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Water Quality Monitoring Program for Bermuda's Coastal Resources Final Report

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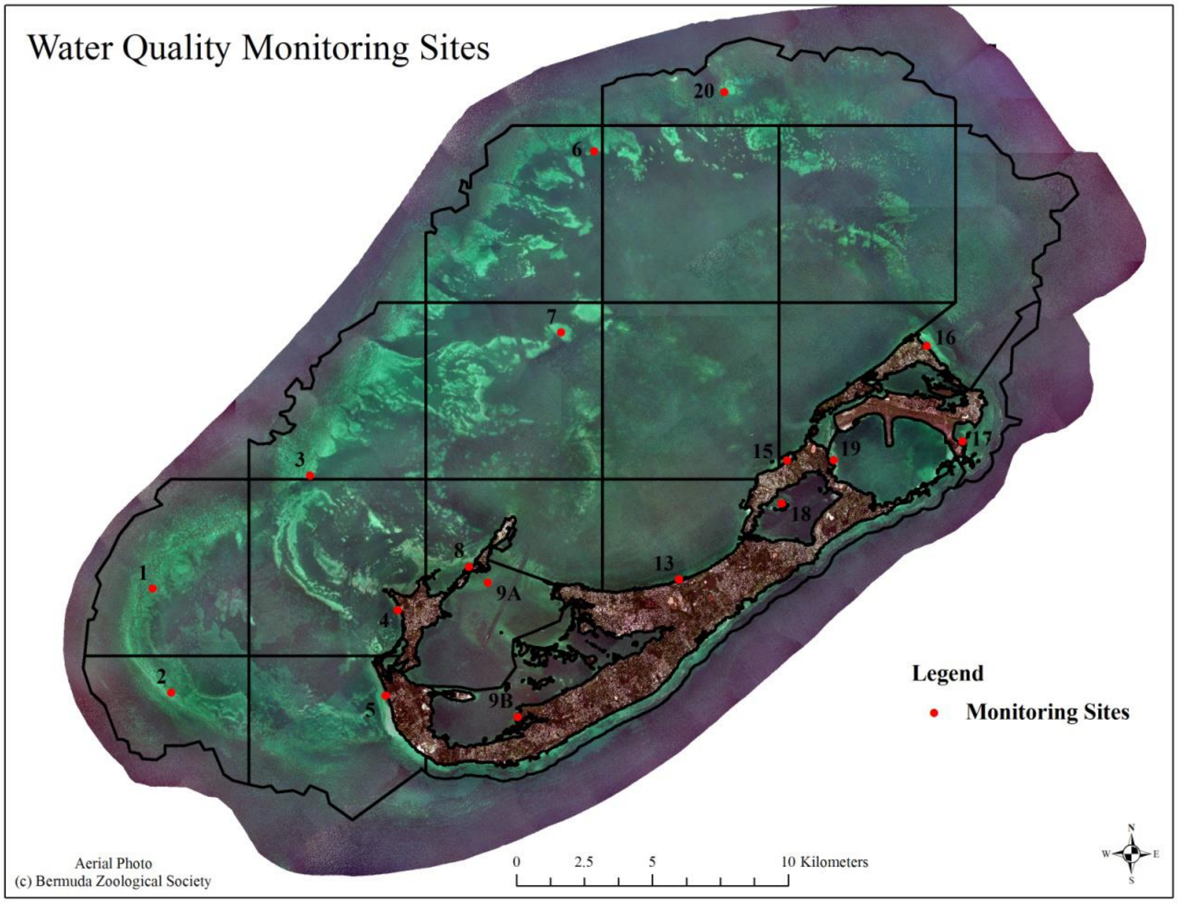
Final Report



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WATER QUALITY MONITORING PROGRAM FOR BERMUDA’S COASTAL RESOURCES

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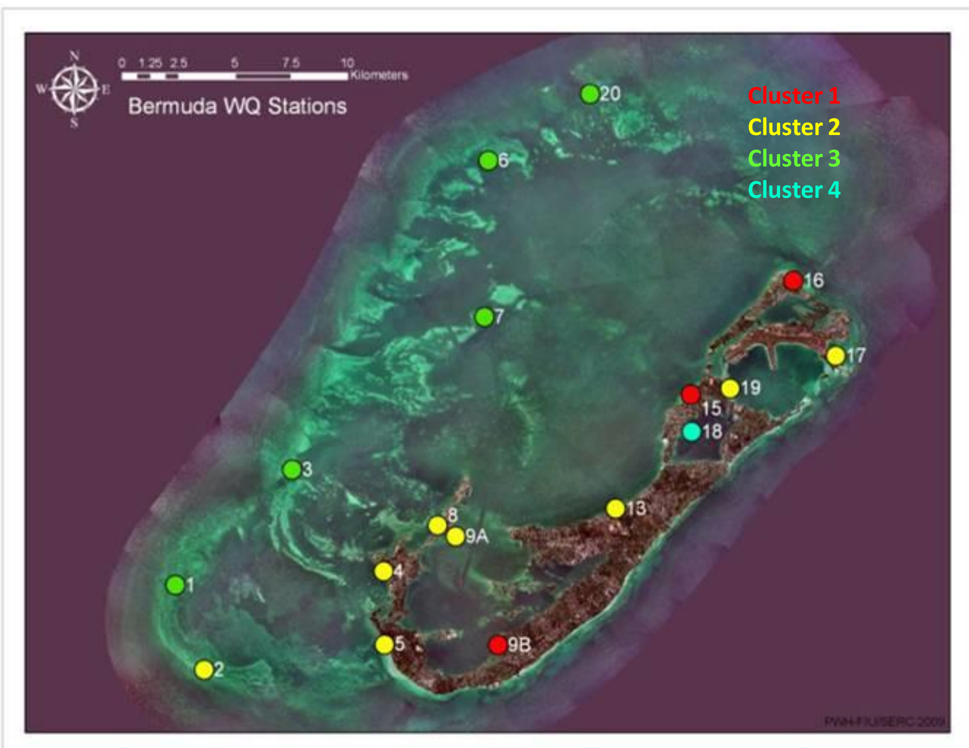
EXECUTIVE SUMMARY

This report serves as a summary of our efforts to date in the execution of the Water Quality Monitoring Program for the Bermuda Department of Conservation Services (BDCS). The Bermuda Government initiated a water quality monitoring program in September, 2007 at 17 sites with seagrass, which are spread across the Bermuda Platform. At each of these sites chemical and physical water quality characteristics are monitored monthly and a continuous temperature data logger is deployed. At least one species of seagrass is present at each site.

The period of record for this report spans from Sept. 2007 up to and including September 2012. Physical, chemical, and biological parameters were collected by BDCS personnel and water samples shipped to the Southeast Environmental Research Center at Florida International University for nutrient analysis. Field parameters measured at each station include salinity (practical salinity scale), temperature (ºC), dissolved oxygen (DO, mg l^{-1}), turbidity (NTU), pH, and Secchi depth (m). Water quality variables include the dissolved nutrients nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), dissolved inorganic nitrogen (DIN), and soluble reactive phosphate (SRP). Total unfiltered concentrations include those of nitrogen (TN), organic nitrogen (TON), organic carbon (TOC), phosphorus (TP), silicate (SiO_2) and chlorophyll *a* (CHLA, µg l^{-1}).

Cluster analysis of water quality variables by site resulted in 4 groups which had distinct differences in water quality. **Cluster 1** (in red) was composed of stations 9B, 15, and 16, which are those sites most strongly affected by anthropogenic nutrient inputs as indicated by their high levels of NO_3^-, TP, TOC, and turbidity. Interestingly, this cluster also showed high DO but did not have elevated CHLA. **Cluster 2** (in yellow) included a mix of stations on the SW and NE part of the platform (#2, 4, 5, 8, 9A, 13, 17, & 19). These sites exhibited lower NO_3^-, TP, TOC, CHLA,

and turbidity than Cluster 1. **Cluster 3** (in green) was composed of far offshore sites along the northwestern part of the platform (#1, 3, 6, 7, & 20). These stations had the lowest NO_{3-}, TP, TOC, SiO_2, CHLA, DO, and turbidity. Interestingly, these sites also had lowest light penetration, not because of optical clarity but because of greater water column depth. Salinity was also the most invariable at these sites. **Cluster 4** (in blue) consisted of only one site, station #18 off Trunk Island, but it was so different than any of the other sites that it had to be treated separately. It had the highest NO_{3-}, NH_{4+}, SRP, SiO_2, CHLA, and the lowest salinity of any other sites in the monitoring network. These all may be due to the location of this site in an enclosed bay. The low salinity reflects a source of terrestrial freshwater from either runoff or outfall and the enclosed nature of the bay (Harrington Sound) means that water residence time is probably higher than other areas. Longer water residence time allows more nutrients to be incorporated into phytoplankton biomass, hence the high CHLA levels at this site.



We developed and maintain a website (serc.fiu.edu/wqmnetwork/BERMUDA/home.html) where anyone can download 1) all data from the program, 2) the interpretive reports, and 3) Google maps of all measured variables, by month, in classified post style. These website structure and components will be transferred to the BDCS.

INTRODUCTION

The Bermuda Government initiated a water quality monitoring program in September, 2007 at 17 sites with seagrass, which are spread across the Bermuda Platform (Fig. 1). At each of these sites chemical and physical water quality characteristics are monitored monthly and a continuous temperature data logger is deployed. At least one species of seagrass is present at each site.

It has long been acknowledged that moorings, anchoring, dredging, and dock construction have impacted Bermuda's inshore seagrass beds but recently it has been recognized that the extensive offshore beds are also in decline. In 2004, intensive site surveys and mapping of Bermuda seagrass meadows, by the Bermuda Reef Ecosystem Assessment and Mapping Programme (of the Bermuda Biodiversity Project), documented a loss of about one-quarter of the total area estimated from aerial images taken in 1997. Other studies indicate a significant loss of seagrass area began about 1995 and was precipitous between then and 1997; however, the recent studies (2006-2010) do not indicate that loss is ongoing at this level, and do not indicate significant recovery of the impacted beds. This decline did not occur uniformly across the Bermuda platform - and massive loss of area was only apparent in meadows far from shore, which we think are removed from local anthropogenic impacts.

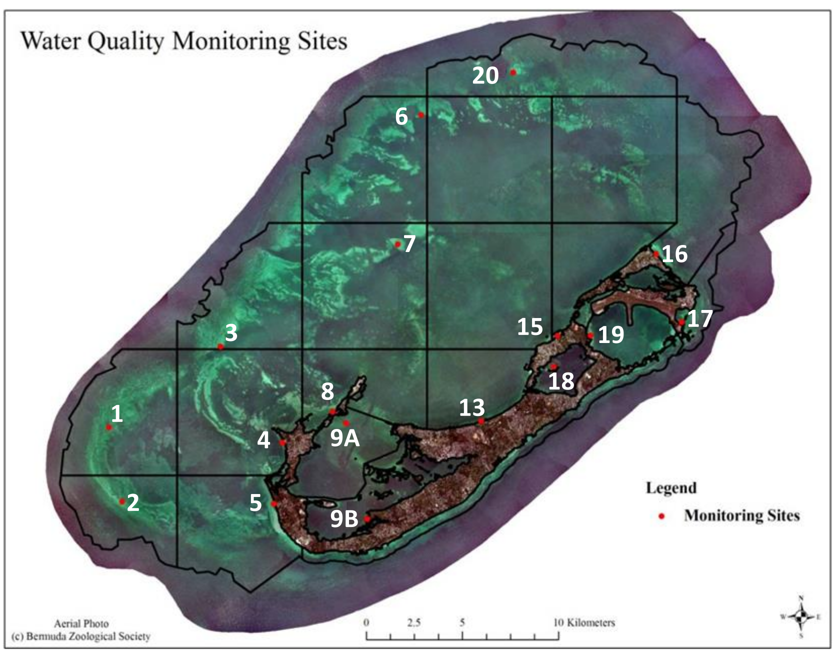


Figure 1. *Location of water quality sampling sites which coincide with existing seagrass sites.*

There are no comprehensive water quality data we can use to explain this decline, in particular there are no applicable data on nutrients, temperature, and light penetration for any of the beds for periods relevant to the onset of seagrass decline.

Water quality and physical characteristics of the water column are among the ultimate limiting conditions for the presence of seagrass. Transmission of light, temperature and the presence of adequate nutrient concentrations can all determine survival of a seagrass bed. Mean salinity, salinity variability, light transmission, and mean nutrient concentrations are important predictor variables to models of landscape-scale changes of marine benthic habitats (Fourqurean et al. 2003). Nutrient levels in the seagrass habitat, which include both pore water and water column, are the primary driving factors to degradation of seagrass beds in the conceptual model of seagrass community dynamics, which underlies this program.

It has been clearly outlined in the Bermuda Seagrass Conservation and Management Plan that comprehensive water quality monitoring is an essential component of overall management of seagrass habitats in Bermuda. Such a program did not exist in Bermuda until the Government initiated their seagrass habitat studies. The water quality monitoring program also can provide useful data to other management and monitoring issues in the marine environment, including tracking terrestrial runoff and ground water and their significance to nutrient loading. We monitor water quality at 17 sites spread across the Bermuda platform in locations at which seagrass occurs or where there are historical records of dense seagrass beds. We do not monitor any sites on or adjacent to the south-east shore of the islands, such as Hungry Bay. There are records of seagrass beds in Hungry Bay, but the condition of these beds has not been checked recently and, anecdotally, it is reported that this bed was lost during Hurricane Fabian (2003).

Seagrass beds in Bermuda occur from the shallow sub-tidal, with just a few beds that are exposed at extreme low tides, to maximum depths of just over 20 meters. These beds occur along the shoreline of the islands, both in bays and along exposed lengths of the shoreline, and around reef patches and barriers as far out as the rim of the shallow platform. The sites we monitor range from about 1 meter depth at extreme low tide to about 13 meters depth.

Four seagrass species are found in the Bermuda seagrass beds, *Thalassia testudinum*, *Syringodium filiforme*, *Halodule* sp. and *Halophila decipiens*. *Syringodium filiforme* is the most widespread and prevalent; the other three species are encountered about equally frequently, with *H. decipiens* occurring at the deepest and lowest light sites. Generally, the presence of a particular species at any site is determined by the combination of light transmission and depth at the site. Sediment characteristics may also be significant, but that has not been investigated to date. Sediments at the water quality monitoring sites range only from fine to medium sands, and do not cover the complete range of sediment types inhabited by seagrass in Bermuda (Sarah A. Manuel and Kathy A. Coates, pers. obs.).

SITE DESCRIPTIONS

The seventeen water quality monitoring sites in Bermuda can be roughly grouped based on some of the environmental and seagrass characteristics we have assessed over the past five years. Seagrass and other habitat characteristics have been measured on a quarterly basis since March 2007, while water quality sampling at these sites has been done on a monthly basis since September 2007. Seagrass density, canopy height, blade nutrient ratios, and other habitat characteristics (e.g., sediment type and water depth) are measured along a 50 m X 0.50 m transect that originates at the “center” of the water quality monitoring site. The following summary of site groupings is based on a visual assessment of these characteristics.

Group I - offshore

1. low seagrass density, east 6, 7, 20
2. high seagrass density, west 1, 2
3. moderate seagrass density, west 3

Group II – nearshore

1. high likelihood anthropogenic nutrients
    a. moderate to dense grass
        i. phosphorus limited 4, 5, 15
        ii. light or slightly phosphorus limited 8, 9B, 16
    b. lower density grass
        i. phosphorous limited 13
        ii. light or slightly phosphorous limited 18
2. other impacts
    a. moderate density Syringodium beds 9A

b. high density beds, low light 17, 19

Group I

Offshore sites either near the rim reefs or in the outer part of the lagoon, associated with patch reefs (mini-atoll like formations). These sites have high light quality (low k values) and are in moderately deep to deep water and are predicted to be subject to very low anthropogenic impacts of any kind.

1. Sites with low density seagrass in the eastern part of the platform.

Sites PS07 and PS20 are reported to have had much higher seagrass cover in (at least) the early to mid 1990's.

PS06 is just inside the rim reef to the west of the popular dive site North Rock. It has a resident population of large, very old, queen conch. It is our deepest site at an average of about 13 meters. The sandy bottom is highly bioturbated, with deep pits and corresponding conical mounds. Water clarity is high year round probably due to the regular intrusion of deep ocean water from outside the rim reef. Of the three sites included in this grouping, PS06 has the most dense seagrass cover, due largely to the regular presence of Halophila decipiens. S. filiforme and Halodule sp are also found here.

PS07 is located among a group of patch reefs collectively called "The Crescent" and is approximately 1700 m southwest of the original Bermuda CARICOMP sites. The decline of the CARICOMP seagrass beds in the mid 1990's was documented by the CARICOMP program. No anthropogenic influences have been identified that are likely to have contributed to the specific decline of this seagrass bed. We have considered this a lagoonal rather than a rim reef associated site, however, few of our measures distinguish it from PS20 and PS06, although it is somewhat shallower. Very sparse T. testudinum and S. filiforme are found at this site.

PS20 is the closest to PS06, located to the east of North Rock. It is somewhat shallower, about 10 m, and the sandy bottom is riffled and not highly bioturbated. There regularly found here, *Halodule* is sometimes found.

2. *Sites with high density grass in the western part of the platform*.

PS01 is located to the north and east of the Chub Head beacon, among reefs that coalesce further west to form a rim on the platform. There is a regular onshore flow of deep clear water, as at the previous locations, and water clarity is on average among the highest of all the monitoring sites. *T. testudinum*, *S. filiforme* and *Halodule* sp. form quite dense and extensive beds in this area.

