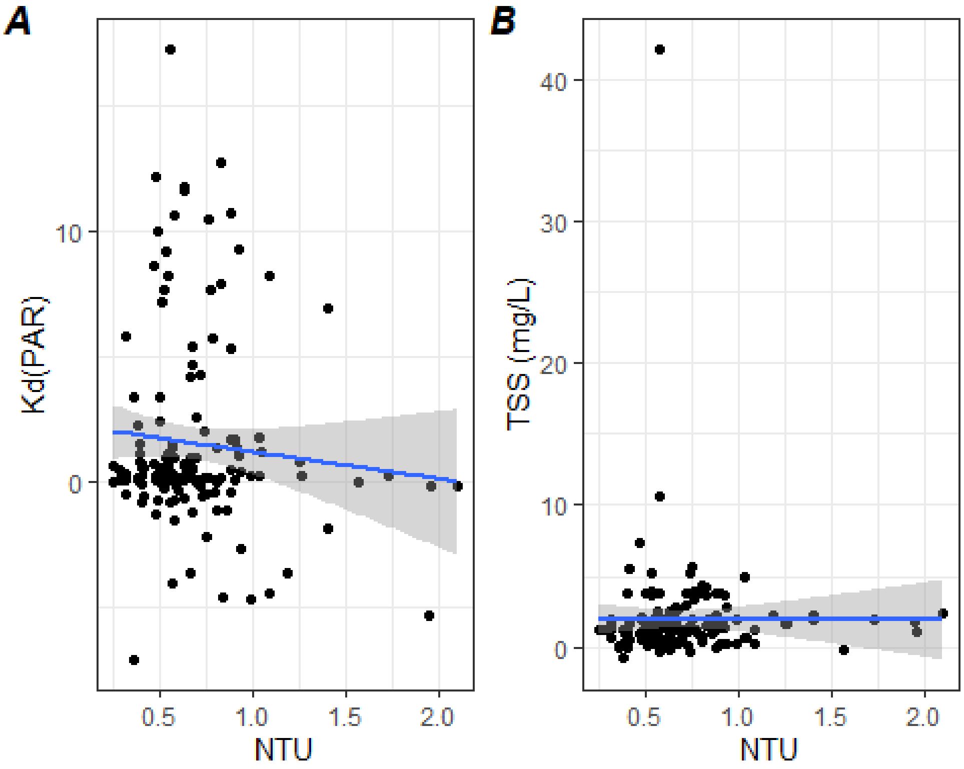

A
Kd(PAR)
10
5
0
0
20
40
60
80
NTU
B
TSS (mg/L)
75
50
25
0
0
20
40
60
80
NTU

Port of Miami

```
cor.test(POM$NTU, POM$Kd, method = "spearman")

##
##  Spearman's rank correlation rho
##
## data:  POM$NTU and POM$Kd
## S = 530853, p-value = 0.4267
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##         rho
## -0.06674138

#Non-significant relationship between NTU and Kd

cor.test(POM$NTU,POM$TSS, method = "spearman")

##
##  Spearman's rank correlation rho
##
## data:  POM$NTU and POM$TSS
## S = 416788, p-value = 0.0517
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##       rho
## 0.1624713

#Non-significant relationship between NTU and TSS (borderline at 0.0517 p-val
ue, but 0.162 rho is quite low)

POM_NTU_Kd<-ggplot(POM, aes(x=NTU, y=Kd))+geom_point()+geom_smooth(method=lm)
+labs(x="NTU",y="Kd(PAR)")+theme_bw()

POM_NTU_TSS<-ggplot(POM, aes(x=NTU, y=TSS))+geom_point()+geom_smooth(method=l
m)+labs(x="NTU",y="TSS (mg/L)")+theme_bw()

POM_Plot<-ggarrange(POM_NTU_Kd, POM_NTU_TSS, ncol=2,nrow=1,labels = c("A","B"
))
```

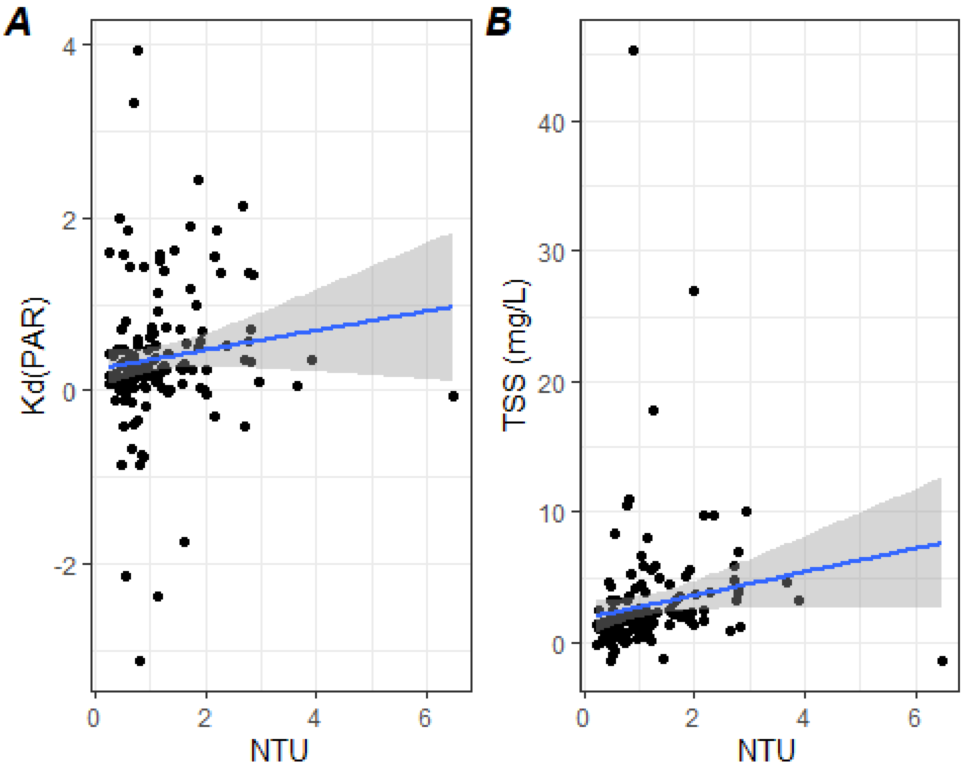

A
B
Kd(PAR)
10
0
0.5
1.0
1.5
2.0
NTU
TSS (mg/L)
40
30
20
10
0
0.5
1.0
1.5
2.0
NTU

```
POM_Plot
```

