TECHNICAL MEMORANDUM

TO:	JOHN HALL	DATE:	JANUARY 10, 2011
		RE:	REVIEW OF NEW HAMPSHIRE DES TOTAL NITROGEN CRITERIA DEVELOPMENT FOR THE GREAT BAY ESTUARY
FROM:	THOMAS W. GALLAGHER CRISTHIAN MANCILLA	FILE:	HAAS.006.000

1. INTRODUCTION

The purpose of this memorandum is three-fold:

a) To review an analysis of eelgrass and nitrogen temporal trends performed by new the Hampshire Department of Environmental Services (NHDES) as presented in Figure 1;
b) To review the NHDES conclusions drawn from Figure 8 with respect to dissolved oxygen (DO) diurnal swings and primary productivity; and
c) To analyze a set of water quality data collected during the summer of 2010 to test the validity of a previous HydroQual analysis that concluded that a significant component of Great Bay Estuary turbidity is associated with inorganic matter and that control of nitrogen alone will not reduce water column turbidity.

2. SUMMARY OF NHDES TN CRITERIA DEVELOPMENT TO PROVIDE SUFFICIENT LIGHT FOR EELGRASS SURVIVAL

There has been a substantial decline in eelgrass in various waters of the Great Bay Estuary since 1996 and an increase in macroalgae. NHDES has considered the potential effects of nitrogen on macroalgae growth and reduction in water column light through nitrogen stimulation of primary productivity. Based on a regression analysis of the water column light attenuation coefficient versus median total nitrogen, NHDES has concluded that water column light attenuation considerations yields a more stringent total nitrogen criterion than macroalgae effects.

NHDES has adopted the Chesapeake Bay Program Office target bottom light of 22% of surface light for the survival of eelgrass. For eelgrass restoration depths of 2.0 m, 2.5 m, and 3.0 m, the equivalent values of K_d are 0.75/m, 0.60/m and 0.50/m. These are the K_d values contained in the proposed NHDES numeric nutrient criteria. NHDES developed a regression of median light attenuation versus median TN for eight Great Bay Estuary monitoring stations. As previously indicated for a target eelgrass restoration depth of 2.0 meters the equivalent light attenuation coefficient is 0.75/m. The regression analysis performed by NHDES indicated that a 0.75/m attenuation coefficient will occur at a median total nitrogen of 0.30 mg/L which is the proposed nitrogen criterion for a restoration depth of 2.0 m.

3. SUMMARY OF NHDES NITROGEN TEMPORAL TRENDS ANALYSIS AND WITHIN DAY DO VARIABILITY ANALYSIS

As shown in Figure 1, NHDES has compared temporal plots of nitrogen (nitrate and dissolved inorganic nitrogen) with changes in eelgrass coverage in acres from 1974 to 2009. Based on these temporal plots, some of the conclusions proposed by NHDES are: a) the apparent increase in inorganic nitrogen is an indicator of an increase in total nitrogen loading to the system; b) since 1995 nitrate levels have exceeded 50 ug/L which they state is the threshold to produce direct effects (toxicity) on eelgrass.

Figure 8 presents DO measurements (%DO saturation) recorded by an in-situ datasonde in the tidal portion of the Squamscott River. Based on this figure, NHDES concluded that primary productivity, via photosynthesis and respiration, is the reason for the DO diurnal swings from supersaturation to 60%-70% saturation.

4. ADDITIONAL DATA ANALYSES AND REVIEW OF NHDES NITROGEN TEMPORAL TRENDS ANALYSIS

HydroQual performed an analysis of temporal trends for several constituents besides the nitrogen forms studied by NHDES. Figures 2 to 4 present temporal plots of annual values of several nitrogen forms, salinity, dissolved oxygen (DO), water temperature, chlorophyll-a, total suspended sediments (TSS), and phosphate (PO4). To be consistent with the NHDES analysis methodology all annual values depicted on these plots represent annual median values. The tabulated values for each year represent the number of samples employed for each annual median computation. For these figures, in contrast to the NHDES analysis that included low tide measurements only, low as well as high tide measurements were considered for the 1988-2009 dataset. Therefore, 24 (2 per month, 1 low and 1 high) is the maximum number of possible samples for each year. The 1973-1981 dataset contained a maximum of 12 samples per year (1 per month) with no indication of the tide stage. The entire database (1973-1981, 1988-2009) provided to HydroQual by NHDES did not contain the required nitrogen forms to compute total nitrogen concentrations. Because the inorganic nitrogen forms included at these plots show an apparent increase for data post 1988, several other constituents were simultaneously analyzed. Salinity was employed to examine for any possible sampling bias with respect to freshwater and ocean water content of the samples. The salinity annual values concurrent with the annual measured nitrogen values, for both time periods, show similar magnitudes and therefore imply a similar freshwater content. Also, DO, PO4 and water temperature show comparable levels for both time periods. Pre 1981 chlorophyll-a shows higher values than then 1988-2000 time period values, but post 2000 chlorophyll-a values represent an increase with respect to previous years. TSS for the period 1993-1998 shows rather constant levels although NHDES considers 1996 as the beginning of the eelgrass decline and asserts that TSS fluctuations are fully explained by changes in eelgrass.

Eelgrass biomass was considered to be a better indicator of eelgrass abundance and therefore used instead of eelgrass coverage. Eelgrass biomass values for several years (1990-2004) were digitized from a report prepared by Morrison et al. (2008). Figure 5 indicates that for several years nitrate levels were greater than or equal to 50 ug/L with no identifiable decrease in eelgrass biomass. For example, in Figure 5 (1973-1981 data), no available eelgrass is available but it is assumed that eelgrass was abundant despite the stated nitrate threshold of 50 ug/L being exceeded during several years. In

several occasions, in Figure 5 (1988-2009 data), eelgrass biomass seems stable or even increasing when nitrate levels are greater than the stated nitrate threshold.

The use of inorganic nitrogen (Figure 2) as an indicator of total nitrogen trends can be inaccurate because with declining eelgrass levels less inorganic nitrogen is taken up from the water column (uptake) by eelgrass primary productivity. Figures 6-1 and 6-2 provide a seasonal analysis (monthly) of several constituents at Adams Point. From these figures, temperature seasonal trends could explain the seasonal variations of water column inorganic nitrogen as the eelgrass nitrogen uptake rate is directly related to temperature.

If a more comprehensive analysis of Great Bay total nitrogen concentrations indicates that there are no increasing trends when eelgrass declines, total nitrogen may not be the cause of declining eelgrass. A comprehensive analysis should identify temporal trends on non-point source and point source total nitrogen loads into the system. Figure 7 is similar to Figure 2 but includes some total nitrogen data at Adams Point queried from Great Bay water quality databasets and used by NHDES for the development of the total nitrogen threshold for eelgrass protection. On this figure, the total nitrogen temporal trends don't follow the inorganic nitrogen trends and depict a more steady pattern. These dissimilar trends could be explained by a re-distribution of nitrogen species for the similar total nitrogen levels due to eelgrass uptake, macroalgae uptake or an unidentified mechanism.

5. REVIEW OF NHDES CONCLUSIONS ON PRIMARY PRODUCTIVITY AND DO DIURNAL VARIATION

Figure 8 presents dissolved oxygen measurements (% saturation) recorded by an in-situ datasonde in the tidal portion of the Squamscott River. NHDES asserts that primary productivity is the reason for the diurnal swings. Although there is evidence of primary productivity as indicated by the supersaturated DO, much of the diel variability is due to tidal translation rather than primary productivity. The evidence for the effect of tidal translation is indicated by peak DO values at night and the one hour per day shift in the diel DO pattern consistent with the shift in the tidal phase by approximately one hour each day. In addition the steep decline in DO within the day can be associated with ebb tide drainage of adjacent marshes with low DO concentrations.

To provide some insight into the tidal translation effects in the DO diurnal variation, high frequency data (15 minutes) was obtained from the National Estuarine Research Reserve System website for the Squamscott River Monitoring Station. The dissolved oxygen saturation data presented in Figure 8 (NHDES) presents data recorded in July 2008, days 16th to 20th. Figure 9-1 presents temporal plots of dissolved oxygen saturation, water depth and turbidity for the same time period depicted in Figure 8. From Figure 9-1, it is evident that the diurnal DO variability is due to tidal translation as the DO saturation values within a day are consistent with the measured tidal phase. Furthermore, other factors may also be responsible for the DO diurnal variation, e.g., increasing turbidity trends seem to correspond to decreasing DO saturation trends. Alternatively, the same graphical analysis was performed with data recorded in July 2005 and similar conclusions can be drawn. Figure 9-2 presents the July 2005 DO analysis. The DO at this river location is the result of site specific factors including degree of stratification, SOD, and atmospheric reaeration and therefore additional data collection and the development of a water quality model are required for the estimation of each component of the DO balance.

6. ANALYSIS OF 2010 WATER QUALITY DATA

As previously indicated, NHDES used a regression of light attenuation coefficient versus total nitrogen to establish a total nitrogen criterion of 0.3 mg/L for eelgrass survival. This relationship implies that nitrogen contributes significantly to a reduction in the water column light attenuation coefficient. The mechanism by which nitrogen may contribute to a reduction in water column clarity is stimulation of the growth of phytoplankton. In addition, organic nitrogen is a surrogate for organic matter (which can lower the water column transparency) associated with non point source loads.

In June 2010, HydroQual performed a review of the NHDES nitrogen criteria development and a preliminary data analysis that suggests that a high percentage of the light reduction associated with turbidity is due to non-volatile suspended solids (NVS) and therefore unrelated to nitrogen. These inert particles are unrelated to effects of nitrogen and are actually silts and clays that are probably resuspended from the bay bottom or brought in with river flows.

In June 2010, HydroQual proposed a short term field program to test the hypothesis that particular organic matter is a small component of the water column turbidity. The sampling program was conducted during the summer of 2010 with the collection of water quality constitutes to compute the non-volatile suspended solids fraction in Great Bay. Five stations were sampled in Great Bay, August 5th to September 2nd 2010. Measurements included: wind speed, tide stage, temperature, salinity, TSS, NVS, POC, PON, CDOM, chlorophyll-a and secchi disk. Measurements of temperature, salinity, TSS, and VSS were taken at surface, mid and bottom depths. The remaining parameters were taken at mid depths only. Figure 10 depicts the station locations. Temporal plots of several constituents are shown in Figures 11 and 12. From these figures it can be seen that chlorophyll-a levels are relatively low. The volatile suspended solids (VSS) concentrations were computed as the difference between TSS and NVS. Temporal plots presented in Figures 11 and 12 include all 5 sampled locations, therefore chlorophyll-a variability for the same sampling day is due to variability across stations while the variability for temperature, salinity, TSS, and NVS is due to variability across stations and also sample depth. Appendix A presents temporal plots for the same water quality parameters included in Figures 11 and 12 but for individual stations.

A regression analysis of NVS versus TSS is shown in Figure 13. The results indicate that NVS is approximately 85% of the TSS concentrations thus supporting HydroQual's assumption that nitrogen is not a significant factor in contributing to a reduction in water column clarity. The remaining 15% of TSS is VSS associated with algae (chlorophyll-a) and detritus. Because chlorophyll-a is quite low (~ 3 ug/L), algae are a minor contributor to a reduction in water column transparency. These results are in agreement with the analysis presented by Morrison et al. (2008) as shown in Figure 14.

7. CONCLUSIONS

a) The nitrogen temporal trends analysis performed by NHDES is not sufficient to affirm that there has been an increasing temporal trend in total nitrogen loading to the system. The use of inorganic nitrogen as an indicator of total nitrogen trends can be inaccurate because with declining eelgrass levels less inorganic nitrogen is taken up from the water column by eelgrass primary productivity. A comprehensive nitrogen temporal trend analysis should

identify temporal trends on non-point source and point source total nitrogen loads into the system.

b) The NHDES proposed nitrate threshold of 50 ug/L has been exceeded several years in the past when abundance of eelgrass beds was assumed. Furthermore, the proposed nitrate threshold has also been exceed for several years for which eelgrass coverage and biomass measurements are available and these show steady abundance patterns over such years.

c) The measured diurnal DO variability in the tidal portion of the Squamscott River is due to tidal translation rather than primary productivity. Additional data collection and the development of a mechanistic water quality model are requited for the estimation of the DO balance components.

d) The analysis of the 2010 water quality dataset shows that nitrogen effects are not a significant factor in reducing water column transparency and therefore the establishment of a total nitrogen criteria of 0.3 mg/L from a regression of water column light attenuation coefficient versus nitrogen is inappropriate. About 15% of TSS is VSS associated with algae (chlorophyll-a) and detritus, because chlorophyll-a is quite low, algae are a minor contributor to a reduction in water column transparency. As a consequence of this analysis, total nitrogen load reductions to Great Bay will not substantially improve the water column transparency.