PS02 is south of the Chub Head beacon and slightly further east than PS01. Of the offshore sites, this has the highest density grass beds. Water clarity is on average lower than at the other sites but this is also the shallowest of the offshore beds. The dense bed is bordered by a permanently grazed area of dense but very short *T. testudinum*. *T. testudinum*, *S. filiforme* and *Halodule* sp. form dense beds in this area. (Note: this site is grouped in a different cluster based on water quality characteristics, of which water clarity is probably of prime significance.)

3. Sites with low to moderate density grass in the western part of the platform

PS03 runs down a slope from about 3 meters to just over 10 meters depth. The shallow area is usually populated by *Halodule* sp; *Halodule* and sparse *Syringodium* are found along the slope and *H. decipiens* is found at the deep end of the slope. Water clarity at this site is quite good, similar to PS02, but the greater depth along the site transect probably limits seagrass density. There is no *Thalassia* at this site.

Group II

These are the nearshore sites and due to the various coastal influences this is a complex and diverse group of sites.

1. Higher probability of anthropogenic influences due to industry or medium to high residential coastlines

a. With moderately dense to dense seagrass, with medium to very poor water quality, shallow to very shallow depths

i. strongly P limited - with seagrass N:P ratios greater than 40

PS04 has moderately poor water clarity and fairly high seagrass cover, only *T. testudinum* occurs at this site. The ratio of N:P for *T. testudinum* is in the low 60's so that P is extremely limited relative to N; which could indicate an unusually high N availability. This site is located to the south of an abattoir and grazing area for a variety of domestic animals. Immediately adjacent to the abattoir is an ecotourism resort.

PS05 has poor water clarity characteristics. Nutrient impacts due to residences and development may in fact be low (possibly misclassified in this group) although the median N:P for *T. testudinum* is about 45. P availability is limiting; this could be due to very limited available P (related possibly to sediment type) or to relatively high levels of available N. Impacts in this grass bed are/have been physical – strong wave action. Exposure at these beds to wind driven waves from the southeast is quite high. *T. testudinum*, *S. filiforme* and *Halodule* sp. are all present in these moderately dense beds.

PS15 is also very shallow with very low water clarity and with high density grass beds. Only *T. testudinum* is found along the site transect line. The coastline around the bay is heavily developed with residential properties and there are many moorings in the bay, but there is no industrial development. N:P ratios for *T. testudinum* (median about 52.7) indicate significant P limitation.

ii. slightly P limited (potentially light limited) – with seagrass N:P ratios in the mid 30's

PS08 has relatively poor water clarity and is moderately deep, about 3 m. Although residential density appears to be low in the immediate area of the site, there is a major road along the adjacent coastline and an open water way to the Great Sound. N:P ratios for *T. testudinum* (median about 35) indicate that P availability is slightly limiting to growth and density but that light may also be a limiting factor. Cover of calcareous green algae is the highest for all the monitoring sites, which might suggest high nutrient (both N and P) availability. *T. testudinum* and *S. filiforme* are both present forming moderately dense beds.

PS09B is a very shallow site with very low water clarity and very high grass cover. *T. testudinum* and *S. filiforme* occur at this site, and there is a relatively dense population (for Bermuda) of the purple sea urchin, *Lytechinus purpuratus*. The small bay where the site is located is surrounded by a regularly watered and fertilized golf course. N:P ratios for *T. testudinum* (median about 34) indicate a fairly balanced supply of these nutrients, P is only slightly limiting. There is regular evidence of cool water seeping up from the bottom into the surface seawater but we have not measured consistently lower salinities at this site.

PS16 is moderately shallow, with moderate water clarity and medium dense seagrass beds. The bottom sediments are quite compact and both wave surge and tidal currents can be moderately strong in this area. *T. testudinum*, *S. filiforme* and *Halodule* sp all occur at this site. A dairy farm is located along the coast immediately west of the site. There is some P limitation, with a median N:P ratio for *T. testudinum* about 36.8.

b. With lower density seagrass

i. strongly P limited - with seagrass N:P ratios greater than 40

PS13 is located in a long semi-continuous bed running along the southern boundary of the North Lagoon. It is offshore of the site of the domestic garbage incinerator, which has a warm water outfall. These beds were studied during an impact assessment program before and after the installation of the outfall. Our permanent site is very near what was identified as the East Impact study in studies done in the mid 1990's. More recently, a reverse osmosis outflow has been installed adjacent to the site. *T. testudinum*, *S. filiforme* and *Halodule* sp are all found at this site. The N:P ratio for *T. testudinum* (median about 50) indicates P limitation at the site, even though water clarity is also moderately low and the site is of a moderate depth light is not the primary limit to the density of this seagrass.

ii. slightly P limited (potentially light limited) – with seagrass N:P ratios in the mid 30's

PS18 is at a small seagrass bed at an occasionally occupied island near the northwest shore of Harrington Sound. The apparent low cover of the seagrass at this site is due to the small size of the bed consisting of *T. testudinum* and *S. filiforme*. Water clarity is moderately low and seagrass is only found here at depths shallower than about 1.3 meters. Near the shoreline there is considerable shading by coastal "cliffs" and this is where the *S. filiforme* is found. The N:P ratio for *T. testudinum* indicates minor P limitation (median about 33); generally nutrients may be highly available in this location although the northwest shore of Harrington Sound has overall much lower density residential development than other parts of the Sound.

2. Anthropogenic impacts, for example nutrient input, not expected to be significant, other impacts such as physical disturbance may be significant either directly or through creating, for example, low light conditions

a. *with low to moderate density seagrass beds, dominated by S. filiforme, moderate water clarity*

PS09A is located near the mouth of Great Sound, off to the northwest. As a whole, this part of the Sound does not appear to be nutrient enriched, but direct experience at the site indicate that physical disturbance at depth may be common, passing boats and ferries create strong surges at depth. The median water clarity is fairly high and the site is of a moderate depth, just under 6 m. Only *S. filiforme* and *Halodule* sp are present at this site, and it is one of the most sexually active/productive *S. filiforme* beds we have found in Bermuda. The lower density of this healthy bed is a reflection of the absence of *T. testudinum*. The N:P ratio for *S. filiforme* (about 38), if assessed the same as has been done for *T. testudinum*, suggests some P limitation for this grass. The absence of *T. testudinum* may be indicative of low light levels at the bottom.

b. *with high density seagrass beds, poor light, very shallow*

PS17 is located in the shallow bay offshore of the southern beach at Clearwater Park. This is a well-used public swimming beach on the recovered lands of the former US Naval Air Base. There are no residences or industries along the immediate coastline and up until the past 20 years access to the area was highly controlled. This site is subjected to strong surge action when the winds are blowing from an easterly direction and the nearshore waters can become very turbid. The physical structure of the seagrass bed, with eroded terraces is related to the shallow depth of the beds and translation of wave energy to the sea bottom. *T. testudinum*, *S. filiforme* and *Halodule* sp are all present at this site; overall these beds have the second highest grass cover of the 17 monitoring sites. N:P ratios (median about 34) for *T. testudinum* suggest minor P limitation.

PS19 is located in the west side of Castle Harbour in the Walsingham National Marine Park. The Walsingham Tract, which is a nature reserve, is riddled with caves and low salinity ponds, some of which drain into Castle Harbour. Residential development is low density. Similar to **PS17**, this site can be affected by easterly winds and can be very turbid; water clarity is on average quite low. *T. testudinum*, *S. filiforme* and *Halodule* sp. are present in the dense beds at this site. N:P ratios for *T. testudinum* (median about 32) suggest minor limitation to growth due to P availability.

METHODS

Field protocols for water quality sampling

Water quality samples were collected by staff of the Bermuda Department of Conservation Services on a monthly basis, over a period of 1-3 days, from 17 permanent monitoring stations as described above (Fig. 1). The period of record of this report was from Sept. 2007 to Sept. 2012 which included 58 monthly sampling events. From September 2007 to present, salinity (practical scale salinity) was measured using a YSI 30 handheld salinity, temperature and conductivity instrument. Dissolved oxygen (DO) was measured using a YSI 550A handheld instrument. Exceptions are dates during which an instrument had been sent away for maintenance. DO (mg l_{-1}) was automatically corrected for temperature (value measured by the instrument), ambient salinity (value manually entered into the instrument) and altitude (value manually entered into the instrument). The YSI salinity instrument was calibrated quarterly (or more frequently), single point, using YSI 3169 conductivity calibrator solution, 50,000 µS. The YSI 550A DO instrument was calibrated in % saturation mode (1 point) each day it was used. These were all surface readings (probe suspended at about 20-30 cm below the water surface).

From June 2008, salinity (practical salinity scale), temperature (^{O}C) (YSI 6560 conductivity/temperature probe), and dissolved oxygen (mg l^{-1}) (YSI 6150 ROX optical dissolved oxygen sensor) were also measured using a YSI 650 MDS with YSI 600 XL sonde. DO was automatically corrected for salinity, temperature and barometric pressure (value in mm manually entered into the instrument daily). The salinity probe was calibrated at least quarterly, single point, using YSI 3169 conductivity calibrator solution, 50,000 µS. Additional calibrations were done when a notable difference between the YSI 550A and the sonde probe was apparent. The DO sensor was calibrated in % saturation mode (1 point) each day of use. From February 2009, pH (YSI 6561 pH probe) was also measured using the YSI sonde system. Two point calibrations, YSI pH 7.00 and 10.00 standards, were done approximately quarterly. Field readings using the sonde system were done at approximately 1 m and at the bottom. Only the 1 m readings are included in this report. Secchi depth (m) was measured as well as water column depth (m) and % Secchi depth relative to water depth was calculated.

Water was collected directly into pre-acidified 250 ml HDPE sample bottles. For chlorophyll *a* (CHLA), 140 ml of water was collected via syringe and filtered by hand through 25 mm Whatman GF/F glass fiber filters. The filters were then placed in 1.8 ml plastic centrifuge tubes, capped, and kept frozen in a dark Nalgene bottle until analysis. Turbidity was measured using a Hach portable turbidimeter model 2100P and reported in NTU.

Laboratory Analysis

Unfiltered water samples were analyzed for total organic carbon (TOC), total nitrogen (TN), total phosphorus (TP), silicate (SiO_2), and turbidity. TOC was measured by direct injection onto hot platinum catalyst in a Shimadzu TOC-5000 after first acidifying to pH<2 and purging with CO^{2-} free air. TN was measured using an ANTEK 7000N Nitrogen Analyzer using O_2 as carrier gas to promote complete recovery of the nitrogen in the water samples (Frankovich and Jones 1998). TP was determined using a dry ashing, acid hydrolysis technique (Solórzano and Sharp 1980). SiO_2 was measured using the molybdosilicate method (Strickland and Parsons 1972). Filtrates were analyzed for nitrate+nitrite (NO_x^-), nitrite (NO_2^-), ammonium (NH_4^+), and soluble reactive phosphorus (SRP) by flow injection analysis (Alpkem model RFA 300, APHA 1999).

Filters for CHLA (µg l^{-1}) to which 1.5 ml of 90% acetone/water were added (Strickland and Parsons 1972) were allowed to extract for a minimum of 2 days at -20° C before analysis. Extracts were analyzed using a Gilford Fluoro IV Spectrofluorometer (excitation = 435 nm, emission = 667 nm). All analyses were completed within 28 days after receipt in accordance to SERC laboratory QA/QC guidelines. Turbidity measurements were completed within 12 hours of sample collection. Some parameters were not measured directly, but were calculated by difference. Nitrate (NO_3^-) was calculated as NO_x^- - NO_2^-, dissolved inorganic nitrogen (DIN) as NO_x^- + NH_4^+, and total organic nitrogen (TON) defined as TN - DIN. All concentrations are reported as µM unless noted. All elemental ratios discussed were calculated on a molar basis. Percent DO saturation in the water column (DO_{sat}) was calculated using the equations of Garcia and Gordon (1992).

Data handling

<u>Cluster Analysis</u>

Stations were stratified according to water quality characteristics (i.e. physical, chemical, and biological variables) using a multivariate statistical approach. Multivariate statistical techniques have been shown to be useful in reducing large data sets into a smaller set of independent, synthetic variables that capture much of the original variance. Briefly, data were first standardized as Z-scores prior to analysis to reduce artifacts of differences in magnitude among variables. Both the mean and SD of the data for each station over the entire period of record were then used as independent variables in a hierarchical cluster analysis (Ward method) in order to aggregate stations into groups of similar water quality.

<u>Box and Whisker Plots</u>

Typically, water quality data are skewed to the left (predominance of low concentrations and below detects) resulting in non-normal distributions. Therefore it is more appropriate to use the median as the measure of central tendency because the mean is inflated by high outliers (Christian et al. 1991). Data distributions of water quality variables are reported as box and whiskers plots. The box-and-whisker plot is a powerful statistic as it shows the median, range, the data distribution as well as serving as a graphical, nonparametric ANOVA. The center horizontal line of the box is the median of the data, the top and bottom of the box are the 25^{th} and 75th percentiles (quartiles), and the ends of the whiskers are the 5th and 95th percentiles. The notch in the box is the 95% confidence interval of the median. When notches between boxes do not overlap, the medians are considered significantly different. Outliers (<5th and >95^{th} percentiles) were excluded from the graphs to reduce visual compression. Differences in Variables were also tested between groups using the Wilcoxon Ranked Sign test (comparable to a t-test) and among groups by the Kruskall-Wallace test (ANOVA) with significance set at $P<0.05$.

Time Series Analysis

Individual site data for the complete period of record were plotted as time series graphs to illustrate any temporal trends that might have occurred over the period of record (Appendix 1). Additionally, linear regression slopes and probabilities were calculated for each variable as a function of time as a proxy for secular trend (Appendix 2).

Web Site Development

We developed and maintain a website (serc.fiu.edu/wqmnetwork/BERMUDA/home.html) where anyone can download 1) all data from the program, 2) the interpretive reports, and 3) Google maps of all measured variables, by month, in classified post style. These website structure and components will be transferred to the BDCS.

RESULTS & DISCUSSION

Overall Conditions

Summary statistics for all water quality variables from all 58 sampling events are shown as median, minimum, maximum, and number of samples (Table 1). Overall, coastal waters in the region were warm and euhaline with a median temperature of 22.6 °C and salinity of 36.7; dissolved oxygen in the water column (DO) was high at 7.6 mg l^{-1}. On this coarse scale, the Bermuda coastal waters exhibited good water quality with median NO_3^-, NH_4^+, and TP concentrations of 0.26, 1.09, and 0.123 µM, respectively. NH_4^+ was the dominant DIN species in almost all of the samples (86%).

However, DIN comprised a small fraction (7%) of the TN pool with TON making up the bulk (median 9.83 µM or 93% of TN). SRP concentrations were low (median 0.04 µM) and comprised 38% of the TP pool. CHLA concentrations were also very low overall (0.20 µg l^{-1}) but ranged from 0.02 to 2.79 µg l^{-1}. Median TOC was 106 µM with DOC making up 96% of the pool. These values are slightly higher than open ocean levels but consistent with coastal areas. Median turbidity was low (0.52 NTU) as reflected in a high Secchi:water column depth (99%). Molar ratios of N to P suggested a strong P limitation of the water column (median TN:TP = 96.0) but this must be tempered by the fact that much of the TN may not be bioavailable.

Spatial Clustering

Cluster analysis of water quality variables by site resulted in 4 groups (Fig. 2) which had distinct characteristics in water quality (Fig 3). **Cluster 1** (in red) was composed of stations 9B, 15, and 16, which are those sites most strongly affected by anthropogenic nutrient inputs as indicated by their high levels of N species, TP, TOC, DOC Si, and N:P. Interestingly, this cluster also showed high DO and medium CHLA levels. **Cluster 2** (in yellow) included a mix of stations on the SW and NE part of the platform (#2, 4, 5, 8, 9A, 17, & 19). These sites exhibited lower nutrients (N, P, Si), DO and CHLA than Cluster 1. **Cluster 3** (in green) was composed of far offshore sites out on the western platform (#1, 3, 6, 7, & 20). These stations had the lowest nutrient, CHLA, DO, and turbidity and greater water column depth. Salinity was also the most invariable at these sites. **Cluster 4** (in blue) consisted of only one site, station #18 off Trunk Island, but it was so different than any of the other sites that it had to be treated separately. It had the highest nutrient and CHLA concentration, and the lowest salinity among sites in the monitoring network which may be due to its location within an enclosed bay. The low salinity reflects a source of terrestrial freshwater from either runoff or outfall and the enclosed nature of the bay means that water residence time is probably higher than other areas. Longer water residence time allows more nutrients to be incorporated into phytoplankton biomass; hence the high CHLA levels at this site.