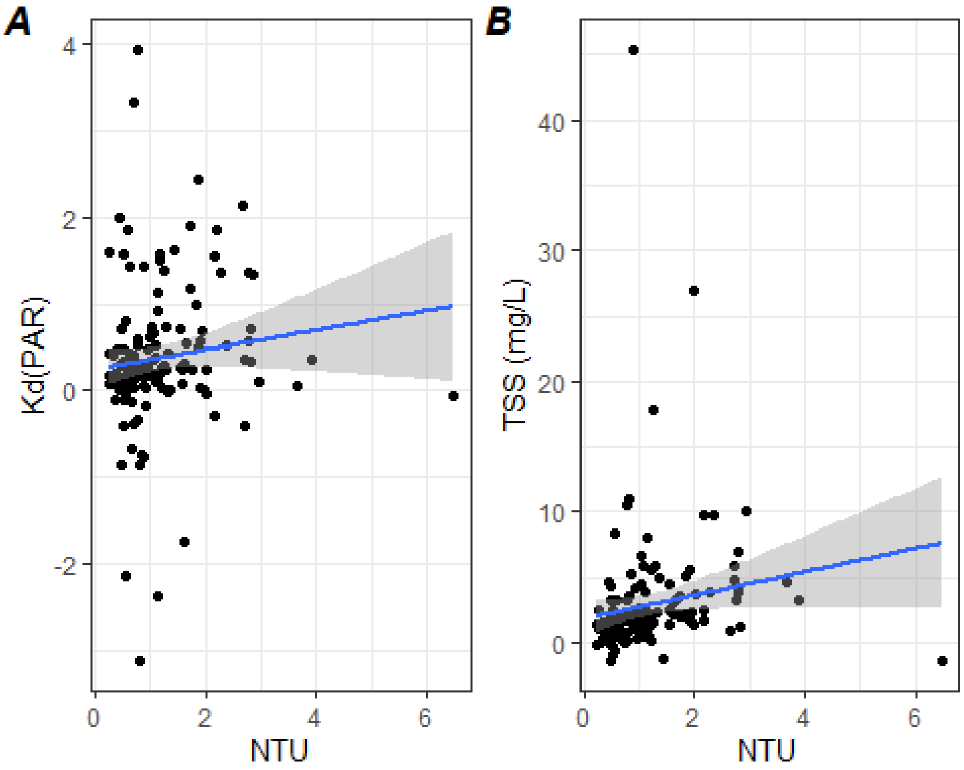

A
B
Kd(PAR)
10
0
0.5
1.0
1.5
2.0
NTU
TSS (mg/L)
40
30
20
10
0
0.5
1.0
1.5
2.0
NTU

Port Everglades

```
cor.test(PE$NTU,PE$Kd,method = "spearman")

##
##  Spearman's rank correlation rho
##
## data:  PE$NTU and PE$Kd
## S = 380973, p-value = 0.00468
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##     rho
## 0.23444

#***Significant relationship between NTU and Kd (p = 0.00468, rho = 0.23444)

cor.test(PE$NTU,PE$TSS,method = "spearman")

##
##  Spearman's rank correlation rho
##
## data:  PE$NTU and PE$TSS
## S = 252285, p-value = 3.432e-10
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##       rho
## 0.4930371

#***Significant relationship between NTU and TSS (p = 3.432e-10, rho = 0.4930
371)

PE_NTU_Kd<-ggplot(PE, aes(x=NTU, y=Kd))+geom_point()+geom_smooth(method=lm)+l
abs(x="NTU",y="Kd(PAR)")+theme_bw()

PE_NTU_TSS<-ggplot(PE, aes(x=NTU, y=TSS))+geom_point()+geom_smooth(method=lm)
+labs(x="NTU",y="TSS (mg/L)")+theme_bw()

PE_Plot<-ggarrange(PE_NTU_Kd,PE_NTU_TSS, ncol=2,nrow=1,labels = c("A","B"))
```