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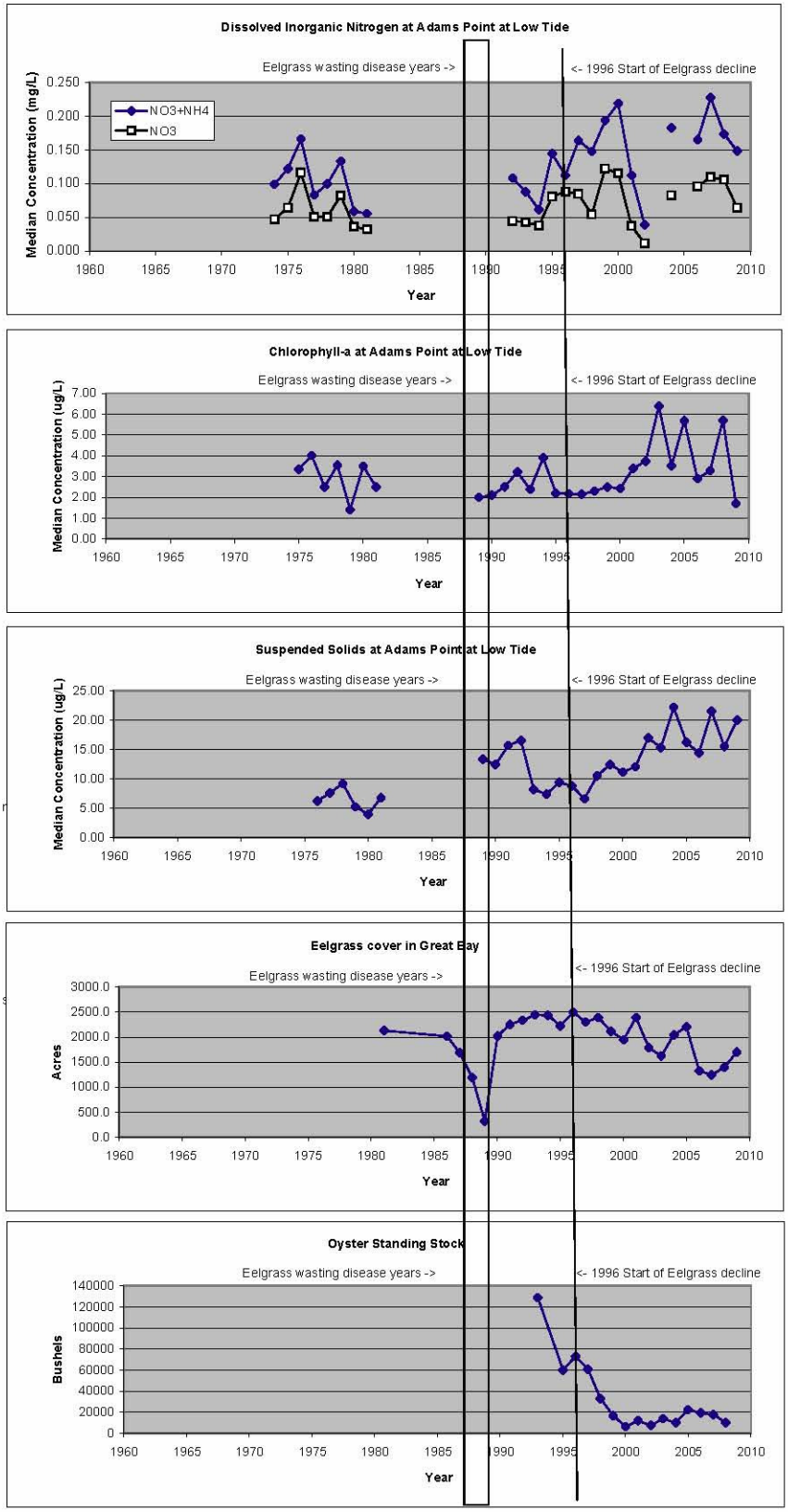