TABLE 1: *Descriptive compositional statistics for Bermuda's coastal water quality*

Descriptive Statistics

	NOx(uM)	NO3(uM)	NO2(uM)	NH4 (uM)	TN(uM)	TIN(uM)
Mean	0.48	0.46	0.02	1.44	17.04	1.92
Std. Dev.	0.69	0.69	0.01	1.29	20.45	1.45
Count	984	982	984	984	984	984
Minimum	0.01	0.01	0.00	0.06	3.30	0.19
Maximum	14.55	14.52	0.25	10.03	179.73	15.12
Median	0.29	0.27	0.02	1.10	11.75	1.54

	TON(uM)	TP(uM)	SRP(uM)	TOC(uM)	DOC(uM)	Si(uM)
Mean	15.15	0.14	0.05	108.64	103.37	0.25
Std. Dev.	20.61	0.07	0.04	22.74	21.30	0.33
Count	982	984	982	984	984	967
Minimum	0.02	0.02	0.00	57.75	53.75	0.00
Maximum	178.93	1.47	0.72	227.92	197.33	2.29
Median	9.84	0.12	0.04	106.00	101.25	0.11

	CHLA(ug/l)	TEMP(oC)	SAL(psu)	DO(mg/l)	TURB(NTU)	pH
Mean	0.24	23.28	36.70	7.50	0.57	8.06
Std. Dev.	0.18	4.01	0.22	0.83	0.27	0.25
Count	866	1019	1020	983	1015	680
Minimum	0.00	15.05	36.00	5.29	0.16	6.67
Maximum	2.79	31.25	37.50	12.11	2.70	8.50
Median	0.21	22.60	36.70	7.56	0.53	8.12

	SECCHI (m)	DEPTH (m)	TN:TP	N:P	TS	%SAT-S
Mean	3.63	3.90	138.51	57.73	-0.08	107.61
Std. Dev.	2.50	3.00	169.74	76.90	0.03	10.44
Count	984	1020	983	981	986	983
Minimum	0.37	0.37	10.73	2.03	-0.13	55.36
Maximum	13.44	13.44	1932.75	846.11	0.09	178.74
Median	2.96	2.99	96.04	36.15	-0.07	106.92

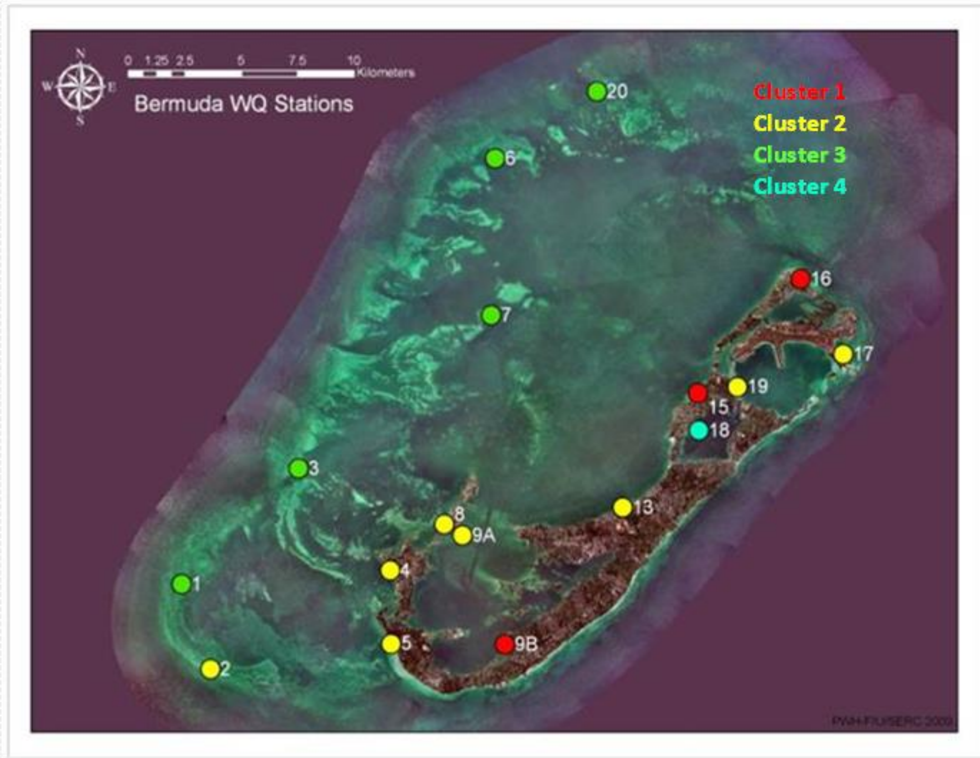


Figure 2. *Google-Earth image showing stations as clustered by water quality conditions.*

Trend Analysis

Measured water quality variables were plotted with time to observe seasonal differences, episodic effects, partial tendencies and secular trend during the five year of monitoring (Appendix 1). Additionally, the slopes of linear regressions of water quality on time were also calculated to express potential secular trends (Appendix 2). The percentage of variables that experienced significant change, out of the 17 water quality variables considered, was calculated and the results are shown in Figure 4. Stations 5, 6 and 2 were the ones which suffered more significant changes and station 8, 16 and 17 the least. Figure 5 differentiates stations with mostly positive changes (e.g. decline nutrient concentration) in water quality (yellow bubbles) from those with mostly negative changes (white bubbles). Results suggest that stations close to shore have continued to become degraded as compared to those away from land and urban development.

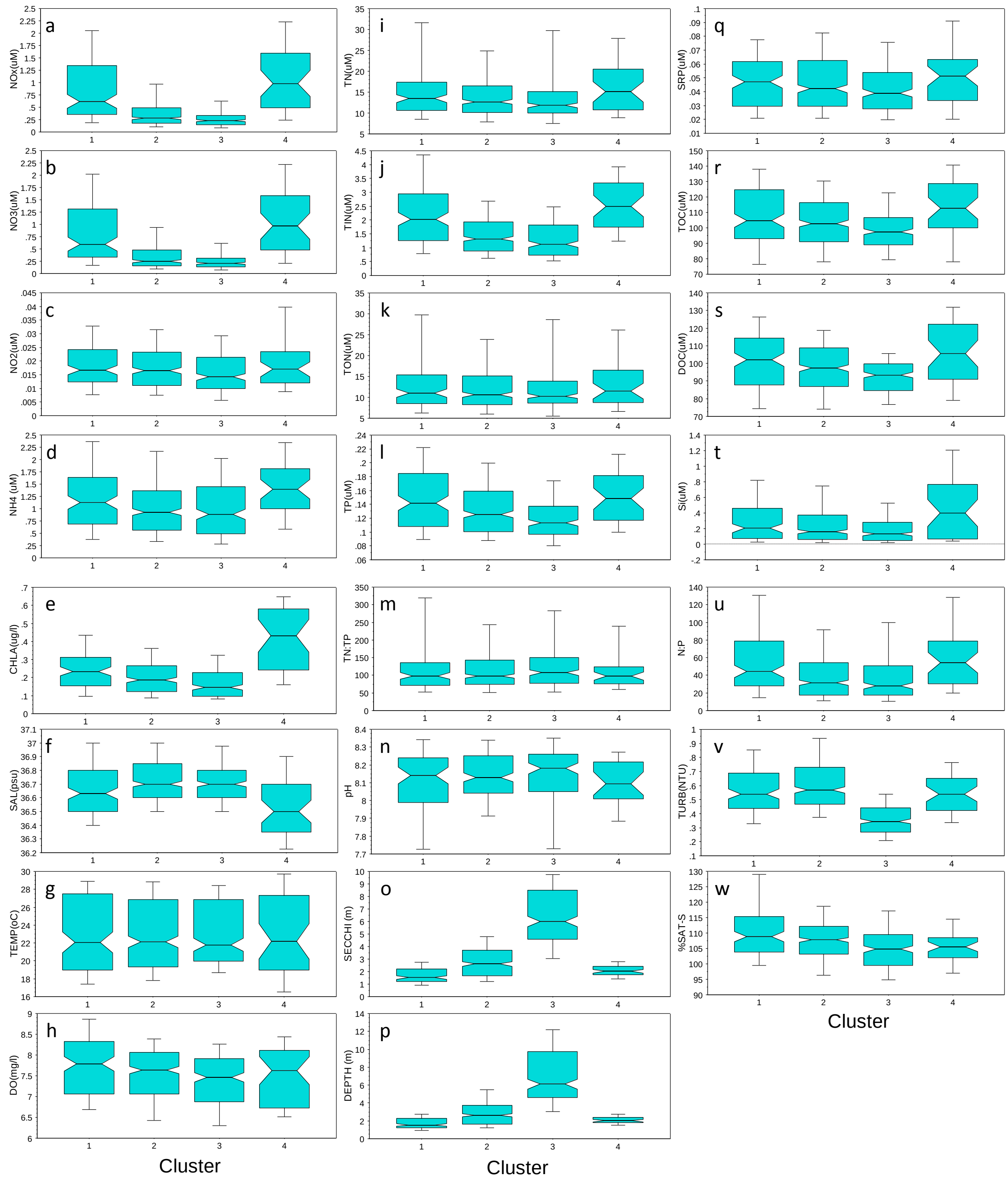


Figure 3: *Box-and-whisker plots for water quality variables in biogeochemical clusters*

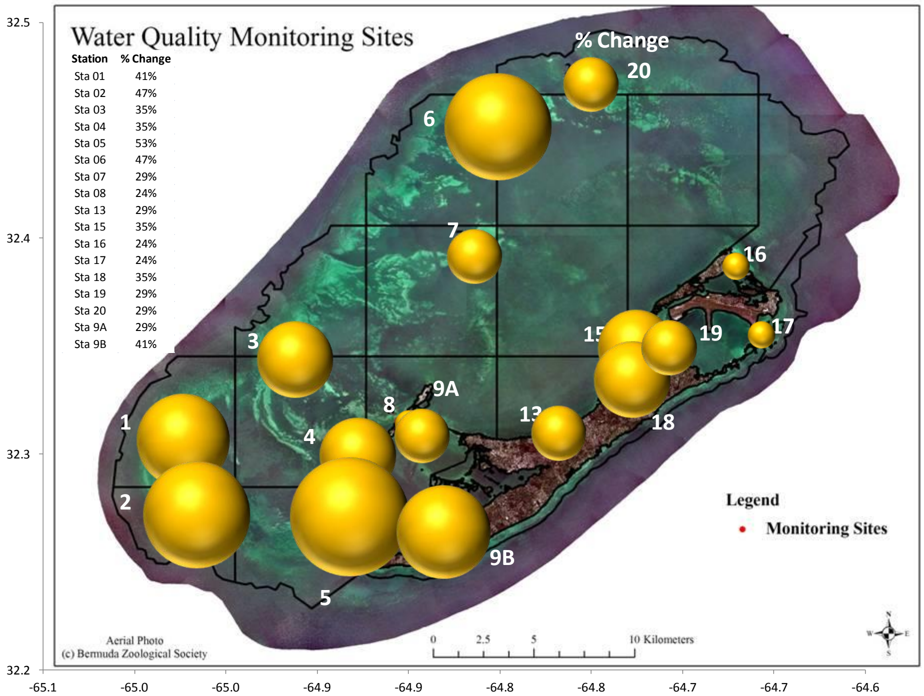


Figure 4: Percentage of WQ variables experiencing significant change (p<0.1)

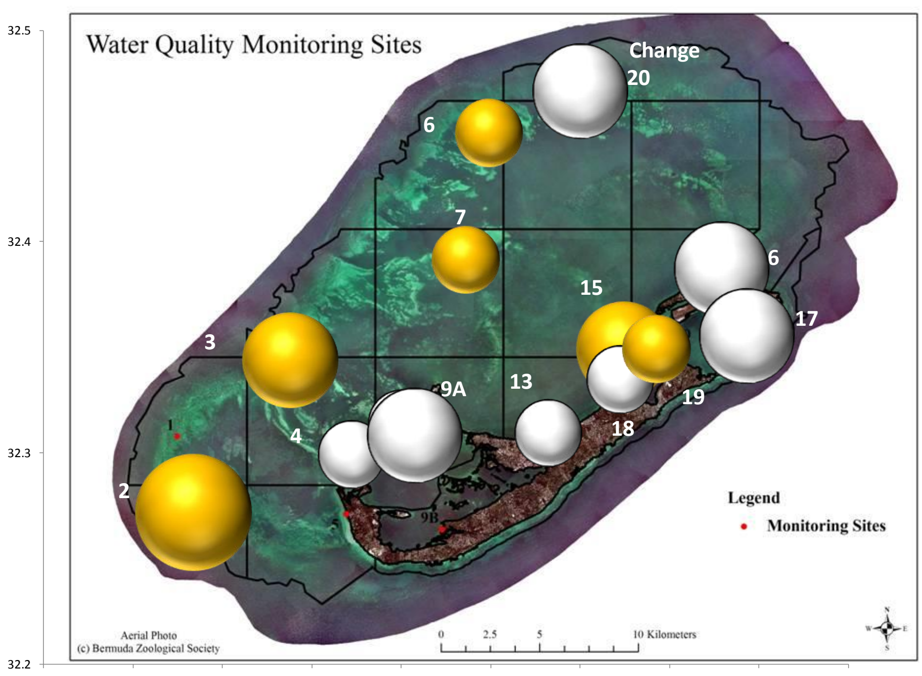


Figure 5: *Stations displaying mostly positive changes (getting "better", yellow) and mostly negative changes (getting "worse", white) in water quality*

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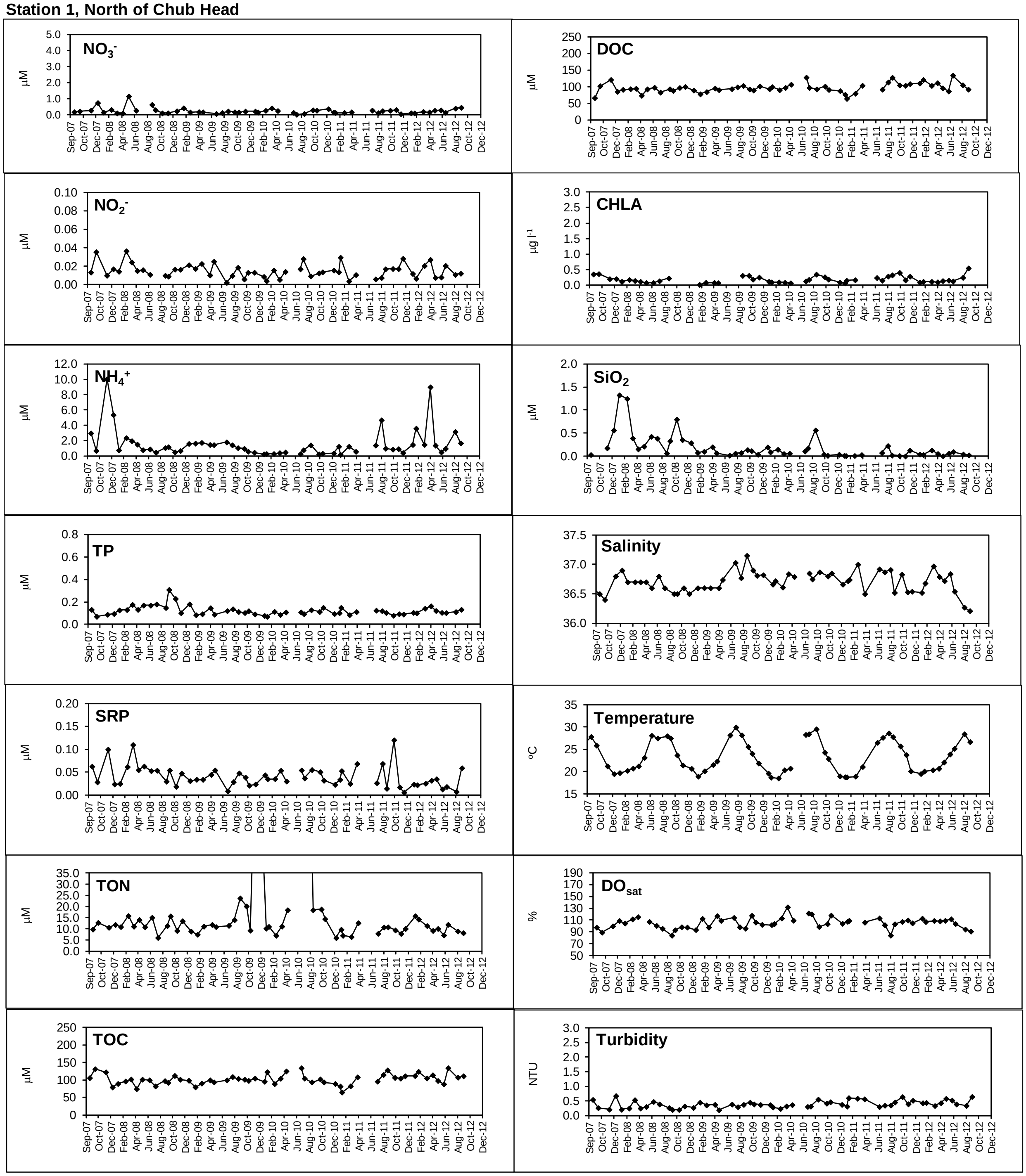
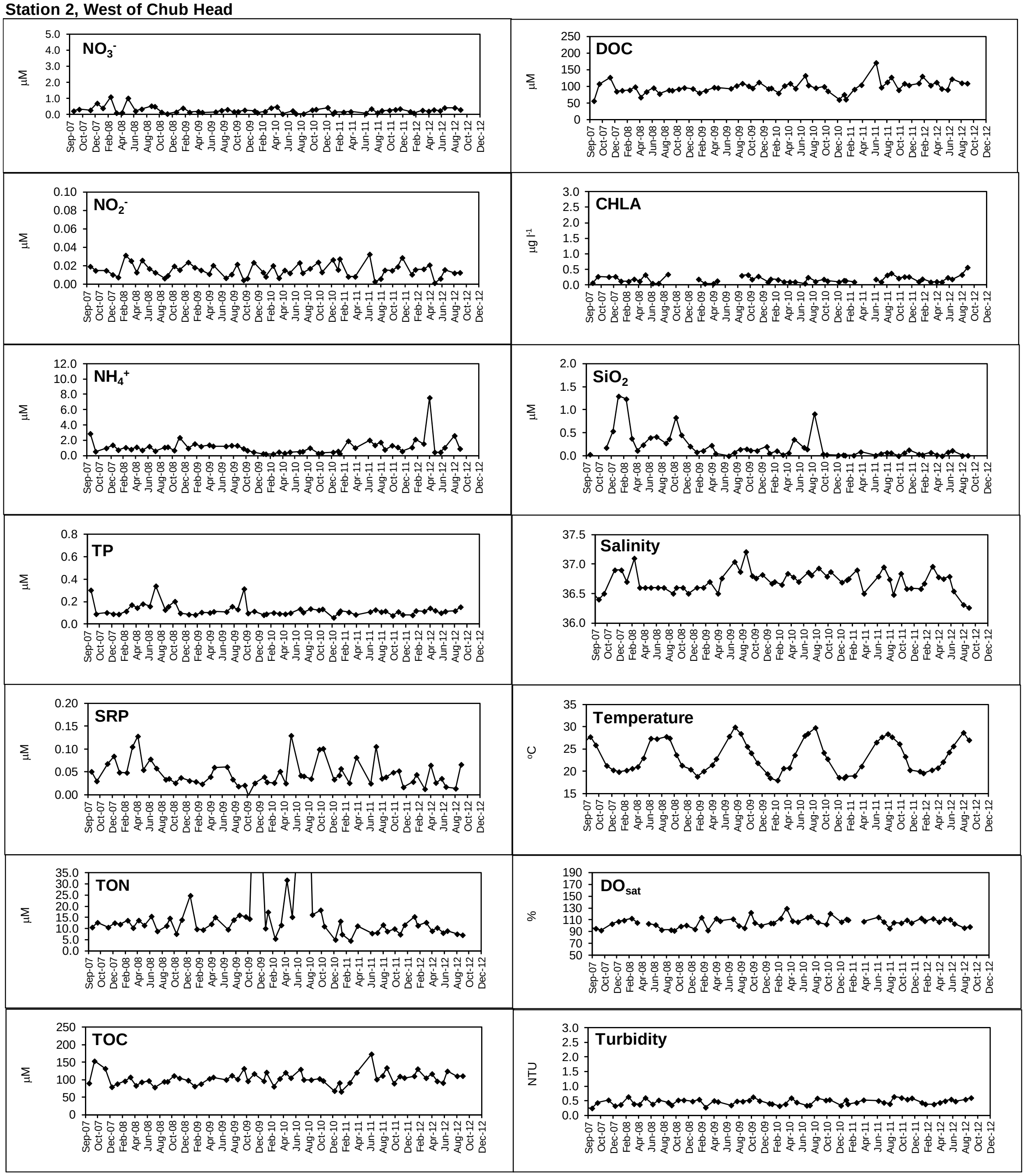
APPENDIX 1