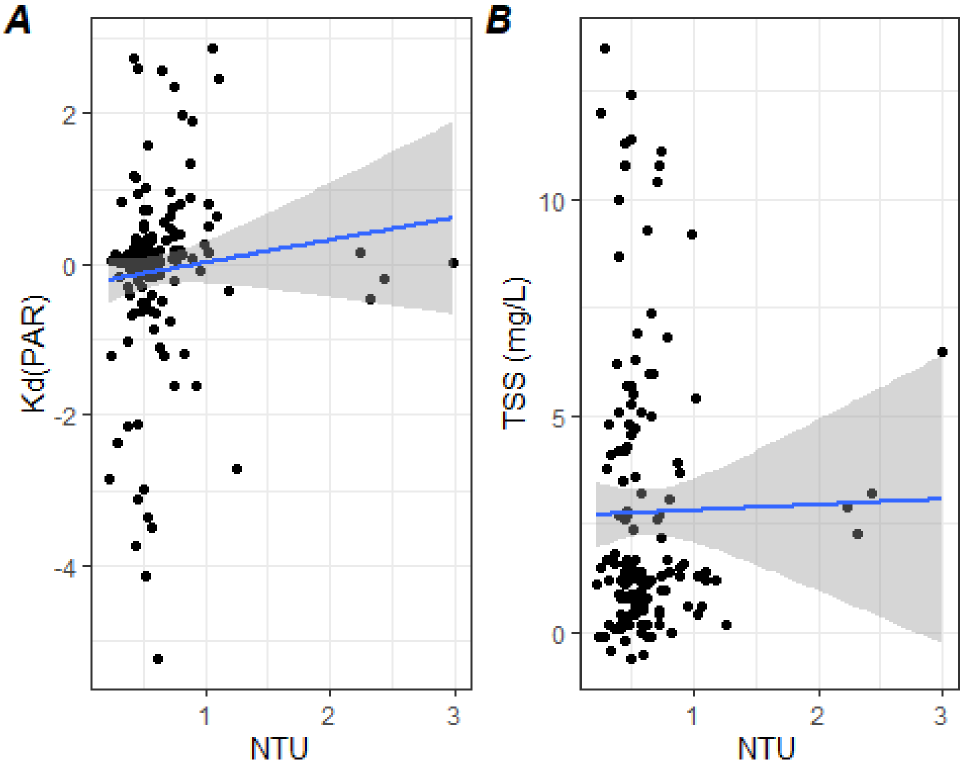

A
B
Kd(PAR)
4
2
0
-2
TSS (mg/L)
40
30
20
10
0
0
2
4
6
NTU
NTU

```
PE_Plot
```

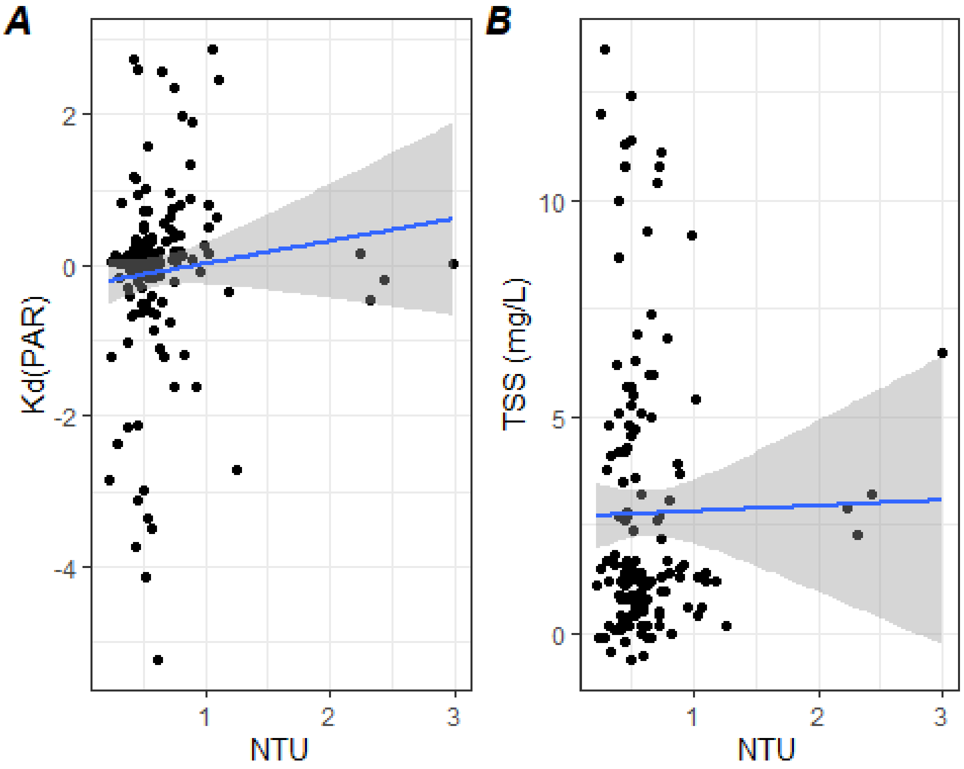

A
B
Kd(PAR)
4
2
0
-2
TSS (mg/L)
40
30
20
10
0
0
2
4
6
NTU
NTU

Lake Worth Inlet

```
cor.test(LWI$NTU,LWI$Kd,method = "spearman")

## 
##  Spearman's rank correlation rho
## 
## data:  LWI$NTU and LWI$Kd
## S = 396345, p-value = 0.02555
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##       rho 
## 0.1867252

#***Significant relationship between NTU and Kd (p = 0.02555, rho = 0.1867252
)

cor.test(LWI$NTU,LWI$TSS,method = "spearman")

## 
##  Spearman's rank correlation rho
## 
## data:  LWI$NTU and LWI$TSS
## S = 486417, p-value = 0.7885
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##        rho 
## 0.02255316

#Non-significant relationship between NTU and TSS

LWI_NTU_Kd<-ggplot(LWI, aes(x=NTU, y=Kd))+geom_point()+geom_smooth(method=lm)
+labs(x="NTU",y="Kd(PAR)")+theme_bw()

LWI_NTU_TSS<-ggplot(LWI, aes(x=NTU, y=TSS))+geom_point()+geom_smooth(method=l
m)+labs(x="NTU",y="TSS (mg/L)")+theme_bw()

LWI_Plot<-ggarrange(LWI_NTU_Kd, LWI_NTU_TSS, ncol=2,nrow=1,labels = c("A","B"
))
```


A
B
Kd(PAR)
2
0
-2
-4
NTU
1
2
3
TSS (mg/L)
10
5
0
NTU
1
2
3

```
LWI_Plot
```


A
B
Kd(PAR)
2
0
-2
-4
NTU
1
2
3
TSS (mg/L)
10
5
0
NTU
1
2
3

```
#This optionally creates image files for the plots. Should stay on eval = F s
o it doesn't run when knitting markdown report.
ggsave(DB_Plot, file = "NTU_Kd_TSS_Plot_DBN.png", height = 4.8, width = 7.5,
units = "in")
ggsave(OR_Plot, file = "NTU_Kd_TSS_Plot_ORN.png", height = 4.8, width = 7.5,
units = "in")
ggsave(POM_Plot, file = "NTU_Kd_TSS_Plot_POM.png", height = 4.8, width = 7.5,
units = "in")
ggsave(PE_Plot, file = "NTU_Kd_TSS_Plot_PE.png", height = 4.8, width = 7.5, u
nits = "in")
ggsave(LWI_Plot, file = "NTU_Kd_TSS_Plot_LWI.png", height = 4.8, width = 7.5,
units = "in")
```

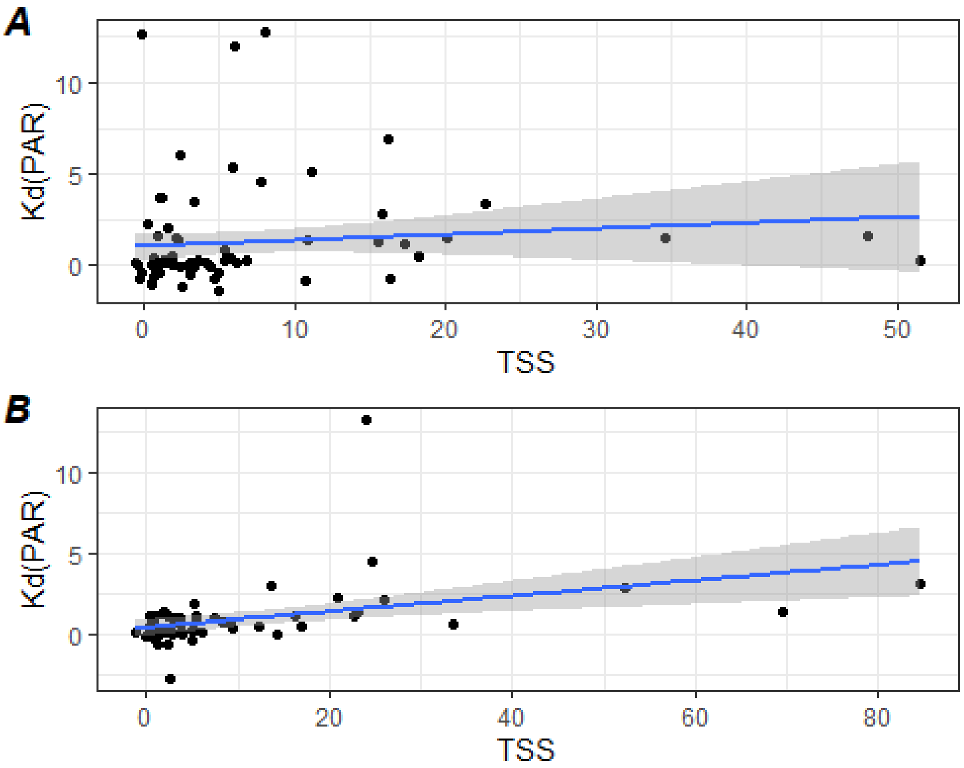
Relationships Between TSS and Kd

These have TSS as dependent variable on x-axis, whereas above NTU was dependent variable. These include Spearman's rank order correlation tests looking at relationships between pairs of values and associated plots of those relationships. For Spearman's test, p tells you if relationship is significant and rho tells you directionality and strength of association.

Delray Beach and Ocean Ridge

```
cor.test(DBBN$TSS, DBBN$Kd,method = "spearman")

##
##  Spearman's rank correlation rho
##
## data:  DBBN$TSS and DBBN$Kd
## S = 61770, p-value = 0.002651
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##       rho
## 0.3277182

#***Significant relationship between TSS and Kd (p = 0.002651, rho = 0.327718
2)

cor.test(ORBN$TSS, ORBN$Kd,method = "spearman")

##
##  Spearman's rank correlation rho
##
## data:  ORBN$TSS and ORBN$Kd
## S = 20656, p-value = 7.649e-06
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##       rho
## 0.5271027
```