Figure 1. NHDES Temporal Trends Analysis

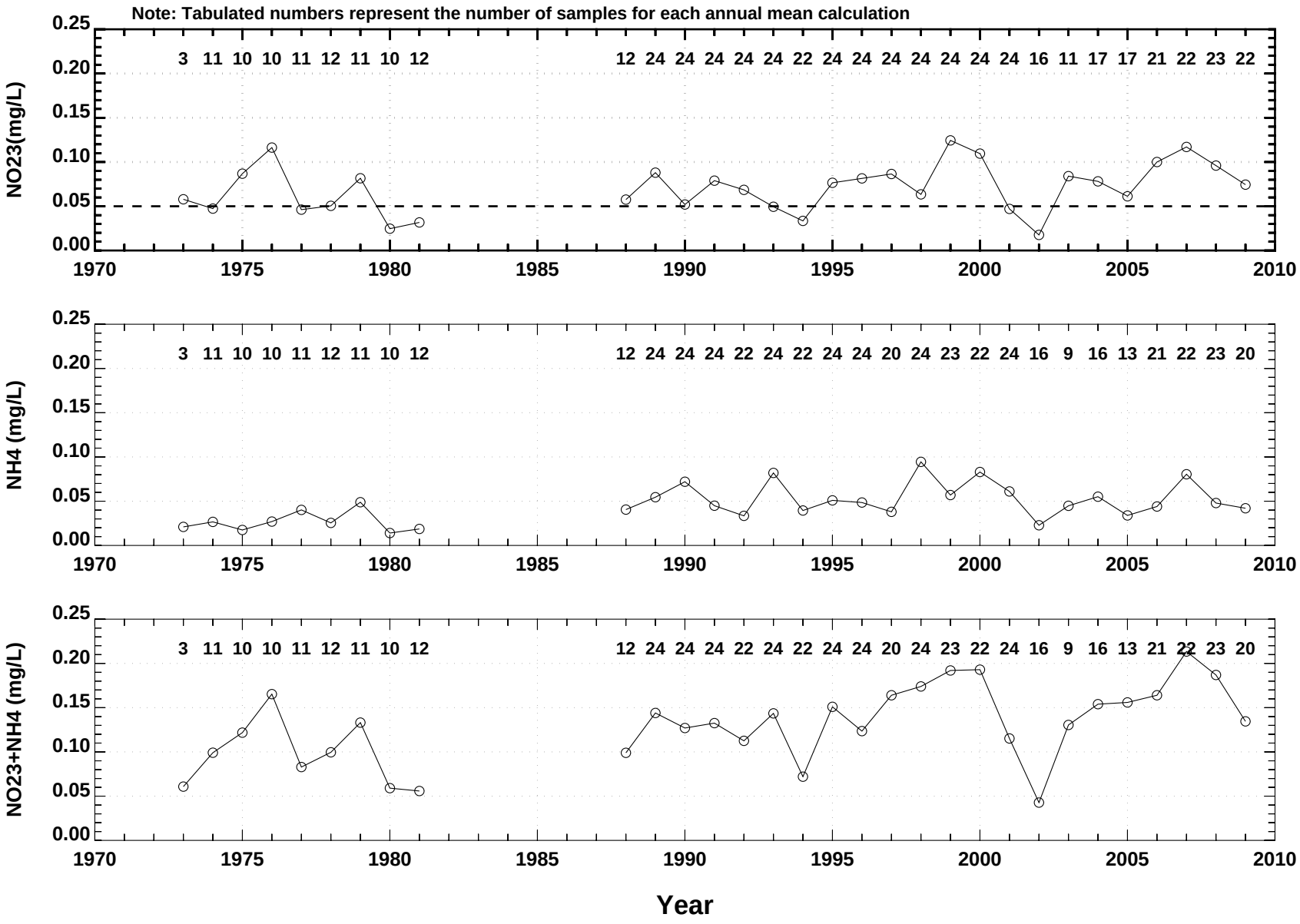

Figure 2. DES Monitoring Data (1973-2009), Adams Point

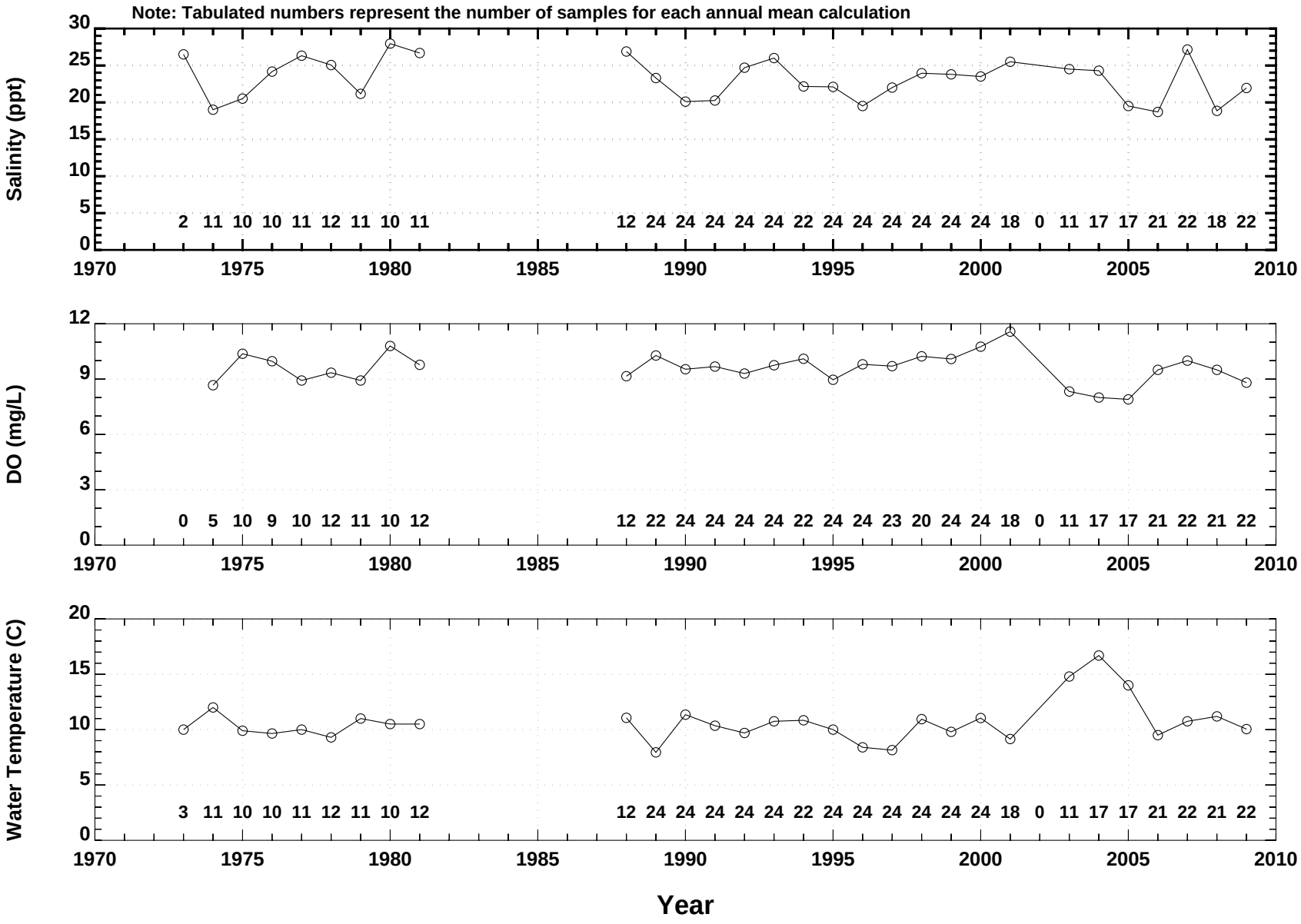

Figure 3. DES Monitoring Data (1973-2009), Adams Point

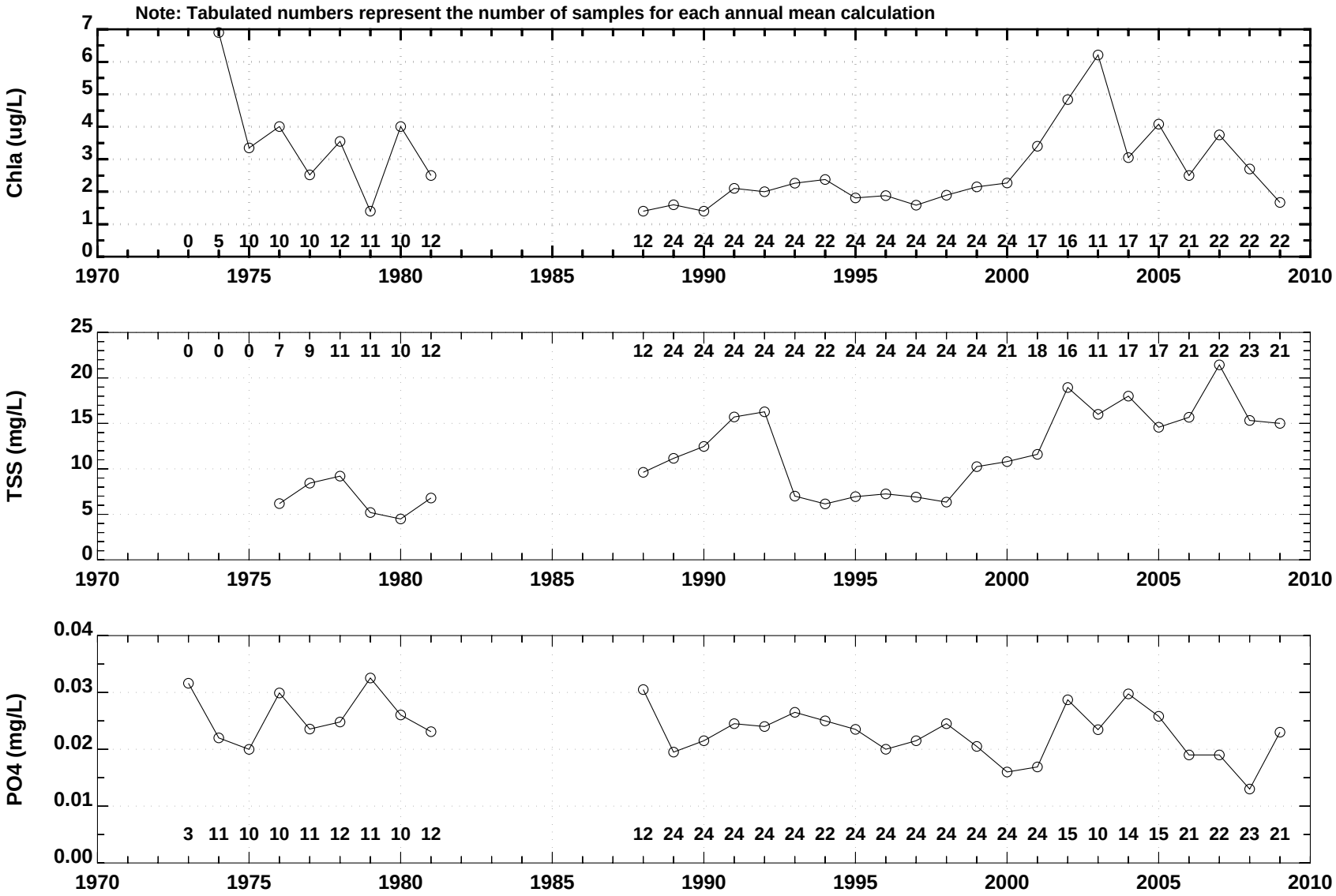

Figure 4. DES Monitoring Data (1988-2009), Adams Point

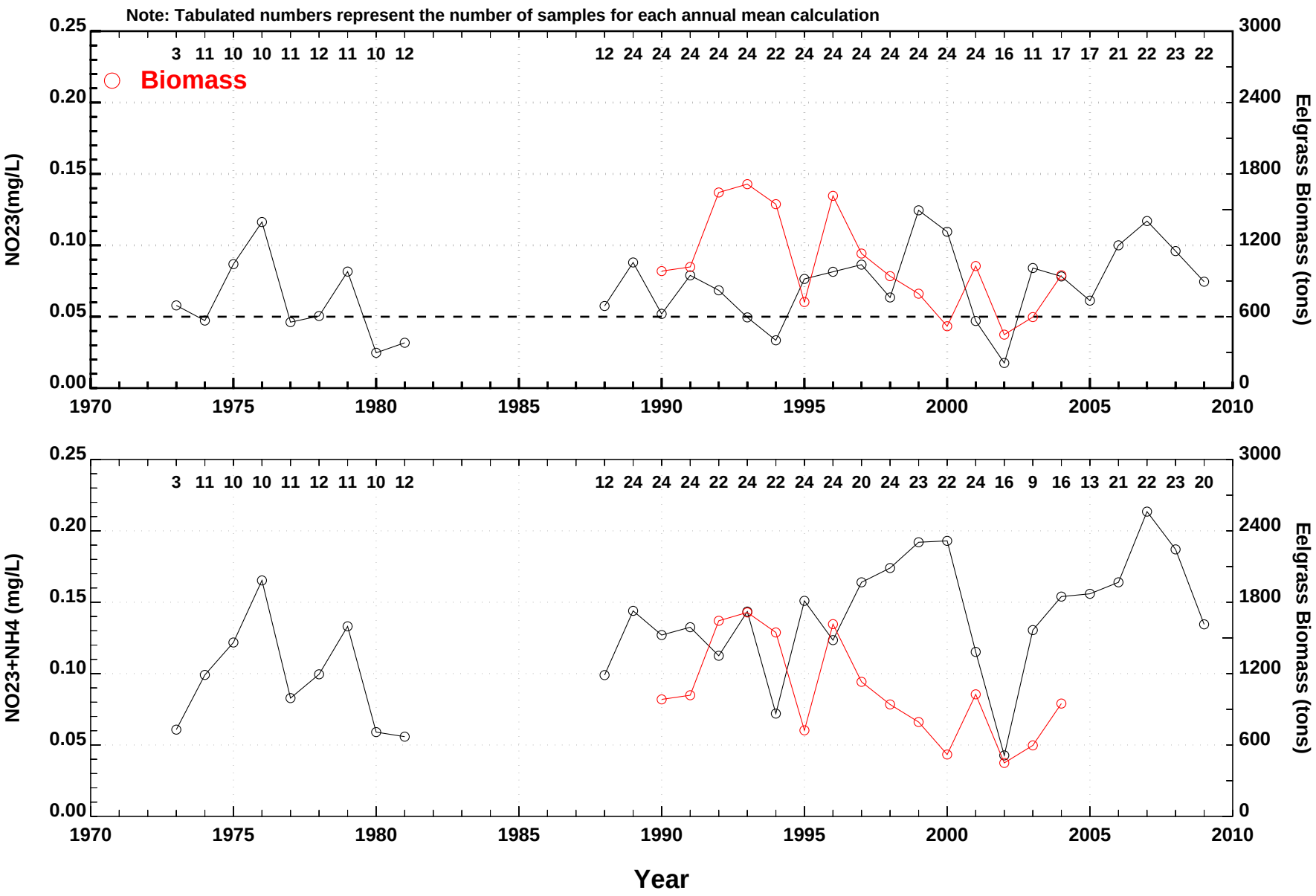

Figure 5. DES Monitoring Data (1973-2009), Adams Point

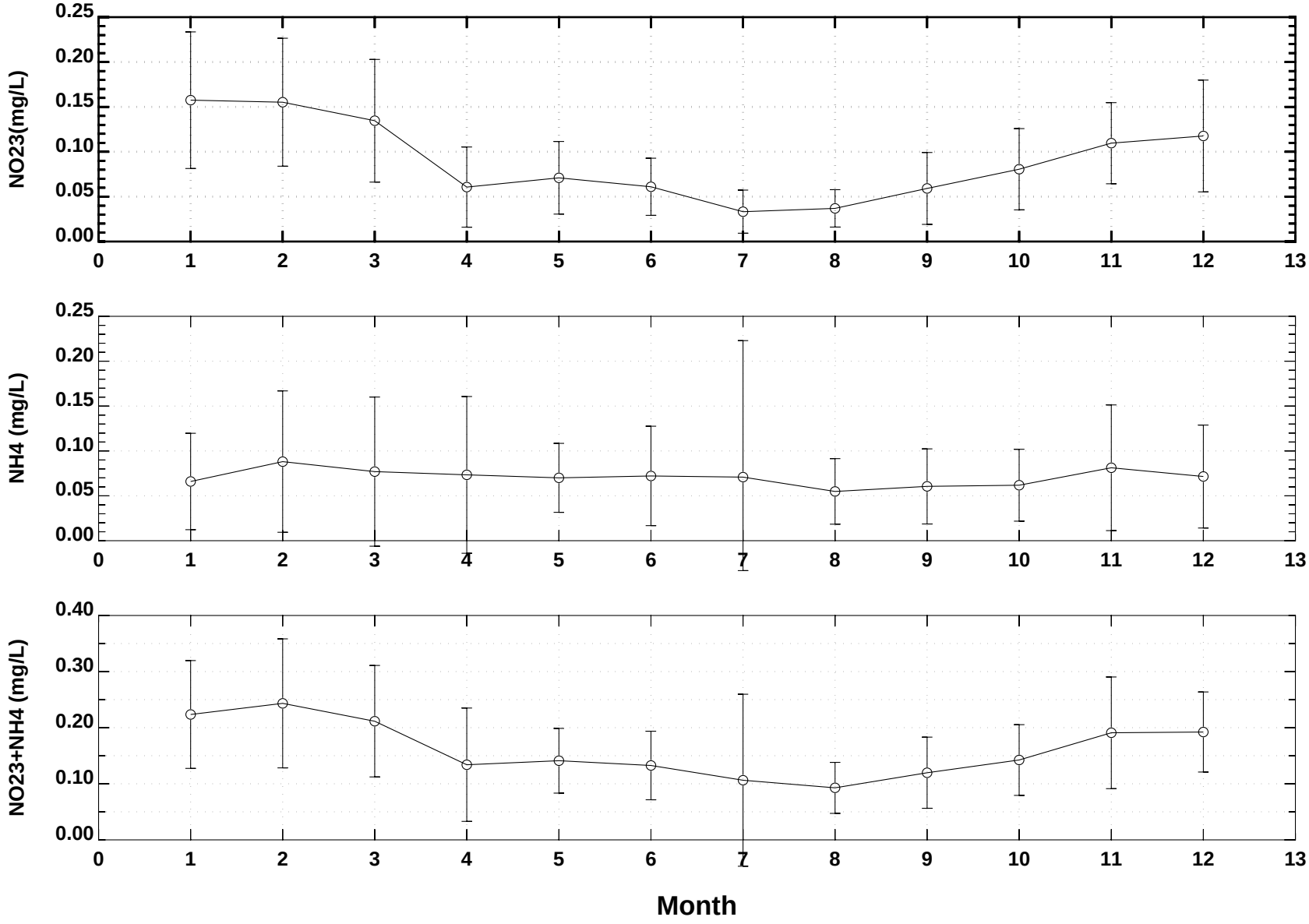

Figure 6-1. DES Monitoring Data (1988-2009), Adams Point