TIME-SERIES OF BIOGEOCHEMICAL VARIABLES

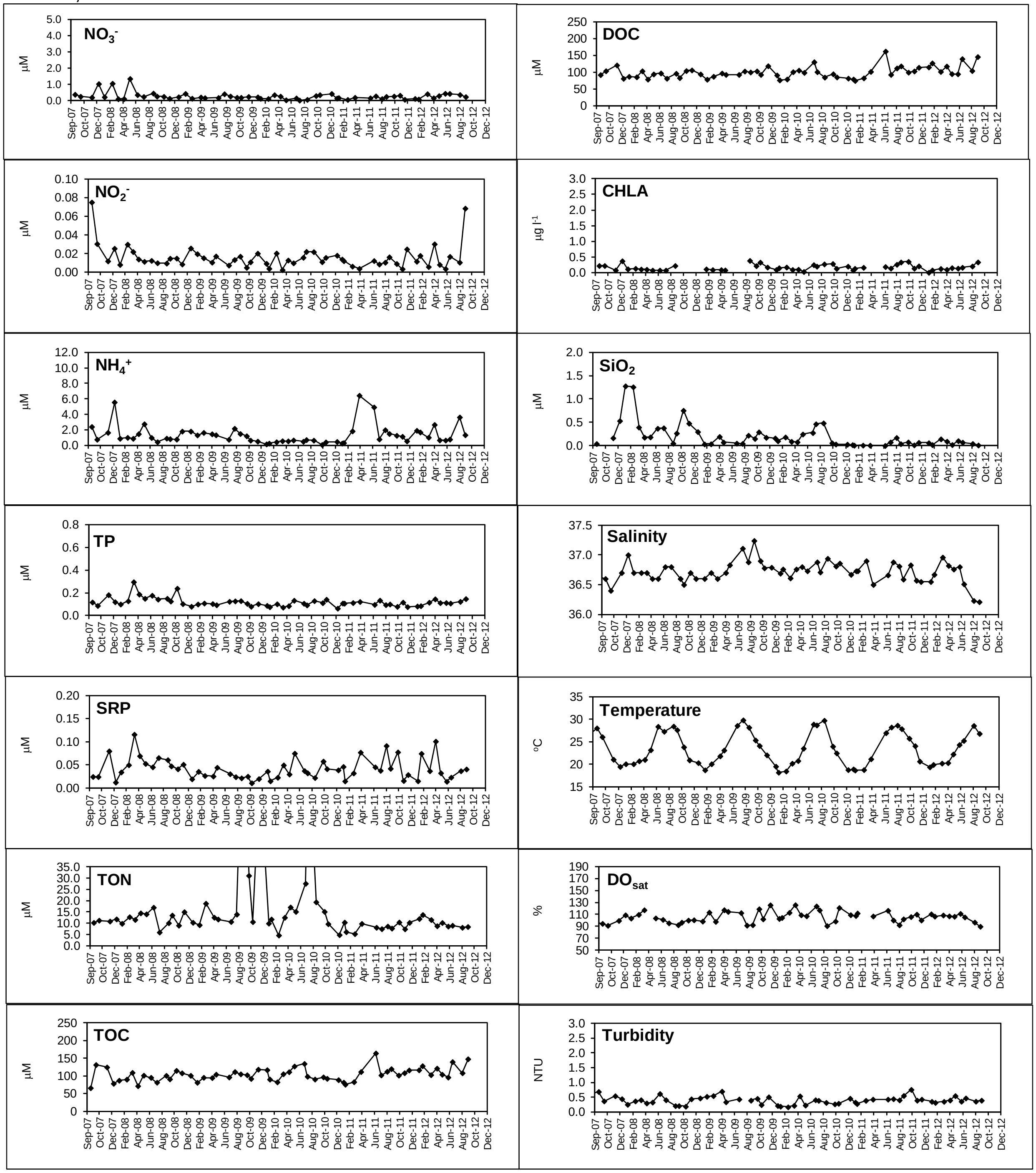
Station 1, North of Chub Head



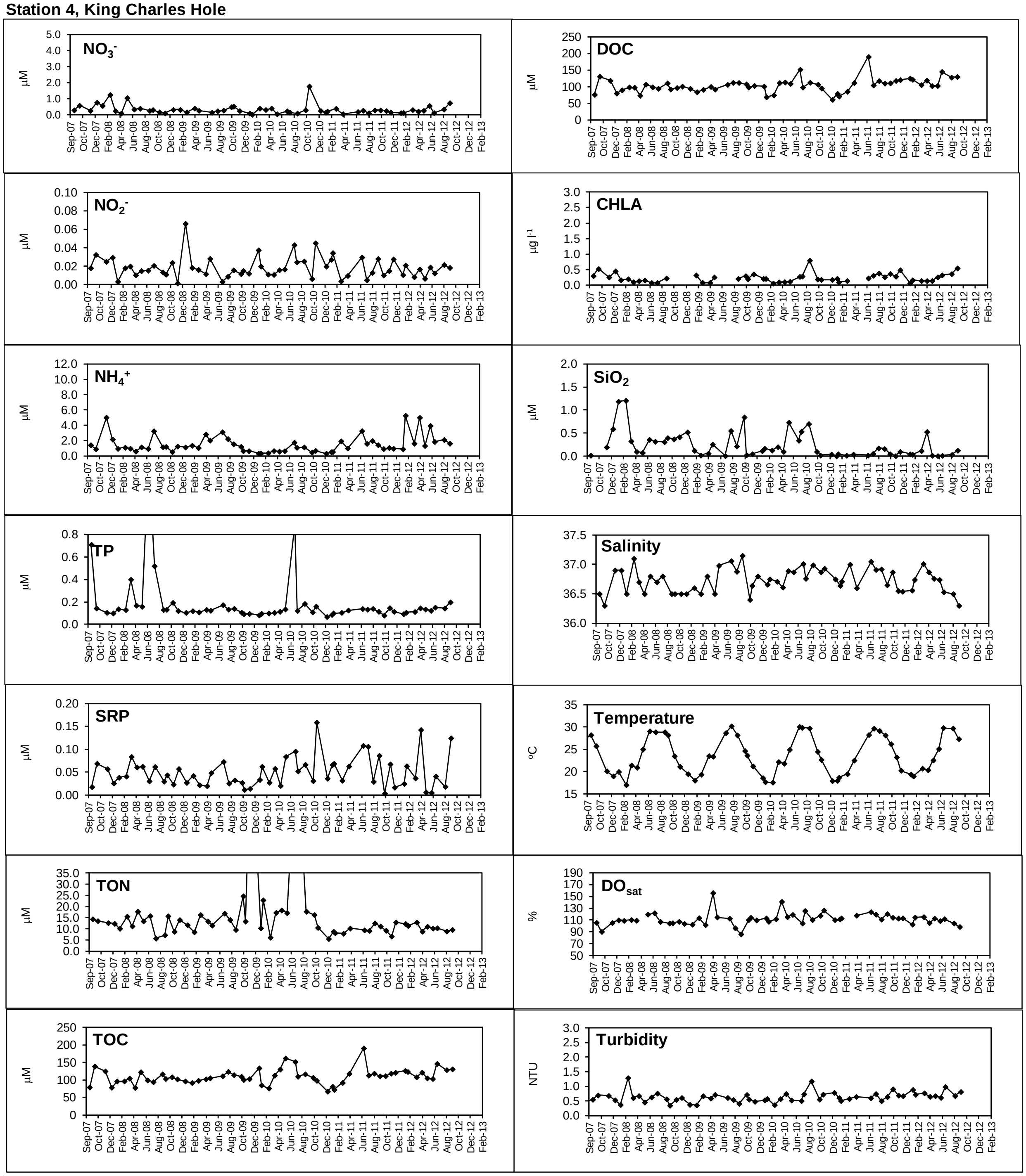
Station 2, West of Chub Head



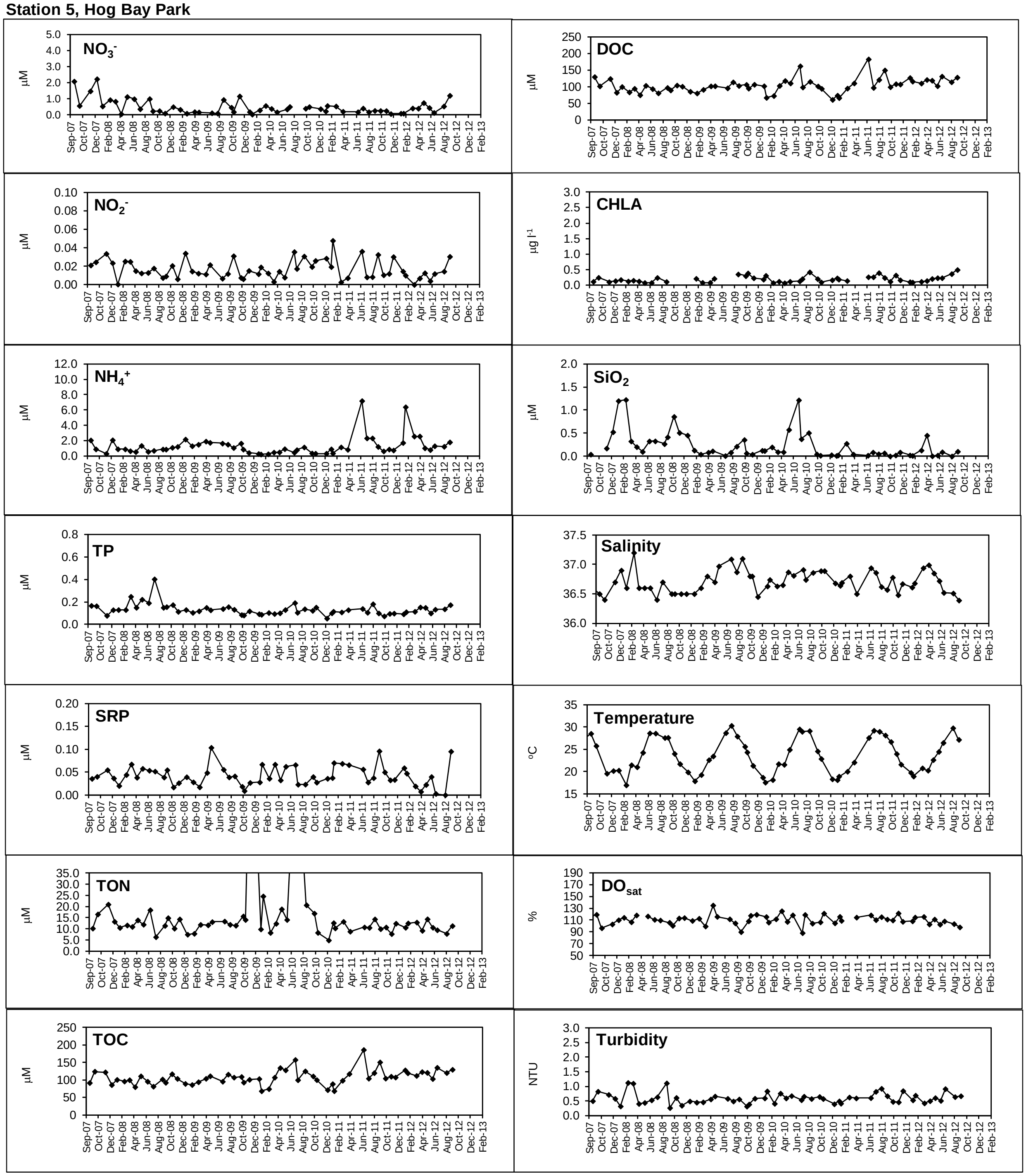
Station 3, Western Blue



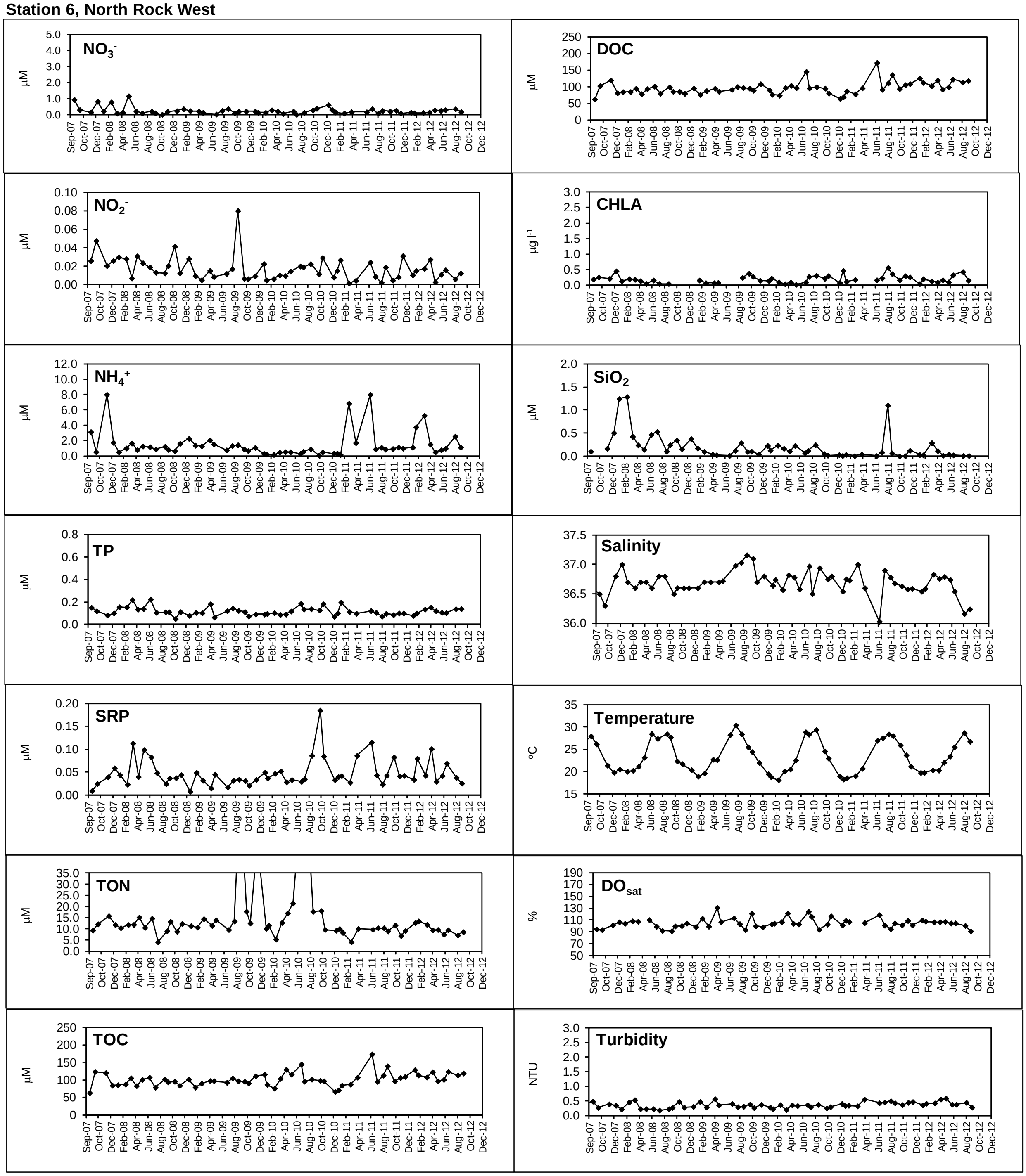
Station 4, King Charles Hole



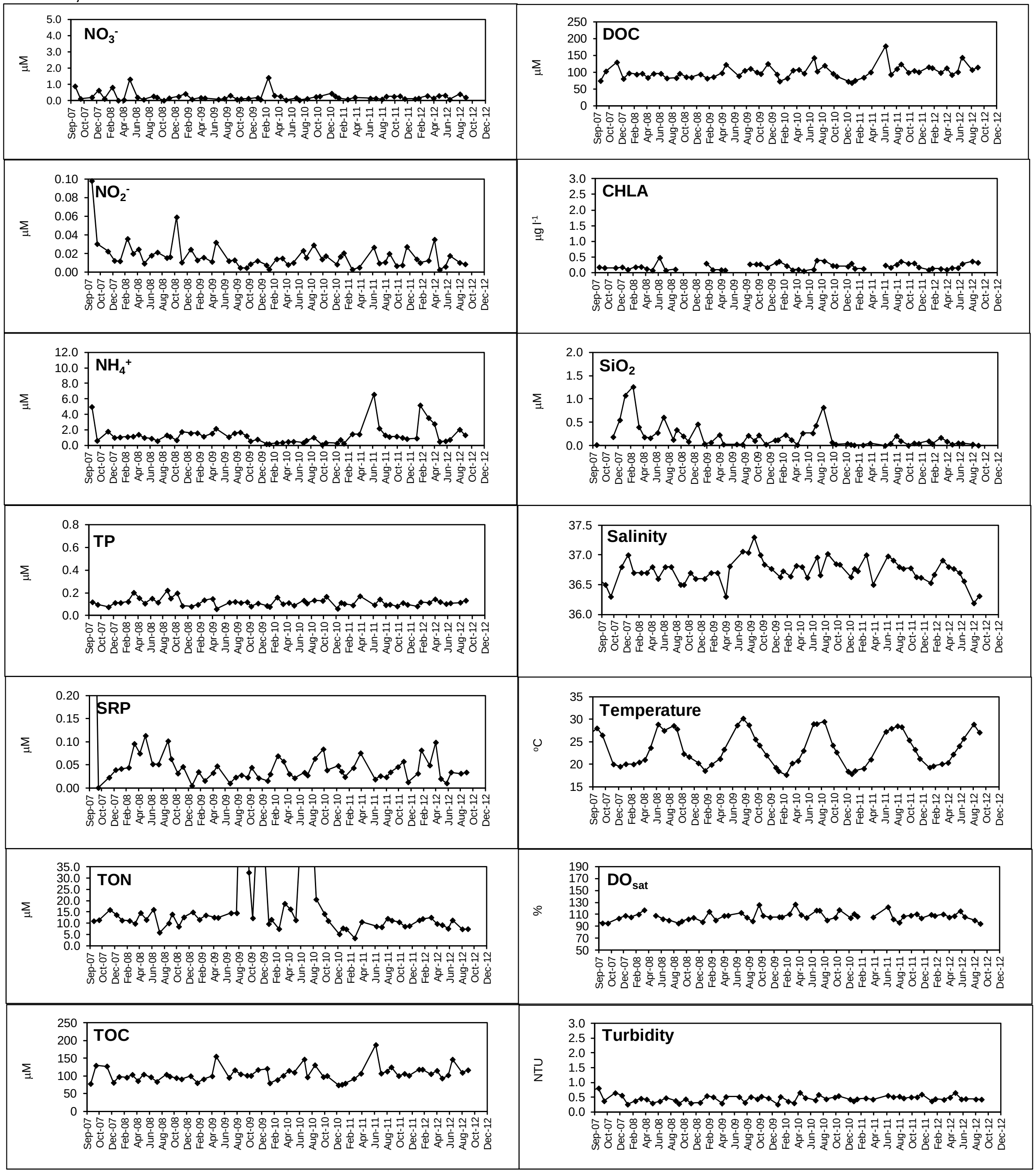
Station 5, Hog Bay Park



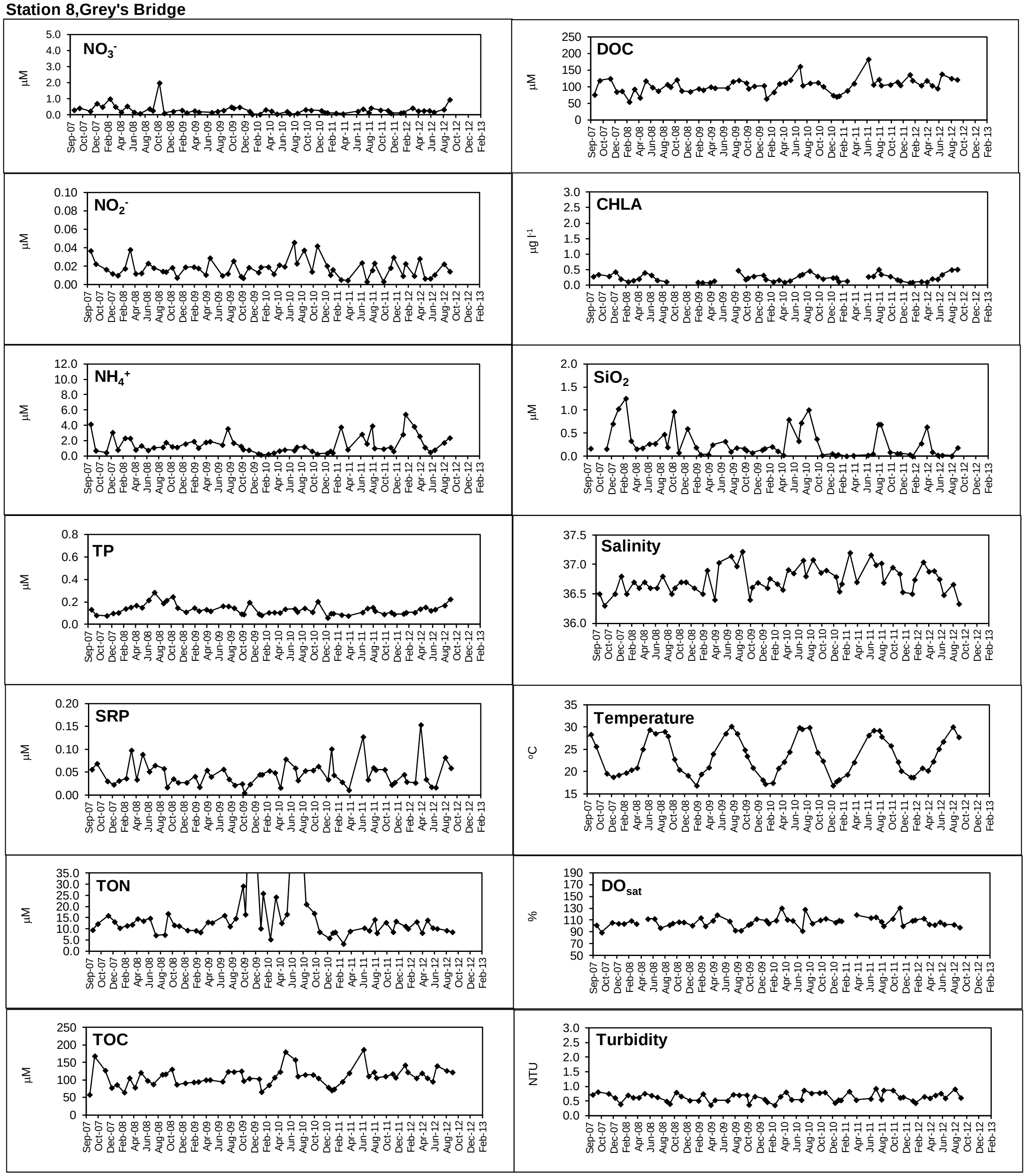
Station 6, North Rock West



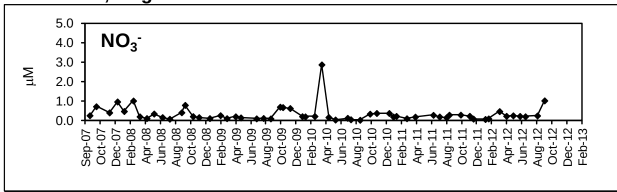
Station 7, Crescent West

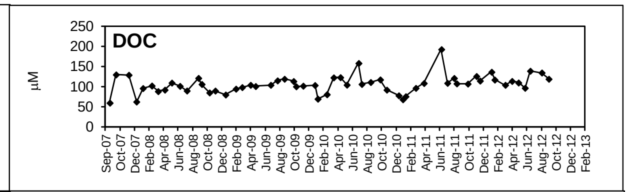


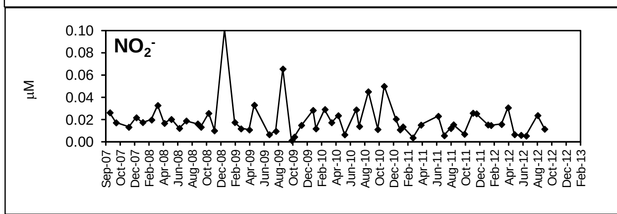
Station 8,Grey's Bridge

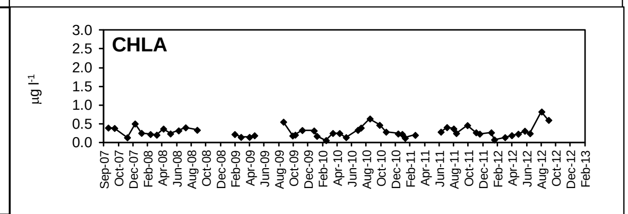


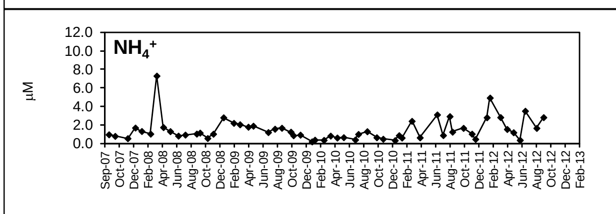
Station 9A, Regatta Island

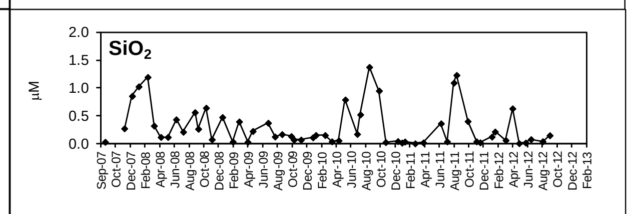


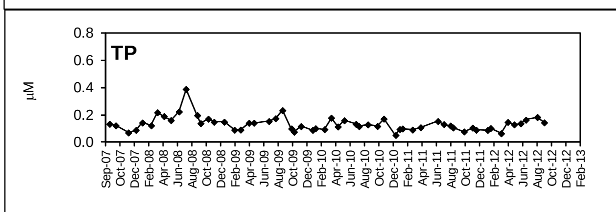


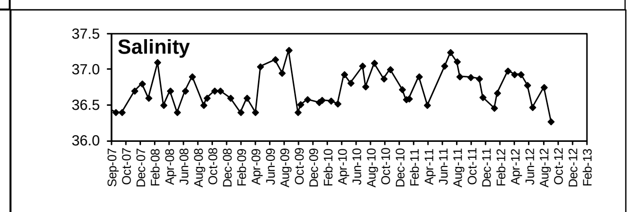


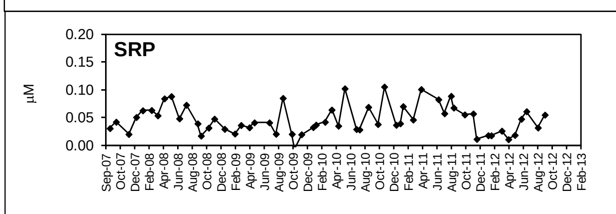


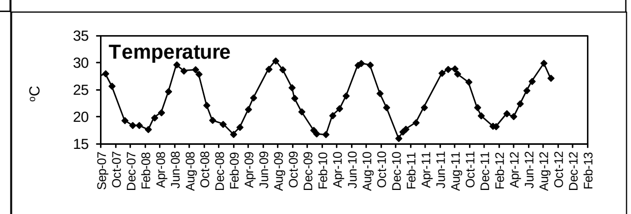


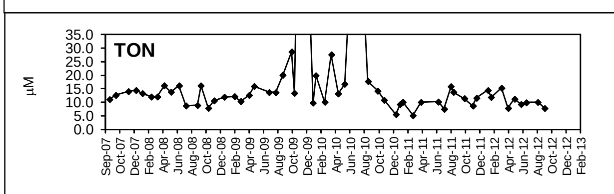


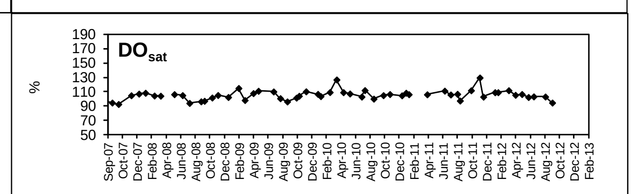


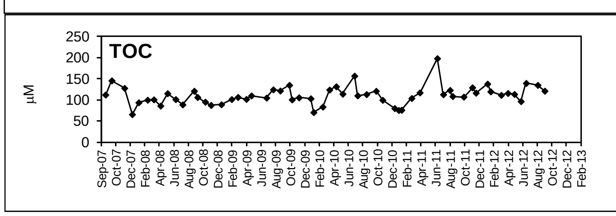


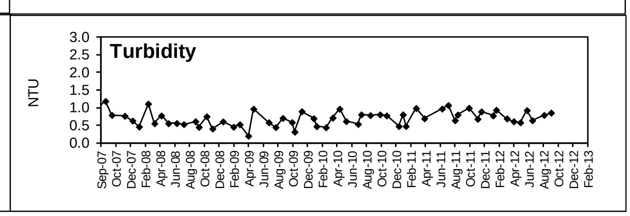




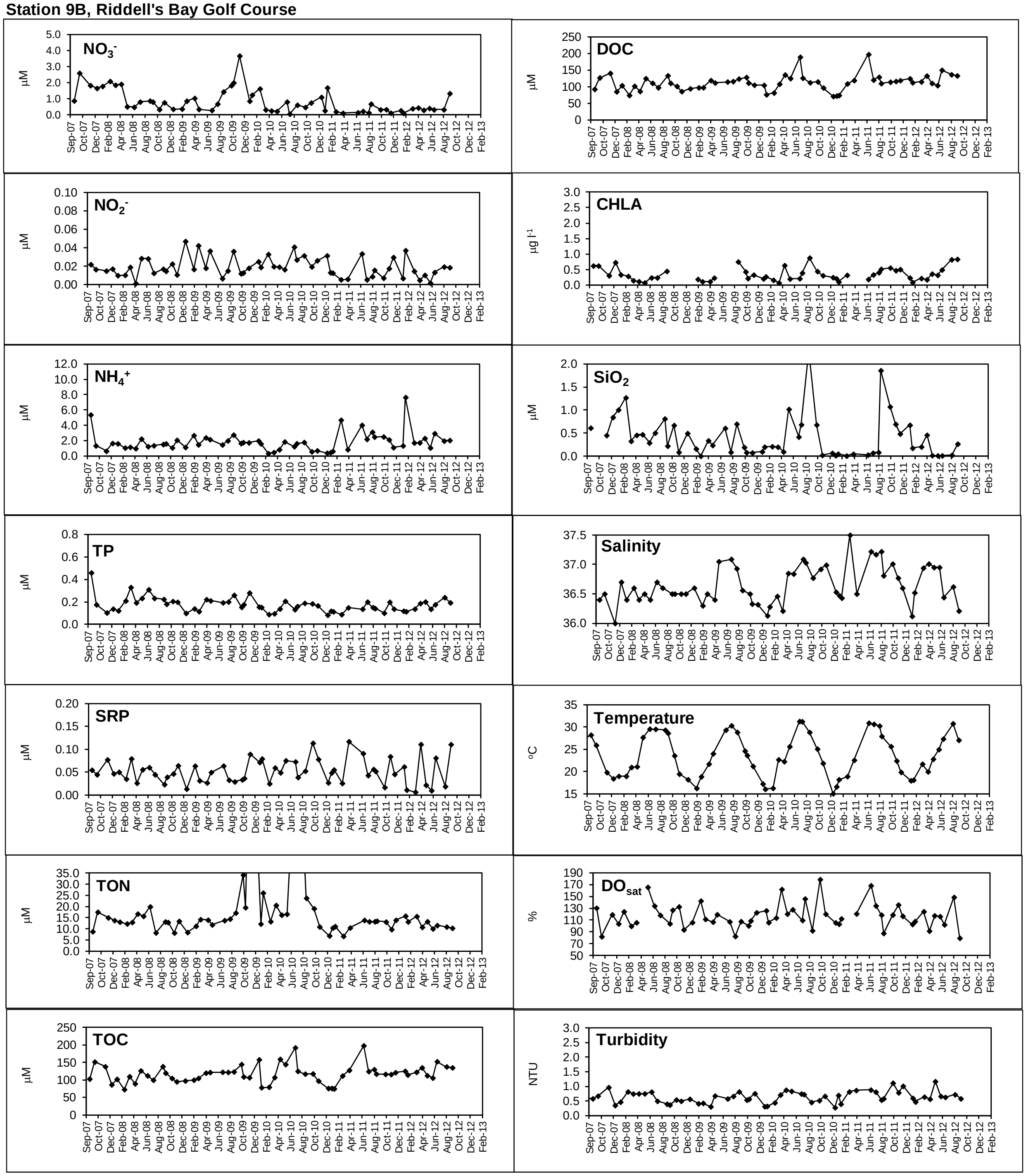




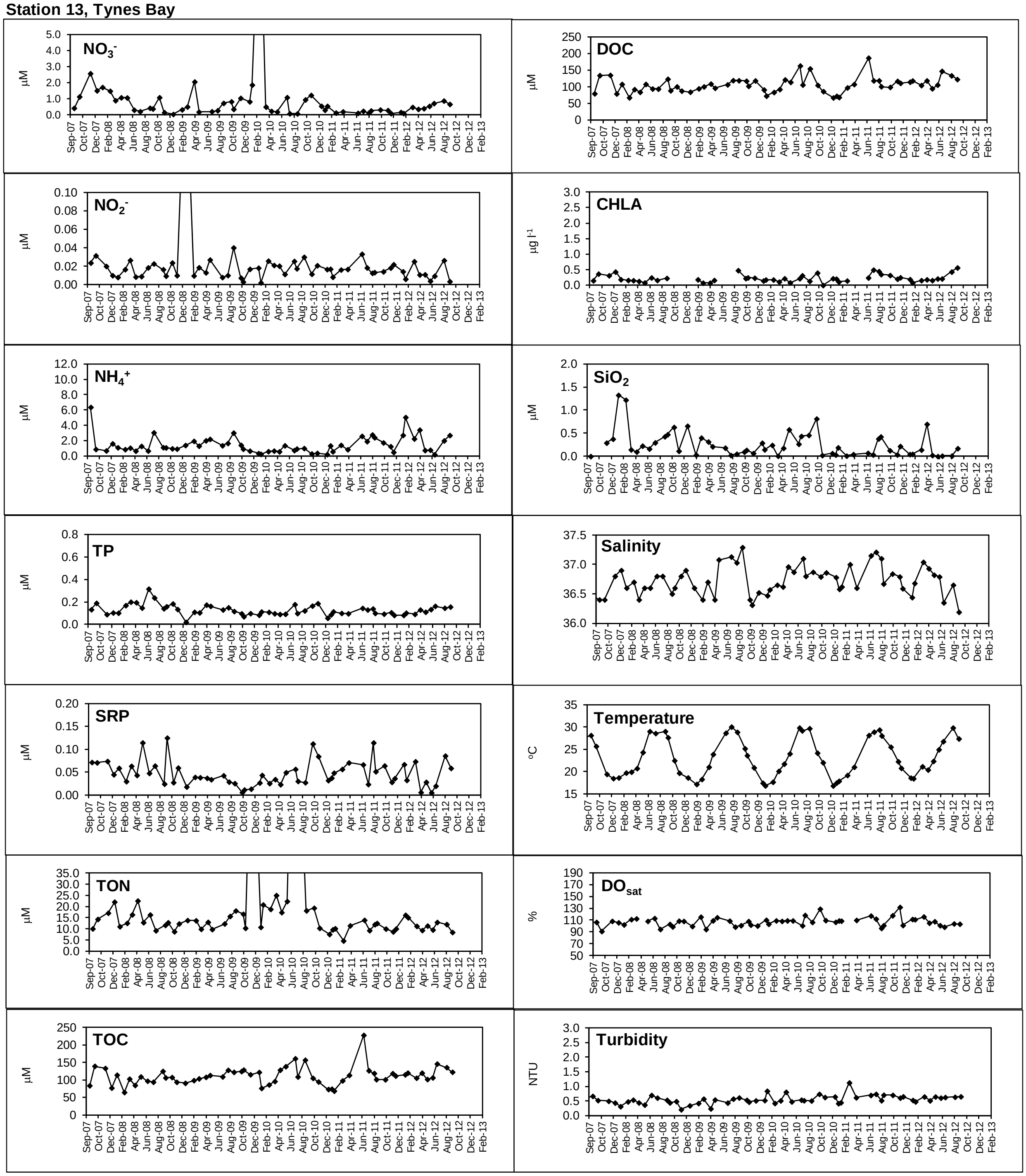




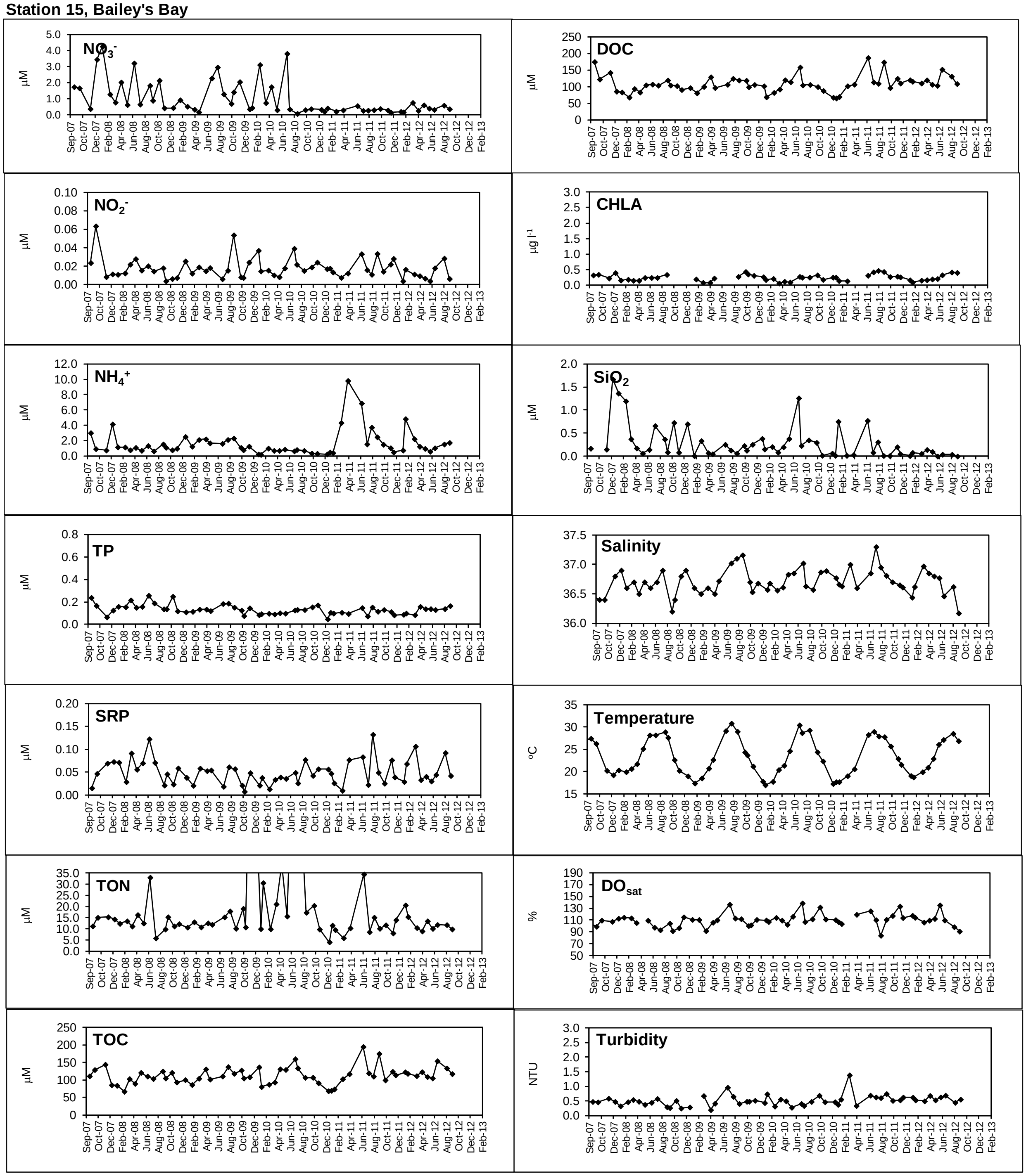
Station 9B, Riddell's Bay Golf Course



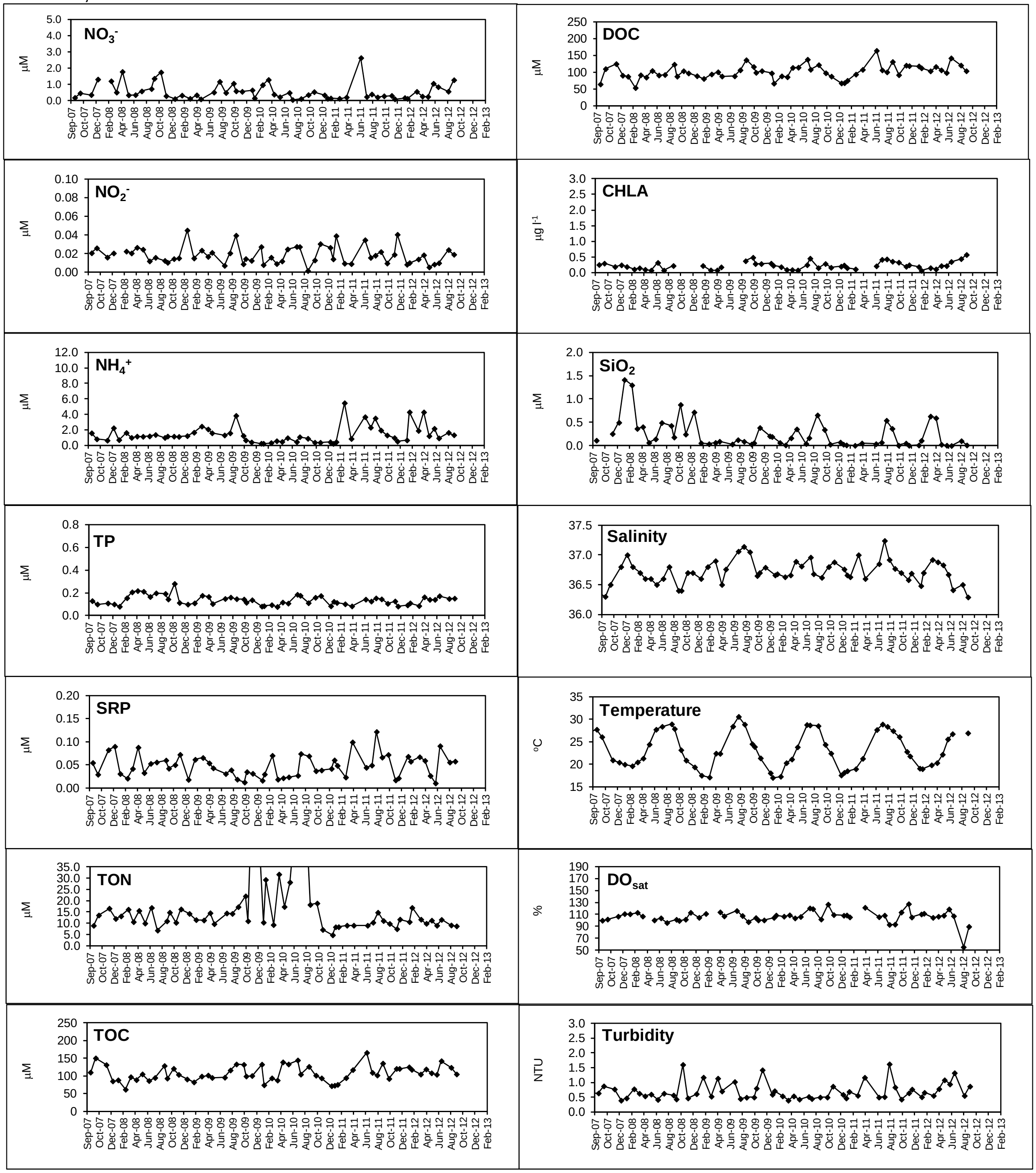
Station 13, Tynes Bay



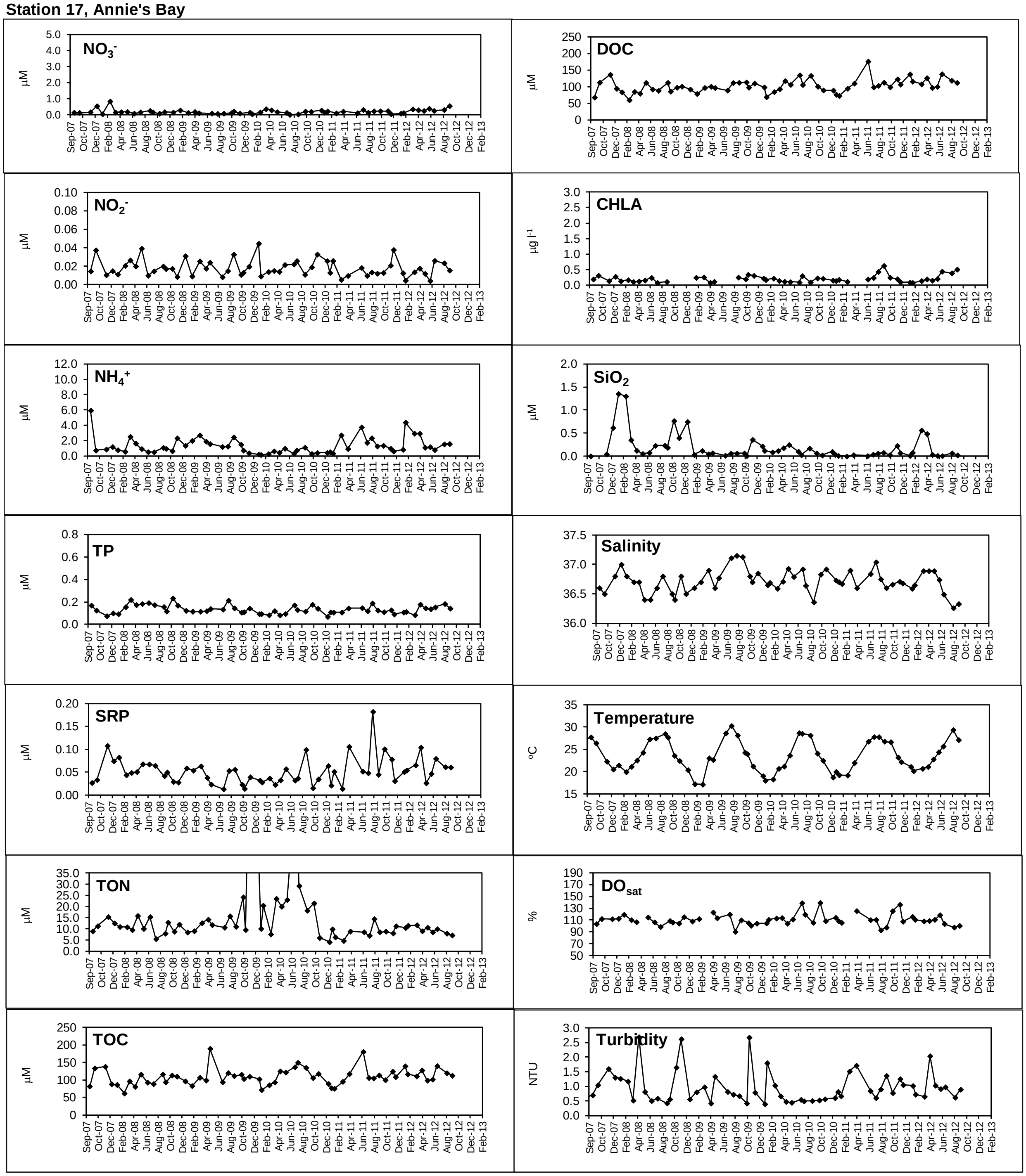
Station 15, Bailey's Bay



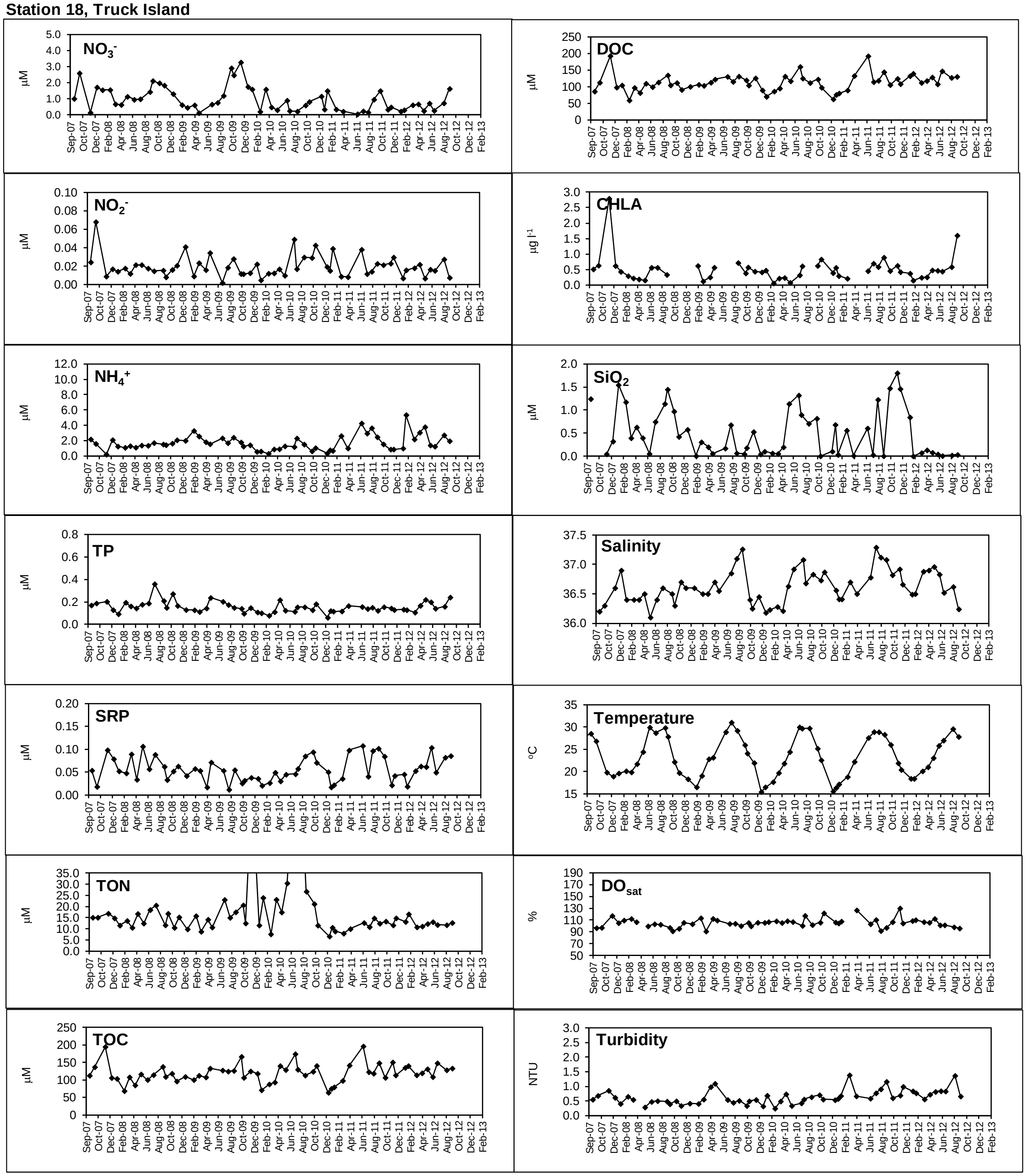
Station 16, Fort St. Catherine's



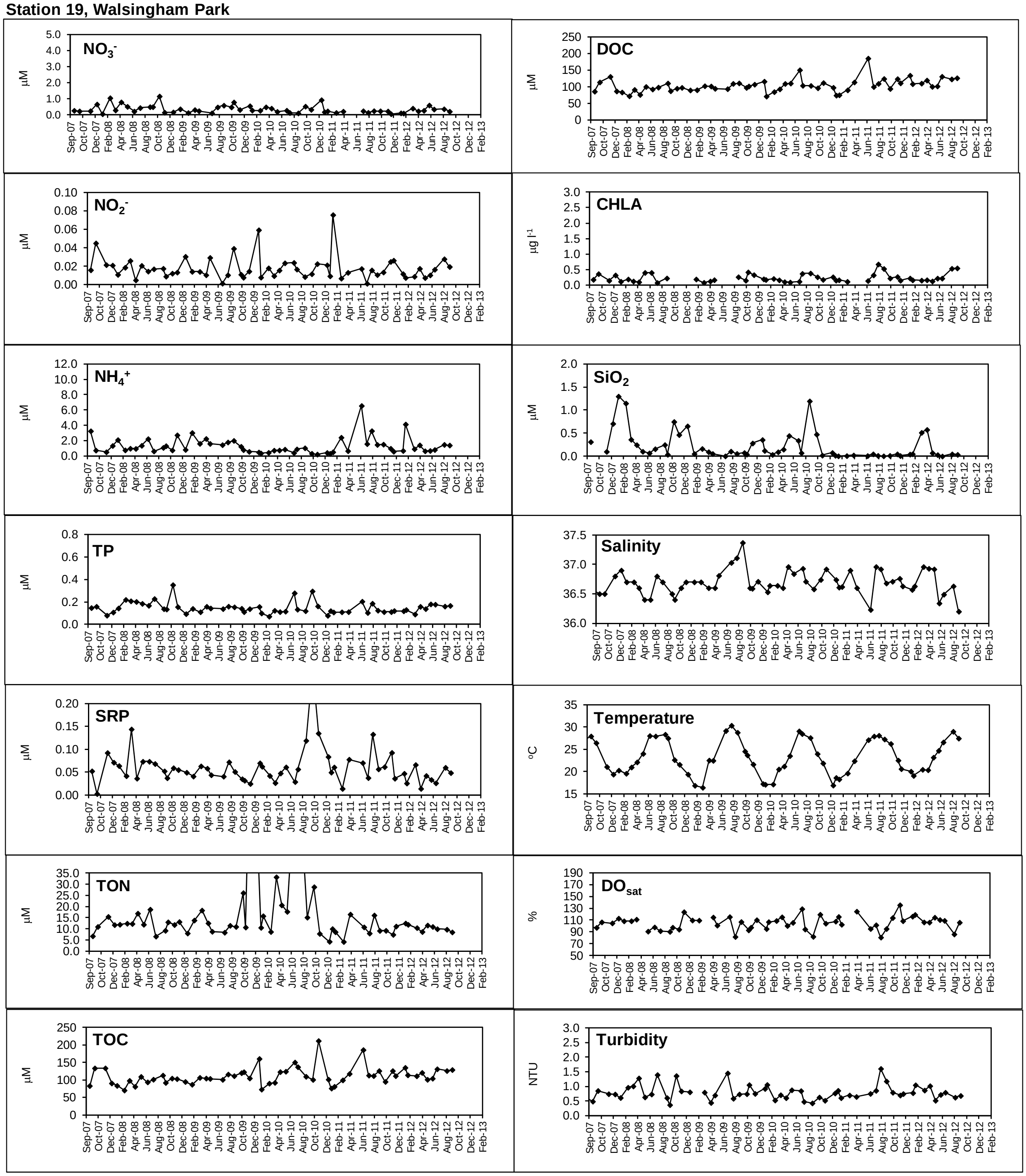
Station 17, Annie's Bay