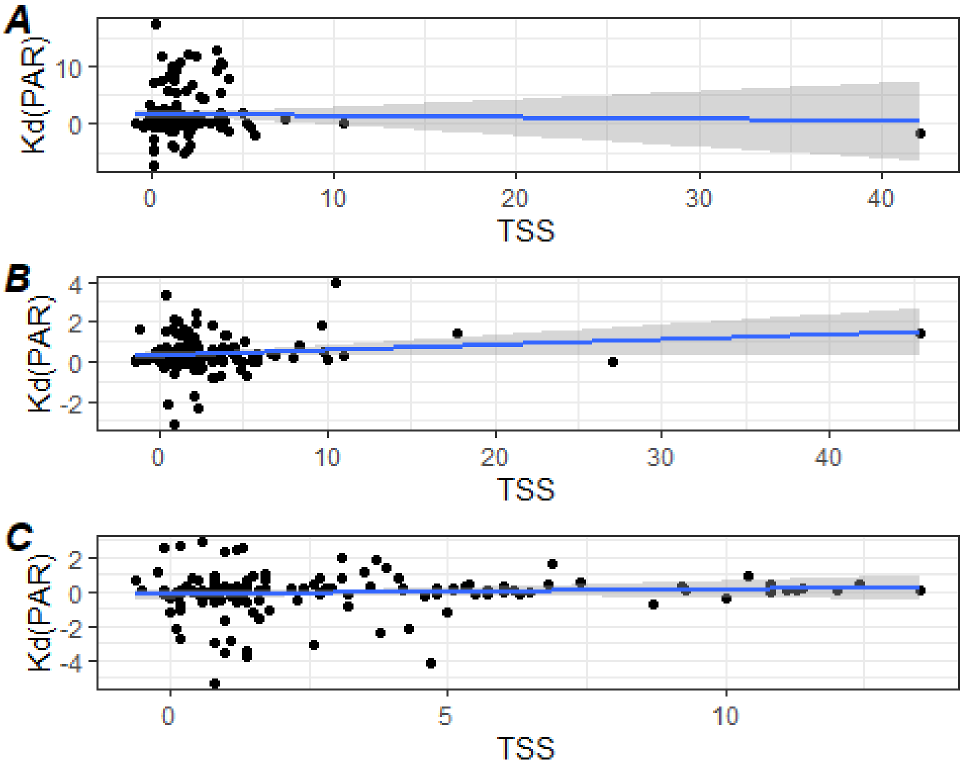
```
#***Significant relationship between TSS and Kd (p = 7.649e-06, rho = 0.52710
27)

DBN_TSS_Kd<-ggplot(DBBN, aes(x=TSS, y=Kd))+geom_point()+geom_smooth(method=lm
)+labs(x="TSS",y="Kd(PAR)")+theme_bw()

ORN_TSS_Kd<-ggplot(ORBN, aes(x=TSS, y=Kd))+geom_point()+geom_smooth(method=lm
)+labs(x="TSS",y="Kd(PAR)")+theme_bw()

DB_OR_Plot<-ggarrange(DBN_TSS_Kd,ORN_TSS_Kd, ncol=1,nrow=2,labels = c("A","B"
))
```



Port of Miami, Port Everglades, and Lake Worth Inlet

```
cor.test(POM$TSS, POM$Kd,method = "spearman")

## 
##  Spearman's rank correlation rho
## 
## data:  POM$TSS and POM$Kd
## S = 456828, p-value = 0.3285
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##        rho 
## 0.08201119
```

```
#Non-significant relationship between Kd and TSS

cor.test(PE$TSS, PE$Kd,method = "spearman")

##
##  Spearman's rank correlation rho
##
## data:  PE$TSS and PE$Kd
## S = 452988, p-value = 0.2848
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##        rho
## 0.08972823

#Non-significant relationship between Kd and TSS

cor.test(LWI$TSS, LWI$Kd,method = "spearman")

##
##  Spearman's rank correlation rho
##
## data:  LWI$TSS and LWI$Kd
## S = 413615, p-value = 0.07129
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
##       rho
## 0.1512867

#Non-significant relationship between Kd and TSS

POM_TSS_Kd<-ggplot(POM, aes(x=TSS, y=Kd))+geom_point()+geom_smooth(method=lm)
+labs(x="TSS",y="Kd(PAR)")+theme_bw()

PE_TSS_Kd<-ggplot(PE, aes(x=TSS, y=Kd))+geom_point()+geom_smooth(method=lm)+l
abs(x="TSS",y="Kd(PAR)")+theme_bw()

LWI_TSS_Kd<-ggplot(LWI, aes(x=TSS, y=Kd))+geom_point()+geom_smooth(method=lm)
+labs(x="TSS",y="Kd(PAR)")+theme_bw()

POM_PE_LWI_Plot<-ggarrange(POM_TSS_Kd,PE_TSS_Kd,LWI_TSS_Kd,ncol=1,nrow=3,labe
ls = c("A","B", "C"))
```



```
#This optionally creates image files for the plots. Should stay on eval = F s
o it doesn't run when knitting markdown report.
ggsave(DB_OR_Plot, file = "TSS_Kd_Plot_DBN_ORN.png", height = 5, width = 7.5,
units = "in")
ggsave(POM_PE_LWI_Plot, file = "TSS_Kd_Plot_POM_PE_LWI.png", height = 7.5, wi
dth = 7.5, units = "in")
```