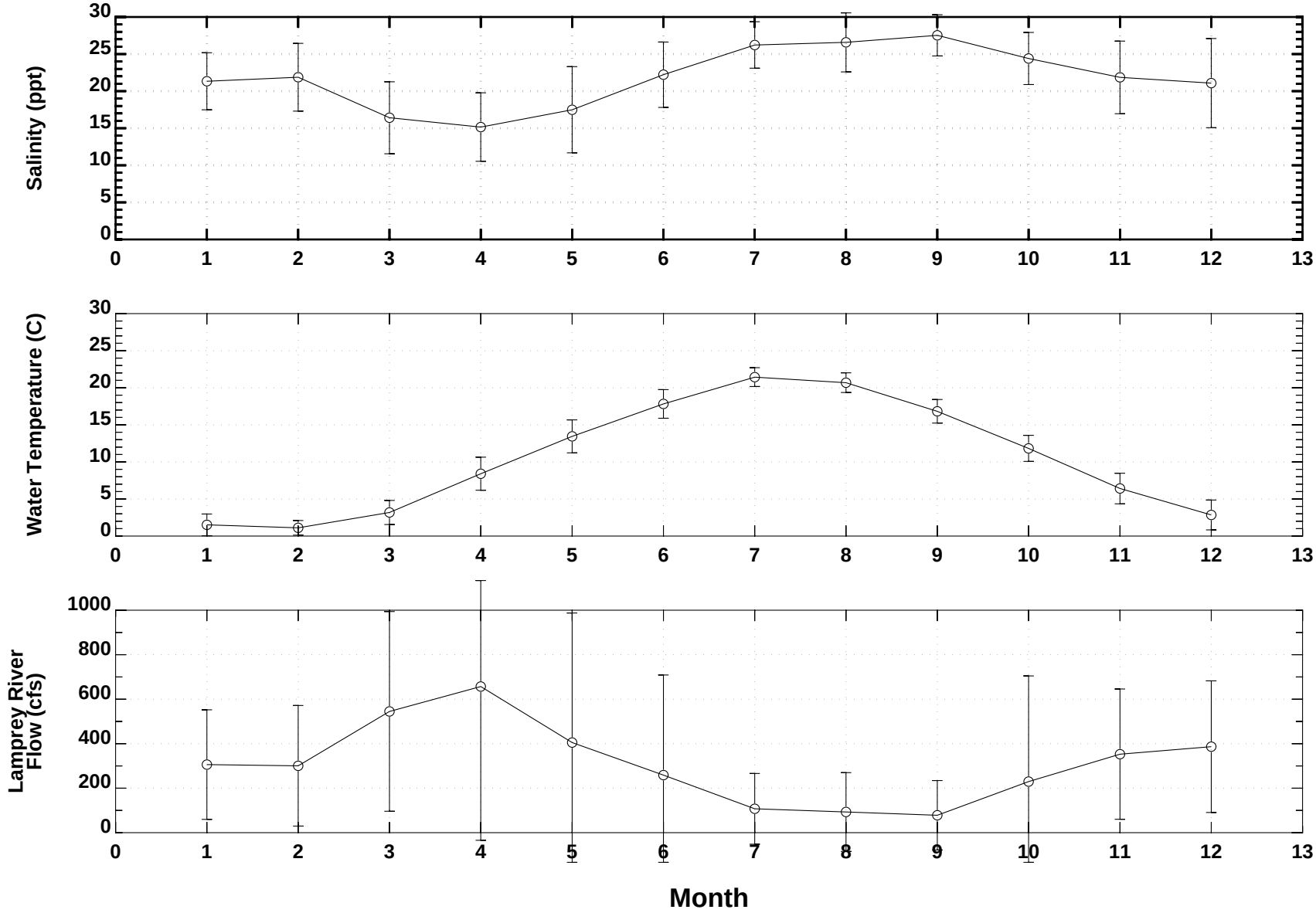

Figure 6-2. DES Monitoring Data (1988-2009), Adams Point

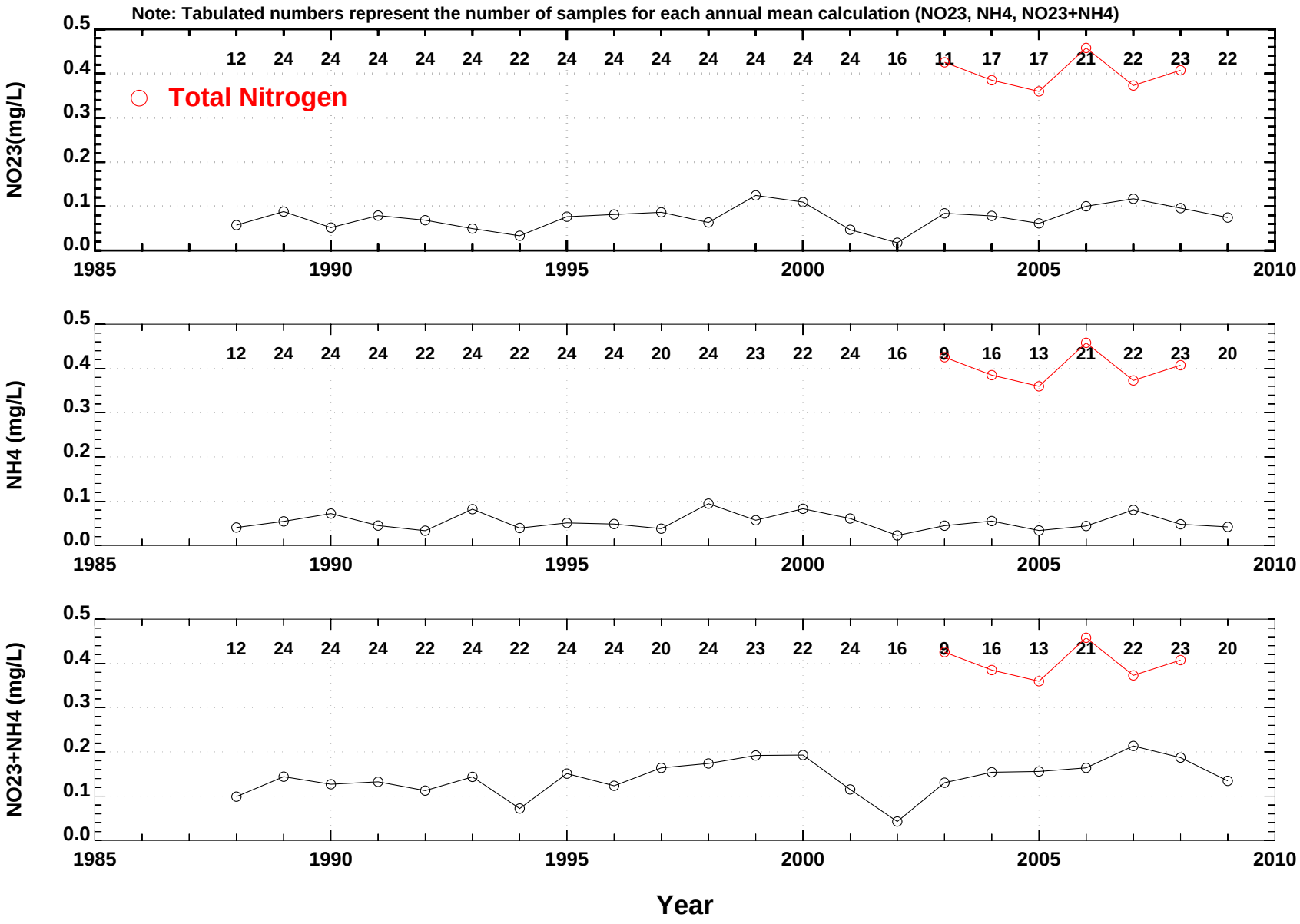

Figure 7. DES Monitoring Data (1988-2009), Adams Point

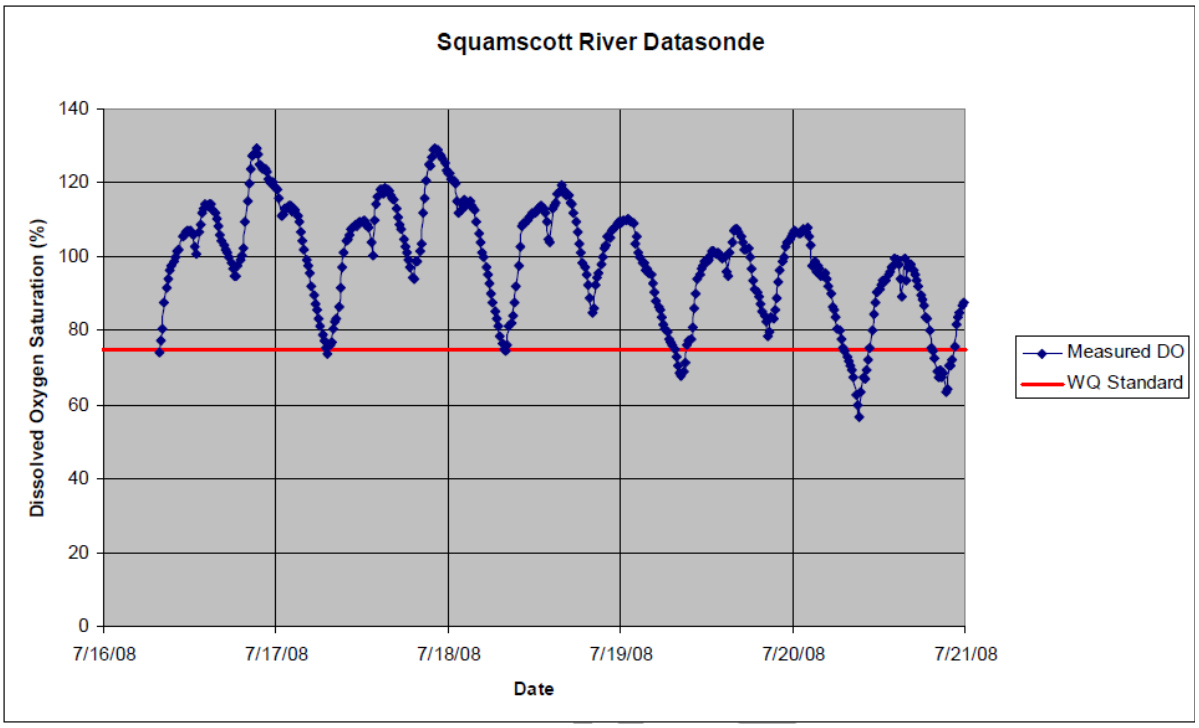

Figure 8. Dissolved Oxygen at the Squamscott River Datasonde Location

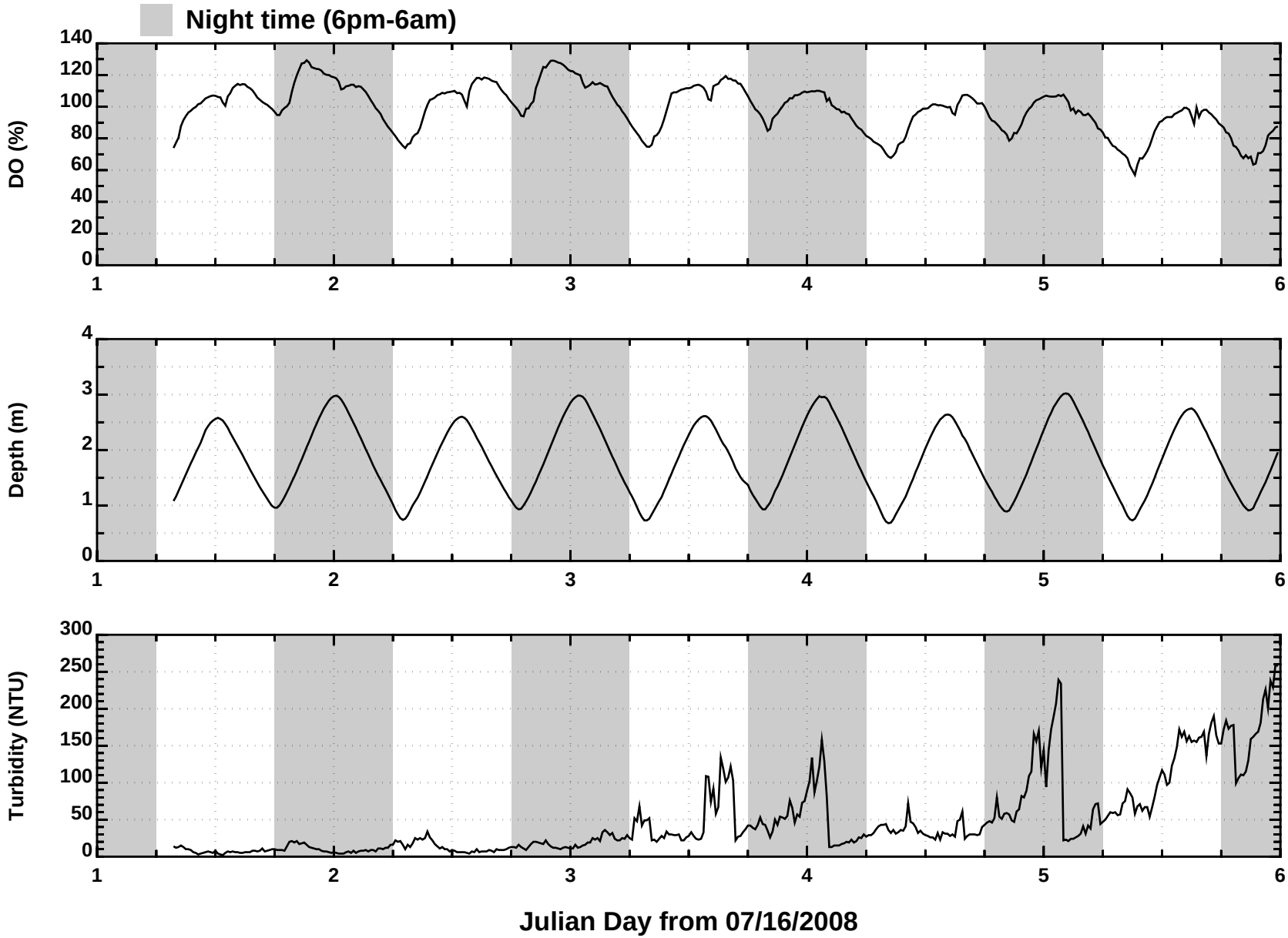

Figure 9-1. Squamscott River Monitoring Data (07/16/2008-07/20/2008)

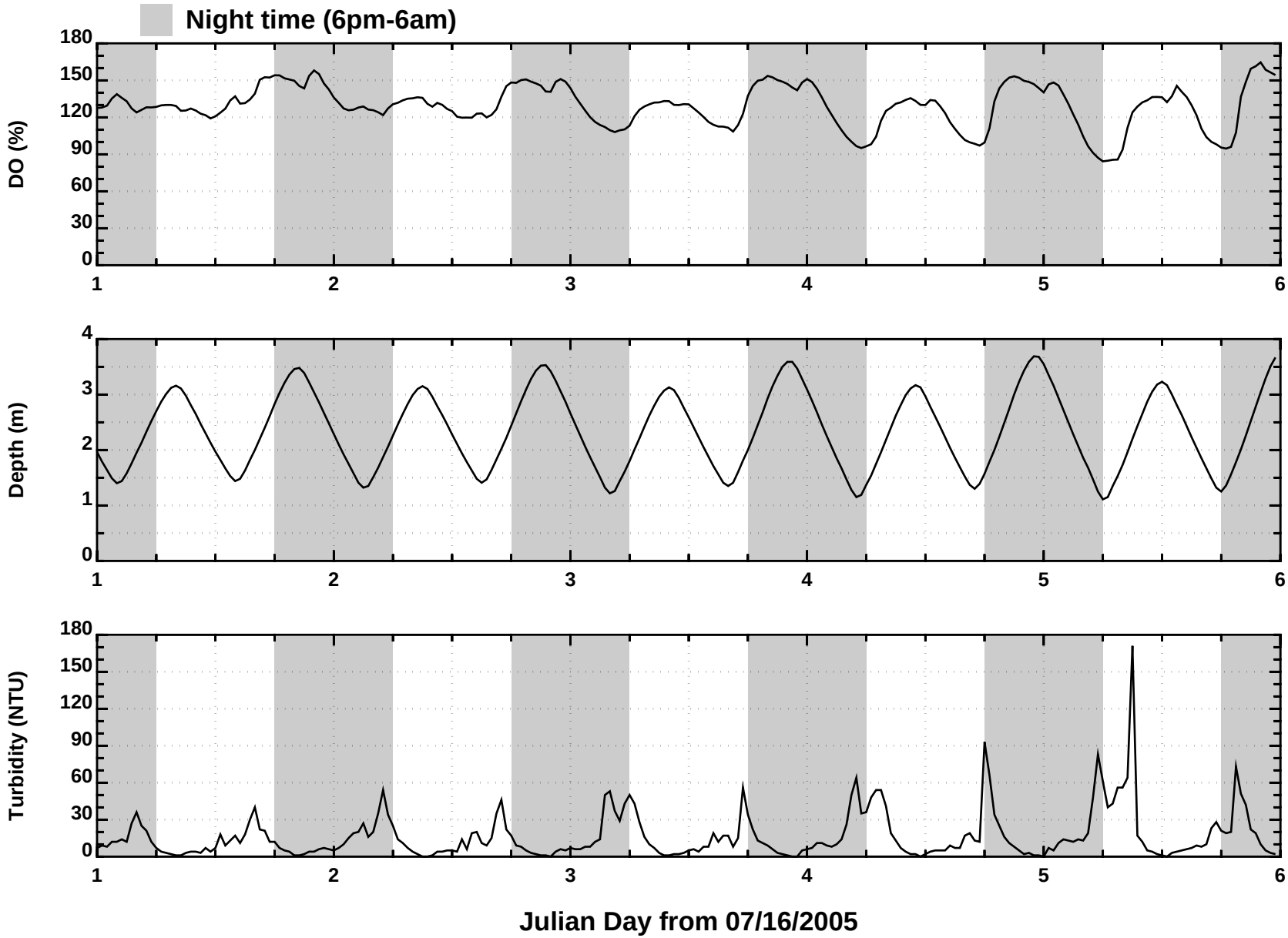

Figure 9-2. Squamscott River Monitoring Data (07/16/2005-07/20/2005)