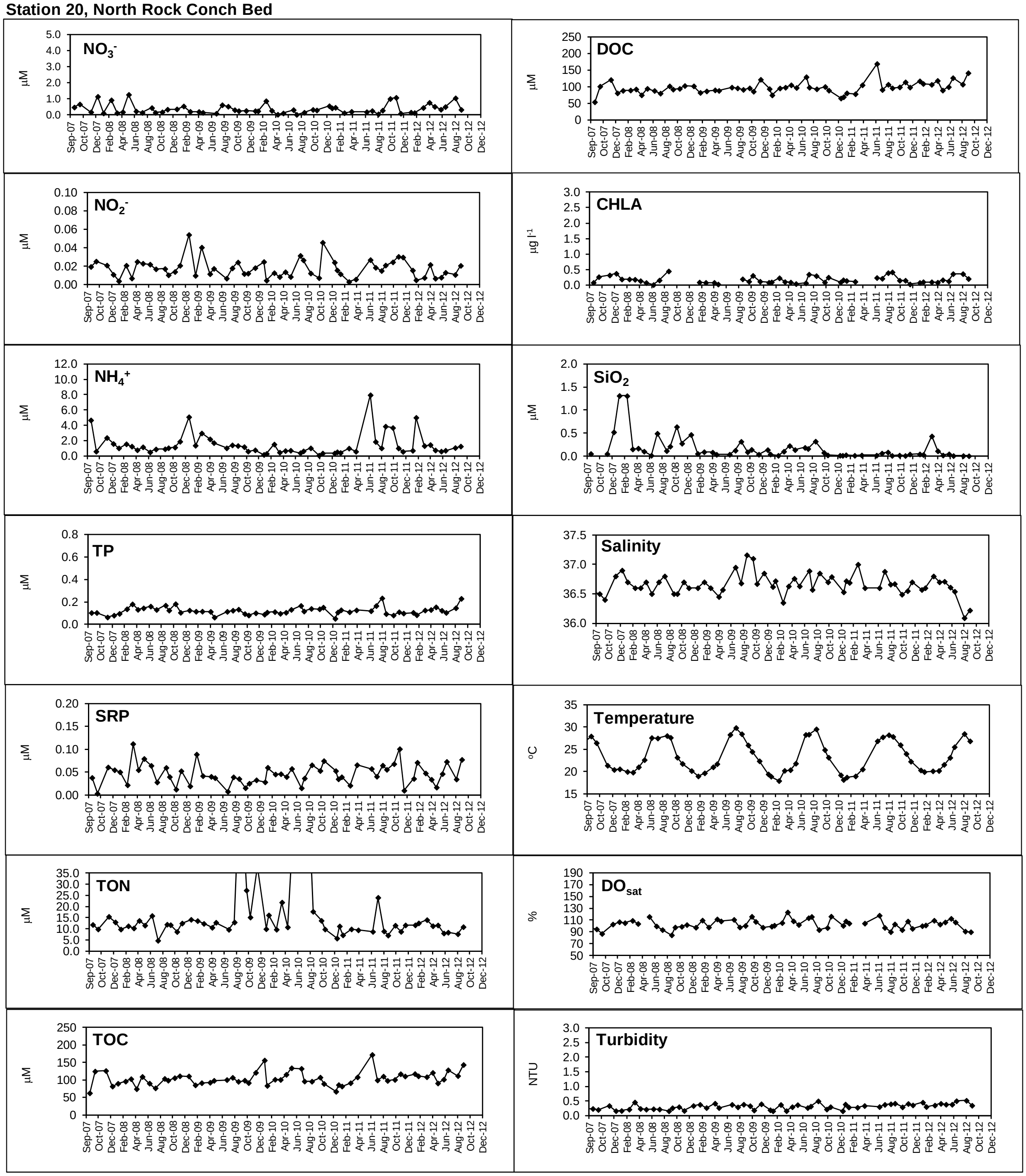
Station 18, Truck Island



Station 19, Walsingham Park



Station 20, North Rock Conch Bed



APPENDIX 2

REGRESSION SLOPE AS PROXY

FOR

SECULAR TREND

(Significant at probability $p<0.1$ highlighted green)

Station	Variable	R2	Slope	p
Sta 01	CHLA(ug/l)	1.60E-02	2.44E-05	3.81E-01
Sta 02	CHLA(ug/l)	2.70E-02	3.16E-05	2.49E-01
Sta 03	CHLA(ug/l)	1.30E-02	1.86E-05	4.30E-01
Sta 04	CHLA(ug/l)	1.60E-02	3.30E-05	3.73E-01
Sta 05	CHLA(ug/l)	1.01E-01	5.83E-05	**2.32E-02**
Sta 06	CHLA(ug/l)	2.90E-02	3.73E-05	2.36E-01
Sta 07	CHLA(ug/l)	3.80E-02	3.58E-05	1.72E-01
Sta 08	CHLA(ug/l)	5.00E-03	1.51E-05	6.38E-01
Sta 13	CHLA(ug/l)	3.20E-02	3.92E-05	2.11E-01
Sta 15	CHLA(ug/l)	1.40E-02	2.18E-05	4.13E-01
Sta 16	CHLA(ug/l)	7.60E-02	6.00E-05	**4.97E-02**
Sta 17	CHLA(ug/l)	7.30E-02	5.64E-05	**5.48E-02**
Sta 18	CHLA(ug/l)	3.00E-03	-4.06E-05	7.07E-01
Sta 19	CHLA(ug/l)	4.10E-02	4.93E-05	1.54E-01
Sta 20	CHLA(ug/l)	1.00E-03	6.25E-06	8.29E-01
Sta 9A	CHLA(ug/l)	9.00E-03	2.50E-05	5.13E-01
Sta 9B	CHLA(ug/l)	2.10E-02	5.55E-05	3.10E-01
Sta 01	DO(mg/l)	6.00E-03	1.06E-04	5.73E-01
Sta 02	DO(mg/l)	2.40E-02	1.92E-04	2.46E-01
Sta 03	DO(mg/l)	2.00E-03	5.56E-05	7.68E-01
Sta 04	DO(mg/l)	1.00E-03	4.43E-05	8.26E-01
Sta 05	DO(mg/l)	1.50E-02	-1.75E-04	3.52E-01
Sta 06	DO(mg/l)	1.00E-03	3.70E-05	8.24E-01
Sta 07	DO(mg/l)	2.00E-03	5.14E-05	7.43E-01
Sta 08	DO(mg/l)	2.00E-03	6.29E-05	7.32E-01
Sta 13	DO(mg/l)	1.00E-03	4.55E-05	7.89E-01
Sta 15	DO(mg/l)	1.30E-02	1.68E-04	3.81E-01
Sta 16	DO(mg/l)	6.15E-06	-3.13E-06	9.85E-01
Sta 17	DO(mg/l)	2.24E-05	6.49E-06	9.72E-01
Sta 18	DO(mg/l)	1.85E-05	-6.05E-06	9.74E-01