8.0 Appendix B – Original Rscript

```
###JI Sampling Events###

JISurf<-read.csv("JISurf.csv")
JISurf
as.factor(JISurf$Group)

kruskal.test(NTU~Group,data=JISurf)
pairwise.wilcox.test(JISurf$NTU,JISurf$Group,p.adjust.method = "BH")
#Background was different to compliance (p=0.014) and mixing (0.014)

kruskal.test(PARSpher~Group,data=JISurf)
#No significant difference in PAR Spherical

kruskal.test(PARTerr~Group,data = JISurf)
```

```
#No significant difference in PAR Terrestrial

kruskal.test(TSS~Group,data=JISurf)
#No significant difference in TSS

#Mid depth comparison
JIMid<-read.csv("JMid.csv")
JIMid
as.factor(JIMid$Group)

kruskal.test(NTU~Group,data=JIMid)
pairwise.wilcox.test(JIMid$NTU,JIMid$Group,p.adjust.method = "BH")
#background significantly different than compliance (0.0166), downcurrent (0.0166), and mixing (0.0039)

kruskal.test(PARSpher~Group,data = JIMid)
#No significant difference in PAR Spherical

kruskal.test(PARTerr~Group,data=JIMid)
#No significant difference in PAR Terrestrial

kruskal.test(TSS~Group,data=JIMid)
pairwise.wilcox.test(JIMid$TSS,JIMid$Group,p.adjust.method = "BH")
#Background significantly different than compliance (0.059) and mixing (0.078)

###OR Sampling Events###

#Surface Values
ORSurf<-read.csv("ORSurf.csv")
ORSurf
as.factor(ORSurf$Group)
kruskal.test(NTU~Group,data=ORSurf)
#No significant difference in NTU between groups
kruskal.test(PARSpher~Group,data=ORSurf)
#No significant difference in PAR Spherical between groups
kruskal.test(PARTerr~Group,data=ORSurf)
#No significant difference in PAR Terrestrial between groups
kruskal.test(TSS~Group,data=ORSurf)
#No significant difference in TSS between groups

#Mid-Depth Values
ORMid<-read.csv("ORMid.csv")
ORMid
kruskal.test(NTU~Group,data=ORMid)
```

```
#No significant difference in NTU between groups
kruskal.test(PARSpher~Group,data=ORMid)
#No significant difference in PAR spherical between groups
kruskal.test(PARTerr~Group,data=ORMid)
#No significant difference in PAR Terrestrial between groups
kruskal.test(TSS~Group,data=ORMid)
#No significant difference in TSS between groups

###DBN Sampling Events###

#Surface Values
DBSurf<-read.csv("DBSurf.csv")
DBSurf
as.factor(DBSurf$Group)

kruskal.test(NTU~Group,data=DBSurf)
pairwise.wilcox.test(DBSurf$NTU,DBSurf$Group,p.adjust.method = "BH")
#Background NTU differed to Compliance NTU p=0.0037

kruskal.test(PARSpher~Group,data=DBSurf)
#No difference in PAR Spherical between groups

kruskal.test(PARTerr~Group,data = DBSurf)
#No difference in PAR Terrestrial between groups

kruskal.test(TSS~Group,data=DBSurf)
pairwise.wilcox.test(DBSurf$TSS,DBSurf$Group,p.adjust.method = "BH")
#Background TSS differed to compliance and downcurrent (p=0.044, 0.027)

#Mid-depth
DBMid<-read.csv("DBMid.csv")
DBMid
as.factor(DBMid$Group)

kruskal.test(NTU~Group, data=DBMid)
pairwise.wilcox.test(DBMid$NTU,DBMid$Group,p.adjust.method = "BH")
#Significant difference between Background and Mixing, Downcurrent and Compliance
(P=0.0005,p=0.004,p=0.0005)

kruskal.test(PARSpher~Group,data=DBMid)
#No significant difference in PAR Spherical between groups

kruskal.test(PARTerr~Group,data=DBMid)
#No significant difference in PAR Terrestrial between groups
```

```
kruskal.test(TSS~Group,data=DBMid)
pairwise.wilcox.test(DBMid$TSS,DBMid$Group,p.adjust.method = "BH")
#Background was significantly different to mixing (p=0.0056)

###JI Surface to Mid Depth###

#Background

JIBG<-read.csv("JIBackground.csv")
JIBG
as.factor(JIBG$Depth)
wilcox.test(NTU~Depth, data=JIBG)
#No difference in background NTU between surface and mid depth

wilcox.test(PARSpher~Depth, data=JIBG)
##########Significant difference in background PAR Spherical between surface and mid depth
(P<0.001)

wilcox.test(PARTerr~Depth, data=JIBG)
#No difference in background PAR terrestrial between surface and mid depth

wilcox.test(TSS~Depth, data=JIBG)
#No difference in background TSS between surface and mid depth

#Compliance
JICOM<-read.csv("JICompliance.csv")
JICOM
as.factor(JICOM$Depth)
wilcox.test(NTU~Depth,data=JICOM)
#No difference in compliance NTU between surface and mid depth

wilcox.test(PARSpher~Depth,data=JICOM)
##########Significant difference in compliance PAR Spherical between surface and mid depth
(P=0.001)

wilcox.test(PARTerr~Depth,data=JICOM)
#No difference in compliance PAR terrestrial between surface and mid depth

wilcox.test(TSS~Depth,data=JICOM)
#No difference in compliance PAR terrestrial between surface and mid depth

#Mixing
JIMIX<-read.csv("JIMixing.csv")
```

```
as.factor(JIMIX$Depth)

wilcox.test(NTU~Depth,data=JIMIX)
#No difference in mixing zone NTU between surface and mid depth

wilcox.test(PARSpher~Depth,data=JIMIX)
#############Significant difference in PAR spherical by depth, p<0.0001###########

wilcox.test(PARTerr~Depth,data=JIMIX)
#No difference in mixing zone PAR terrestrial between surface and mid depth

wilcox.test(TSS~Depth,data=JIMIX)
#No difference in mixing zone TSS between surface and mid depth

#Downcurrent
JIDC<-read.csv("JIDowncurrent.csv")
as.factor(JIDC$Depth)

wilcox.test(NTU~Depth,data=JIDC)
#No difference in mixing zone NTU between surface and mid depth

wilcox.test(PARSpher~Depth,data=JIDC)
#############Significant difference in PAR spherical by depth, p=.003###########


wilcox.test(PARTerr~Depth,data=JIDC)
#No difference in mixing zone PAR terrestrial between surface and mid depth

wilcox.test(TSS~Depth,data=JIDC)
#No difference in mixing zone TSS between surface and mid depth

####DBN Surface to Mid####

#Background

DBBG<-read.csv("DBBackground.csv")
DBBG
as.factor(DBBG$Depth)
wilcox.test(NTU~Depth, data=DBBG)
#No difference in background NTU between surface and mid depth

wilcox.test(PARSpher~Depth, data=DBBG)
#No difference in background PAR Spherical between surface and mid depth
```

```
wilcox.test(PARTerr~Depth, data=DBBG)
#No difference in background PAR terrestrial between surface and mid depth

wilcox.test(NTU.1~Depth, data=DBBG)
#No difference in background TSS between surface and mid depth

#Compliance
DBCOM<-read.csv("DBCompliance.csv")
DBCOM
as.factor(ORCOM$Depth)
wilcox.test(NTU~Depth,data=DBCOM)
#No difference in compliance NTU between surface and mid depth

wilcox.test(PARSpher~Depth,data=DBCOM)
#No difference in compliance PAR Spherical between surface and mid depth

wilcox.test(PARTerr~Depth,data=DBCOM)
#No difference in compliance PAR terrestrial between surface and mid depth

wilcox.test(TSS~Depth,data=DBCOM)
#No difference in compliance PAR terrestrial between surface and mid depth

#Mixing
DBMIX<-read.csv("DBMix.csv")
as.factor(DBMIX$Depth)

wilcox.test(NTU~Depth,data=DBMIX)
#No difference in mixing zone NTU between surface and mid depth

wilcox.test(PARSpher~Depth,data=DBMIX)
#############Significant difference in PAR spherical by depth, p=0.021###########

wilcox.test(PARTerr~Depth,data=DBMIX)
#No difference in mixing zone PAR terrestrial between surface and mid depth

wilcox.test(TSS~Depth,data=DBMIX)
#No difference in mixing zone TSS between surface and mid depth

#Downcurrent
DBDC<-read.csv("DBDowncurrent.csv")
as.factor(DBDC$Depth)

wilcox.test(NTU~Depth,data=DBDC)
#No difference in mixing zone NTU between surface and mid depth
```

```
wilcox.test(PARSpher~Depth,data=DBDC)
#No difference in mixing zone PAR spherical between surface and mid depth

wilcox.test(PARTerr~Depth,data=DBDC)
#No difference in mixing zone PAR terrestrial between surface and mid depth

wilcox.test(TSS~Depth,data=DBDC)
#No difference in mixing zone TSS between surface and mid depth

###OR Surface to Mid Depth####

#No difference in background TSS between surface and mid depth