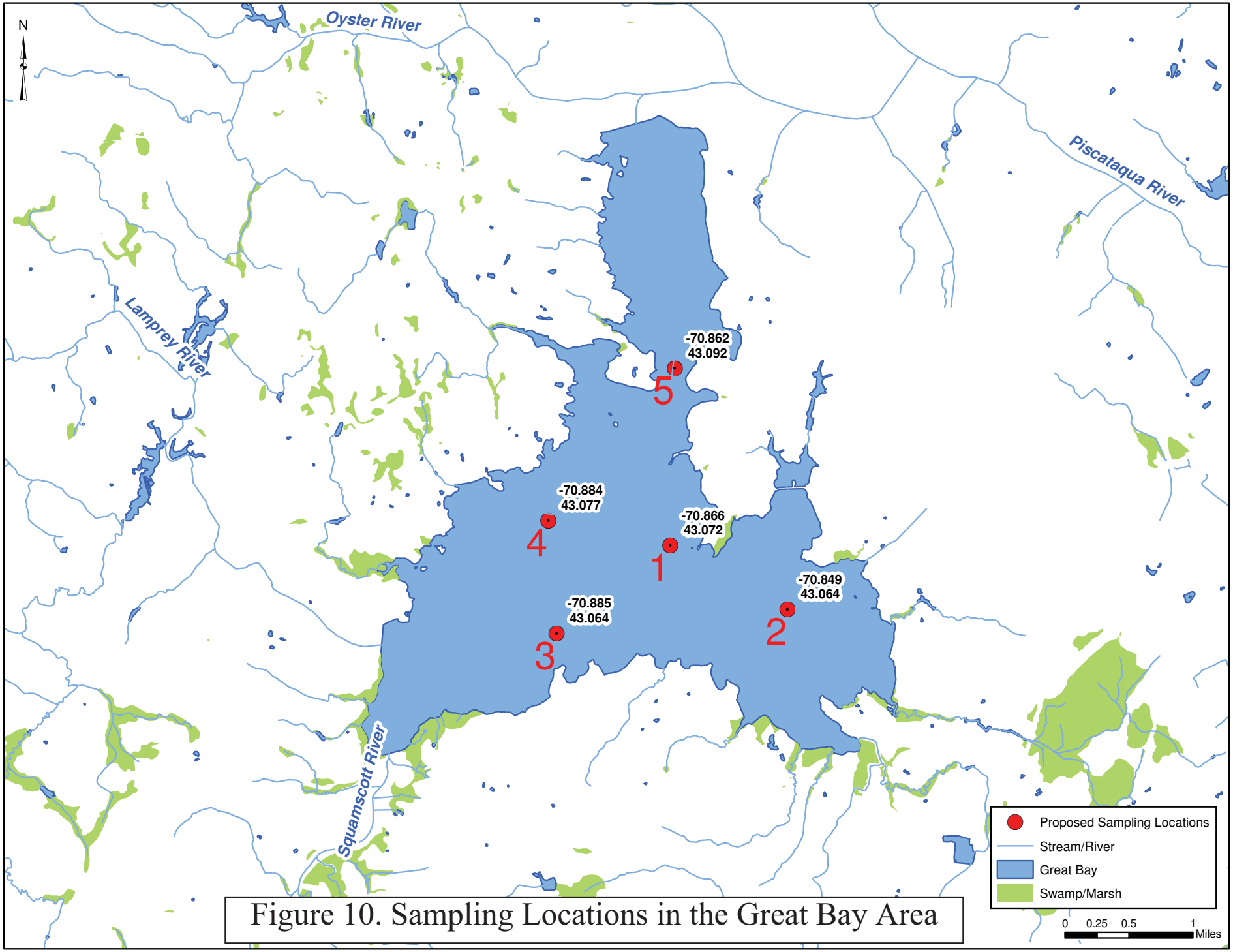

Figure 10. Sampling Locations in the Great Bay Area

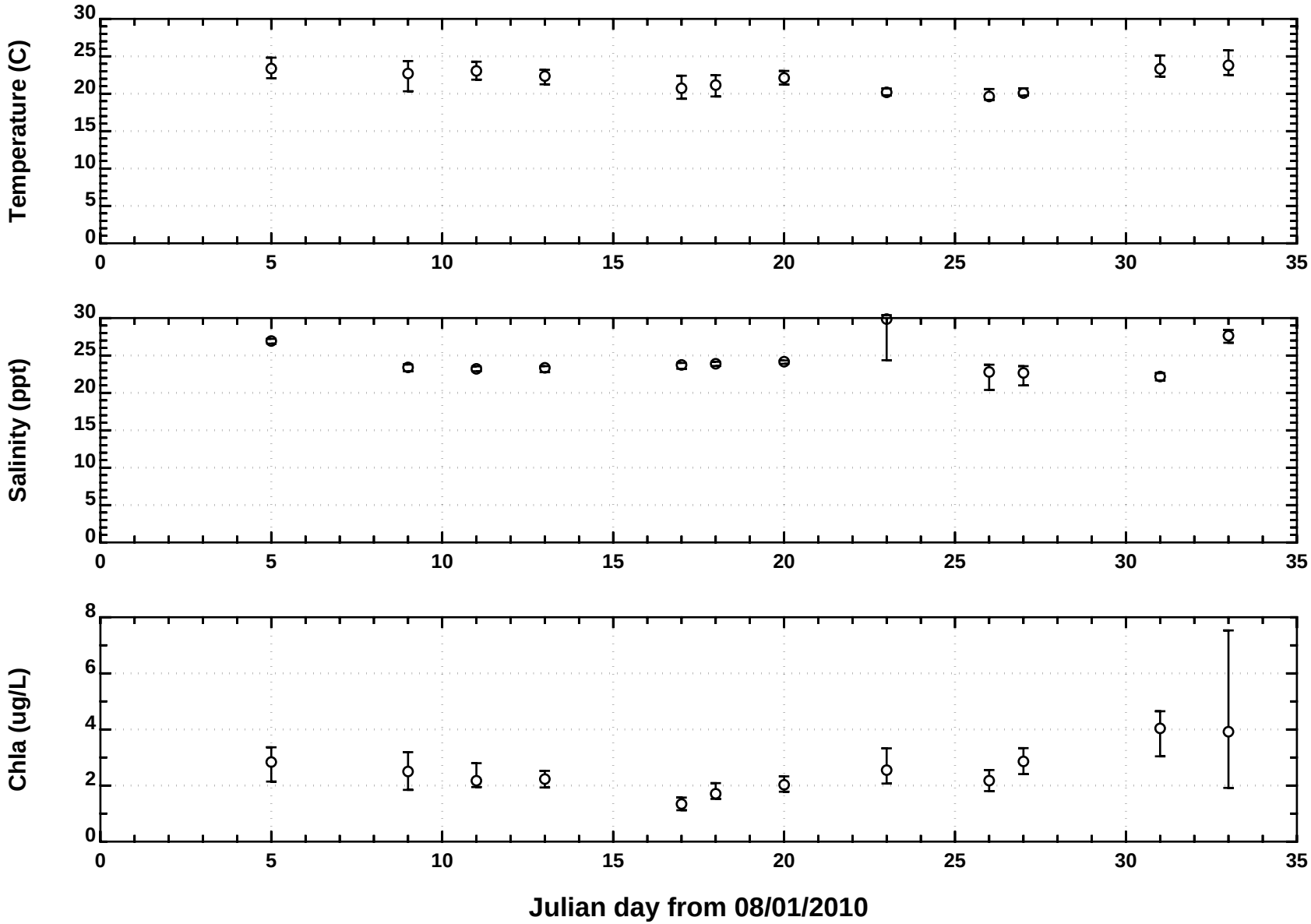

Figure 11. 2010 Great Bay Water Quality Data (Station 1-5)

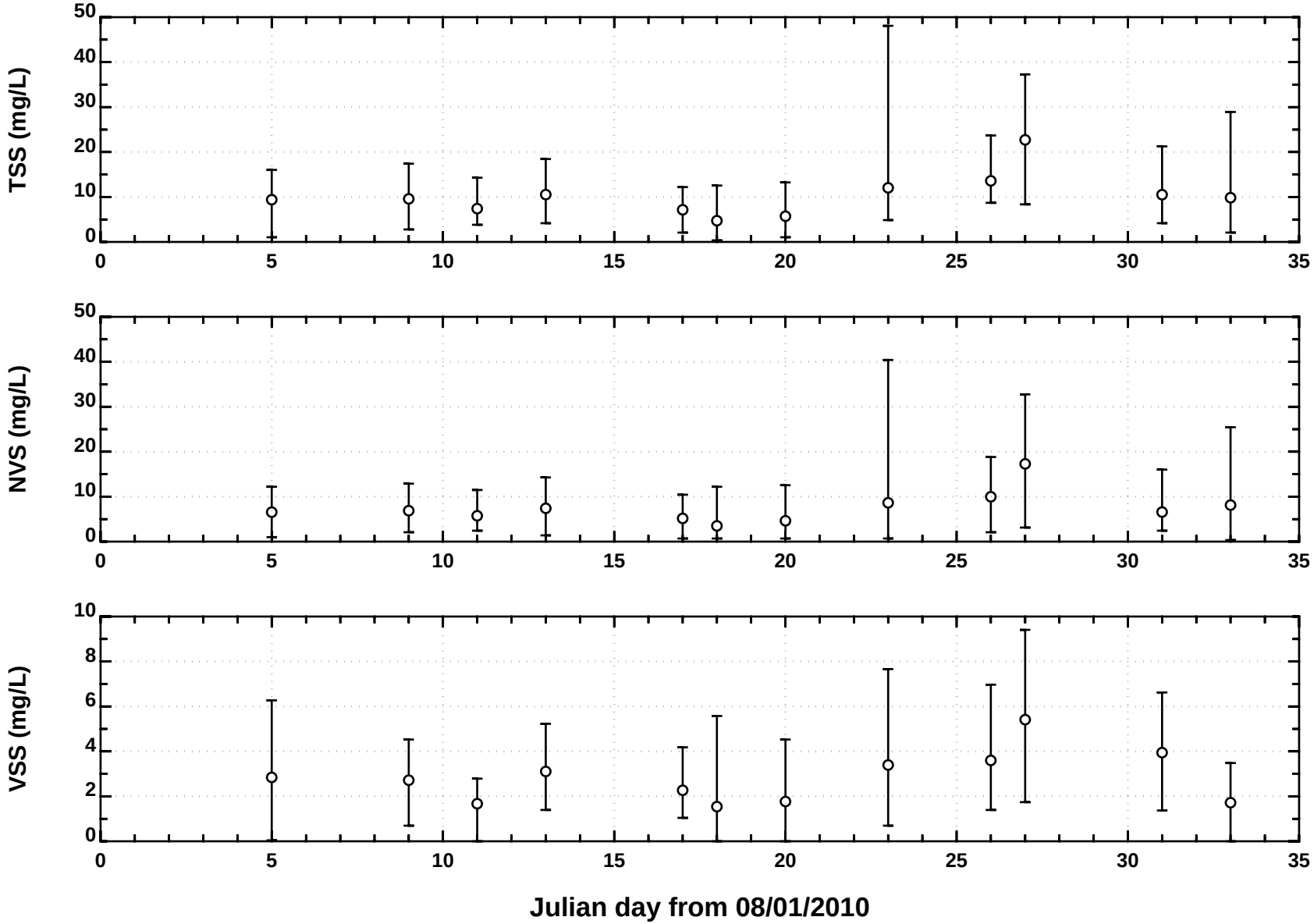

Figure 12. 2010 Great Bay Water Quality Data (Station 1-5)