Sta 19	DO(mg/l)	6.00E-03	1.30E-04	5.66E-01
Sta 20	DO(mg/l)	1.00E-03	-4.49E-05	7.88E-01
Sta 9A	DO(mg/l)	2.00E-03	5.84E-05	7.29E-01
Sta 9B	DO(mg/l)	8.00E-03	-2.56E-04	5.06E-01
Sta 01	DOC(uM)	1.39E-01	9.00E-03	**4.60E-03**
Sta 02	DOC(uM)	1.31E-01	1.30E-02	**5.20E-03**
Sta 03	DOC(uM)	1.58E-01	1.30E-02	**2.00E-03**
Sta 04	DOC(uM)	1.41E-01	1.50E-02	**3.70E-03**
Sta 05	DOC(uM)	1.18E-01	1.40E-02	**8.20E-03**
Sta 06	DOC(uM)	1.78E-01	1.50E-02	**1.00E-03**
Sta 07	DOC(uM)	1.00E-01	1.10E-02	**1.55E-02**
Sta 08	DOC(uM)	1.48E-01	1.60E-02	**2.80E-03**
Sta 13	DOC(uM)	9.10E-02	1.30E-02	**2.10E-02**
Sta 15	DOC(uM)	3.60E-02	9.00E-03	1.52E-01
Sta 16	DOC(uM)	1.51E-01	1.50E-02	**2.60E-03**
Sta 17	DOC(uM)	1.64E-01	1.50E-02	**1.60E-03**
Sta 18	DOC(uM)	7.30E-02	1.30E-02	**4.03E-02**
Sta 19	DOC(uM)	1.79E-01	1.50E-02	**9.00E-04**
Sta 20	DOC(uM)	1.64E-01	1.40E-02	**1.60E-03**
Sta 9A	DOC(uM)	1.38E-01	1.50E-02	**4.10E-03**
Sta 9B	DOC(uM)	9.40E-02	1.40E-02	**1.89E-02**

Station	Variable	R2	Slope	p
Sta 01	NH4 (uM)	3.00E-03	-1.82E-04	6.97E-01
Sta 02	NH4 (uM)	2.20E-02	2.85E-04	2.71E-01
Sta 03	NH4 (uM)	1.70E-04	3.00E-05	9.23E-01
Sta 04	NH4 (uM)	2.10E-02	3.11E-04	2.75E-01
Sta 05	NH4 (uM)	5.40E-02	1.00E-03	**7.83E-02**
Sta 06	NH4 (uM)	4.35E-04	6.58E-05	8.77E-01
Sta 07	NH4 (uM)	7.00E-03	1.85E-04	5.39E-01
Sta 08	NH4 (uM)	1.10E-02	2.26E-04	4.28E-01
Sta 13	NH4 (uM)	7.00E-03	1.82E-04	5.23E-01
Sta 15	NH4 (uM)	1.90E-02	4.19E-04	3.09E-01
Sta 16	NH4 (uM)	4.60E-02	4.47E-04	1.05E-01
Sta 17	NH4 (uM)	2.00E-03	8.20E-05	7.64E-01
Sta 18	NH4 (uM)	7.00E-02	4.95E-04	**4.41E-02**
Sta 19	NH4 (uM)	8.49E-05	1.86E-05	9.45E-01