#Compliance
ORCOM<-read.csv("ORCompliance.csv")
ORCOM
as.factor(ORCOM$Depth)
wilcox.test(NTU~Depth,data=ORCOM)
#No difference in compliance NTU between surface and mid depth

wilcox.test(PARSpher~Depth,data=ORCOM)
#No difference in compliance PAR Spherical between surface and mid depth

wilcox.test(PARTerr~Depth,data=ORCOM)
#No difference in compliance PAR terrestrial between surface and mid depth

wilcox.test(TSS~Depth,data=ORCOM)
#No difference in compliance PAR terrestrial between surface and mid depth

#Mixing
ORMIX<-read.csv("ORMixing.csv")
as.factor(ORMIX$Depth)

wilcox.test(NTU~Depth,data=ORMIX)
#No difference in mixing zone NTU between surface and mid depth

wilcox.test(PARSpher~Depth,data=ORMIX)
#No difference in mixing zone PAR spherical between surface and mid depth

wilcox.test(PARTerr~Depth,data=ORMIX)
#No difference in mixing zone PAR terrestrial between surface and mid depth

wilcox.test(TSS~Depth,data=ORMIX)
```

```
#No difference in mixing zone TSS between surface and mid depth

#Downcurrent
ORDC<-read.csv("ORDowncurrent.csv")
as.factor(ORDC$Depth)

wilcox.test(NTU~Depth,data=ORDC)
#No difference in mixing zone NTU between surface and mid depth

wilcox.test(PARSpher~Depth,data=ORDC)
#No difference in mixing zone PAR spherical between surface and mid depth

wilcox.test(PARTerr~Depth,data=ORDC)
#No difference in mixing zone PAR terrestrial between surface and mid depth

wilcox.test(TSS~Depth,data=ORDC)
#No difference in mixing zone TSS between surface and mid depth

####LWI Surface to Mid####

LWICom<-read.csv("LWIDepthCompare.csv")
LWICom
as.factor(LWICom$Depth)

#NTU
wilcox.test(NTU~Depth,data=LWICom)
# No significant difference in NTU by depth

wilcox.test(PARSpher~Depth,data=LWICom)
####Significant difference in PAR spherical, p<0.001

wilcox.test(PARTerr~Depth,data=LWICom)
#No significant difference in PAR Terrestrial by depth

wilcox.test(Reported.Value~Depth,data=LWICom)
#No Significant difference in TSS by depth

#####PE Surface to Mid####
PECom<-read.csv("PEDepthCompare.csv")
as.factor(PECom$Depth)

#NTU
wilcox.test(NTU~Depth,data=PECom)
#####significant difference in NTU by depth P=0.01
```

```
wilcox.test(PARSpher~Depth,data=PECom)
####Significant difference in PAR spherical, p=0.001

wilcox.test(PARTerr~Depth,data=PECom)
#No significant difference in PAR Terrestrial by depth

wilcox.test(TSS~Depth,data=PECom)
#####Significant difference in TSS by depth p=0.04

###POM Surface to Mid####
POMCom<-read.csv("POMDepthCompare.csv")
as.factor(POMCom$Depth)

#NTU
wilcox.test(NTU~Depth,data=POMCom)
#No significant difference in NTU by depth

wilcox.test(PARSpher~Depth,data=POMCom)
####Significant difference in PAR spherical, p=0.003

wilcox.test(PARTerr~Depth,data=POMCom)
#No significant difference in PAR Terrestrial by depth

wilcox.test(TSS~Depth,data=POMCom)
#No significant difference in TSS by depth


#####Scatterplot####
library(ggplot2)

DBNPlot<-read.csv("DBN_NTU_PAR_TSS.csv")
DBN_NTU_PARSpher<-ggplot(DBNPlot, aes(x=NTU,
y=PARSpher))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="PAR-Spherical
Quantum Sensor")+theme_bw()
DBN_NTU_PARSpher
dbnparspher<-cor.test(DBNPlot$NTU, DBNPlot$PARSpher,method = "spearman")
dbnparspher
DBN_NTU_PARTerr<-ggplot(DBNPlot, aes(x=NTU,
y=PARTerr))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="PAR-Terrestrial
Quantum Sensor")+theme_bw()
DBN_NTU_PARTerr
dbnparterr<-cor.test(DBNPlot$NTU,DBNPlot$PARTerr, method = "spearman")
dbnparterr
```

```
DBN_NTU_TSS<-ggplot(DBNPlot, aes(x=NTU,
y=TSS))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="TSS (mg/L)")+theme_bw()
DBN_NTU_TSS
dbntss<-cor.test(DBNPlot$NTU,DBNPlot$TSS, method = "spearman")
dbntss
DBN<-ggarrange(DBN_NTU_PARSpher,DBN_NTU_PARTerr,DBN_NTU_TSS,ncol=2,nrow=2,labels
= c("A","B","C"))
DBN

ORNPlot<-read.csv("ORN_NTU_PAR_TSS.csv")
ORN_NTU_PARSpher<-ggplot(ORNPlot, aes(x=NTU,
y=PARSpher))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="PAR-Spherical
Quantum Sensor")+theme_bw()
ORN_NTU_PARSpher
ornparspher<-cor.test(ORNPlot$NTU,ORNPlot$PARSpher, method = "spearman")
ornparspher
ORN_NTU_PARTerr<-ggplot(ORNPlot, aes(x=NTU,
y=PARTerr))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="PAR-Terrestrial
Quantum Sensor")+theme_bw()
ORN_NTU_PARTerr
ornparterr<-cor.test(ORNPlot$NTU,ORNPlot$PARTerr, method = "spearman")
ornparterr
ORN_NTU_TSS<-ggplot(DBNPlot, aes(x=NTU,
y=TSS))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="TSS (mg/L)")+theme_bw()
ORN_NTU_TSS
orntss<-cor.test(ORNPlot$NTU,ORNPlot$TSS, method = "spearman")
orntss
ORN<-ggarrange(ORN_NTU_PARSpher,ORN_NTU_PARTerr,ORN_NTU_TSS,
ncol=2,nrow=2,labels = c("A","B","C"))
ORN

JBNPlot<-read.csv("JBN_NTU_PAR_TSS.csv")
JBN_NTU_PARSpher<-ggplot(JBNPlot, aes(x=NTU,
y=PARSpher))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="PAR-Spherical
Quantum Sensor")+theme_bw()
JBN_NTU_PARSpher
jbnparspher<-cor.test(ORNPlot$NTU,ORNPlot$PARSpher, method = "spearman")
jbnparspher
JBN_NTU_PARTerr<-ggplot(ORNPlot, aes(x=NTU,
y=PARTerr))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="PAR-Terrestrial
Quantum Sensor")+theme_bw()
JBN_NTU_PARTerr
jbnparterr<-cor.test(JBNPlot$NTU,JBNPlot$PARTerr, method="spearman")
jbnparterr
```

```
as.numeric(JBNPlot$TSS)
JBN_NTU_TSS<-ggplot(ORNPlot, aes(x=NTU,
y=TSS))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="TSS (mg/L)")+theme_bw()
JBN_NTU_TSS
jbntss<-cor.test(JBNPlot$NTU,JBNPlot$TSS, method = "spearman")
jbntss
JBN<-ggarrange(JBN_NTU_PARSpher,JBN_NTU_PARTerr,JBN_NTU_TSS, ncol=2,nrow=2,labels =
c("A","B","C"))
JBN

POMPlot<-read.csv("POM_NTU_PAR_TSS.csv")
POM_NTU_PARSpher<-ggplot(POMPlot, aes(x=NTU,
y=PARSpher))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="PAR-Spherical
Quantum Sensor")+theme_bw()
POM_NTU_PARSpher
pomparspher<-cor.test(POMPlot$NTU, POMPlot$PARSpher, method = "spearman")
pomparspher
POM_NTU_PARTerr<-ggplot(POMPlot, aes(x=NTU,
y=PARTerr))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="PAR-Terrestrial
Quantum Sensor")+theme_bw()
POM_NTU_PARTerr
pomparterr<-cor.test(POMPlot$NTU,POMPlot$PARTerr, method = "spearman")
pomparterr
POM_NTU_TSS<-ggplot(POMPlot, aes(x=NTU,
y=TSS))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="TSS (mg/L)")+theme_bw()
POM_NTU_TSS
pomtss<-cor.test(POMPlot$NTU,POMPlot$TSS, method = "spearman")
pomtss
POM<-ggarrange(POM_NTU_PARSpher,POM_NTU_PARTerr,POM_NTU_TSS,
ncol=2,nrow=2,labels = c("A","B","C"))
POM

PEPlot<-read.csv("PE_NTU_PAR_TSS.csv")
PE_NTU_PARSpher<-ggplot(PEPlot, aes(x=NTU,
y=PARSpher))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="PAR-Spherical
Quantum Sensor")+theme_bw()
PE_NTU_PARSpher
peparspher<-cor.test(PEPlot$NTU,PEPlot$PARSpher,method = "spearman")
PE_NTU_PARTerr<-ggplot(POMPlot, aes(x=NTU,
y=PARTerr))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="PAR-Terrestrial
Quantum Sensor")+theme_bw()
peparspher
PE_NTU_PARTerr
peparterr<-cor.test(PEPlot$NTU,PEPlot$PARTerr,method = "spearman")
```

```
peparterr
PE_NTU_TSS<-ggplot(POMPlot, aes(x=NTU,
y=TSS))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="TSS (mg/L)")+theme_bw()
PE_NTU_TSS
petss<-cor.test(PEPlot$NTU,PEPlot$TSS,method = "spearman")
petss
PE<-ggarrange(PE_NTU_PARSpher,PE_NTU_PARTerr,PE_NTU_TSS, ncol=2,nrow=2,labels =
c("A","B","C"))
PE

LWIPlot<-read.csv("LWI.csv")
LWI_NTU_PARSpher<-ggplot(LWIPlot, aes(x=NTU,
y=PARSpher))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="PAR-Spherical
Quantum Sensor")+theme_bw()
LWI_NTU_PARSpher
lwiparspher<-cor.test(LWIPlot$NTU,LWIPlot$PARSpher,method = "spearman")
lwiparspher
LWI_NTU_PARTerr<-ggplot(LWIPlot, aes(x=NTU,