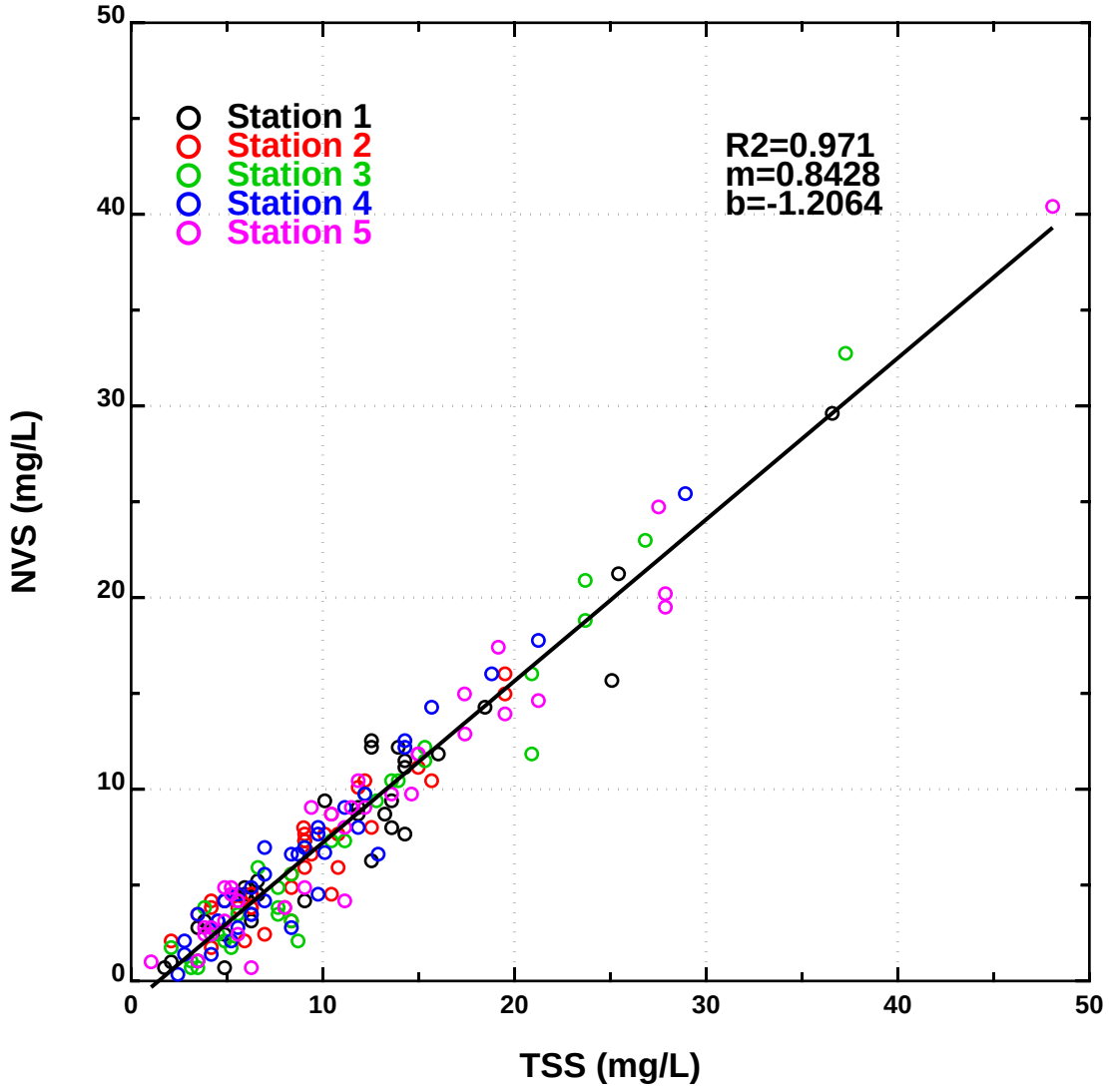

Figure 13. 2010 Great Bay Water Quality Data

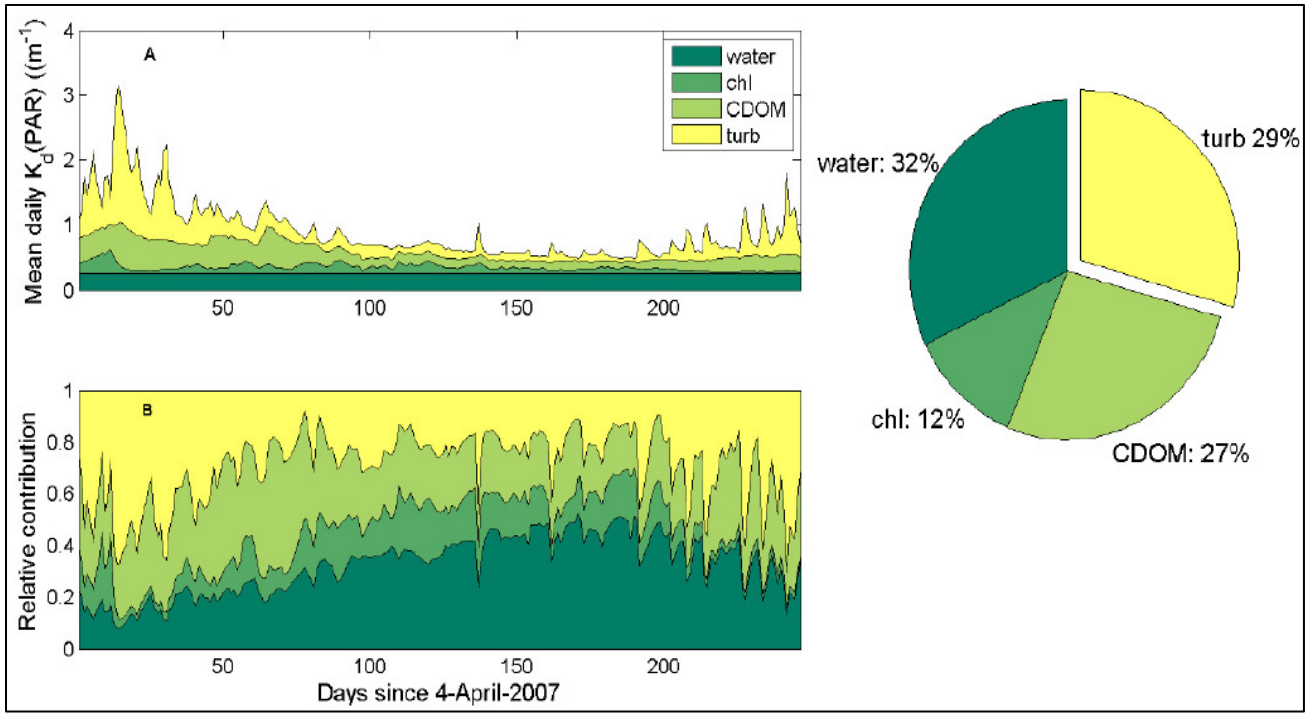

Figure 14. Contributions to Kd (PAR) measured at the Great Bay Buoy (From Morrison et al, 2008)