Sta 20	NH4 (uM)	2.30E-04	-4.01E-05	9.10E-01
Sta 9A	NH4 (uM)	1.30E-02	2.52E-04	4.02E-01
Sta 9B	NH4 (uM)	3.30E-02	4.17E-04	1.74E-01
Sta 01	NO2(uM)	1.40E-02	-1.70E-06	3.84E-01
Sta 02	NO2(uM)	9.00E-03	-1.29E-06	4.75E-01
Sta 03	NO2(uM)	1.90E-02	-3.25E-06	2.98E-01
Sta 04	NO2(uM)	5.00E-03	-1.46E-06	6.09E-01
Sta 05	NO2(uM)	5.00E-03	-1.37E-06	5.97E-01
Sta 06	NO2(uM)	1.00E-01	-7.58E-06	**1.55E-02**
Sta 07	NO2(uM)	1.24E-01	-9.54E-06	**6.80E-03**
Sta 08	NO2(uM)	1.50E-02	-2.13E-06	3.65E-01
Sta 13	NO2(uM)	1.70E-02	-7.85E-06	3.23E-01
Sta 15	NO2(uM)	1.50E-02	-2.63E-06	3.52E-01
Sta 16	NO2(uM)	6.00E-03	-1.36E-06	5.68E-01
Sta 17	NO2(uM)	2.40E-02	-2.58E-06	2.47E-01
Sta 18	NO2(uM)	6.00E-03	-1.67E-06	5.69E-01
Sta 19	NO2(uM)	7.00E-03	-1.91E-06	5.42E-01
Sta 20	NO2(uM)	1.00E-02	-1.86E-06	4.58E-01
Sta 9A	NO2(uM)	2.50E-02	-4.64E-06	2.35E-01
Sta 9B	NO2(uM)	2.00E-02	-2.75E-06	2.96E-01
Sta 01	NO3(uM)	3.40E-02	-6.15E-05	1.71E-01
Sta 02	NO3(uM)	5.80E-02	-8.98E-05	**6.95E-02**
Sta 03	NO3(uM)	7.30E-02	-1.17E-04	**4.09E-02**
Sta 04	NO3(uM)	3.50E-02	-1.02E-04	1.61E-01
Sta 05	NO3(uM)	1.48E-01	-3.25E-04	**3.20E-03**
Sta 06	NO3(uM)	7.80E-02	-1.12E-04	**3.32E-02**
Sta 07	NO3(uM)	3.30E-02	-9.12E-05	1.72E-01
Sta 08	NO3(uM)	4.40E-02	-1.15E-04	1.15E-01
Sta 13	NO3(uM)	1.50E-02	-4.29E-04	3.64E-01
Sta 15	NO3(uM)	2.37E-01	-1.00E-03	**1.00E-04**
Sta 16	NO3(uM)	2.50E-02	-1.49E-04	2.38E-01
Sta 17	NO3(uM)	1.00E-02	2.60E-05	4.53E-01
Sta 18	NO3(uM)	1.47E-01	-1.00E-03	**2.90E-03**
Sta 19	NO3(uM)	9.40E-02	-1.36E-04	**2.06E-02**
Sta 20	NO3(uM)	1.71E-04	7.28E-06	9.23E-01
Sta 9A	NO3(uM)	1.50E-02	-9.40E-05	3.61E-01
Sta 9B	NO3(uM)	2.43E-01	-1.00E-03	**<.0001**