y=PARTerr))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="PAR-Terrestrial
Quantum Sensor")+theme_bw()
LWI_NTU_PARTerr
lwiparterr<-cor.test(LWIPlot$NTU,LWIPlot$PARTerr,method = "spearman")
lwiparterr
LWI_NTU_TSS<-ggplot(LWIPlot, aes(x=NTU,
y=TSS))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="TSS (mg/L)")+theme_bw()
LWI_NTU_TSS
LWI<-ggarrange(LWI_NTU_PARSpher,LWI_NTU_PARTerr,LWI_NTUTSS2, ncol=2,nrow=2,labels =
c("A","B","C"))
LWI

LWIPlot2<-read.csv("LWI_NTU_TSS.csv")
LWI_NTUTSS2<-ggplot(LWIPlot2, aes(x=NTU,
y=TSS))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="TSS (mg/L)")+theme_bw()
LWI_NTUTSS2
lwitss<-cor.test(LWIPlot2$NTU, LWIPlot2$TSS, method="spearman")
lwitss

###sedmod###
DBNMOD<-read.csv("DBN_MOD.csv")

#NTU vs Sediment Characteristics
dbnntu.lm<-lm(NTU~Silt,data=DBNMOD)
summary.lm(dbnntu.lm)
dbnntu.res = resid(dbnntu.lm)
```

```
dbnntu.res

anova(dbnntu.lm)

qqnorm(resid(dbnntu.lm))
qqline(resid(dbnntu.lm))
hist(resid(dbnntu.lm))

#Silt: Adjusted Rsquared -0.2988, p=0.6337
#Size:Adj Rsquared -0.3552, p=0.6893
#Size+Silt: Adj rsquared -1.596, p=0.9303

#PARSpher vs Sediment Characteristics
dbnparspher.lm<-lm(PARSpher~Size+Silt,data=DBNMOD)
summary.lm(dbnparspher.lm)
dbnntu.res = resid(dbnparspher.lm)
dbnntu.res

anova(dbnparspher.lm)

qqnorm(resid(dbnparspher.lm))
qqline(resid(dbnparspher.lm))
hist(resid(dbnparspher.lm))

#Silt: adj r -0.0423, p=0.4476
#Size: adj r -0.4993, p=0.9789
#Size+Silt: adj r 0.5829, p=0.3729

#PARTerr vs Sediment Characteristics
dbnparterr.lm<-lm(PARTerr~Size+Silt,data=DBNMOD)
summary.lm(dbnparterr.lm)
dbnparterr.res = resid(dbnparterr.lm)
dbnparterr.res

anova(dbnparterr.lm)

qqnorm(resid(dbnparterr.lm))
qqline(resid(dbnparterr.lm))
hist(resid(dbnparterr.lm))

#Silt: adj r -0.4673, p=0.8524
#Size: adj r -0.42858, p=0.6222
#Size+Silt: adj r -1.338, p=0.8828
```

```
#TSS vs Sediment Characteristics
dbntss.lm<-lm(TSS~Size+Silt,data=DBNMOD)
summary.lm(dbntss.lm)
dbntss.res = resid(dbntss.lm)
dbntss.res

anova(dbntss.lm)

qqnorm(resid(dbntss.lm))
qqline(resid(dbntss.lm))
hist(resid(dbntss.lm))

#Silt: adj r 0.1509, p=0.3413
#Size: adj r -0.0609, p=0.459
#Size+Silt: adj r -0.6982, p=0.7524

ornMOD<-read.csv("ORN_GLM.csv")

#NTU vs Sediment Characteristics
ornntu.lm<-glm(NTU~Size+Silt,data=ornMOD)
summary.lm(ornntu.lm)
ornntu.res = resid(ornntu.lm)
ornntu.res

anova(ornntu.lm)

qqnorm(resid(ornntu.lm))
qqline(resid(ornntu.lm))
hist(resid(ornntu.lm))

#Silt: Adjusted Rsquared 0.3214, p=0.1404
#Size:Adj Rsquared -0.1029, p=0.5056
#Size+Silt: Adj rsquared 0.1102, p=0.3901

#PARSpher vs Sediment Characteristics
ornparspher.glm<-glm(PARSpher~Size+Silt,data=ornMOD)
summary.lm(ornparspher.lm)
ornntu.res = resid(ornparspher.lm)
ornntu.res

anova(ornparspher.lm)

qqnorm(resid(ornparspher.lm))
qqline(resid(ornparspher.lm))
```

```
hist(resid(ornparspher.lm))

#Silt: adj r 0.2397, p=0.1837
#Size: adj r 0.1522, p=0.2404
#Size+Silt: adj r -0.3260, p=0.7096

#PARTerr vs Sediment Characteristics
ornparterr.glm<-lm(PARTerr~Size+Silt,data=ornMOD)
summary.lm(ornparterr.lm)
ornparterr.res = resid(ornparterr.lm)
ornparterr.res

anova(ornparterr.lm)

qqnorm(resid(ornparterr.lm))
qqline(resid(ornparterr.lm))
hist(resid(ornparterr.lm))

#Silt: adj r -0.0017, p=0.3757
#Size: adj r -0.1790, p=0.6492
#Size+Silt: adj r -1.338, p=0.8828

#TSS vs Sediment Characteristics
orntss.lm<-glm(TSS~Size+Silt,data=ornMOD)
summary.lm(orntss.lm)
orntss.res = resid(orntss.lm)
orntss.res

anova(orntss.lm)

qqnorm(resid(orntss.lm))
qqline(resid(orntss.lm))
hist(resid(orntss.lm))

#Silt: adj r 0.1803, p=0.2209
#Size: adj r 0.1467, p=0.2444
#Size+Silt: adj r 0.1343, p=0.3743

jimod<-read.csv("JI_MOD.csv")

#NTU vs Sediment Characteristics
jintu.lm<-glm(NTU~Silt+Size,data=jimod)
summary.lm(jintu.lm)
jintu.res = resid(jintu.lm)
```

```
jintu.res

anova(jintu.lm)

qqnorm(resid(jintu.lm))
qqline(resid(jintu.lm))
hist(resid(jintu.lm))

#Silt: Adjusted Rsquared -0.01356, p=0.4452 right skew
#Size:Adj Rsquared -0.02963, p=0.7804 right skew
#Size+Silt: Adj rsquared -0.0450, p=0.7351

#PARSpher vs Sediment Characteristics
jiparspher.lm<-glm(PARSpher~Silt+Size,data=jimod)
summary.lm(jiparspher.lm)
jiparspher.res = resid(jiparspher.lm)
jiparspher.res

anova(jiparspher.lm)

qqnorm(resid(jiparspher.lm))
qqline(resid(jiparspher.lm))
hist(resid(jiparspher.lm))

#Silt: adj r -0.0282, p=0.7589
#Size: adj r -0.0114, p=0.4341
#Size+Silt: adj r -0.0413, p=0.7105

#PARTerr vs Sediment Characteristics
jiparterr.lm<-glm(PARTerr~Silr+Size,data=jimod)
summary.lm(jiparterr.lm)
jiparterr.res = resid(jiparterr.lm)
jiparterr.res

anova(jiparterr.lm)

qqnorm(resid(jiparterr.lm))
qqline(resid(jiparterr.lm))
hist(resid(jiparterr.lm))

#Silt: adj r -0.0212, p=0.5781
#Size: adj r -0.0293, p=0.8046
#Size+Silt: adj r -0.0293, p=0.8046
```

```
#TSS vs Sediment Characteristics
jitss.lm<-glm(TSS~Silt+Size,data=jimod)
summary.lm(jitss.lm)
jitss.res = resid(jitss.lm)
jitss.res

anova(jitss.lm)

qqnorm(resid(jitss.lm))
qqline(resid(jitss.lm))
hist(resid(jitss.lm))

#Silt: adj r -0.0261, p=0.6905
#Size: adj r -0.0274, p=0.7301
#Size+Silt: adj r -0.0549, p=0.8687

#####TSS Scatterplot#####
library(ggplot2)

DBNPlot<-read.csv("DBN_NTU_PAR_TSS.csv")
DBN_NTU_PARSpher<-ggplot(DBNPlot, aes(x=TSS,
y=PARSpher))+geom_point()+geom_smooth(method=lm)+labs(x="TSS",y="PAR-
S")+theme_bw()
DBN_NTU_PARSpher
dbnparspher<-cor.test(DBNPlot$TSS, DBNPlot$PARSpher,method = "spearman")
dbnparspher
DBN_NTU_PARTerr<-ggplot(DBNPlot, aes(x=TSS,
y=PARTerr))+geom_point()+geom_smooth(method=lm)+labs(x="TSS",y="PAR-T")+theme_bw()
DBN_NTU_PARTerr
dbnparterr<-cor.test(DBNPlot$TSS,DBNPlot$PARTerr, method = "spearman")
dbnparterr

DBN<-ggarrange(DBN_NTU_PARSpher,DBN_NTU_PARTerr,DBN_NTU_TSS,ncol=2,nrow=2,labels
= c("A","B","C"))
DBN

ORNPlot<-read.csv("ORN_NTU_PAR_TSS.csv")
ORN_NTU_PARSpher<-ggplot(ORNPlot, aes(x=TSS,
y=PARSpher))+geom_point()+geom_smooth(method=lm)+labs(x="TSS",y="PAR-
S")+theme_bw()
ORN_NTU_PARSpher
ornparspher<-cor.test(ORNPlot$TSS,ORNPlot$PARSpher, method = "spearman")
ornparspher
```

```
ORN_NTU_PARTerr<-ggplot(ORNPlot, aes(x=TSS,
y=PARTerr))+geom_point()+geom_smooth(method=lm)+labs(x="TSS",y="PAR-T")+theme_bw()
ORN_NTU_PARTerr
ornparterr<-cor.test(ORNPlot$TSS,ORNPlot$PARTerr, method = "spearman")
ornparterr

ORN<-ggarrange(ORN_NTU_PARSpher,ORN_NTU_PARTerr,ORN_NTU_TSS,
ncol=2,nrow=2,labels = c("A","B","C"))
ORN

JBNPlot<-read.csv("JBN_NTU_PAR_TSS.csv")
JBN_NTU_PARSpher<-ggplot(JBNPlot, aes(x=TSS,
y=PARSpher))+geom_point()+geom_smooth(method=lm)+labs(x="TSS",y="PAR-
S")+theme_bw()
JBN_NTU_PARSpher
jbnparspher<-cor.test(ORNPlot$TSS,ORNPlot$PARSpher, method = "spearman")
jbnparspher
JBN_NTU_PARTerr<-ggplot(ORNPlot, aes(x=TSS,
y=PARTerr))+geom_point()+geom_smooth(method=lm)+labs(x="TSS",y="PAR-T")+theme_bw()
JBN_NTU_PARTerr
  jbnparterr<-cor.test(JBNPlot$TSS,JBNPlot$PARTerr, method="spearman")
jbnparterr

JBN<-
ggarrange(JBN_NTU_PARSpher,JBN_NTU_PARTerr,DBN_NTU_PARSpher,DBN_NTU_PARTerr,OR
N_NTU_PARSpher,ORN_NTU_PARTerr, ncol=2,nrow=6,labels = c("A","B","C","D","E","F"))
JBN


POMPlot<-read.csv("POM_NTU_PAR_TSS.csv")
POM_NTU_PARSpher<-ggplot(POMPlot, aes(x=TSS,
y=PARSpher))+geom_point()+geom_smooth(method=lm)+labs(x="TSS",y="PAR-
S")+theme_bw()
POM_NTU_PARSpher
pomparspher<-cor.test(POMPlot$TSS, POMPlot$PARSpher, method = "spearman")
pomparspher
POM_NTU_PARTerr<-ggplot(POMPlot, aes(x=TSS,
y=PARTerr))+geom_point()+geom_smooth(method=lm)+labs(x="TSS",y="PAR-T")+theme_bw()
POM_NTU_PARTerr
pomparterr<-cor.test(POMPlot$TSS,POMPlot$PARTerr, method = "spearman")
pomparterr

POM<-ggarrange(POM_NTU_PARSpher,POM_NTU_PARTerr,POM_NTU_TSS,
ncol=2,nrow=2,labels = c("A","B","C"))
```