APPENDIX A

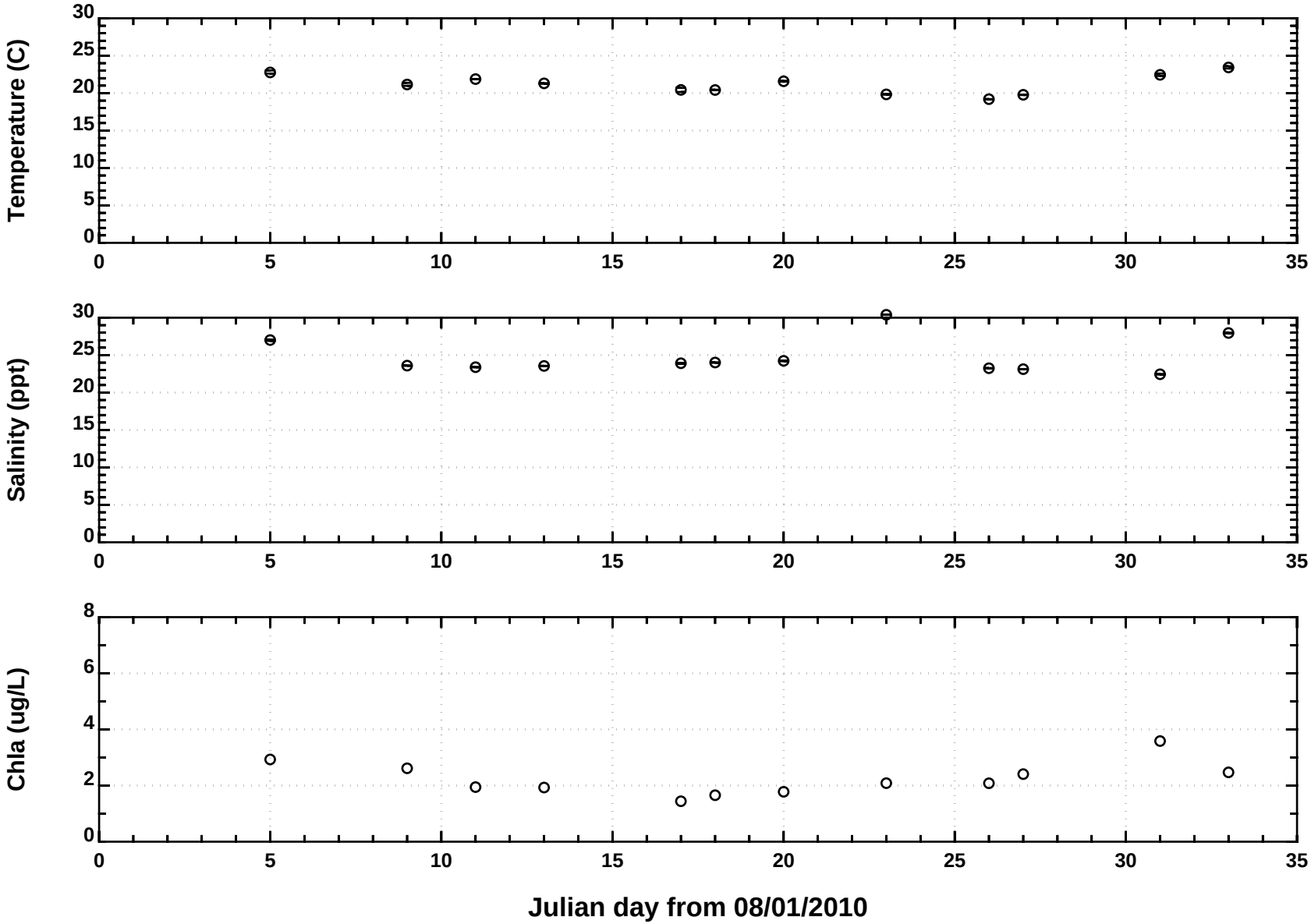

Figure 1-1. 2010 Great Bay Water Quality Data, Station 1

Appendix A

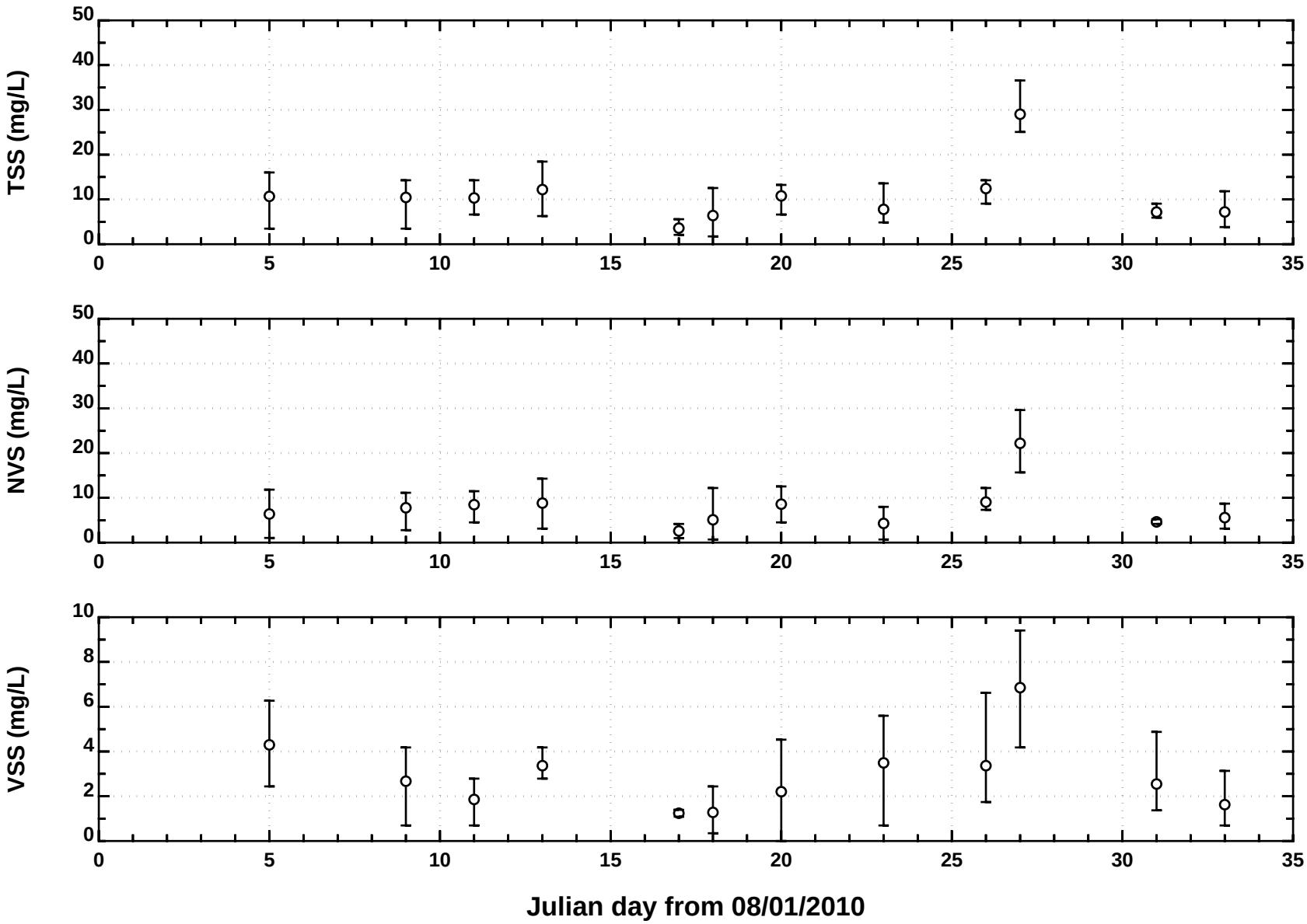

Figure 1-2. 2010 Great Bay Water Quality Data, Station 1

Appendix A

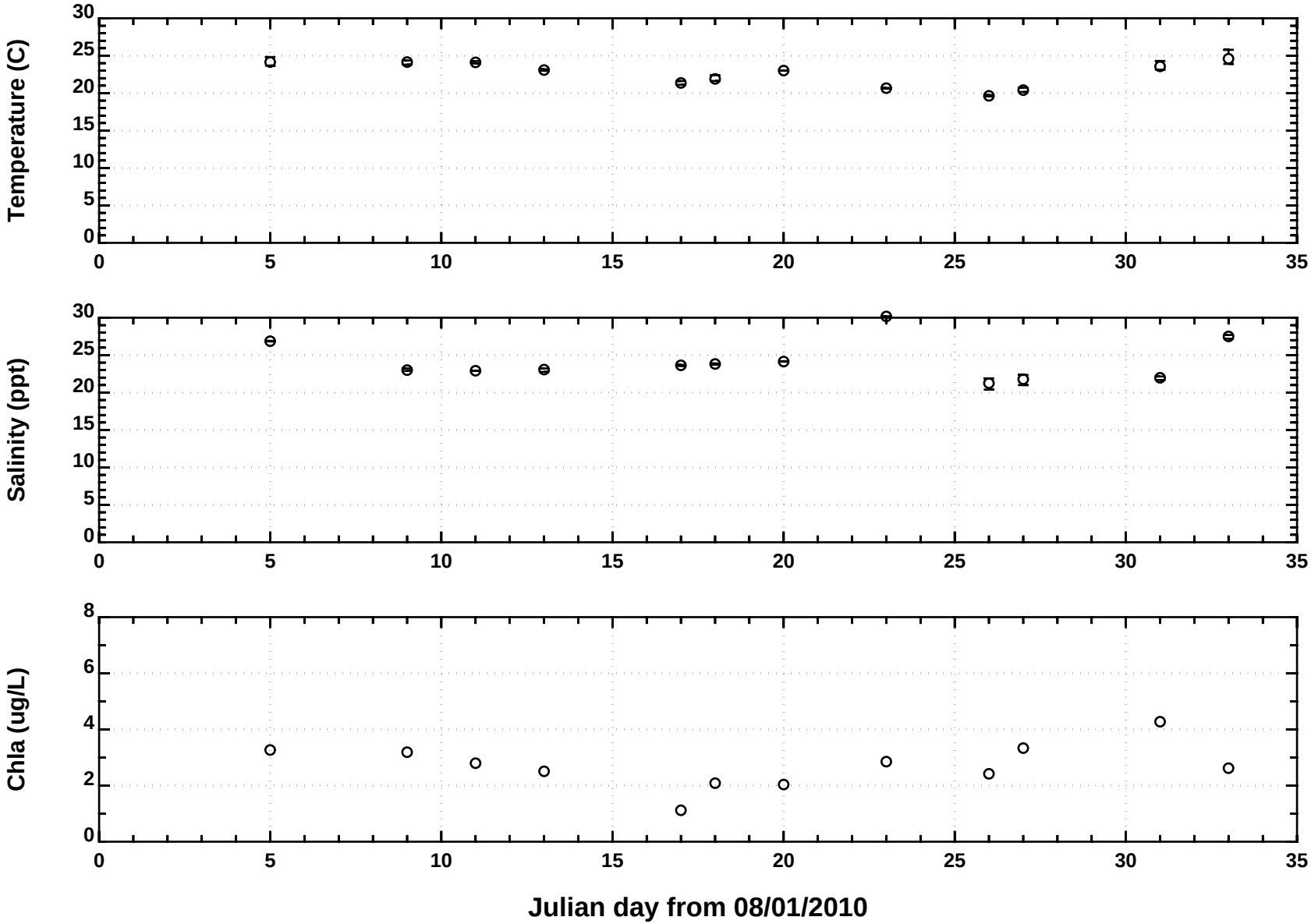

Figure 2-1. 2010 Great Bay Water Quality Data, Station 2

Appendix A

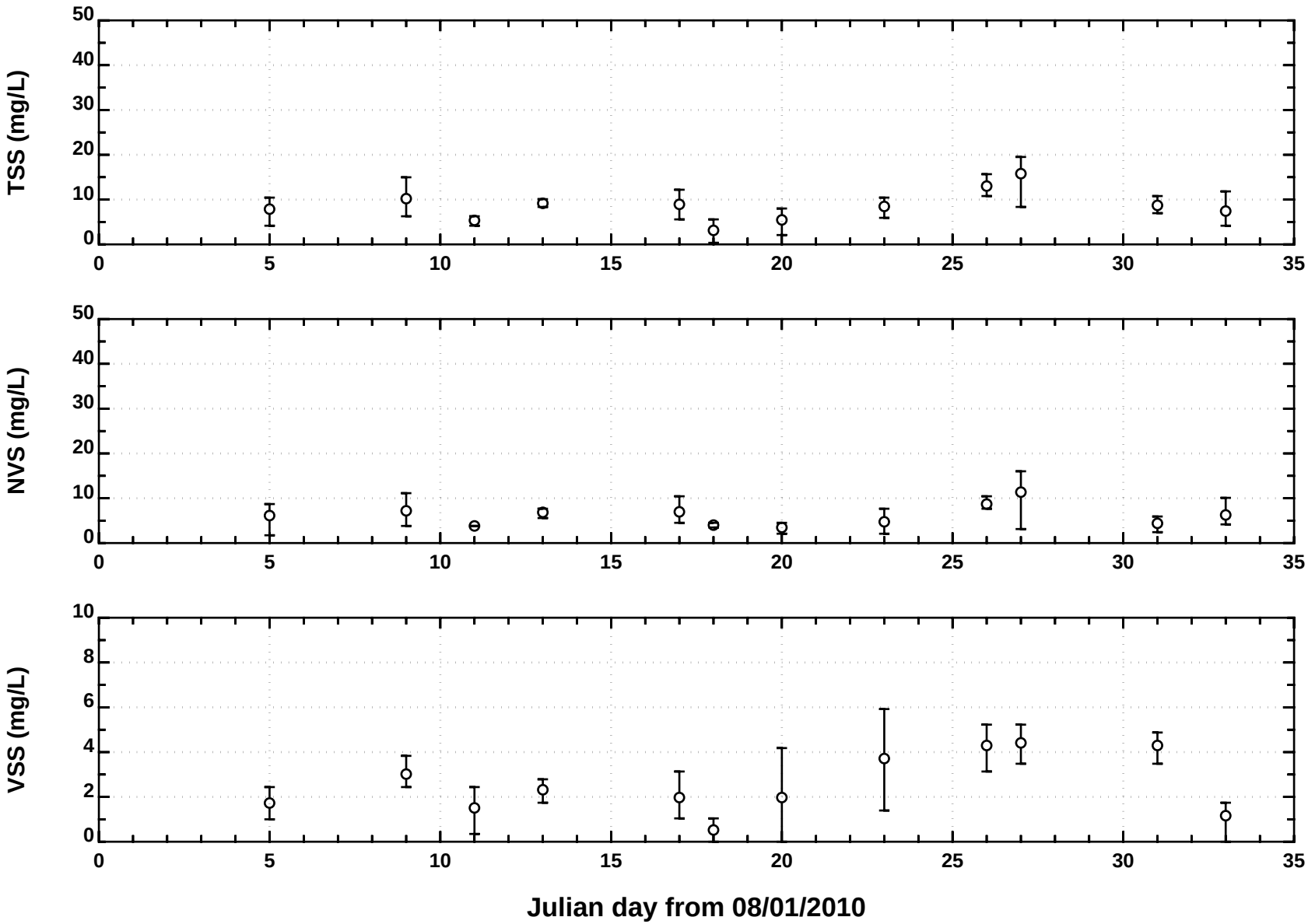

Figure 2-2. 2010 Great Bay Water Quality Data, Station 2

Appendix A

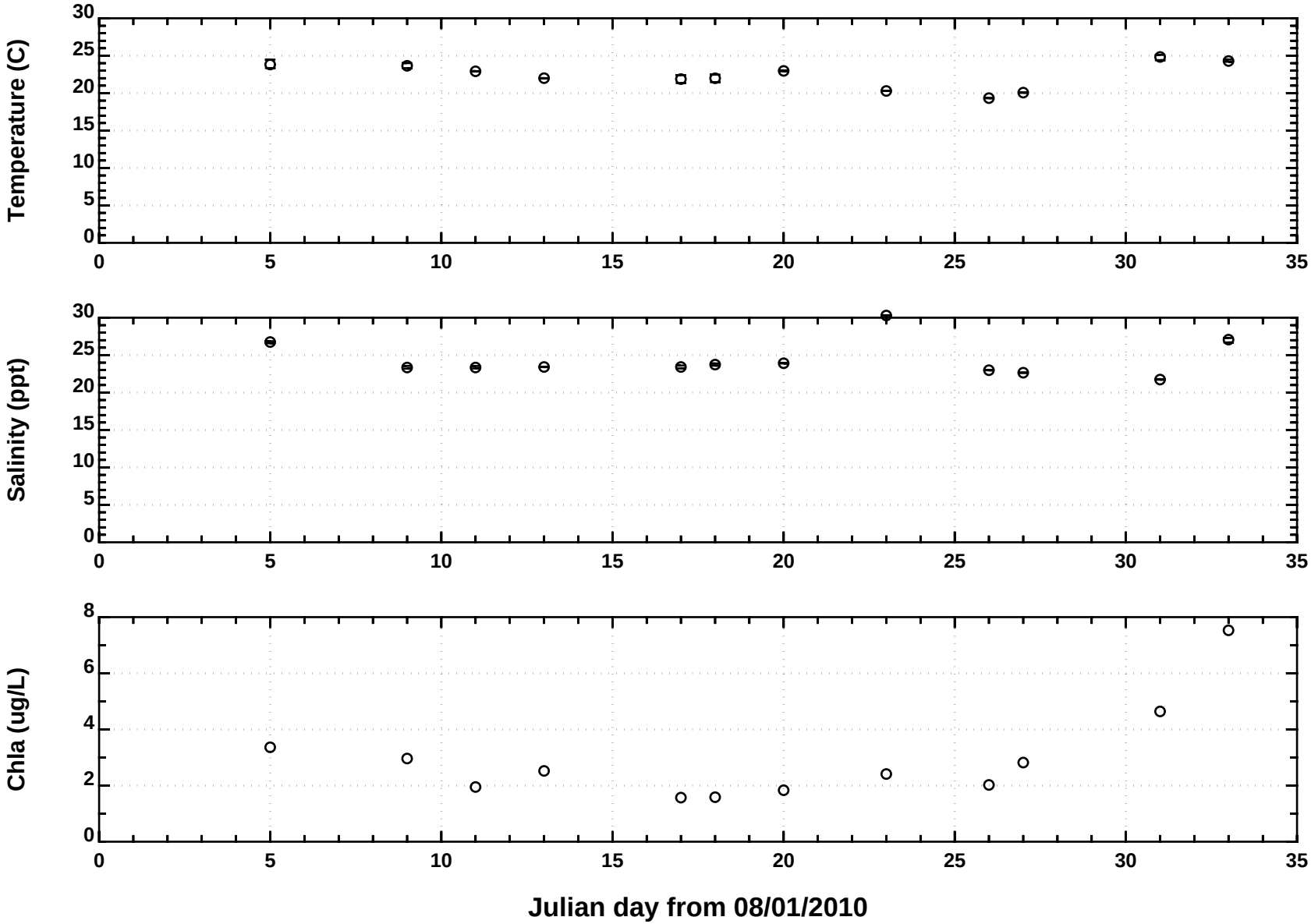

Figure 3-1. 2010 Great Bay Water Quality Data, Station 3