Station	Variable	R2	Slope	p
Sta 01	NOx(uM)	3.60E-02	-6.32E-05	1.58E-01
Sta 02	NOx(uM)	5.80E-02	-9.10E-05	**6.74E-02**
Sta 03	NOx(uM)	7.60E-02	-1.20E-04	**3.66E-02**
Sta 04	NOx(uM)	3.50E-02	-1.04E-04	1.59E-01
Sta 05	NOx(uM)	1.49E-01	-3.31E-04	**2.80E-03**
Sta 06	NOx(uM)	8.70E-02	-1.20E-04	**2.44E-02**
Sta 07	NOx(uM)	3.90E-02	-1.01E-04	1.35E-01
Sta 08	NOx(uM)	4.50E-02	-1.17E-04	1.08E-01
Sta 13	NOx(uM)	1.50E-02	-4.37E-04	3.55E-01
Sta 15	NOx(uM)	2.38E-01	-1.00E-03	**1.00E-04**
Sta 16	NOx(uM)	2.50E-02	-1.50E-04	2.34E-01
Sta 17	NOx(uM)	8.00E-03	2.34E-05	4.98E-01
Sta 18	NOx(uM)	1.48E-01	-1.00E-03	**2.90E-03**
Sta 19	NOx(uM)	1.03E-01	-1.44E-04	**1.40E-02**
Sta 20	NOx(uM)	9.36E-05	5.41E-06	9.43E-01
Sta 9A	NOx(uM)	1.70E-02	-9.86E-05	3.36E-01
Sta 9B	NOx(uM)	2.46E-01	-1.00E-03	**<.0001**
Sta 01	NP	5.50E-02	3.40E-02	**8.13E-02**
Sta 02	NP	8.70E-02	2.00E-02	**2.62E-02**
Sta 03	NP	2.00E-02	-1.90E-02	2.86E-01
Sta 04	NP	5.30E-02	5.00E-02	**8.08E-02**
Sta 05	NP	6.90E-02	3.80E-02	**4.79E-02**
Sta 06	NP	5.40E-02	-3.30E-02	**8.02E-02**
Sta 07	NP	2.10E-02	-3.00E-02	2.75E-01
Sta 08	NP	1.14E-05	-3.10E-04	9.80E-01
Sta 13	NP	1.50E-02	2.70E-02	3.54E-01
Sta 15	NP	1.90E-02	-2.20E-02	2.99E-01
Sta 16	NP	1.20E-02	1.20E-02	4.06E-01
Sta 17	NP	8.00E-03	-7.00E-03	4.98E-01
Sta 18	NP	8.00E-03	-9.00E-03	5.18E-01
Sta 19	NP	9.00E-03	-9.00E-03	4.80E-01
Sta 20	NP	6.40E-02	-2.90E-02	**5.48E-02**
Sta 9A	NP	3.40E-02	1.70E-02	1.68E-01
Sta 9B	NP	3.20E-02	3.20E-02	1.78E-01
Sta 01	SAL(psu)	2.34E-04	5.20E-06	9.09E-01
Sta 02	SAL(psu)	3.63E-05	-2.12E-06	9.63E-01
Sta 03	SAL(psu)	1.00E-03	-8.25E-06	8.54E-01
Sta 04	SAL(psu)	1.50E-02	5.07E-05	3.52E-01
Sta 05	SAL(psu)	5.00E-03	2.64E-05	5.89E-01
Sta 06	SAL(psu)	1.50E-02	-4.90E-05	3.41E-01
Sta 07	SAL(psu)	1.11E-04	4.19E-06	9.36E-01
Sta 08	SAL(psu)	7.30E-02	1.15E-04	**3.47E-02**
Sta 13	SAL(psu)	3.90E-02	8.99E-05	1.27E-01
Sta 15	SAL(psu)	2.40E-02	6.35E-05	2.38E-01
Sta 16	SAL(psu)	1.70E-02	5.02E-05	3.17E-01
Sta 17	SAL(psu)	3.00E-03	1.89E-05	6.99E-01
Sta 18	SAL(psu)	1.68E-01	2.11E-04	**1.00E-03**
Sta 19	SAL(psu)	2.00E-03	1.71E-05	7.58E-01
Sta 20	SAL(psu)	6.00E-03	-2.83E-05	5.40E-01
Sta 9A	SAL(psu)	5.20E-02	1.01E-04	**7.71E-02**
Sta 9B	SAL(psu)	1.50E-01	2.26E-04	**2.00E-03**

Station	Variable	R2	Slope	p
Sta 01	Si(uM)	2.65E-01	-2.59E-04	**<.0001**
Sta 02	Si(uM)	2.65E-01	-2.70E-04	**<.0001**
Sta 03	Si(uM)	2.63E-01	-2.52E-04	**<.0001**
Sta 04	Si(uM)	1.82E-01	-2.25E-04	**9.00E-04**
Sta 05	Si(uM)	1.77E-01	-2.36E-04	**1.10E-03**
Sta 06	Si(uM)	1.81E-01	-2.22E-04	**1.00E-03**
Sta 07	Si(uM)	2.15E-01	-2.20E-04	**3.00E-04**
Sta 08	Si(uM)	9.20E-02	-1.75E-04	**2.21E-02**
Sta 13	Si(uM)	1.13E-01	-1.78E-04	**1.07E-02**
Sta 15	Si(uM)	1.59E-01	-2.75E-04	**2.10E-03**
Sta 16	Si(uM)	1.38E-01	-2.13E-04	**4.40E-03**
Sta 17	Si(uM)	1.43E-01	-2.03E-04	**3.80E-03**
Sta 18	Si(uM)	2.50E-02	-1.54E-04	2.39E-01
Sta 19	Si(uM)	1.35E-01	-2.12E-04	**4.90E-03**
Sta 20	Si(uM)	2.00E-01	-2.21E-04	**5.00E-04**
Sta 9A	Si(uM)	2.90E-02	-1.14E-04	2.08E-01
Sta 9B	Si(uM)	2.60E-02	-1.38E-04	2.30E-01
Sta 01	SRP(uM)	8.60E-02	-1.25E-05	**2.86E-02**
Sta 02	SRP(uM)	4.00E-02	-1.02E-05	1.38E-01
Sta 03	SRP(uM)	1.00E-03	-1.55E-06	7.87E-01
Sta 04	SRP(uM)	2.40E-02	9.59E-06	2.43E-01
Sta 05	SRP(uM)	2.00E-03	-1.93E-06	7.22E-01
Sta 06	SRP(uM)	2.30E-02	8.60E-06	2.59E-01
Sta 07	SRP(uM)	6.00E-02	-4.17E-05	**6.32E-02**
Sta 08	SRP(uM)	8.00E-03	4.71E-06	4.95E-01
Sta 13	SRP(uM)	9.00E-03	-4.76E-06	4.86E-01
Sta 15	SRP(uM)	4.06E-05	3.18E-07	9.62E-01
Sta 16	SRP(uM)	5.00E-03	3.18E-06	5.98E-01
Sta 17	SRP(uM)	2.20E-02	8.12E-06	2.68E-01
Sta 18	SRP(uM)	1.00E-02	4.90E-06	4.58E-01
Sta 19	SRP(uM)	1.00E-03	-1.82E-06	8.56E-01
Sta 20	SRP(uM)	8.00E-03	3.65E-06	5.16E-01
Sta 9A	SRP(uM)	1.53E-04	-5.55E-07	9.27E-01
Sta 9B	SRP(uM)	9.00E-03	4.75E-06	4.80E-01
Sta 01	TEMP(oC)	3.00E-03	3.18E-04	7.04E-01
Sta 02	TEMP(oC)	6.00E-03	4.77E-04	5.62E-01
Sta 03	TEMP(oC)	5.00E-03	4.51E-04	5.96E-01
Sta 04	TEMP(oC)	1.30E-02	1.00E-03	3.85E-01
Sta 05	TEMP(oC)	1.20E-02	1.00E-03	3.97E-01
Sta 06	TEMP(oC)	3.00E-03	3.53E-04	6.78E-01
Sta 07	TEMP(oC)	4.00E-03	4.45E-04	6.15E-01
Sta 08	TEMP(oC)	1.20E-02	1.00E-03	3.99E-01
Sta 13	TEMP(oC)	1.30E-02	1.00E-03	3.81E-01
Sta 15	TEMP(oC)	8.00E-03	1.00E-03	4.81E-01
Sta 16	TEMP(oC)	2.00E-03	2.77E-04	7.69E-01
Sta 17	TEMP(oC)	9.00E-03	1.00E-03	4.58E-01
Sta 18	TEMP(oC)	6.00E-03	1.00E-03	5.55E-01
Sta 19	TEMP(oC)	8.00E-03	1.00E-03	5.07E-01
Sta 20	TEMP(oC)	6.00E-03	4.84E-04	5.64E-01
Sta 9A	TEMP(oC)	1.10E-02	1.00E-03	4.19E-01
Sta 9B	TEMP(oC)	1.00E-02	1.00E-03	4.52E-01

Station	Variable	R2	Slope	p
Sta 01	TIN(uM)	5.00E-03	-2.45E-04	6.03E-01
Sta 02	TIN(uM)	1.00E-02	1.94E-04	4.57E-01
Sta 03	TIN(uM)	1.00E-03	-9.04E-05	7.83E-01
Sta 04	TIN(uM)	9.00E-03	2.08E-04	4.76E-01
Sta 05	TIN(uM)	7.00E-03	1.97E-04	5.35E-01
Sta 06	TIN(uM)	2.88E-04	-5.37E-05	8.99E-01
Sta 07	TIN(uM)	1.00E-03	8.41E-05	7.88E-01
Sta 08	TIN(uM)	2.00E-03	1.09E-04	7.17E-01
Sta 13	TIN(uM)	5.00E-03	-2.55E-04	6.16E-01
Sta 15	TIN(uM)	2.10E-02	-1.00E-03	2.79E-01
Sta 16	TIN(uM)	1.60E-02	2.96E-04	3.41E-01
Sta 17	TIN(uM)	3.00E-03	1.05E-04	7.00E-01
Sta 18	TIN(uM)	4.02E-04	-4.17E-05	8.81E-01
Sta 19	TIN(uM)	4.00E-03	-1.25E-04	6.27E-01
Sta 20	TIN(uM)	1.63E-04	-3.46E-05	9.24E-01
Sta 9A	TIN(uM)	4.00E-03	1.54E-04	6.20E-01
Sta 9B	TIN(uM)	1.20E-02	-2.61E-04	4.14E-01
Sta 01	TN(uM)	2.17E-06	7.34E-05	9.91E-01
Sta 02	TN(uM)	1.00E-03	-1.00E-03	8.37E-01
Sta 03	TN(uM)	7.00E-03	-3.00E-03	5.33E-01
Sta 04	TN(uM)	2.00E-03	-1.00E-03	7.37E-01
Sta 05	TN(uM)	1.00E-03	-1.00E-03	8.35E-01
Sta 06	TN(uM)	3.00E-03	-1.00E-03	6.96E-01
Sta 07	TN(uM)	5.00E-03	-3.00E-03	6.07E-01
Sta 08	TN(uM)	1.00E-03	-1.00E-03	8.65E-01
Sta 13	TN(uM)	2.07E-04	-1.00E-03	9.15E-01
Sta 15	TN(uM)	3.77E-06	8.62E-05	9.89E-01
Sta 16	TN(uM)	1.00E-03	-1.00E-03	8.04E-01
Sta 17	TN(uM)	2.00E-03	-2.00E-03	7.40E-01
Sta 18	TN(uM)	1.78E-04	-4.37E-04	9.21E-01
Sta 19	TN(uM)	1.00E-03	-1.00E-03	8.68E-01
Sta 20	TN(uM)	3.78E-04	-1.00E-03	8.85E-01
Sta 9A	TN(uM)	1.00E-03	-1.00E-03	8.18E-01
Sta 9B	TN(uM)	7.75E-05	-3.41E-04	9.48E-01
Sta 01	TNTP	3.18E-04	1.00E-02	8.96E-01
Sta 02	TNTP	2.34E-07	1.90E-04	9.97E-01
Sta 03	TNTP	1.00E-03	-8.00E-03	8.45E-01
Sta 04	TNTP	3.04E-05	-1.00E-03	9.67E-01
Sta 05	TNTP	3.94E-05	2.00E-03	9.63E-01
Sta 06	TNTP	3.00E-03	-1.10E-02	6.92E-01
Sta 07	TNTP	4.00E-03	-2.30E-02	6.24E-01
Sta 08	TNTP	4.78E-09	-1.60E-05	1.00E+00
Sta 13	TNTP	3.75E-04	-8.00E-03	8.85E-01
Sta 15	TNTP	3.00E-03	1.80E-02	6.91E-01
Sta 16	TNTP	1.00E-03	-5.00E-03	8.64E-01
Sta 17	TNTP	2.00E-03	-1.10E-02	7.41E-01
Sta 18	TNTP	4.19E-04	5.00E-03	8.79E-01
Sta 19	TNTP	3.46E-04	-5.00E-03	8.90E-01
Sta 20	TNTP	3.00E-03	-1.50E-02	6.65E-01
Sta 9A	TNTP	4.86E-05	2.00E-03	9.59E-01
Sta 9B	TNTP	3.00E-03	1.20E-02	6.93E-01

Station	Variable	R2	Slope	p
Sta 01	TOC(uM)	5.00E-02	6.00E-03	**9.78E-02**
Sta 02	TOC(uM)	3.40E-02	7.00E-03	1.64E-01
Sta 03	TOC(uM)	1.46E-01	1.30E-02	**3.10E-03**
Sta 04	TOC(uM)	9.20E-02	1.20E-02	**2.04E-02**
Sta 05	TOC(uM)	1.40E-01	1.50E-02	**3.80E-03**
Sta 06	TOC(uM)	1.35E-01	1.30E-02	**4.60E-03**
Sta 07	TOC(uM)	6.30E-02	1.00E-02	**5.83E-02**
Sta 08	TOC(uM)	7.70E-02	1.30E-02	**3.48E-02**
Sta 13	TOC(uM)	6.60E-02	1.20E-02	**5.12E-02**
Sta 15	TOC(uM)	6.70E-02	1.20E-02	**5.04E-02**
Sta 16	TOC(uM)	5.80E-02	1.00E-02	**6.90E-02**
Sta 17	TOC(uM)	6.90E-02	1.20E-02	**4.67E-02**
Sta 18	TOC(uM)	4.30E-02	1.00E-02	1.19E-01
Sta 19	TOC(uM)	1.06E-01	1.50E-02	**1.24E-02**
Sta 20	TOC(uM)	9.50E-02	1.10E-02	**1.89E-02**
Sta 9A	TOC(uM)	9.10E-02	1.20E-02	**2.16E-02**
Sta 9B	TOC(uM)	5.90E-02	1.20E-02	**6.54E-02**
Sta 01	TON(uM)	3.99E-05	3.18E-04	9.63E-01
Sta 02	TON(uM)	1.00E-03	-1.00E-03	8.12E-01
Sta 03	TON(uM)	6.00E-03	-3.00E-03	5.50E-01
Sta 04	TON(uM)	3.00E-03	-2.00E-03	7.04E-01
Sta 05	TON(uM)	1.00E-03	-1.00E-03	8.06E-01
Sta 06	TON(uM)	1.00E-03	-1.00E-03	7.81E-01
Sta 07	TON(uM)	5.00E-03	-3.00E-03	5.99E-01
Sta 08	TON(uM)	2.49E-04	-4.97E-04	9.07E-01
Sta 13	TON(uM)	8.76E-05	-4.84E-04	9.44E-01
Sta 15	TON(uM)	1.86E-04	1.00E-03	9.19E-01
Sta 16	TON(uM)	2.00E-03	-1.00E-03	7.56E-01
Sta 17	TON(uM)	2.00E-03	-2.00E-03	7.27E-01
Sta 18	TON(uM)	1.46E-04	-3.96E-04	9.28E-01
Sta 19	TON(uM)	3.49E-04	-1.00E-03	8.89E-01
Sta 20	TON(uM)	3.28E-04	-1.00E-03	8.93E-01
Sta 9A	TON(uM)	1.00E-03	-1.00E-03	7.98E-01
Sta 9B	TON(uM)	4.37E-06	-8.07E-05	9.88E-01
Sta 01	TP(uM)	6.40E-02	-1.89E-05	**5.94E-02**
Sta 02	TP(uM)	8.30E-02	-2.85E-05	**2.81E-02**
Sta 03	TP(uM)	1.12E-01	-2.43E-05	**1.03E-02**
Sta 04	TP(uM)	6.50E-02	-1.05E-04	**5.29E-02**
Sta 05	TP(uM)	1.01E-01	-3.00E-05	**1.52E-02**
Sta 06	TP(uM)	2.10E-02	-9.74E-06	2.77E-01
Sta 07	TP(uM)	2.70E-02	-1.01E-05	2.15E-01
Sta 08	TP(uM)	2.90E-02	-1.43E-05	2.02E-01
Sta 13	TP(uM)	7.70E-02	-2.43E-05	**3.47E-02**
Sta 15	TP(uM)	1.29E-01	-2.87E-05	**5.70E-03**
Sta 16	TP(uM)	3.80E-02	-1.50E-05	1.43E-01
Sta 17	TP(uM)	1.90E-02	-9.53E-06	3.04E-01
Sta 18	TP(uM)	2.70E-02	-1.52E-05	2.14E-01
Sta 19	TP(uM)	2.10E-02	-1.38E-05	2.82E-01
Sta 20	TP(uM)	1.60E-02	8.06E-06	3.50E-01
Sta 9A	TP(uM)	6.80E-02	-2.53E-05	**4.89E-02**
Sta 9B	TP(uM)	1.12E-01	-4.08E-05	**1.03E-02**