POM

```
PEPlot<-read.csv("PE_NTU_PAR_TSS.csv")
PE_NTU_PARSpher<-ggplot(PEPlot, aes(x=TSS, y=PARSpher))+geom_point()+geom_smooth(method=lm)+labs(x="TSS",y="PAR-S")+theme_bw()
PE_NTU_PARSpher
peparspher<-cor.test(PEPlot$TSS,PEPlot$PARSpher,method = "spearman")
PE_NTU_PARTerr<-ggplot(POMPlot, aes(x=TSS, y=PARTerr))+geom_point()+geom_smooth(method=lm)+labs(x="TSS",y="PAR-T")+theme_bw()
peparspher
PE_NTU_PARTerr
peparterr<-cor.test(PEPlot$TSS,PEPlot$PARTerr,method = "spearman")
peparterr

PE<-ggarrange(PE_NTU_PARSpher,PE_NTU_PARTerr,PE_NTU_TSS, ncol=2,nrow=2,labels = c("A","B","C"))
PE

LWIPlot<-read.csv("LWI.csv")
LWI_NTU_PARSpher<-ggplot(LWIPlot, aes(x=TSS, y=PARSpher))+geom_point()+geom_smooth(method=lm)+labs(x="TSS",y="PAR-S")+theme_bw()
LWI_NTU_PARSpher
lwiparspher<-cor.test(LWIPlot$TSS,LWIPlot$PARSpher,method = "spearman")
lwiparspher
LWI_NTU_PARTerr<-ggplot(LWIPlot, aes(x=TSS, y=PARTerr))+geom_point()+geom_smooth(method=lm)+labs(x="TSS",y="PAR-T")+theme_bw()
LWI_NTU_PARTerr
lwiparterr<-cor.test(LWIPlot$TSS,LWIPlot$PARTerr,method = "spearman")
lwiparterr

LWI<-ggarrange(LWI_NTU_PARSpher,LWI_NTU_PARTerr,POM_NTU_PARSpher,POM_NTU_PARTerr,PE_NTU_PARSpher,PE_NTU_PARTerr, ncol=2,nrow=6,labels = c("A","B","C","D","E","F"))
LWI

LWIPlot2<-read.csv("LWI_NTU_TSS.csv")
LWI_NTUTSS2<-ggplot(LWIPlot2, aes(x=NTU, y=TSS))+geom_point()+geom_smooth(method=lm)+labs(x="NTU",y="TSS (mg/L)")+theme_bw()
LWI_NTUTSS2
lwitss<-cor.test(LWIPlot2$NTU, LWIPlot2$TSS, method="spearman")
lwitss
```