Appendix A

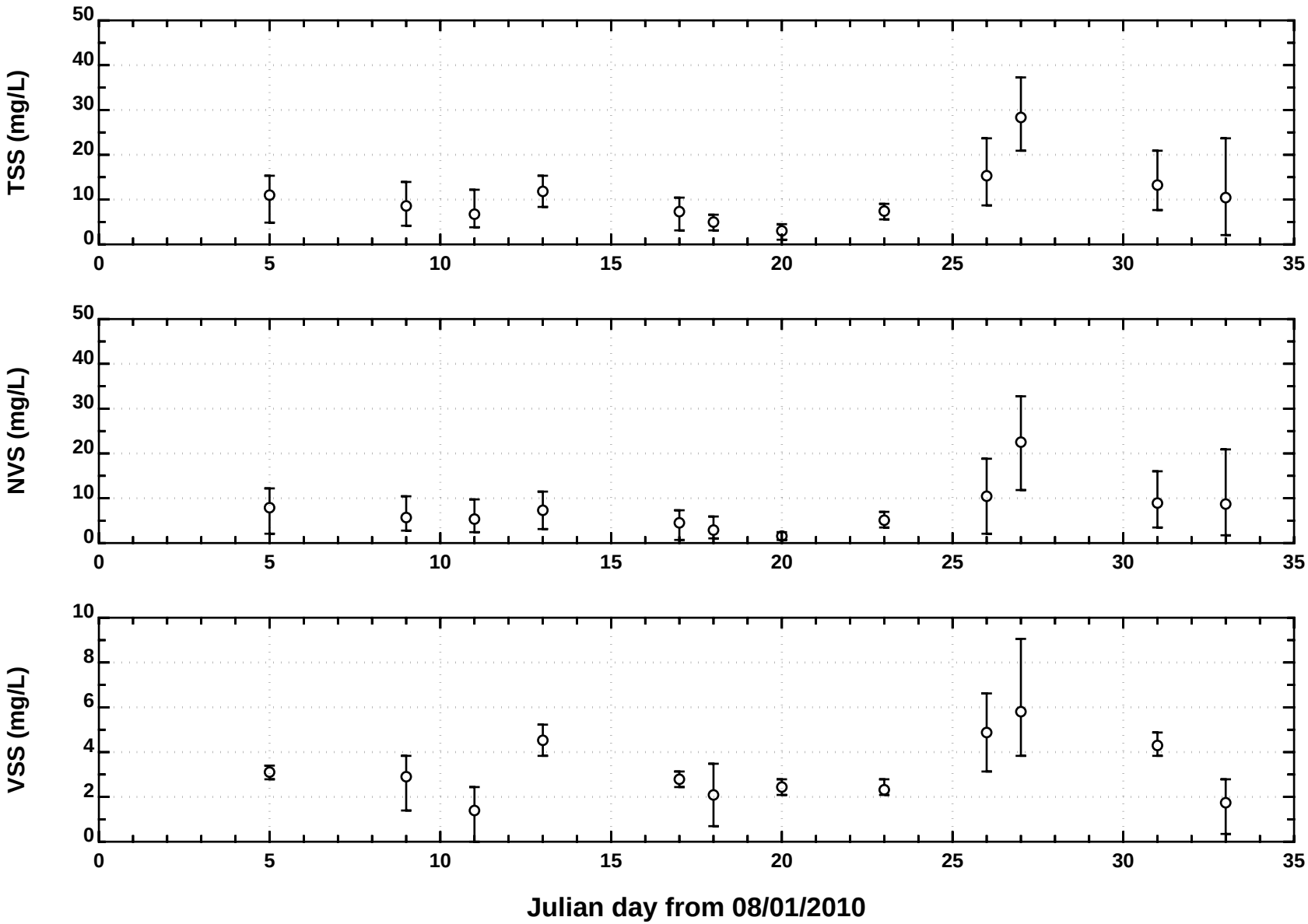

Figure 3-2. 2010 Great Bay Water Quality Data, Station 3

Appendix A

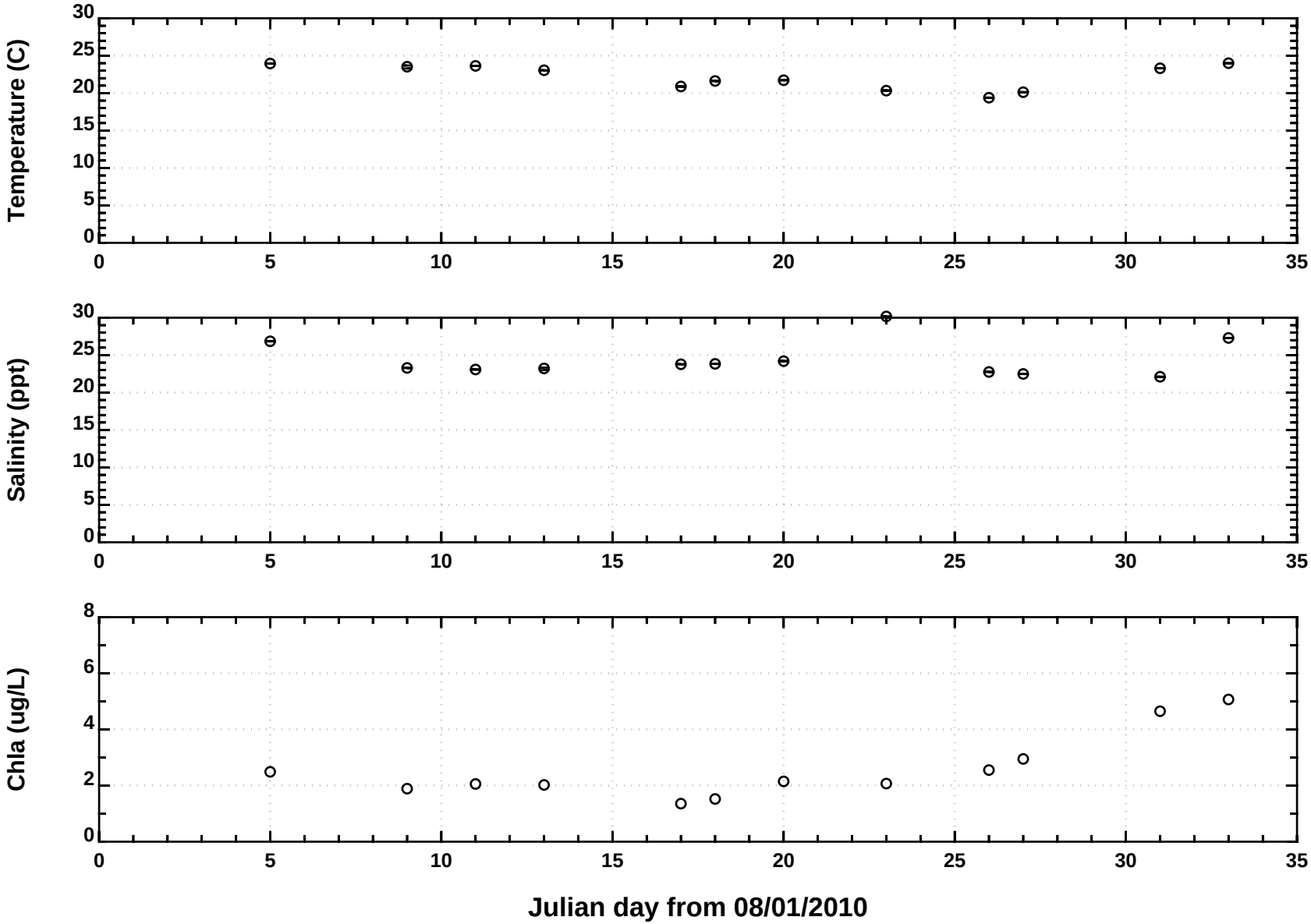

Figure 4-1. 2010 Great Bay Water Quality Data, Station 4

Appendix A

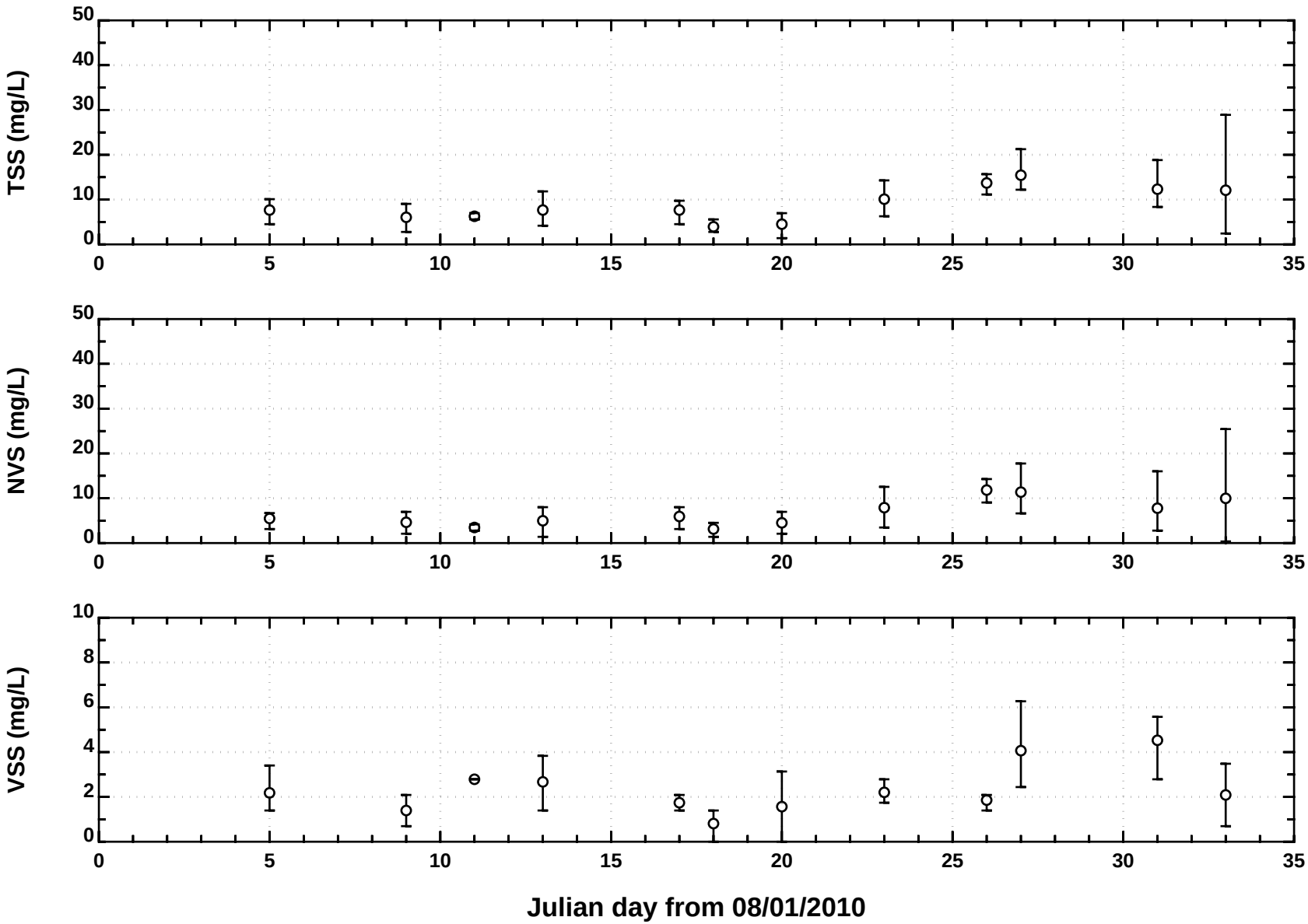

Figure 4-2. 2010 Great Bay Water Quality Data, Station 4

Appendix A

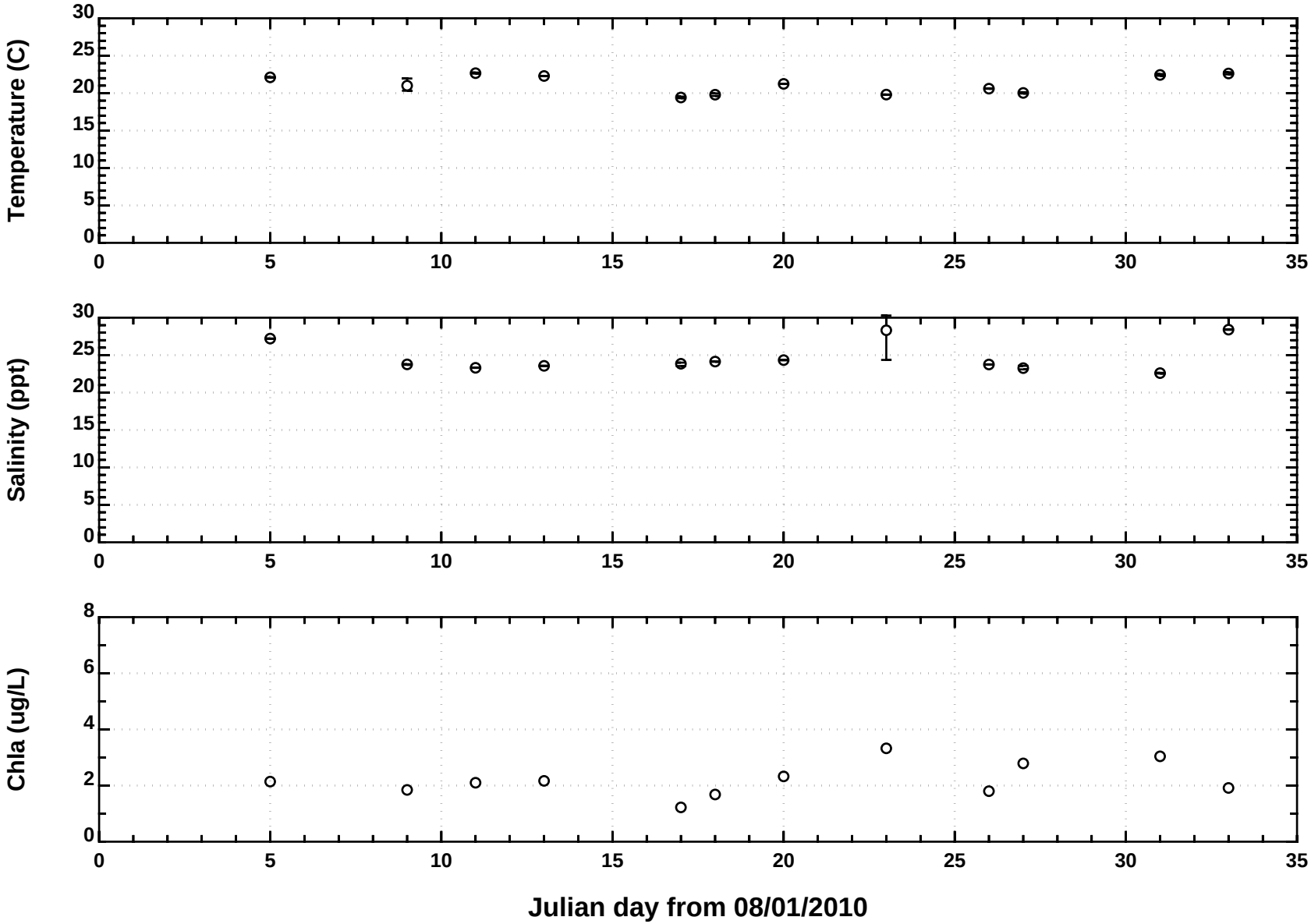

Figure 5-1. 2010 Great Bay Water Quality Data, Station 5

Appendix A

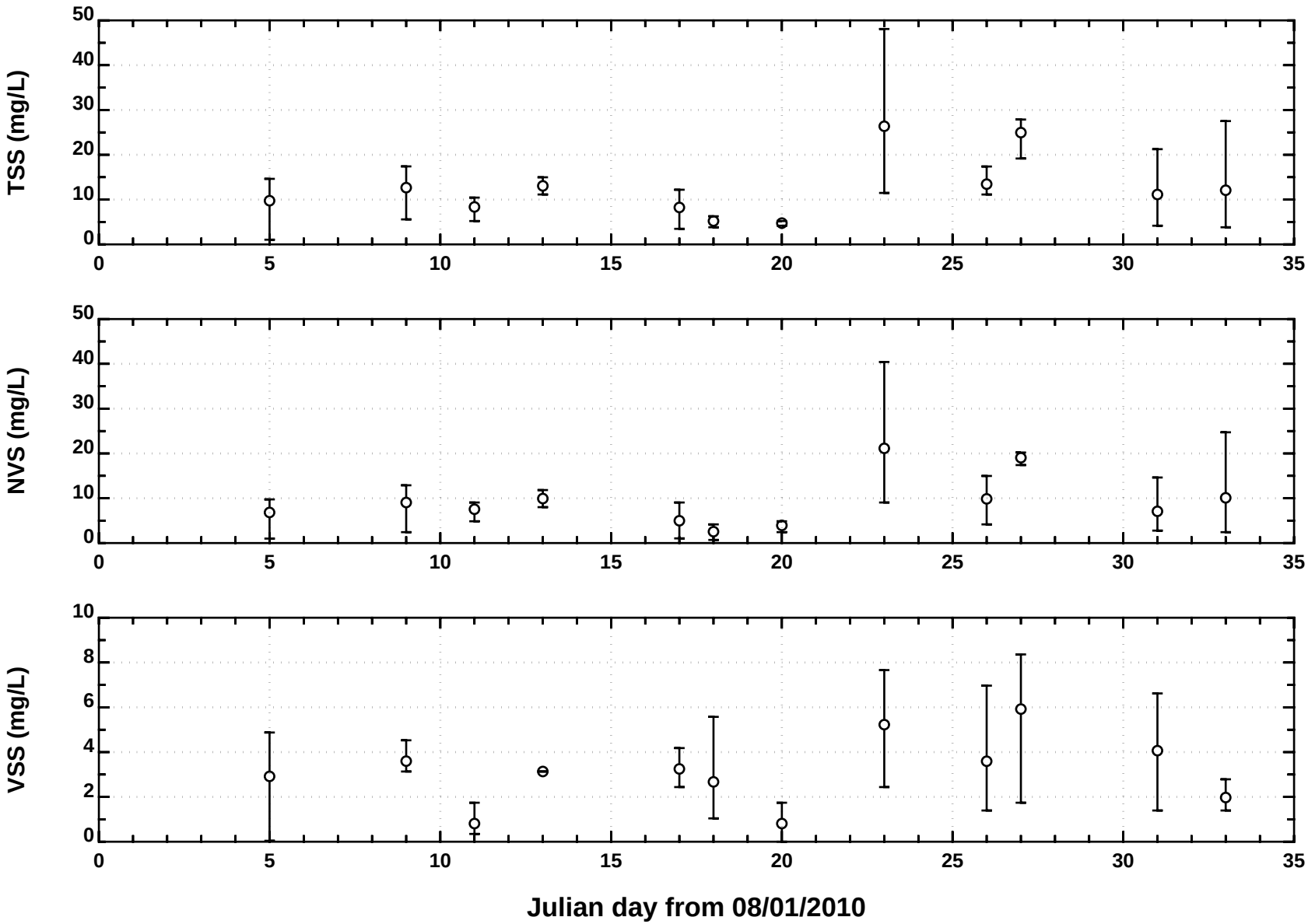

Figure 5-2. 2010 Great Bay Water Quality Data, Station 5

Appendix A